Journal of Signal and Information Processing, 2016, 7, 34-38
Published Online February 2016 in SciRes. http://www.scirp.org/journal/jsip
http://dx.doi.org/10.4236/jsip.2016.71005

A New Scheme to Construct Orthogonal Channel Matrix for MIMO STBC by Givens Rotation

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Received 3 July 2015; accepted 23 February 2016; published 26 February 2016

Abstract

This paper proposes a scheme to construct orthogonal channel matrix for full rate quasi-orthogonal STBC based on givens rotation with lower bit error rate. The transmission diversity method rotates every single information symbol. The scheme can suppress channel noise and eliminate the interference term well. Simulation results show that the method can improve performance better than conventional algorithm without increasing decoding complexity.

Keywords

QO-STBC, MIMO, Givens Rotation

1. Introduction

Because of its efficient maximum likelihood decoding, MIMO (Multiple-Input Multiple-Output) system has been received the significant amount of attention. In 1998, Alamouti proposed orthogonal STBC applied on two transmitting antennae firstly which is usually regarded as the OSTBC with full diversity and full transmission rate and has been used in mobile communication system [1]. More antennas can get more diversity gain. But it has been proved that full diversity and full rate complex design exists only for two transmit antennas. Due to this drawback, various linear quasi-orthogonal STBCs have been proposed to achieve a full rate (R = 1) for more than 2 transmit antennas at the expense of loosing the diversity gain and increasing the decoding complexity.

2. Background

For O-STBC with N transmitting antennas, coding matrix S has following equation:

How to cite this paper: Zhang, H.M., Xian, K.Y., Feng, L.J. and Hu, C.K. (2016) A New Scheme to Construct Orthogonal Channel Matrix for MIMO STBC by Givens Rotation. *Journal of Signal and Information Processing*, **7**, 34-38.
http://dx.doi.org/10.4236/jsip.2016.71005

$$S^H S = \left(\sum_{k=1}^{K} |s_k|^2 \right) I_N \tag{1}$$

where S^H is conjugate transpose of S, $s_1, s_2, \cdots, s_k, \cdots, s_K$ are transmitting symbols, I_N is identity matrix with order N. And up to now, (2), (3) and (4) are orthogonal STBC be found with rate 1, 3/4, 3/4 respectively, as following Equations (2)-(4) [2]:

$$S_1 = \begin{bmatrix} s_1 & s_2 \\ -s_2^* & s_1^* \end{bmatrix} \tag{2}$$

$$S_2 = \begin{bmatrix} s_1 & s_2 & s_3 \\ -s_2^* & s_1^* & 0 \\ s_3^* & 0 & -s_1^* \\ 0 & s_3^* & -s_2^* \end{bmatrix} \tag{3}$$

$$S_3 = \begin{bmatrix} s_1 & s_2 & s_3 & 0 \\ -s_2^* & s_1^* & 0 & s_3 \\ s_3^* & 0 & -s_1^* & s_2 \\ 0 & s_3^* & -s_2^* & -s_1^* \end{bmatrix} \tag{4}$$

And for QO-STBC, proposed by Jafarkhani [3], has following signal matrix:

$$S = \begin{bmatrix} s_1 & s_2 & s_3 & s_4 \\ -s_2^* & s_1^* & -s_4^* & s_3^* \\ -s_3^* & -s_4^* & s_1^* & s_2^* \\ s_4 & -s_3 & -s_2 & s_1 \end{bmatrix} \tag{5}$$

S is an orthogonal matrix, it has the following feature:

$$S^H S = \begin{bmatrix} \alpha & 0 & 0 & \beta \\ 0 & \alpha & -\beta & 0 \\ 0 & -\beta & \alpha & 0 \\ \beta & 0 & 0 & \alpha \end{bmatrix} \tag{6}$$

where, α represents channel gain for the four transmit antennas, and β represents interference terms from neighboring signals.

$$\alpha = \sum_{i=1}^{4} |s_i|^2 I \tag{7}$$

$$\beta = 2\operatorname{Re}\left(s_1 s_4^* - s_2 s_3^* \right) \tag{8}$$

So S is a quasi-orthogonal matrix. And it is well known that the presence of the channel dependent interference can cause the performance degradation in contrast to the optimal orthogonal design.

3. Constructing Orthogonal Channel Matrix by Givens Rotation

For a MIMO system, the received signal r is expressed as:

$$r = Ch + n \tag{9}$$

where C represents signal matrix and n is noise, the equivalent equation $\tilde{r}$ of r is given by

$$\tilde{r} = Hs + \tilde{n} \tag{10}$$

When C is chose suitably [4], H can satisfy the following format:

$$(H)^H H = \Delta \tag{11}$$

Δ is a diagonal matrix, so estimated value of s at the receiver is given by

$$\hat{s} = H^H \tilde{r} = H^H Hs + H^H \tilde{n} = \Delta s + H^H \tilde{n} \tag{12}$$

