



Interference Cancellation Method without Feedback Amount for Three Users Interference Channel

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Abstract

In this paper, we investigate how to cancel multi-user interference without feedback amount over multiple-input multiple-output (MIMO) interference channel using space-time code. Three transmitter-receiver pairs are considered and each node is equipped with four antennas. Space-time codeword with dimension 4×4 is designed for three transmitters, respectively. The number of interfering codeword is reduced through the design of codeword. Then, multi-user interference is cancelled by a linear operation on the received signals. Compared with the existing scheme for the same scene, the transmission efficiency is improved, and the unidirectional cooperative link is not required. Simulation results demonstrate the validity of theoretical analysis.

Subject Areas

Information and Communication Theory and Algorithms

Keywords

Interference Channel, Space-Time Codeword, Multi-User Interference, Interference Cancellation, Transmission Efficiency

1. Introduction

Reliability and effectiveness are important factors for wireless communications. Multiple-input multiple-output (MIMO) systems have the ability to improve both and hence, are immensely popular. In theory, MIMO systems can achieve extremely high spectral efficiency by transmitting independent data stream simultaneously. However, multiple users, transmitting different codewords to multiple receivers simultaneously using the same band, are not able to collaborate with each other [1]. There is serious interference at each receiver, and the

effectiveness becomes limited. Therefore, it is quite important to design transmission techniques to eliminate multi-user interference [2].

Several kinds of interference cancellation methods have been conducted, such as pre-coding at the transmitters, multi-user detection of the receivers, and interference alignment [3] [4]. Interference alignment methods align the interference caused at each receiver from all the transmitters along the same direction while the desired signals occupy linearly independent signal dimensions. In this case, the desired signals can be decoded free from interference by zero-forcing algorithm.

A popular way to approximating the sum-capacity for interference alignment is using the concept of degrees of freedom (DoF), in terms of transmission efficiency. Many works have been conducted to evaluate DoF [5] [6]. However, effectiveness is contract to reliability in communication systems. With high DoF, reliability in terms of the diversity gain is needed to be improved. Therefore, it is meaningful to combine interference alignment and space-time code, which can offer diversity gain [7] [8]. [9] proposes a new interference alignment scheme using Alamouti code for two users MIMO X channel, in which zero vector is introduced into each codeword. The diversity gain of [9] is 2, which is brought by Alamouti code. Space-time codeword with dimension 4×4 is designed and zero vectors are introduced into each codeword over two users MIMO X channel with four antennas at each user, in which the diversity gain is 4 [10]. The multi-user interference is mitigated through interference alignment and linear operation on the received signals. Motivated by [9], interference alignment and Alamouti code are introduced into MIMO interference channel with three transmitter- receiver pairs [11]. The multi-user interference is mitigated through interference alignment and unidirectional cooperative link. However, channel state information (CSI) is required at the transmitters. It is very difficult to estimate the CSI in a mobility environment. Therefore, it is crucial to consider transmission scheme combined interference alignment and space-time code without CSI.

Under this motivation, interference cancellation method without feedback is proposed for MIMO interference channel with three transmitter-receiver pairs where each node is equipped with four antennas. Space-time codeword with dimension 4×4 is designed for three transmitters, respectively. Each codeword includes eight independent modulated symbols and zero matrices are introduced into each codeword, through which the number of interfering codeword is reduced. Then, multi-user interference is cancelled by a linear operation on the received signals. The transmission efficiency of the proposed scheme is higher than that of [11]. Theoretical analysis shows that the diversity of the proposed scheme is the same as that of [11].

Notation: The operators $(\cdot)^*$ and $(\cdot)^H$ stand for complex conjugation and conjugation transpose, respectively. $\|\cdot\|$ denotes Frobenius norm of the enclosed term. $E(\cdot)$ is the expectation operations.

