



New Transmission Scheme Based on Space-Time Code for Massive MIMO

Xinji Tian, Wenjie Jia, Haotian Zhang

School of Physics and Electronic Information Engineering, Henan Polytechnic University, Jiaozuo, China

Email: 718213108@qq.com

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Abstract

New transmission scheme based on space-time code is proposed for massive MIMO system, which consists of K users and a base station. Each user is equipped with four antennas and two of them are selected to send space-time codeword with Alamouti coded by using the method of generalized spatial modulation. The base station estimates the index of transmit antennas used by each user at first, and then uses an iterative method to separate each space-time codeword and decode modulated signals of each code-word. Compared with the existing scheme for the same scene, the proposed scheme reduces the complexity of decoding, while keeping the same transmission rate. Simulation results demonstrate that the proposed scheme outperforms the existing scheme in the same scene when the base station is equipped with large amount of antennas.

Subject Areas

Information and Communication Theory and Algorithms

Keywords

Massive MIMO Systems, Space-Time Code, Decoding Complexity, Generalized Spatial Modulation

1. Introduction

Transmission rate and spectrum efficiency are particularly important for multi-cell communication. Massive MIMO technology have the ability to improve spectrum efficiency, cut down transmission power, reduce intra cell interference and inter-cell interference of the system without increasing spectrum resources [1]. So, it becomes one of the breakthrough technologies in the future [2].

In massive MIMO system, the base station is equipped with hundreds of antennas. K users transmit modulated signals simultaneously, or transmit the sig-

nals after precoding at the same time in a single cell uplink system [3]. If all of the users are equipped with n_t antennas, there will be n_t modulation symbols sent by each user per time slot [4] [5]. Generalized spatial modulation is studied in [6], in which not only transmit antennas send symbols, but also different antenna combinations are mapped into several bits. Thus, the transmission efficiency is improved. However, the decoding complexity of Maximum Likelihood (ML) decoding, Message Passing (MP) decoding and Channel Hardening Exploiting Message Passing (CHEMP) in [6] is too high.

In order to reduce the decoding complexity, the transmission based on space-time coding is proposed in single-cell massive MIMO uplink system. All of the users are equipped with 4 antennas and generalized spatial modulation is used at each user. According to the information sequence, two of the antennas are selected to transmit the space-time code which has Alamouti structure. Firstly, the serial number of the transmit antenna used at each user are estimated at the base station. Then, each space-time codeword is separated using the orthogonality of Alamouti code. Finally, modulation symbols in each codeword are detected. The ML decoding complexity of the proposed scheme is proportional to the square of the modulation order. The simulation results show that the reliability of the proposed scheme is better than [6].

2. System Model

The system model of the proposed scheme is shown in **Figure 1**, which contains K users and a base station. All users are equipped with 4 antennas and the base station is equipped with $N(N \geq 4K)$ antennas. Generalized spatial modulation proposed in [6] is adopted. Each user selects two antennas to transmit signals according to the information sequence. When the information sequences are 00, 01, 10 and 11, the corresponding antenna combinations are (1, 2), (1, 3), (1, 4) and (2, 3), respectively.

Rate-2 space-time code proposed in [7] is used at user k , $k = 1, 2, \dots, K$. The codeword at user k , denoted by \mathbf{X}'_k , is expressed as

$$\mathbf{X}'_k = \begin{bmatrix} \mathbf{x}_1 \\ \mathbf{x}_2 \end{bmatrix} = \begin{bmatrix} x'_{k,1} & -x'_{k,2}^* \\ x'_{k,2} & x'_{k,1}^* \end{bmatrix} = \begin{bmatrix} x_{k,1} + e^{j\theta} x_{k,2} & -x_{k,3}^* - e^{-j\theta} x_{k,4} \\ x_{k,3} + e^{j\theta} x_{k,4} & x_{k,1}^* + e^{-j\theta} x_{k,2}^* \end{bmatrix} \quad (1)$$

