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A New Approach to Joint Full-Rate STBC and Long-Code WCDMA for Four Transmit Antenna MIMO Systems

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Abstract

In this work, we propose a novel combination of an extended orthogonal space-time block code (EO-STBC) or a quasi-orthogonal space-time block code (QO-STBC) and a long-code wideband code division multiple access (WCDMA) scheme to exploit spatial diversity in future wireless communication systems. For a mobile communication system, a key parameter is the system capacity. Multiple antennas at the transmitter and receiver in a system have been recognized as a major technology breakthrough to increase the capacity of a wireless communication network. To mitigate this limited capacity problem, two full transmit rate STBCs are integrated into the long-code WCDMA system with four transmit antenna. The bit error rate (BER) performance for the proposed technique is compared with other conventional methods for quasi-static wireless channels. Simulation results show that the proposed full rate STBC scheme when combined with the receive antenna selection technique method yields improved BER performance schemes.

Keywords: EO-STBC, QO-STBC, subspace structure, diversity, full-rate, long-code WCDMA, quasi-static channel.

1. Introduction

Third-generation mobile radio networks, often dubbed as 3G, have been a subject of intense research and discussion recently and began to emerge around 2000[1]. Wideband Code Division Multiple Access (WCDMA) is an integral part of the 3G standard and its advancement. But there are still some problems which need to be improved, such as limited capacity. A number of methods to increase system capacity in a WCDMA system have been discussed in [3,4]. Transmit diversity, such as by exploiting a Space-Time Block Code (STBC), has been recognized as an available technology to increase the capacity in a wireless communication network. Alamouti first proposed a space-time (ST) code for two transmitter antennae and two symbol periods in [2], which demonstrated that ST technology can enhance

bandwidth efficiency. Recently, many works have appeared on signal processing and modulation techniques for transmit diversity over fading channels in order to exploit the large capacity available in a multi-antenna system [5,6,7]. Complex symbol Orthogonal Space-Time Block Code (O-STBC) is a very important kind of Space-Time Code due to its ability to provide optimal transmit diversity by requiring only simple linear processing at the receiver [9]. However, a full-rate complex O-STBC for complex constellations does not exist for more than two transmit antennas [6]. For achieving the full-rate STBC, a new type of STBC--Quasi-Orthogonal STBC (QO-STBC) has been introduced in [8], which trades some degree of diversity advantage and increases the decoding complexity. In [9], a new extended orthogonal STBC (EO-STBC) with three and four transmit antennas has been recently presented, which has been shown to achieve high transmit diversity and full transmit rate for more than two transmit antennas.

In this paper, we focus on full-rate STBC coherent long code WCDMA systems which exploit the subspace structure of the long code WCDMA transmission. The proposed method can achieve high transmit diversity and full transmit rate as compared with the O-STBC in the same evaluation framework.

The rest of this paper is organized as follows. Section 2 describes the data model of the extended orthogonal space-time block coded WCDMA system which exploits the subspace structure. A simple linear matrix transform method and some convention algorithms are presented for analyzing the character of a full-rate STBC WCDMA system in Section 3. In Section 4, we develop the simulations and results. Section 5 concludes the paper.

2. Data Model

We adopt the transmit diversity technique in a WCDMA communication system. Specifically, we consider an Extended Orthogonal Space Time Block Code asynchronous WCDMA communication system with four transmit antennas and four receiver antennas, and that a base-station has K users with aperiodic

spreading sequences of spreading gain G , and slotted transmissions of M symbols per slot. We will consider a quasi-static time-varying channel for each transmit and receiver antenna pair, i.e., that the channel doesn't change in a slot period. Here, an FIR channel model with channel impulse response $\{h(i), i \in \{0, \dots, L_h\}\}$ has been considered. An EO-STBC structure was presented earlier in [10]. The code matrix was proposed as follows.

$$EA = \begin{bmatrix} s_1 & s_1 & s_2 & s_2 \\ -s_2^* & -s_2^* & s_1^* & s_1^* \end{bmatrix} \quad (1)$$