2. System Model

The system model is shown in **Figure 1**. There are three dedicated transmitter-receiver pairs, where each transmitter has an individual message to be communicated to its respectively receiver. All the transmitters and receivers are assumed to have four antennas. We assume CSI is not available at each transmitter.

a_k , b_k and c_k , which take values from a set such that $E[|a_k|^2] = E[|b_k|^2] = E[|c_k|^2] = 1$, $k = 1, 2, \dots, 8$, represent the modulated signals at transmitter 1, transmitter 2 and transmitter 3, respectively. a_k , b_k and c_k are encoded into 2×2 space-time codeword, denoted by A_i , B_i and C_i , respectively, $i = 1, 2$. A_i , B_i and C_i are expressed as

$$\begin{aligned} A_i &= \begin{bmatrix} a_{4i-3} + e^{j\theta} a_{4i-1} & -a_{4i-2}^* - e^{-j\theta} a_{4i}^* \\ a_{4i-2} + e^{j\theta} a_{4i} & a_{4i-3}^* + e^{-j\theta} a_{4i-1}^* \end{bmatrix} \\ B_i &= \begin{bmatrix} b_{4i-3} + e^{j\theta} b_{4i-1} & -b_{4i-2}^* - e^{-j\theta} b_{4i}^* \\ b_{4i-2} + e^{j\theta} b_{4i} & b_{4i-3}^* + e^{-j\theta} b_{4i-1}^* \end{bmatrix} \\ C_i &= \begin{bmatrix} c_{4i-3} + e^{j\theta} c_{4i-1} & -c_{4i-2}^* - e^{-j\theta} c_{4i}^* \\ c_{4i-2} + e^{j\theta} c_{4i} & c_{4i-3}^* + e^{-j\theta} c_{4i-1}^* \end{bmatrix} \end{aligned} \quad (1)$$

where, $j = \sqrt{-1}$, $0 < \theta < 2\pi$. The elements of A_i , the elements of B_i and the elements of C_i are nonzero by the proper value of θ . Each element of A_i , each element of B_i and each element of C_i includes two independent symbols, with the purpose of improving transmission efficiency. If we see the elements of A_i , the elements of B_i and the elements of C_i as the modulated signals, $i = 1, 2$, A_i , B_i and C_i have an Alamouti structure. The motive for such design is that the effective channel matrix of Alamouti code has orthogonal columns, which can be used to reduce decoding complexity.

At transmitter 1, A_1 and A_2 are combined according to a certain rule to get codeword A . Similarly, B_1 and B_2 are combined to obtain codeword B while C_1 and C_2 are combined to obtain codeword C . A , B and C are given by

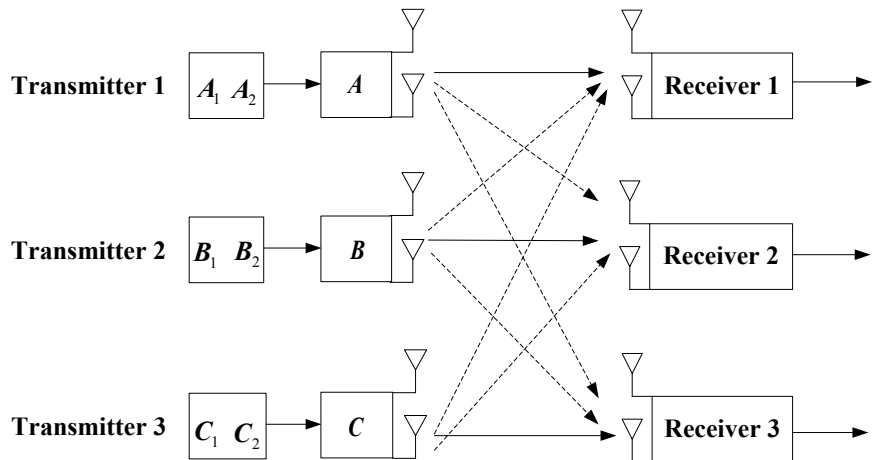


Figure 1. The system model of the proposed scheme.

$$A = \begin{bmatrix} A_1 & \mathbf{0}_2 \\ A_2 & \mathbf{0}_2 \end{bmatrix}, B = \begin{bmatrix} B_1 & \mathbf{0}_2 \\ \mathbf{0}_2 & B_2 \end{bmatrix}, C = \begin{bmatrix} \mathbf{0}_2 & C_1 \\ \mathbf{0}_2 & C_2 \end{bmatrix} \quad (2)$$

where, $\mathbf{0}_2$ represents 2×2 zero matrix. $\mathbf{0}_2$ is introduced because it can be used to mitigate partial multi-user interference, as shown later. A , B and C are the desired codewords for the three receivers, respectively.