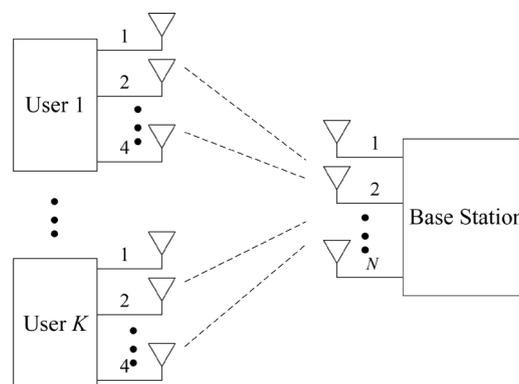


Figure 1. System model of the proposed scheme.

where, $x_{k,\lambda}$ represents the modulation symbols, $\lambda = 1, 2, 3, 4$, $j = \sqrt{-1}$, $(\cdot)^*$ represents conjugate. The value of θ makes the elements of \mathbf{X}'_k nonzero.

Assume that (μ_k, ν_k) are the antenna numbers selected by user k , $\mu_k \neq \nu_k \in \{1, 2, 3, 4\}$, $\mu_k < \nu_k$. Then the antenna μ_k at user k sends x_1 , the antenna ν_k sends x_2 and the other antennas send $[0 \ 0]$. Use \mathbf{X}_k to represent the codeword send by user k . The dimension of \mathbf{X}_k is 4×2 . The elements of \mathbf{X}_k in the row of μ_k and ν_k are x_1 and x_2 respectively, and the elements in other rows are zero.

The received signals at the base station, denoted by \mathbf{Y} , can be expressed as

$$\mathbf{Y} = \mathbf{H}_1 \mathbf{X}_1 + \mathbf{H}_2 \mathbf{X}_2 + \dots + \mathbf{H}_K \mathbf{X}_K + \mathbf{N}$$

$$= \underbrace{\begin{bmatrix} h_{1,1}^1 & \dots & h_{1,4}^1 & h_{1,1}^2 & \dots & h_{1,4}^2 & \dots & h_{1,1}^K & \dots & h_{1,4}^K \\ \vdots & \ddots & \vdots & \vdots & \ddots & \vdots & \ddots & \vdots & \ddots & \vdots \\ h_{N,1}^1 & \dots & h_{N,4}^1 & h_{N,1}^2 & \dots & h_{N,4}^2 & \dots & h_{N,1}^K & \dots & h_{N,4}^K \end{bmatrix}}_{\mathbf{H}} \begin{bmatrix} \mathbf{x}_{1,1} & \mathbf{x}_{1,2} \\ \vdots & \vdots \\ \mathbf{x}_{K,1} & \mathbf{x}_{K,2} \end{bmatrix} + \underbrace{\begin{bmatrix} n_{1,1} & n_{1,2} \\ \vdots & \vdots \\ n_{N,1} & n_{N,2} \end{bmatrix}}_{\mathbf{N}} \quad (2)$$

where, dimension of \mathbf{Y} and \mathbf{N} are both $N \times 2$. \mathbf{N} represents the complex Gauss noise matrix with zero mean and variance of σ^2 . \mathbf{H}_k , with dimension $N \times 4$, represents the channel fading coefficient from user k to the base station. The dimension of $\mathbf{x}_{k,1}$ and $\mathbf{x}_{k,2}$ are both 4×1 . The μ_k -th and ν_k -th elements of $\mathbf{x}_{k,1}$ are $x'_{k,1}$ and $x'_{k,2}$, respectively. The μ_k -th element and ν_k -th element of $\mathbf{x}_{k,2}$ are $x'_{k,1}$ and $x'_{k,2}$, respectively. The other elements of $\mathbf{x}_{k,1}$ and $\mathbf{x}_{k,2}$ are zeros.

3. Detection

The detection at the base station can be divided into two steps. Firstly, the serial number of the transmit antennas at each user is estimated at the base station according to the received signals and the channel state information (CSI). Then, each codeword is separated and each element of the codeword is estimated using iterative method at the base station.