Considering a flat fading channel over four time slots with 4 transmit antennas and 1 receive antenna, the channel gain is denoted by $[h_1, h_2, h_3, h_4]$, its channel matrix is as follows after calculated through Givens rotation [4]-[6]:

$$H_{41} = \begin{bmatrix} h_1 - h_3 & h_2 - h_4 & h_1 + h_3 & h_2 + h_4 \\ h_2^* - h_4^* & -h_1^* + h_3^* & h_2^* + h_4^* & -h_1^* + h_3^* \\ h_3 - h_1 & h_4 - h_2 & h_1 + h_2 & h_2 + h_4 \\ h_4^* - h_2^* & h_1^* - h_3^* & h_2^* + h_4^* & -h_3^* - h_1^* \end{bmatrix} \tag{13}$$

The symbol matrix S_{41} corresponding to H_{41} is expressed as:

$$S_{41} = \begin{bmatrix} s_1 + s_3 & s_2 + s_4 & s_1 - s_3 & s_4 - s_2 \\ -s_2^* - s_4^* & s_1^* + s_3^* & s_2^* - s_4^* & s_3^* - s_1^* \\ s_3 - s_1 & s_4 - s_2 & s_1 + s_3 & s_2 + s_4 \\ s_2^* - s_4^* & s_3^* - s_1^* & -s_3^* - s_4^* & s_1^* + s_3^* \end{bmatrix} \tag{14}$$

So, although the new coding matrix S_{41} is quasi-orthogonal, H_{41} is an orthogonal matrix, linear decoding can be used to reduce decoding complexity (12) [7]. For an improved QO-STBC system based on givens rotation, we choose constant a_i as follow:

$$a_i = r_i \mathrm{e}^{j\theta_i} \ (i = 1, 2, 3, 4) \tag{15}$$

$$S = \begin{bmatrix} a_1 s_1 & a_2 s_2 & a_3 s_3 & a_4 s_4 \\ -a_2^* s_2^* & a_1^* s_1^* & -a_4^* s_4^* & a_3^* s_3^* \\ a_3 s_3 & a_4 s_4 & a_1 s_1 & a_2 s_2 \\ -a_4^* s_4^* & a_3^* s_3^* & -a_2^* s_2^* & a_1^* s_1^* \end{bmatrix} \tag{16}$$

The encoding matrix after rotation is described as:

$$S = \begin{bmatrix} a_1 s_1 + a_3 s_3 & a_2 s_2 + a_4 s_4 & a_1 s_1 - a_3 s_3 & a_4 s_4 - a_2 s_2 \\ -a_2^* s_2^* - a_4^* s_4^* & a_1^* s_1^* + a_3^* s_3^* & a_2^* s_2^* - a_4^* s_4^* & a_3^* s_3^* - a_1^* s_1^* \\ a_3 s_3 - a_1 s_1 & a_4 s_4 - a_2 s_2 & a_1 s_1 + a_3 s_3 & a_2 s_2 + a_4 s_4 \\ a_2^* s_2^* - a_4^* s_4^* & a_3^* s_3^* - a_1^* s_1^* & -a_2^* s_2^* - a_4^* s_4^* & a_1^* s_1^* + a_3^* s_3^* \end{bmatrix} \tag{17}$$

Especially, when $a_1 = 1, a_2 = \mathrm{e}^{j\frac{\pi}{4}}, a_3 = 1, a_4 = \mathrm{e}^{j\frac{\pi}{4}}$ as a list,

$$S = \begin{bmatrix} s_1 + s_3 & s_2 \mathrm{e}^{j\frac{\pi}{4}} + s_4 \mathrm{e}^{j\frac{\pi}{4}} & s_1 - s_3 & s_4 \mathrm{e}^{j\frac{\pi}{4}} - s_2 \mathrm{e}^{j\frac{\pi}{4}} \\ -s_2^* \mathrm{e}^{-j\frac{\pi}{4}} - s_4^* \mathrm{e}^{-j\frac{\pi}{4}} & s_1^* + s_3^* & s_2^* \mathrm{e}^{-j\frac{\pi}{4}} - s_4^* \mathrm{e}^{-j\frac{\pi}{4}} & s_3^* - s_1^* \\ s_3 - s_1 & s_4 \mathrm{e}^{j\frac{\pi}{4}} - s_2 \mathrm{e}^{j\frac{\pi}{4}} & s_1 + s_3 & s_2 \mathrm{e}^{j\frac{\pi}{4}} + s_4 \mathrm{e}^{j\frac{\pi}{4}} \\ s_2^* \mathrm{e}^{-j\frac{\pi}{4}} - s_4^* \mathrm{e}^{-j\frac{\pi}{4}} & s_3^* - s_1^* & -s_2^* \mathrm{e}^{-j\frac{\pi}{4}} - s_4^* \mathrm{e}^{-j\frac{\pi}{4}} & s_1^* + s_3^* \end{bmatrix} \tag{18}$$