As shown in **Figure 1**, three transmitters send A , B and C on the same frequency band at the same time. The received signals at receiver i , denoted by Y_i , are expressed as

$$Y_1 = H_{11}A + H_{12}B + H_{13}C + N_1 \quad (3)$$

$$Y_2 = H_{21}A + H_{22}B + H_{23}C + N_2 \quad (4)$$

$$Y_3 = H_{31}A + H_{32}B + H_{33}C + N_3 \quad (5)$$

where, $i = 1, 2, 3$, H_{ik} is the channel from transmitter k to receiver i and N_i is the complex additive white Gaussian noise at receiver i . The dimension of H_{ik} and N_i are both 4×4 . To avoid degenerate channel conditions, we assume that the channel coefficient values are drawn i.i.d. from a continuous distribution and the absolute value of all the channel coefficients is bounded between a nonzero minimum value and a finite maximum value.

The term $H_{11}A$ in Equation (3) is the desired signals for receiver 1 and the term $H_{12}B + H_{13}C$ in Equation (3) is the interference signals for receiver 1. The term $H_{22}B$ in Equation (4) is the desired signals for receiver 2 and the term $H_{21}A + H_{23}C$ in Equation (4) is the interference signals for receiver 2. The term $H_{33}C$ in Equation (5) is the desired signals for receiver 3 and the term $H_{31}A + H_{32}B$ in Equation (5) is the interference signals for receiver 3.

3. Interference Cancellation Method

We describe the interference cancellation method at R_1 . It can be similarly used to mitigate interference at R_2 and to mitigate interference R_3 .

3.1. Remove the Undesired Codeword

Let $H_{11} = [H_1 \ H_2]$, $H_{12} = [H_3 \ H_4]$, $H_{13} = [H_5 \ H_6]$, $Y_1 = [Y_{11} \ Y_{21}]$ and $N_1 = [N_{11} \ N_{21}]$. The dimension of H_l , N_{i1} and Y_{i1} are both 4×2 , $l = 1, 2, \dots, 6$, $i = 1, 2$. Then, (3) can be expressed as

$$\begin{bmatrix} Y_{11} & Y_{21} \end{bmatrix} = \begin{bmatrix} H_1 A_1 + H_2 A_2 + H_3 B_1 & H_4 B_2 + H_5 C_1 + H_6 C_2 \end{bmatrix} + \begin{bmatrix} N_{11} & N_{21} \end{bmatrix} \quad (6)$$

(6) is equivalent to the following two equations,

$$Y_{11} = H_1 A_1 + H_2 A_2 + H_3 B_1 + N_{11} \quad (7)$$

$$Y_{21} = H_4 B_2 + H_5 C_1 + H_6 C_2 + N_{21} \quad (8)$$

The codeword of transmitter 1 and the partial codeword of transmitter 2 are encompassed by Y_{11} . The codeword of transmitter 3 and the partial codeword of transmitter 2 are encompassed by Y_{21} . So, the number of interfering codeword is reduced by the introduction of zero matrices. However, both the desired codeword for receiver 1 and the undesired codeword for receiver 1 in terms of

\mathbf{B}_1 are included by \mathbf{Y}_{11} . In what follows, we represent how to cancel the undesired codeword \mathbf{B}_1 .