Use \mathbf{y}'_1 to represent the first column of \mathbf{Y} . Let $\mathbf{g} = \text{pinv}(\mathbf{H}) \mathbf{y}'_1$, which $\text{pinv}(\cdot)$ represents pseudo inverse. \mathbf{g} is a vector with a dimension of $4K \times 1$. Use $\bar{\mathbf{g}}_k$ to represent the vector with a dimension of 4×1 , which consists of the $4(k-1)+1$ -th element to $4k$ -th element of \mathbf{g} , $k = 1, 2, \dots, K$. According to the estimation method of transmitting antennas' number in (2) and [8], the serial number of the transmit antennas for user k obtained at the base station can be expressed as

$$(\mu_{k0}, \nu_{k0}) = \arg \max_{\substack{g_{\mu'_k}, g_{\nu'_k} \in \bar{\mathbf{g}}_k \\ \mu'_k \neq \nu'_k}} (\|g_{\mu'_k}\| + \|g_{\nu'_k}\|) \quad (3)$$

where, $\mu_{k0} \neq \nu_{k0} \in \{1, 2, 3, 4\}$, $g_{\mu'_k}$ and $g_{\nu'_k}$ represents the μ' -th and ν' -th element of $\bar{\mathbf{g}}_k$. $\|\cdot\|$ represents norm.

After the serial number of transmit antenna is estimated, the zero elements in (2) can be removed. Then, (2) can be equivalently expressed as

$$\mathbf{Y} = \mathbf{H}'_1 \mathbf{X}'_1 + \mathbf{H}'_2 \mathbf{X}'_2 + \dots + \mathbf{H}'_K \mathbf{X}'_K + \mathbf{N} \quad (4)$$

where, \mathbf{X}'_k represents a 2×2 matrix after removing the zero elements in \mathbf{X}_k , which is expressed as (1), $k=1,2,\dots,K$. \mathbf{H}'_k represents a $N \times 2$ matrix, which consists of μ_k -th column and ν_k -th column of \mathbf{H}_k .

Since \mathbf{X}'_k has Alamouti structure, (4) can be expressed as

$$\begin{bmatrix} y_1 \\ y_2 \\ \vdots \\ y_N \end{bmatrix} = \begin{bmatrix} \mathbf{H}_1^1 & \mathbf{H}_1^2 & \cdots & \mathbf{H}_1^K \\ \vdots & \vdots & \ddots & \vdots \\ \mathbf{H}_N^1 & \mathbf{H}_N^2 & \cdots & \mathbf{H}_N^K \end{bmatrix} \begin{bmatrix} s_1 \\ \vdots \\ s_K \end{bmatrix} + \begin{bmatrix} n_1 \\ n_2 \\ \vdots \\ n_N \end{bmatrix} \quad (5)$$

where $\mathbf{H}_i^k = \begin{bmatrix} h_{i,1}^k & h_{i,2}^k \\ h_{i,2}^{k*} & -h_{i,1}^{k*} \end{bmatrix}$, $\mathbf{n}_i = [n_{i,1} \quad n_{i,2}^*]^T$, $y_{i,j}$ represents the element of \mathbf{Y} in row i and column j , $j=1,2$. $(\cdot)^T$ represents the transpose.

According to the method of separating Alamouti codewords in [9] and [10], (5) can be decomposed into $\Lambda = \lfloor N/K \rfloor$ sub-equations, which $\lfloor \cdot \rfloor$ represents round down operation. Each sub-equation can be expressed as