If we define D as the estimating error, $D = S - \hat{S}$, then:

$$E = D^H D = \begin{bmatrix} 2(\Delta\alpha - \Delta\beta)^2 & 0 & 0 & 0 \\ 0 & 2(\Delta\alpha - \Delta\beta)^2 & 0 & 0 \\ 0 & 0 & 2(\Delta\alpha - \Delta\beta)^2 & 0 \\ 0 & 0 & 0 & 2(\Delta\alpha - \Delta\beta)^2 \end{bmatrix} \tag{19}$$

Here, $\Delta\alpha = |\Delta s_1|^2 + |\Delta s_2|^2 + |\Delta s_3|^2 + |\Delta s_4|^2$, $\Delta\beta = 2\,\mathrm{Re}\left(\Delta s_1 \Delta s_4^* \mathrm{e}^{-j\frac{\pi}{4}} - \Delta s_2 \Delta s_3^* \mathrm{e}^{-j\frac{\pi}{4}}\right)$, $\Delta s_i = s_i - \hat{s}_i$, E is a full rank matrix. So S gets coding gain.

4. Simulation Results and Performance Analysis

In this section, we make simulation for ABBA scheme, Jafarkhani scheme [8] and the new code by **Figure 1** as following.

Figure 2 shows the BER performance of the three schemes. It can be seen that the new scheme has better performance.

5. Conclusion

Maximum transmit rate and diversity gain can be improved by givens rotation to non-orthogonal channel correlation of STBC. And also linear decoding complexity can be decreased at receive terminal. Transposition of

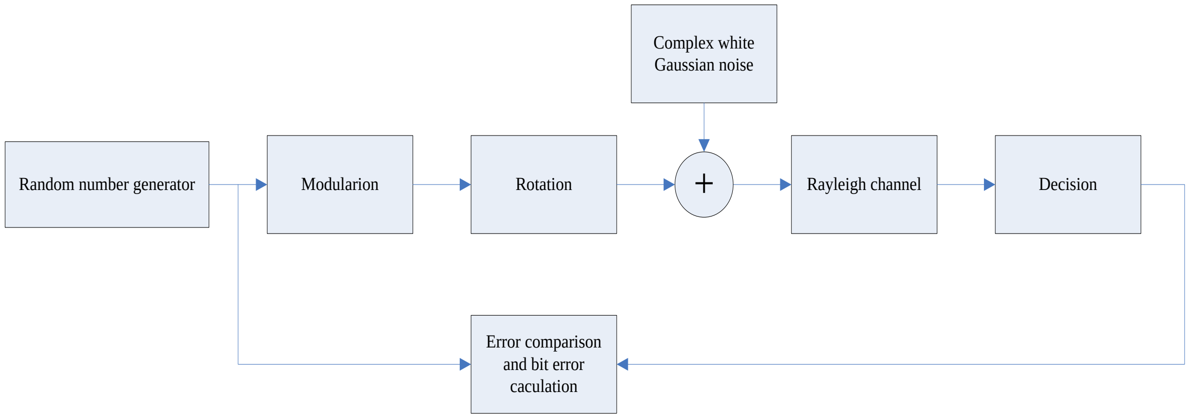

Figure 1. Simulation block diagram of QO-STBC.

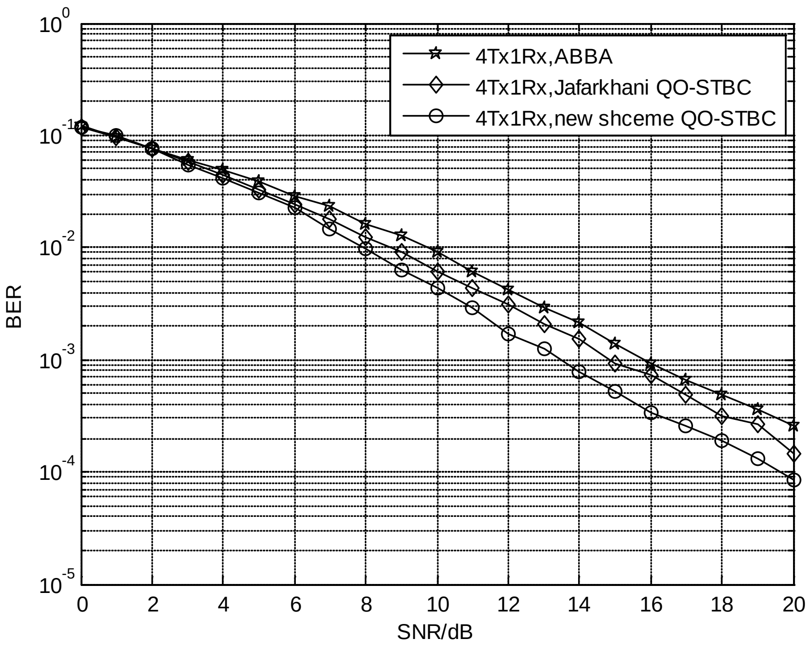

Figure 2. BER versus SNR of three QO-STBC schemes.

channel matrix and Givens rotation are applied to eliminate part of interference terms and achieve a triangular matrix.

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