$$\text{Let } \mathbf{H}_1 = \begin{bmatrix} h_{11}^1 & h_{12}^1 \\ h_{21}^1 & h_{22}^1 \\ h_{31}^1 & h_{32}^1 \\ h_{41}^1 & h_{42}^1 \end{bmatrix}, \mathbf{H}_2 = \begin{bmatrix} h_{11}^2 & h_{12}^2 \\ h_{21}^2 & h_{22}^2 \\ h_{31}^2 & h_{32}^2 \\ h_{41}^2 & h_{42}^2 \end{bmatrix} \text{ and } \mathbf{H}_3 = \begin{bmatrix} h_{11}^3 & h_{12}^3 \\ h_{21}^3 & h_{22}^3 \\ h_{31}^3 & h_{32}^3 \\ h_{41}^3 & h_{42}^3 \end{bmatrix}. \text{ Use } y_{ij} \text{ and}$$

n_{ij} to denote the element of \mathbf{Y}_{11} and \mathbf{N}_{11} , $i=1,2,3,4$, $j=1,2$. The elements of \mathbf{Y}_{11} can be effectively written as

$$\mathbf{y}_1 = \mathbf{G}_{11} \begin{bmatrix} a_1 + e^{j\theta} a_3 \\ a_2 + e^{j\theta} a_4 \end{bmatrix} + \mathbf{G}_{12} \begin{bmatrix} a_5 + e^{j\theta} a_7 \\ a_6 + e^{j\theta} a_8 \end{bmatrix} + \mathbf{G}_{13} \begin{bmatrix} b_1 + e^{j\theta} b_3 \\ b_2 + e^{j\theta} b_4 \end{bmatrix} + \mathbf{n}_1 \quad (9)$$

$$\mathbf{y}_2 = \mathbf{G}_{21} \begin{bmatrix} a_1 + e^{j\theta} a_3 \\ a_2 + e^{j\theta} a_4 \end{bmatrix} + \mathbf{G}_{22} \begin{bmatrix} a_5 + e^{j\theta} a_7 \\ a_6 + e^{j\theta} a_8 \end{bmatrix} + \mathbf{G}_{23} \begin{bmatrix} b_1 + e^{j\theta} b_3 \\ b_2 + e^{j\theta} b_4 \end{bmatrix} + \mathbf{n}_2 \quad (10)$$

$$\mathbf{y}_3 = \mathbf{G}_{31} \begin{bmatrix} a_1 + e^{j\theta} a_3 \\ a_2 + e^{j\theta} a_4 \end{bmatrix} + \mathbf{G}_{32} \begin{bmatrix} a_5 + e^{j\theta} a_7 \\ a_6 + e^{j\theta} a_8 \end{bmatrix} + \mathbf{G}_{33} \begin{bmatrix} b_1 + e^{j\theta} b_3 \\ b_2 + e^{j\theta} b_4 \end{bmatrix} + \mathbf{n}_3 \quad (11)$$

$$\mathbf{y}_4 = \mathbf{G}_{41} \begin{bmatrix} a_1 + e^{j\theta} a_3 \\ a_2 + e^{j\theta} a_4 \end{bmatrix} + \mathbf{G}_{42} \begin{bmatrix} a_5 + e^{j\theta} a_7 \\ a_6 + e^{j\theta} a_8 \end{bmatrix} + \mathbf{G}_{43} \begin{bmatrix} b_1 + e^{j\theta} b_3 \\ b_2 + e^{j\theta} b_4 \end{bmatrix} + \mathbf{n}_4 \quad (12)$$

where, $\mathbf{G}_{ij} = \begin{bmatrix} h_{i1}^j & h_{i2}^j \\ h_{i2}^{j*} & -h_{i1}^{j*} \end{bmatrix}$, $\mathbf{y}_i = \begin{bmatrix} y_{i1} \\ y_{i2} \end{bmatrix}$, $\mathbf{n}_i = \begin{bmatrix} n_{i1} \\ n_{i2} \end{bmatrix}$, $i=1,2,3,4$, $j=1,2,3$. y_i

and \mathbf{n}_i are the effective received signals and the effective noise at the i -th antenna, respectively. $\begin{bmatrix} a_1 + e^{j\theta} a_3 \\ a_2 + e^{j\theta} a_4 \end{bmatrix}$, $\begin{bmatrix} a_5 + e^{j\theta} a_7 \\ a_6 + e^{j\theta} a_8 \end{bmatrix}$ and $\begin{bmatrix} b_1 + e^{j\theta} b_3 \\ b_2 + e^{j\theta} b_4 \end{bmatrix}$ are the effective transmitted signals of the three transmitters. \mathbf{G}_{ij} is the effective channel matrix corresponding to the effective transmitted signals, $i=1,2,3,4$,