$$\begin{aligned} \underbrace{\begin{bmatrix} y_1 \\ \vdots \\ y_K \end{bmatrix}}_{\mathbf{y}_1} &= \underbrace{\begin{bmatrix} \mathbf{H}_1^1 & \mathbf{H}_1^2 & \cdots & \mathbf{H}_1^K \\ \vdots & \vdots & \ddots & \vdots \\ \mathbf{H}_K^1 & \mathbf{H}_K^2 & \cdots & \mathbf{H}_K^K \end{bmatrix}}_{\mathbf{H}_1} \begin{bmatrix} s_1 \\ \vdots \\ s_K \end{bmatrix} + \underbrace{\begin{bmatrix} n_1 \\ \vdots \\ n_K \end{bmatrix}}_{\mathbf{n}_1} \\ &\vdots \\ \underbrace{\begin{bmatrix} y_{(\Lambda-1)K+1} \\ \vdots \\ y_{\Lambda K} \end{bmatrix}}_{\mathbf{y}_\Lambda} &= \underbrace{\begin{bmatrix} \mathbf{H}_{(\Lambda-1)K+1}^1 & \mathbf{H}_{(\Lambda-1)K+1}^2 & \cdots & \mathbf{H}_{(\Lambda-1)K+1}^K \\ \vdots & \vdots & \ddots & \vdots \\ \mathbf{H}_{\Lambda K}^1 & \mathbf{H}_{\Lambda K}^2 & \cdots & \mathbf{H}_{\Lambda K}^K \end{bmatrix}}_{\mathbf{H}_\Lambda} \begin{bmatrix} s_1 \\ \vdots \\ s_K \end{bmatrix} + \underbrace{\begin{bmatrix} n_{(\Lambda-1)K+1} \\ \vdots \\ n_{\Lambda K} \end{bmatrix}}_{\mathbf{n}_\Lambda} \end{aligned} \quad (6)$$

Let

$$\begin{aligned} \mathbf{G}_{\ell,j}(l) &= \begin{bmatrix} \mathbf{I}_2 & \mathbf{F}_{\ell,j}^H(l) \end{bmatrix}^H \\ &= \begin{bmatrix} \mathbf{I}_2 & -\frac{\overline{\mathbf{H}}_{\ell,j}^{K-l+1}(l-1) \overline{\mathbf{H}}_{\ell,K-l+1}^{K-l+1}(l-1)}{\underbrace{\|\overline{\mathbf{H}}_{\ell,K-l+1}^{K-l+1}(l-1)\|^2}_{\mathbf{F}_{\ell,j}^H(l)}} \end{bmatrix}, \\ &l \in \{1, \dots, K-1\}, \quad j \in \{1, \dots, K-l \mid l\} \end{aligned} \quad (7)$$

where, $(\cdot)^H$ represents conjugate transpose, \mathbf{I}_2 represents a unit matrix with a dimension of 2×2 . From (4)-(8) in [10], codewords can be separated gradually by $(K-1)$ times iteration. The matrix, vector and element with subscript ℓ belong to the ℓ -th sub-equation after decomposition, $\ell=1,\dots,\Lambda$.

From (25) in [10], we can find that, the ℓ -th sub-formula from (6) can be expressed as (8) after $(K-1)$ times iterative,

$$\hat{\mathbf{G}}_\ell^H \mathbf{y}_\ell = \hat{\mathbf{G}}_\ell^H \begin{bmatrix} \mathbf{H}_{(\ell-1)K+1}^1 \\ \vdots \\ \mathbf{H}_{\ell K}^1 \end{bmatrix} s_1 + \hat{\mathbf{G}}_\ell^H \mathbf{n}_\ell = \hat{\mathbf{G}}_\ell^H \underbrace{\begin{bmatrix} \overline{h}_{\ell,1} & \overline{h}_{\ell,2} \end{bmatrix}}_{\mathbf{H}_\ell} s_1 + \hat{\mathbf{G}}_\ell^H \mathbf{n}_\ell \quad (8)$$

$$\text{where, } \hat{\mathbf{G}}_\ell = \begin{bmatrix} \mathbf{A}_{\ell,1} \\ \mathbf{A}_{\ell,2} \\ \mathbf{A}_{\ell,3} \\ \vdots \\ \mathbf{A}_{\ell,K} \end{bmatrix} = \begin{bmatrix} \mathbf{I}_2 \\ \mathbf{F}_{\ell,1}(K-1) \\ \mathbf{F}_{\ell,1}(K-2) + \varphi_\ell^{(1)}(\mathbf{A}_{\ell,2})\mathbf{F}_{\ell,1}(K-1) \\ \vdots \\ \sum_{l=1}^{K-1} \varphi_\ell^{(K-l)}(\mathbf{A}_{\ell,l})\mathbf{F}_{\ell,1}(l) \end{bmatrix}, \varphi_\ell^{(n)}(\mathbf{A}_{\ell,k})$$