This is an extension of the well-known Alamouti 2×2 scheme [2]

$$A = \begin{bmatrix} s_1 & s_2 \\ -s_2^* & s_1^* \end{bmatrix} \quad (2)$$

for four transmit antennas, where $s_i^*, i=1,2$ denote complex conjugation of the symbols s_1 and s_2 . The EO-STBC scheme is particularly attractive practically as. There is no increase in RF processing complexity over the 2×2 scheme [10]. The channel's transmission paths $h_{i,l}$, where $i=1,2,3,4$, and $l=1, \dots, L$, are assumed to be resolvable and independent complex valued random variables with zero mean and unity variance, where i denotes the transmit antenna index and l denotes the multipath index.

At the transmitter, the i th user's data sequences are denoted $\{s_{i,m}^{(1)}\}_{m=1}^{Mi}$, $\{s_{i,m}^{(2)}\}_{m=1}^{Mi}$, $\{s_{i,m}^{(3)}\}_{m=1}^{Mi}$ and $\{s_{i,m}^{(4)}\}_{m=1}^{Mi}$, one for each transmitter, in each slot, where Mi denotes the slot size for user i . The data for user i is extended orthogonal space-time encoded as:

$$\begin{aligned} s_{i,m}^{(1)} &= s_{i,m}, & s_{i,m+1}^{(1)} &= -s_{i,m+1}^*; \\ s_{i,m}^{(2)} &= s_{i,m}, & s_{i,m+1}^{(2)} &= -s_{i,m+1}^*; \\ s_{i,m}^{(3)} &= s_{i,m+1}, & s_{i,m+1}^{(3)} &= s_{i,m}^*; \\ s_{i,m}^{(4)} &= s_{i,m+1}, & s_{i,m+1}^{(4)} &= s_{i,m}^*, \quad m = 1, 5, 9, \dots, Mi-1, \end{aligned} \quad (3)$$

where $s_{i,m}$ is the input data sequence, $s_{i,m}^{(j)}, j=1,2,3,4$, denotes the encoded data sequence for transmit antenna j . Following this, signals from each transmit antenna are all spread by the same spreading code.

We also assume that the transmitted signal is corrupted by other user interference and additive noise in the channel. This gives us the long-code WCDMA system model as illustrated in Fig.1.

To increase temporal diversity, the receiver signal is typically sampled at the rate T_F faster than or equal to the chip rate T_C . In this case, we let the receiver signal $y(t)$ pass through the chip-matched filter, and sample it at the chip rate. Stacking the chip rate samples, we obtain the discrete-time received signal vector.

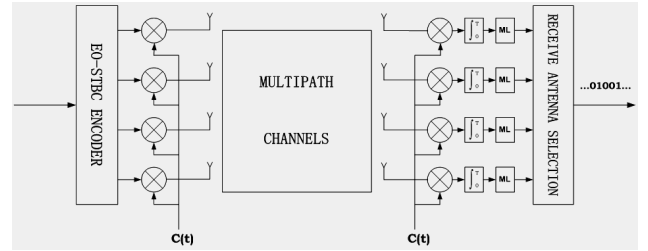


Fig.1 Baseband model of the space-time coded WCDMA systems

The receiver segment y_{im} which corresponds to the m th symbol of user i will be considered first. y_{im} is given by

$$y_{i,m} = T_{i,m} [h_i^{(1)} s_{i,m}^{(1)} + h_i^{(2)} s_{i,m}^{(2)} + h_i^{(3)} s_{i,m}^{(3)} + h_i^{(4)} s_{i,m}^{(4)}],$$

where T_{im} is the Toeplitz matrix whose first column is made of $(m-1)G_i + d_i$ zeros followed by the code vector c_{im} (the m th segment of G_i chips of the spreading code of user i) and additional zeros that make the size of y_{im} the total number of chips of the entire slot plus $\max\{d_i, i=1, \dots, K\}$ (see Fig. 2).