$j=1,2,3$. \mathbf{G}_{ij} , having orthogonal columns, satisfies $\frac{\mathbf{G}_{ij}^H \mathbf{G}_{ij}}{\|\mathbf{G}_{ij}\|^2} = \mathbf{I}_2$, where \mathbf{I}_2 is

unit matrix with dimension 2×2 . The third terms at the right side of Equation (9-12) are the interference signals, which can be mitigated using interference cancellation method as follows

$$\mathbf{z}_1 = \frac{\mathbf{G}_{13}^H \mathbf{y}_1}{\|\mathbf{G}_{13}\|^2} - \frac{\mathbf{G}_{23}^H \mathbf{y}_2}{\|\mathbf{G}_{23}\|^2} = \mathbf{P}_1 \begin{bmatrix} a_1 + e^{j\theta} a_3 \\ a_2 + e^{j\theta} a_4 \end{bmatrix} + \mathbf{P}_2 \begin{bmatrix} a_5 + e^{j\theta} a_7 \\ a_6 + e^{j\theta} a_8 \end{bmatrix} + \mathbf{w}_1 \quad (13)$$

$$\mathbf{z}_2 = \frac{\mathbf{G}_{33}^H \mathbf{y}_3}{\|\mathbf{G}_{33}\|^2} - \frac{\mathbf{G}_{43}^H \mathbf{y}_4}{\|\mathbf{G}_{43}\|^2} = \mathbf{P}_3 \begin{bmatrix} a_1 + e^{j\theta} a_3 \\ a_2 + e^{j\theta} a_4 \end{bmatrix} + \mathbf{P}_4 \begin{bmatrix} a_5 + e^{j\theta} a_7 \\ a_6 + e^{j\theta} a_8 \end{bmatrix} + \mathbf{w}_2 \quad (14)$$

where, $\mathbf{P}_i = \frac{\mathbf{G}_{13}^H \mathbf{G}_{1i}}{\|\mathbf{G}_{13}\|^2} - \frac{\mathbf{G}_{23}^H \mathbf{G}_{2i}}{\|\mathbf{G}_{23}\|^2}$, $\mathbf{P}_j = \frac{\mathbf{G}_{33}^H \mathbf{G}_{3(j-2)}}{\|\mathbf{G}_{33}\|^2} - \frac{\mathbf{G}_{43}^H \mathbf{G}_{4(j-2)}}{\|\mathbf{G}_{43}\|^2}$,

$\mathbf{w}_1 = \frac{\mathbf{G}_{13}^H \mathbf{n}_1}{\|\mathbf{G}_{13}\|^2} - \frac{\mathbf{G}_{23}^H \mathbf{n}_2}{\|\mathbf{G}_{23}\|^2}$, $\mathbf{w}_2 = \frac{\mathbf{G}_{33}^H \mathbf{n}_3}{\|\mathbf{G}_{33}\|^2} - \frac{\mathbf{G}_{43}^H \mathbf{n}_4}{\|\mathbf{G}_{43}\|^2}$, $i=1,2$, $j=1,2$. \mathbf{z}_i and \mathbf{w}_i are

the signals and the noise after linear operation, respectively, $i=1,2$. \mathbf{P}_i is effective channel matrix after linear operation, $i=1,2,3,4$. The dimension of \mathbf{z}_i and the dimension \mathbf{w}_i are both 2×1 , $i=1,2$. The dimension of \mathbf{P}_i is 2×2 ,

$i = 1, 2, 3, 4$. Symbols transmitted from transmitter 2 and symbols transmitted from transmitter 3 are not included in (13-14). So multi-user interference is mitigated through linear operation on the received signals.