represents a function replace all of $\mathbf{F}_{\ell,\psi}(l)$ in $\mathbf{A}_{\ell,k}$ to $\mathbf{F}_{\ell,\psi+n}(l-n)$, $n \in \{1, \dots, K-1\}$, $\psi \in \{1, \dots, K-1\}$. $\varphi_\ell^{(n)}(\mathbf{I}_2) = \mathbf{I}_2$, $\mathbf{A}_{\ell,k}$ is a matrix with dimension 2×2 , $\bar{\mathbf{h}}_{\ell,1}$ and $\bar{\mathbf{h}}_{\ell,2}$ represent the 1-*th* column and 2-*th* column of $\left[(\mathbf{H}_{(\ell-1)K+1}^1)^H \quad (\mathbf{H}_{(\ell-1)K+2}^1)^H \quad \dots \quad (\mathbf{H}_{\ell K}^1)^H \right]^H$ respectively.

$$\text{Let } \tilde{\mathbf{H}}_\ell = \hat{\mathbf{G}}_\ell^H \begin{bmatrix} \bar{\mathbf{h}}_{\ell,1} & \bar{\mathbf{h}}_{\ell,2} \end{bmatrix}, \text{ and multiply both sides of (8) by } \tilde{\mathbf{H}}_\ell^H \text{ to get} \quad (9)$$

$$\tilde{\mathbf{H}}_\ell^H \hat{\mathbf{G}}_\ell^H \bar{\mathbf{y}}_\ell = \tilde{\mathbf{H}}_\ell^H \tilde{\mathbf{H}}_\ell \mathbf{s}_1 + \tilde{\mathbf{H}}_\ell^H \hat{\mathbf{G}}_\ell^H \bar{\mathbf{n}}_\ell$$

Since the matrix with Alamouti structure is closed for addition, multiplication, and conjugate transpose operations, $\tilde{\mathbf{H}}_\ell$ has Alamouti structure, which result in $\tilde{\mathbf{H}}_\ell^H \tilde{\mathbf{H}}_\ell = (\bar{\mathbf{h}}_{1,1}^H \hat{\mathbf{G}}_1 \hat{\mathbf{G}}_1^H \bar{\mathbf{h}}_{1,1} + \dots + \bar{\mathbf{h}}_{\Lambda,1}^H \hat{\mathbf{G}}_\Lambda \hat{\mathbf{G}}_\Lambda^H \bar{\mathbf{h}}_{\Lambda,1}) \mathbf{I}_2$. Use \tilde{r}_1 to represent the first element of $\tilde{\mathbf{H}}_\ell^H \hat{\mathbf{G}}_\ell^H \bar{\mathbf{y}}_\ell$, then (10) can be obtained by (6)-(9).

$$\begin{aligned} \tilde{r}_1 &= (\bar{\mathbf{h}}_{1,1}^H \hat{\mathbf{G}}_1 \hat{\mathbf{G}}_1^H \bar{\mathbf{h}}_{1,1} + \dots + \bar{\mathbf{h}}_{\Lambda,1}^H \hat{\mathbf{G}}_\Lambda \hat{\mathbf{G}}_\Lambda^H \bar{\mathbf{h}}_{\Lambda,1}) x'_{1,1} \\ &\quad + (\bar{\mathbf{h}}_{1,1}^H \hat{\mathbf{G}}_1 \hat{\mathbf{G}}_1^H \bar{\mathbf{n}}_1 + \dots + \bar{\mathbf{h}}_{\Lambda,1}^H \hat{\mathbf{G}}_\Lambda \hat{\mathbf{G}}_\Lambda^H \bar{\mathbf{n}}_\Lambda) \end{aligned} \quad (10)$$

The base station can get $x'_{1,1}$ from \tilde{r}_1 directly. The detection of the other modulation symbols is similar. Since \mathbf{X}'_k has Alamouti structure and each codeword consists of two modulation symbols, the complexity of ML decoding is proportional to the square of the modulation order.

