2,4개 전송 안테나를 위한 완전 다이버시티 고 부호율 STBC

Full-Diversity High-Rate STBC for 2 and 4 TransmittedAntennas

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*Abstract*We design a new rate-3/2 full-diversity orthogonal space-time block code (STBC) for QPSK and 2 transmit antennas (TX) and 4 transmit antennas (TX) by enlarging the signalling set from the set of quaternions used in the Alamouti[1] and extendedcode and using additional members of the set of orthogonal matrices or Quasi-orthogonal matrices and higher than rate-5/4. Selective power scaling of information symbols is used to guarantee full-diversity while maximizing the coding gain (CG) and minimizing the transmitted signal peak-to-minimum power ratio (PMPR). The optimum power scaling factor is derived analytically and shown to outperform schemes based only on constellation rotation while still enjoying a low-complexity maximum likelihood (ML) decoding algorithm.

Keywords :full-diversity, high-rate, STBC

I. INTRODUCTION

Our objective in this paper is to design a new class of full-diversity high-rate (> 1) space-time block codes (STBC) by exploiting the inherent algebraic structure in existing orthogonal designs based on quaternions for 2 transmit antennas[1] and quasi-orthogonal designs for 4 transmit antennas [2].The simplest example of a complex orthogonal design is the 2×2 code

$$G=\begin{bmatrix} x_1 & x_2 \\ -x_2^* & x_1^* \end{bmatrix} \qquad G_i=U_iG$$

discovered by Alamouti [1] where $(.)^*$ denotes the complex conjugate transpose. This code achieves rate-1 at full diversity and enjoys low-complexity ML decoding using matched filtering. Consider the set of x given by 2×2 orthogonal matrices.While we can choose others G_i space-time trellis codes proposed in this paper which multiplied by the unitary matrix U_i to keep the matrix G_i full diversity property and extend the Alamouti scheme to a big size S which has full diversity for a STBC.

$$G_0(x_1,x_2,00)=\begin{bmatrix} x_1 & x_2 \\ -x_2^* & x_1^* \end{bmatrix}$$

$$G_1(x_1,x_2,01)=\begin{bmatrix} -x_1 & -x_2 \\ -x_2^* & x_1^* \end{bmatrix}$$

$$G_2(x_1,x_2,10)=\begin{bmatrix} x_1 & x_2 \\ x_2^* & -x_1^* \end{bmatrix}$$

$$G_3(x_1,x_2,11)=\begin{bmatrix} -x_1 & -x_2 \\ x_2^* & -x_1^* \end{bmatrix}$$

We will use the expanded set S to construct new high-rate (> 1) full diversity space-time block code with low complexity decoding and optimized available coding gain.

2.PROPOSEDCODEFOR2TX

A.Transmission Scheme: The columns of G represent different antennas, the rows represent different time slots, and

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the entries are the two symbols to be transmitted assuming a quasi-static flat-fading channel. Our code construction is applicable to any M-PSK constellation. However, to simplify the presentation, we will focus on *QPSK* modulation. In our proposed scheme, the transmitted space-time signaling matrix is selected from either G_0 or G_1, G_2, G_3 according to an additional information bit of 00 or 01,10,11 respectively (Fig.1). Hence, the proposed scheme achieves a 50% information rate increase compared to the traditional Alamouti scheme for *QPSK* modulation without requiring any additional system resources (power or bandwidth).

B. Code Design Criteria: Consider two distinct codewords $S_i, S_j \in S$. In order to ensure full spatial diversity, the codeword difference matrix $B = (S_i - S_j)$ between any two distinct codewords in the extended set S must have full rank [4]. When both codewords S_i and S_j belong to G_i or G_j, B will be full rank.However if $S_i \in G_i$ and $S_j \in G_{j\neq i}$ (or vice versa), B loses rank. To restore full-diversity, schemes based on rotations of information symbols have been proposed (see *e.g.* [3], [7]). In this paper, we propose to divide the information symbols in $G_{j\neq i}$ only by a real scalar $K(>1)$ to guarantee full-diversity, hence the name selective power scaling. For a unit-radius QPSK constellation, this scaling results in an overall signal constellation consisting of two concentric circles of radius 1 and $1/k$.

C. Finding the Optimum Power Scaling Factor: The main objective of introducing the power scaling factor K is to ensure full diversity for the proposed high-rate STBC.Since $K > 1$, the average transmitted power is even reduced compared to the case of no scaling. Two important selection criteria for K are maximizing the CG and minimizing the PMPR resulting from power scaling. If the QPSK symbols on the outer constellation circle are normalized to unity, and the radius of the inner circle is 1/K , the PMPR equals K^2.In addition, CG is defined as the minimum product of the nonzero singular values of B over all distinct codeword pairs. We propose to select K by optimizing the cost function:

$$K_{opt} = \arg\max_{K>1} \frac{CG}{PMPR}$$

$$= \arg\max_{K>1} \frac{\min_{S_i \in G_i, S_j \in G_j, S_i \neq S_j} \det(BB^*)}{k^2}$$

