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Orthogonal Space-Time Block Code with Full Diversity and Rate for Four Transmit Antenna

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Abstract: we present a complex, full-rate orthogonal space-time block code for four transmit antennas. Using carefully tailored constellation phase rotations, we show that this code achieves full diversity for specialized PSK-based constellations. The optimal receiver for the new code decouples the symbol detection problem into pairs of symbols, thus greatly reducing complexity. Finally, we present and compare performance of the new code with several other codes in the literature. The new code is shown to perform as well as the best known code of its class.

Index Terms: Diversity, multiple antennas, phase rotation, orthogonal designs, space-time codes, wireless communications.

Ⅰ. Introduction

The Alamouti code [1], remarkable for having an elegant linear receiver, is now a paradigm in space-time block coding. Orthogonal designs [2] generalize Alamouti's scheme to use more antennas. Unfortunately, the Hurwitz-Radon theorem shows that complex orthogonal designs can not achieve full diversity and rate simultaneously for *all* symbol constellations, except in the two transmit antenna case [2]. Other codes show promise, including the STTD-OTD code [3], which is orthogonal but not full diversity, and constellation rotating codes [4], which achieve full rate and diversity but are not orthogonal.

In this work we use carefully tailored rotated PSK constellations to design a full rate, full diversity complex orthogonal space-time block code for 4 transmit antennas.

Ⅱ. The New Code

We assume the standard slow, flat Rayleigh fading channel model. The goal is to design $N_t = 4$ transmit antenna orthogonal space-time block code with *M*-PSK constellations.

The new code has the same form as the orthogonal STTD-OTD code [3] defined by,

$$S = \begin{bmatrix} s_1 & s_2 & s_3 & s_4 \\ -s_2^* & s_1^* & -s_4^* & s_3^* \\ s_1 & s_2 & -s_3 & -s_4 \\ -s_2^* & s_1^* & s_4^* & -s_3^* \end{bmatrix} = \begin{bmatrix} A & B \\ A & -B \end{bmatrix} \quad (1)$$

Where A and B are Alamouti blocks. The symbols of the data matrix S are redefined to be linear combinations of complex "base" symbols, *d*1, *d*2, *d*3, and *d*4. We use the following encoding scheme which normalizes the energy transmitted.

$$s_1 = \frac{d_1 + d_2}{\sqrt{2}}, \quad (2)$$

$$s_2 = \frac{d_3 + d_4}{\sqrt{2}}, \quad (3)$$

$$s_3 = \frac{d_1 - d_2}{\sqrt{2}}, \quad (4)$$

$$s_4 = \frac{d_3 - d_4}{\sqrt{2}}. \quad (5)$$

A measure of the quality of a square space-time code is the diversity product [5], $\zeta_v = \frac{1}{2}\min_{s_1 \neq s_2 \in v} \left|\det(s_1 - s_2)\right|^{\frac{1}{N_t}}$, where V is the set of all data matrices S. We observe that $0 \le \zeta_v \le 1$ and any square code with $\zeta_v > 0$ is said to achieve full diversity.

To find ζ_v for the new code, notice that $\det(s_1 - s_2) = 4\det(A_1 - A_2)\det(B_1 - B_2)$, where s_1 and s_2

are matrices of the same form as in (1) and Ai and Bi are Alamouti blocks. For full diversity we need $\det(A_1 - A_2) \neq 0$, or equivalently $d_1^1 - d_1^2 + d_2^1 - d_2^2 \neq 0$ and $d_3^1 - d_3^2 + d_4^1 - d_4^2 \neq 0$, where d_j^i is the j-th base symbol of Ai. A similar result follows from $\det(B_1 - B_2) \neq 0$. Note that rotating the M-PSK base constellations of d_2 and d_4 by (for example) $\frac{\pi}{M}$ with respect to d_1 and d_3 gives the code full diversity. Thus, the new code with modified M-PSK constellations is an orthogonal full diversity and full rate space-time code for 4 transmit antennas. At first, it appears the new code violates the Hurwitz-Radon theorem, which states that such orthogonal designs cannot exist for all possible symbol constellations. However, they do exist for *some* specific constellations.

Ⅲ. Performance

The symbol error rates (SER) for the new code with QPSK symbols and other comparable codes in known quasi-static fading are presented in Fig. 1. The plot shows the new code performance against a rate 1=2 STTD orthogonal design with 16-QAM [2] and a constellation rotating code with QPSK [4]. Performance of maximal ratio combining is also presented with SNR normalized by 6 dB (Nr = 4). The new code outperforms all other transmit diversity codes compared.

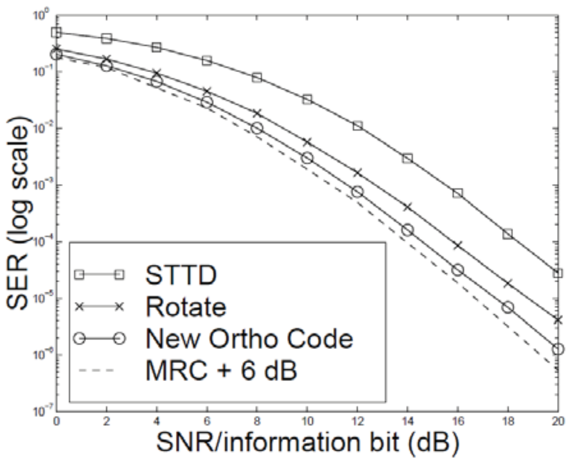

Figure 1: Comparison with other 4-transmit antenna codes at 2 bits/sec/Hz.

Ⅳ. Conclusion

We have introduced a new quasi-orthogonal code and have shown that it has a receiver with moderate complexity, which can decouple symbols into pairs. In general, the new code matrix does not always achieve full diversity, but with constellation phase rotations full diversity is easily attained. The new code with rotated QPSK constellations performs nearly identically to Papadias' improved quasi-orthogonal code at the same complexity. These codes have the best performance of all known codes in their class. An advantage of the new code is a highly symmetrical nature for easy analysis, while a disadvantage is the expanded transmitted constellation.

Ⅴ. References

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