4. Bit Error Rate Analysis

Let P_{e1} and P_{e2} represents the error probability of estimating the number of transmit antennas and the symbol error rate (SER) of the second step. Then the SER of the system can be expressed as

$$P_e = 1 - (1 - P_{e1})(1 - P_{e2}) \quad (11)$$

We deduce P_{e2} firstly. Assume the mathematical expectation of the modulation signal is P_1 . The signal-noise ratio (SNR) during the process of decoding $x'_{1,1}$, denoted by ρ , can be obtained from (10).

$$\rho = \frac{P_1 \left(\bar{\mathbf{h}}_{1,1}^H \hat{\mathbf{G}}_1 \hat{\mathbf{G}}_1^H \bar{\mathbf{h}}_{1,1} \right)^2 + \dots + \left(\bar{\mathbf{h}}_{\Lambda,1}^H \hat{\mathbf{G}}_\Lambda \hat{\mathbf{G}}_\Lambda^H \bar{\mathbf{h}}_{\Lambda,1} \right)^2}{\sigma^2 \bar{\mathbf{h}}_{1,1}^H \hat{\mathbf{G}}_1 \hat{\mathbf{G}}_1^H \hat{\mathbf{G}}_1 \hat{\mathbf{G}}_1^H \bar{\mathbf{h}}_{1,1} + \dots + \bar{\mathbf{h}}_{\Lambda,1}^H \hat{\mathbf{G}}_\Lambda \hat{\mathbf{G}}_\Lambda^H \hat{\mathbf{G}}_\Lambda \hat{\mathbf{G}}_\Lambda^H \bar{\mathbf{h}}_{\Lambda,1}} \quad (12)$$

According to the estimation method of SER in [10] and [11], the probability of estimating $x'_{1,1}$ as $\hat{x}'_{1,1}$, denoted by P_{e2} , can be expressed as

$$\begin{aligned} P_{e2} &= P(x'_{1,1} \rightarrow \hat{x}'_{1,1}) = \mathbb{E} \left[Q \left(\sqrt{\frac{|x'_{1,1} - \hat{x}'_{1,1}|^2 \rho}{2}} \right) \right] \\ &\leq \mathbb{E} \left[\frac{1}{2} \exp \left(-\frac{|x'_{1,1} - \hat{x}'_{1,1}|^2 \rho}{4} \right) \right] \leq \frac{1}{2} \left| \mathbf{I}_2 + \frac{|x'_{1,1} - \hat{x}'_{1,1}|^2 \rho}{4} \right|^{-1} \leq \frac{1}{2} |x'_{1,1} - \hat{x}'_{1,1}| \left(\frac{1}{4} \rho \right)^{-2} = |x'_{1,1} - \hat{x}'_{1,1}| \rho^{-2} \end{aligned} \quad (13)$$

where, $\mathbb{E}(\cdot)$ represents mathematical expectation. The value of $|x'_{1,1} - \hat{x}'_{1,1}|$ depends on the modulation mode.

In what follows, we derive P_{e1} . According to the consistent bound method proposed by (12) in [12] and [13], P_{e1} satisfies the following equation

$$P_{e1} \leq \mathbb{E} \left[\sum_{\xi} N(\xi, \hat{\xi}) P(\mathbf{x}_0 \rightarrow \hat{\mathbf{x}}_0) \right] \leq \sum_{\xi=1}^4 \sum_{q=1}^M \sum_{\hat{\xi}=1}^4 \frac{N(\xi, \hat{\xi}) P(\mathbf{x}_0 \rightarrow \hat{\mathbf{x}}_0)}{4M} \quad (14)$$

where, M represents the modulation order, ξ represents the serial number of transmit antennas, $\hat{\xi}$ is the number of antennas estimated by the base station. \mathbf{x}_0 is the first column of \mathbf{X}_1 . $\hat{\mathbf{x}}_0$ is the decoding results obtained by decoding the first column of \mathbf{X}_1 . $N(\xi, \hat{\xi})$ represents the number of error bits between ξ and $\hat{\xi}$.