3.2. Separate the Desired Codewords

Even if multi-user interference is cancelled, the desired codeword at receiver 1 includes 8 independent modulated symbols, namely a_1, a_2, \dots, a_8 , as shown in (13-14). If we decode a_1, a_2, \dots, a_8 based on (13-14), the complexity of maximum likelihood (ML) algorithm is proportional to the 8th power of modulation order, which is extremely high. So, it is necessary to divide these symbols into several groups. Take operation on z_1 and z_2 to get,

$$x_1 = \frac{P_2^H z_1}{\|P_2\|^2} - \frac{P_4^H z_2}{\|P_4\|^2} = Q_1 \begin{bmatrix} a_1 + e^{j\theta} a_3 \\ a_2 + e^{j\theta} a_4 \end{bmatrix} + w_3 \tag{15}$$

$$x_2 = \frac{P_1^H z_1}{\|P_1\|^2} - \frac{P_3^H z_2}{\|P_3\|^2} = Q_2 \begin{bmatrix} a_5 + e^{j\theta} a_7 \\ a_6 + e^{j\theta} a_8 \end{bmatrix} + w_4 \tag{16}$$

where, $Q_1 = \frac{P_2^H P_1}{\|P_2\|^2} - \frac{P_4^H P_3}{\|P_4\|^2}$, $Q_2 = \frac{P_1^H P_2}{\|P_1\|^2} - \frac{P_3^H P_4}{\|P_3\|^2}$, $w_3 = \frac{P_2^H w_1}{\|P_2\|^2} - \frac{P_4^H w_2}{\|P_4\|^2}$,

$$w_4 = \frac{P_1^H w_1}{\|P_1\|^2} - \frac{P_3^H w_2}{\|P_3\|^2}. a_1, a_2, a_3 \text{ and } a_4 \text{ are encompassed by } A_1 \text{ whereas}$$

a_5, a_6, a_7 and a_8 are encompassed by A_2 . So, the elements of A_1 and the elements of A_2 are separated, as shown in (15-16). The decoding complexity can be reduced.

From the above analysis, not only multi-user interference is cancelled, but also the two desired codewords A_1 and A_2 are separated. Similar operation can be performed at the other two receivers. Note that neither feedback information nor the unidirectional cooperative link is required.

4. Decoding Method

In this section, we will show how to decode, taking receiver 1 as example.

G_{ij} has an Alamouti structure, $i = 1, 2, 3, 4$, $j = 1, 2, 3$. Due to the completeness of matrix addition, matrix multiplication, and the scalar multiplication of the Alamouti matrix, Q_1 and Q_2 still have the Alamouti structure. Let

$$Q_1 = \begin{bmatrix} q_1 & -q_2^* \\ q_2 & q_1^* \end{bmatrix} \text{ and } Q_2 = \begin{bmatrix} q_3 & -q_4^* \\ q_4 & q_3^* \end{bmatrix}. \text{ Multiply both sides of (15) with } Q_1^H \text{ to}$$

get

$$Q_1^H x_1 = \begin{bmatrix} x_1 \\ x_2 \end{bmatrix} = \begin{bmatrix} |q_1|^2 + |q_2|^2 & 0 \\ 0 & |q_1|^2 + |q_2|^2 \end{bmatrix} \begin{bmatrix} a_1 + e^{j\theta} a_3 \\ a_2 + e^{j\theta} a_4 \end{bmatrix} + Q_1^H w_3 \tag{17}$$

Multiply both sides of (16) with Q_2^H to get

$$Q_2^H x_2 = \begin{bmatrix} x_3 \\ x_4 \end{bmatrix} = \begin{bmatrix} |q_3|^2 + |q_4|^2 & 0 \\ 0 & |q_3|^2 + |q_4|^2 \end{bmatrix} \begin{bmatrix} a_5 + e^{j\theta} a_7 \\ a_6 + e^{j\theta} a_8 \end{bmatrix} + Q_2^H w_4 \tag{18}$$

In (17), the channel corresponding to $a_1 + e^{j\theta} a_3$ is orthogonal to the channel corresponding to $a_2 + e^{j\theta} a_4$. So we can decode $a_1 + e^{j\theta} a_3$ and $a_2 + e^{j\theta} a_4$ separately. Similarly, we can decode $a_5 + e^{j\theta} a_7$ and $a_6 + e^{j\theta} a_8$ separately as well. According to the analysis mentioned above, the decoding method is as follows.