The two codewords have the form

$$S_i = \begin{bmatrix} x_1 & x_2 \\ -x_2^* & x_1^* \end{bmatrix}, \quad S_j = \begin{bmatrix} y_1/k & y_2/k \\ -(y_2/k)^* & (y_1/k)^* \end{bmatrix}$$

Hence, $\det(BB^*) = \det(B)\det(B^*)$

$$= \frac{\left|(1-k^2)^2 + K^2\left[\mathrm{Re}(x_1 y_1^* + x_2 y_2^*\right]^2\right|}{K^4}$$

There exists specific choices of $\{x\}$ and $\{y\}$ (*e.g.* when $x_1 = y_1$ and $x_2 = -y_2$) that result in $x_1 y_1^* + x_2 y_2^* = 0$ and these choices set the minimum value of $\det(BB^*)$ with respect to $\{x\}$ and $\{y\}$ and irrespective of K. Therefore, we can write

$$K_{opt} = \arg\max_{K>1} \frac{\left[1-K^2\right]}{K^3}$$

Then we can use the first and second derivative test for this formula

$$K'_{opt} = \frac{-2k^4 - 3K^2(1-k^2)}{K^6} = 0 \Rightarrow k^2 = 3$$

$$K''_{opt} < 0 \Rightarrow K_{opt} = \sqrt{3}$$

Similarly, for any M-PSK constellation, the value of K can be optimized offline as a function of M and the achievablerate in this case is $1 + 1/1 + \log_2 M$.

D. Low-Complexity Decoding

The output symbols r_1, r_2 received over two consecutive symbol periods can be represented as follows:

$$r_i = HS_i + Z_i, \quad r_j = HS_j + Z_j, \quad H = \begin{bmatrix} h_1 & h_2 \\ -h_2^* & h_1^* \end{bmatrix}$$

where r_i and r_j are 2×2 complex matrix representations of the received signals corresponding to transmitted codewords in the form of G_i and $G_{j\neq i}$, respectively. The *path gains* from the two transmit antennas to the mobile are *h*1, *h*2, and the noise samples z_1, z_2 are independent samples of a zero-mean complex Gaussian random variable. The channel matrix H is a quaternion and we have $HH^* = (|h_1|^2 + |h_2|^2)I_2$. Two simple matched-filtering operations, H^*G_i and $H^*G_{i\neq j}$ are performed to generate two candidate solutions, namely, $\hat{S}_i$ and $\hat{S}_{j\neq i}$ which are then compared using the metric $\|[r_1 \quad r_2] - [h_1 \quad h_2]S\|^2$. The decoding of $b0$ follows directly once the decision between S_i or $S_{j\neq i}$ is made.

3.Extensionto4TX

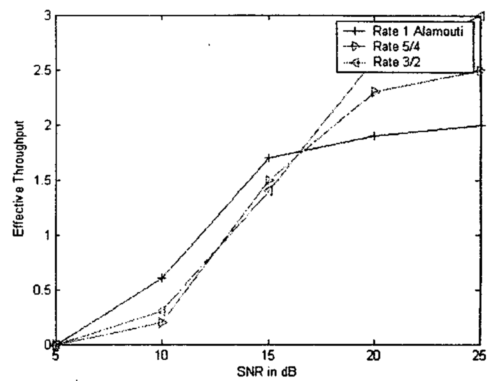
Consider the following example of a rate-1 full-diversity complex quasi-orthogonal design based on Quasi-orthogonal STTC proposed by Jafarkhani[5].In our proposition ,we extend the set of transmission signal matrices by multiplied a unitary matrix to the quasi-orthogonal matrix .The proposed matrices keep the same diversity with the original matrix.

$$G = \begin{bmatrix} x_1 & x_2 & x_3 & x_4 \\ -x_2^* & x_1^* & -x_4^* & x_3^* \\ -x_3^* & -x_4^* & x_1^* & x_2^* \\ x_4 & -x_3 & -x_2 & x_1 \end{bmatrix}$$

We expand the signaling set and increase the rate to 10/8 (for QPSK) by considering the follow-ing code multiplied by the unitary matrices set (U_0, U_1, U_2, U_3)

4.NUMERICALRESULTS

We assume QPSK modulation, a single antenna at the receiver, and coherent ML decoding. Figure 2 shows that the ratio *CG/PMPR* reaches its maximum at $k_{opt} = \sqrt{3}$ which corroborates our analysis in Section II-C. In Figure 3, we compare our proposed rate-3/2 code with the Alamouti [1] code using the measure of Effective Throughput η defined as $\eta = (1 - FER) * R \times \log_2 M$, where R is the code rate ,M is the constellation size, and *FER* denotes the frame error rate. This Figure shows that at high SNR (where FER $\approx$ 0), our code achieves a higher throughput level of 3 bits per channel use (PCU) whereas the achievable throughput for the Alamouti code is 2 bits PCU.We can switch between the Alamouti code and our proposed code to maximize throughput at all SNR levels .The power scaling factor K ensures full-diversity and high rate at the cost of reduced coding gain; the cross-over point is a function of K. Different values of K correspond to different tradeoffs between control over PMPR and reduction in coding gain. It is also possible to turn this coding loss into gain by introducing block codes for the fadingchannel as in [6]. For an overall rate of 1, this combination of coding techniques .



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