It is known from (18) in [12] and (5) in [14],

$$P(\mathbf{x}_0 \rightarrow \hat{\mathbf{x}}_0) = f(\alpha)^N \sum_{\beta=0}^{N-1} \binom{N-1+\beta}{\beta} (1-f(\alpha))^\beta \quad (15)$$

where, $f(\alpha) = \frac{1}{2} \left(1 - \sqrt{\frac{\alpha}{1+\alpha}} \right)$, $\alpha = \frac{1}{4\sigma^2} \sum_{\xi=1}^4 |x_\xi - \tilde{x}_\xi|^2$, x_ξ represent the ξ -th element of \mathbf{x}_0 , $\xi \in \{1, 2, 3, 4\}$. Substitute (15) into (14) to get

$$P_{e1} \leq \sum_{\xi=1}^4 \sum_{q=1}^M \sum_{\hat{\xi}=1}^4 \frac{N(\xi, \hat{\xi}) f(\alpha)^N \sum_{\beta=0}^{N-1} \binom{N-1+\beta}{\beta} (1-f(\alpha))^\beta}{4M} \quad (16)$$

Take (13) and (16) into (11) to get the SER of the system, as shown in (17).

$$P_e \leq 1 - \left(1 - \sum_{\xi=1}^4 \sum_{q=1}^M \sum_{\hat{\xi}=1}^4 \frac{N(\xi, \hat{\xi}) f(\alpha)^N \sum_{\beta=0}^{N-1} \binom{N-1+\beta}{\beta} (1-f(\alpha))^\beta}{4M} \right) \left(1 - |x'_{1,1} - \hat{x}'_{1,1}| \rho^{-2} \right) \quad (17)$$

5. Simulation Results and Analysis

This chapter simulates the reliability of the proposed scheme and the reliability of [6]. Assume the channel follows the Rayleigh distribution and the noise is Gaussian white noise. There are 16 users using 4QAM modulation without channel coding.

The error probability P_{e1} of estimating the transmit antenna number when the base station is equipped with 64 antennas is shown in **Figure 2**. Simulation results show that when the SNR is 22dB, the error probability is about 10^{-3} . Since the number of transmit antennas and the transmitted symbols are estimated simultaneously in [6], P_{e1} can't be obtained. So the error probability by estimating the transmit antenna number in [6] is not shown in **Figure 2**. It can be seen that when $N = 128$, the P_{e1} is 0 while $\text{SNR} \geq 0$. The reason is that the more the number of receiving antennas, the more accurate of the judgment.

Therefore, the error probability of the estimate of transmit antenna number is not plot in **Figure 2** when $N = 128$.

The SER curves of the proposed scheme and the scheme in [6] with 64 antennas and 128 antennas is shown in **Figure 3** and **Figure 4** respectively. Simulation results show that when $N = 64$, the reliability of the proposed scheme is lower than [6], when $N = 128$, the reliability of the proposed scheme is better than [6]. That is because when $N = 64$ the P_{e1} of the proposed scheme is higher, but when $N = 128$ the P_{e1} of the proposed scheme is zero. From **Figure 4**, the gain of the proposed scheme is about 2.5 dB at the SER of 10^{-3} compared with the MP-GSM scheme, the gain is about 2.7 dB compared with the CHEMP-GSM scheme, and the gain is about 2.9 dB compared with the ML scheme.