Step1, obtain $\mathbf{G}_{11}, \mathbf{G}_{12}, \dots, \mathbf{G}_{43}$ from the channel matrices, and then compute $\mathbf{P}_1, \mathbf{P}_2, \mathbf{P}_3$ and \mathbf{P}_4 from $\mathbf{G}_{11}, \mathbf{G}_{12}, \dots, \mathbf{G}_{43}$;

Step 2, compute $\mathbf{Q}_1 = \frac{\mathbf{P}_2^H \mathbf{P}_1}{\|\mathbf{P}_2\|^2} - \frac{\mathbf{P}_4^H \mathbf{P}_3}{\|\mathbf{P}_4\|^2}$ and $\mathbf{Q}_2 = \frac{\mathbf{P}_1^H \mathbf{P}_2}{\|\mathbf{P}_1\|^2} - \frac{\mathbf{P}_3^H \mathbf{P}_4}{\|\mathbf{P}_3\|^2}$ through direct multiplications and subtraction ;

Step 3, obtain y_1, y_2, y_3 and y_4 according to the received signals, as in (9-12);

Step 4, take operation on y_1, y_2, y_3 and y_4 to get z_1 and z_2 ,

$$z_1 = \frac{\mathbf{G}_{13}^H y_1}{\|\mathbf{G}_{13}\|^2} - \frac{\mathbf{G}_{23}^H y_2}{\|\mathbf{G}_{23}\|^2}, \quad z_2 = \frac{\mathbf{G}_{33}^H y_3}{\|\mathbf{G}_{33}\|^2} - \frac{\mathbf{G}_{43}^H y_4}{\|\mathbf{G}_{43}\|^2};$$

Step 5, take operation on z_1 and z_2 to get $x_1 = \frac{\mathbf{P}_2^H z_1}{\|\mathbf{P}_2\|^2} - \frac{\mathbf{P}_4^H z_2}{\|\mathbf{P}_4\|^2}$ and $x_2 = \frac{\mathbf{P}_1^H z_1}{\|\mathbf{P}_1\|^2} - \frac{\mathbf{P}_3^H z_2}{\|\mathbf{P}_3\|^2}$, furthermore, computer $\begin{bmatrix} x_1 \\ x_2 \end{bmatrix} = \mathbf{Q}_1^H \mathbf{x}_1$ and $\begin{bmatrix} x_3 \\ x_4 \end{bmatrix} = \mathbf{Q}_2^H \mathbf{x}_2$ through direct multiplications;

Step 6, estimate a_1 and a_3 by

$$(\hat{a}_1, \hat{a}_3) = \underset{a_1, a_3}{\arg \min} \left[x_1 - (|q_1|^2 + |q_2|^2)(a_1 + e^{j\theta} a_3) \right],$$
 where \hat{a}_1 and \hat{a}_3 are the estimation of a_1 and a_3 , respectively;

Step 7, estimate a_2 and a_4 by

$$(\hat{a}_2, \hat{a}_4) = \underset{a_2, a_4}{\arg \min} \left[x_2 - (|q_1|^2 + |q_2|^2)(a_2 + e^{j\theta} a_4) \right],$$
 where \hat{a}_2 and \hat{a}_4 are the estimation of a_2 and a_4 , respectively;

Step 8, estimate a_5 and a_6 by

$$(\hat{a}_5, \hat{a}_6) = \underset{a_5, a_6}{\arg \min} \left[x_3 - (|q_1|^2 + |q_2|^2)(a_5 + e^{j\theta} a_6) \right],$$
 where \hat{a}_5 and \hat{a}_6 are the estimation of a_5 and a_6 , respectively;

Step 9, estimate a_7 and a_8 by

$$(\hat{a}_7, \hat{a}_8) = \underset{a_7, a_8}{\arg \min} \left[x_4 - (|q_1|^2 + |q_2|^2)(a_7 + e^{j\theta} a_8) \right],$$
 where \hat{a}_7 and \hat{a}_8 are the estimation of a_7 and a_8 , respectively;

The ML decoding complexity in step (6-9) is proportional to the square of modulation order.