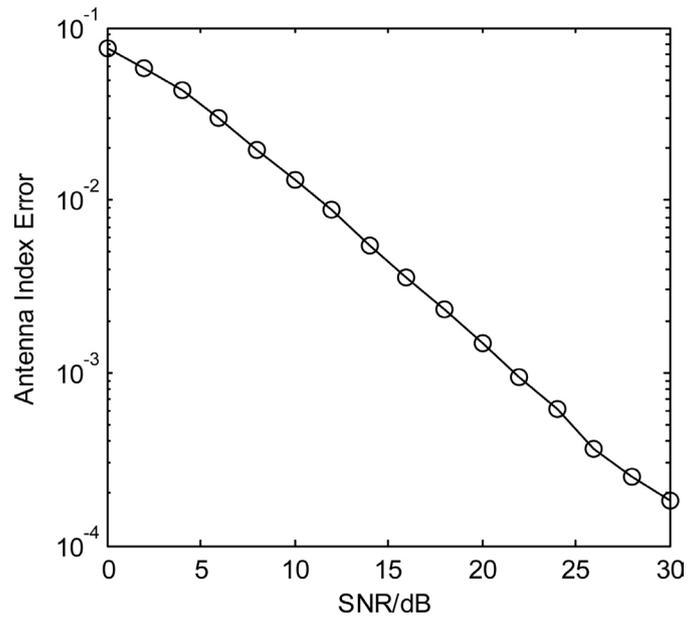


Figure 2. The error probability of estimating the transmit antenna with $N = 64$.

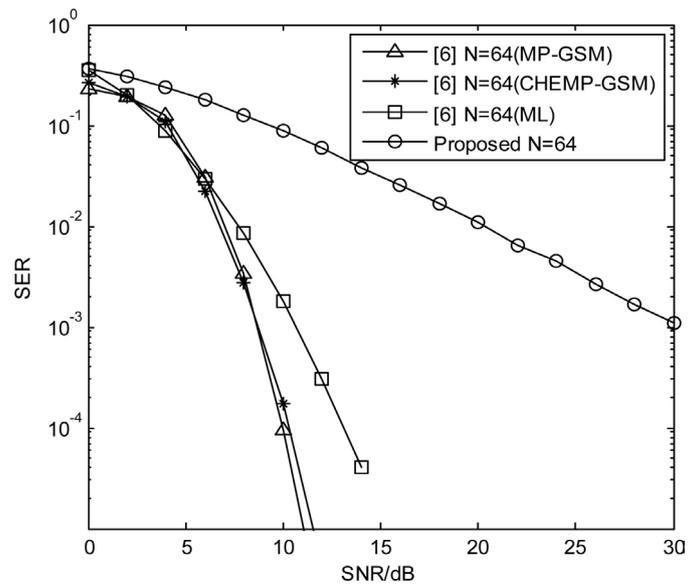


Figure 3. SER curves with $N = 64$.

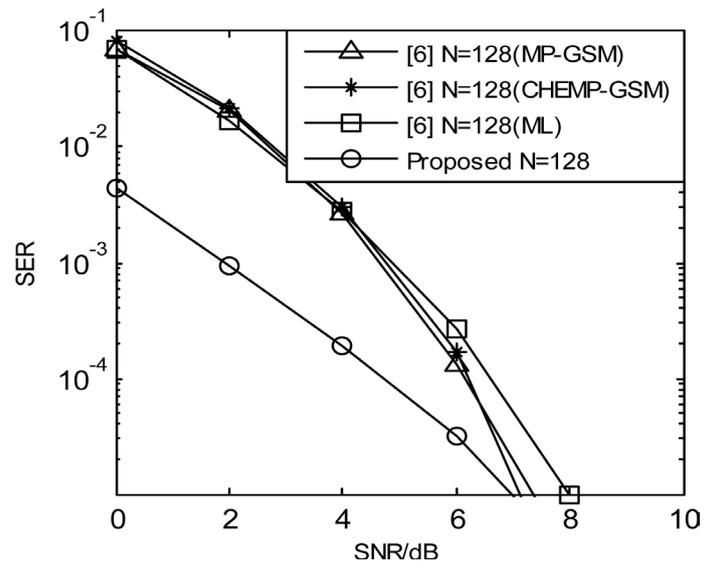


Figure 4. SER curves with $N = 128$.

6. Conclusion

Compared with the existing scheme, each user adopts rate-2 space-time code. The transmission efficiency is the same as the existing scheme. The proposed scheme uses the orthogonal characteristics of the equivalent channel matrix corresponding to the Alamouti codeword to gradually separate each codeword, and then decodes each symbol of the codewords. The decoding complexity is greatly reduced. However, the reliability of the proposed scheme is greatly dependent on the estimated of the transmission antenna. How to reduce the dependency of the reliability of the system on the estimated transmit antenna number requires further study.

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