It is easy to see from (17) that the channel corresponding to $a_1 + e^{j\theta} a_3$ is $|q_1|^2 + |q_2|^2$, which includes two independent path with gain $|q_1|^2$ and $|q_2|^2$. So $a_1 + e^{j\theta} a_3$ has a diversity gain of two, which is equal to that of [11]. Similar arguments can be used to prove that other symbols achieve a diversity of two as well.

5. Simulation Results

6 independent modulated signals are sent over two time slots in [11]. Feedback information, namely 16 complex numbers, are required at the transmitters, which occupy 16/3 time slot if these three receivers adopt the same transmission and the same code mode as the transmitters. So, 22/3 time slot is required to send 6 independent modulated signals in [11]. The transmission efficiency is 3/22 symbol per antenna per time slot. 24 independent modulated signals are sent over four time slots in the proposed scheme. The transmission efficiency is 1/2 symbol per antenna per time slot, which is 11/3 times as that of [11].

Performance of the proposed scheme and performance of the scheme in [11] are compared in Table 1. Two schemes have the same diversity gain. The advantage of the proposed scheme is that neither feedback information nor unidirectional cooperative link is required, and the transmission efficiency is improved. The disadvantage is that the decoding complexity is proportional to the square of modulation order, higher than that of [11], which is proportional to the modulation order.

In Figure 2, we simulate the average BER curves of the proposed scheme and the scheme in [11]. We consider uncoded systems, in which all the underlying links experience Rayleigh fading channels. The data symbols are assumed to be 4QAM symbols and 16QAM symbols, generated independently at each transmitter. The average BER is determined through monte-carlo simulations. The

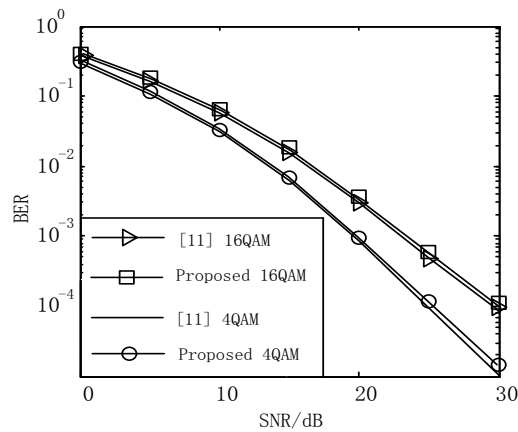


Figure 2. The BER curves of the two schemes.

Table 1. Performance of the two schemes.

Scheme	Proposed	Ref. [11]
Transmission efficiency	1/2 symbol/antenna/time slot	3/22 symbol/antenna/time slot
Diversity gain	2	2
Feedback	No	Local CSI
Unidirectional cooperative link	No	Transmit two complex number
Decoding complexity	Proportional to the square of modulation order	Proportional to the modulation order

slope of BER curves represents diversity gain, which is 2 in these two schemes. It can be seen from this figure that the slope of BER curves of the proposed scheme is almost the same as that of [11], which demonstrate the validity of theoretical analysis.

6. Conclusion

In this paper, the multi-user interference is cancelled by the design of the code-word and linear operation on the received signals. Compared with the existing scheme for the same scene, the proposed scheme doesn't require feedback information and doesn't require unidirectional cooperative link, while keeping the same diversity gain. However, the scheme is limited to three transmitter-receiver pairs, where each node is equipped with four antennas. Future work on this scheme includes extending the application scene.

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