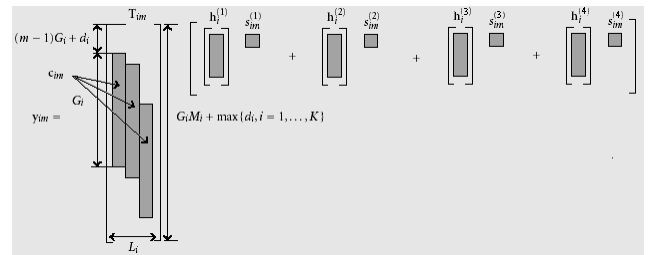


Fig.2: Noiseless single symbol output y_{im} [11]

Including all users and the noise, we have

$$\begin{aligned} y &= THs + w \\ T &:= [T_1, \dots, T_K] \end{aligned} \quad (4)$$

$$H := \text{diag}(I_{M_1} \otimes H_1, \dots, I_{M_K} \otimes H_k), \quad (5)$$

where w is a vector representing the additive white Gaussian noise. And we will assume the receiver knows the spread code c , the paths L_i , and the delay coefficients D_i of all users.

3. A simple linear matrix transform method and detection for the EO-STBC WCDMA system

After the matched filter, the output is given by

$$z = \text{diag}(I_{M_1} \otimes h_1, \dots, I_{M_K} \otimes h_k) s + n, \quad (6)$$

and because we consider the perfect known channel method, it is easy to detect the symbol. But the code matrix H can be large, a K -user synchronous system with spreading gain of G and L multipath fingers for each user and M symbols in each slot will have a code matrix of size approximately $MKL \times 4M$, the complexity of directly inverting H is of order $16M^3KL$.

Now the two subvectors corresponding to four consecutive symbols $2n-3, 2n-2, 2n-1, 2n$ of user i are given by

$$z_{in} = \begin{bmatrix} z_{i,2n-1} \\ z_{i,2n} \end{bmatrix} = \begin{bmatrix} H_i \begin{bmatrix} s_{2n-1} \\ s_{2n-1} \\ s_{2n} \\ s_{2n} \end{bmatrix} \\ H_i \begin{bmatrix} -s_{2n}^* \\ -s_{2n}^* \\ s_{2n-1}^* \\ s_{2n-1}^* \end{bmatrix} \end{bmatrix} + N_{in} \quad (7)$$

where $n = 1, 2, \dots, M/2$ and

$$H_i = [h_i^1, h_i^2, h_i^3, h_i^4] \quad (8)$$

In here, we consider the maximum likelihood detection to obtain the symbol sequence. Rewriting (7) given as

$$\begin{bmatrix} z_{i,2n-1} \\ z_{i,2n} \end{bmatrix} = \begin{bmatrix} (h_i^1 + h_i^2) & (h_i^3 + h_i^4) \\ (h_i^3 + h_i^4)^* & -(h_i^1 + h_i^2)^* \end{bmatrix} \begin{bmatrix} s_{2n-1} \\ s_{2n} \end{bmatrix} + W_{in}$$

and neglecting the colored noise, the maximum likelihood estimates for symbol s_{2n-1} and s_{2n} are given by

$$\begin{bmatrix} \hat{s}_{2n-1} \\ \hat{s}_{2n} \end{bmatrix} = Q \left(\frac{1}{\beta} \right) \begin{bmatrix} (h_i^1 + h_i^2)^H & (h_i^3 + h_i^4)^T \\ (h_i^3 + h_i^4)^H & -(h_i^1 + h_i^2)^T \end{bmatrix} \begin{bmatrix} z_{i,2n-1} \\ z_{i,2n} \end{bmatrix}$$

Where $\beta = (\|h_i^1 + h_i^2\|^2 + \|(h_i^3 + h_i^4)\|^2)$ and Q is the quantization function which selects the symbol vector with minimum distance.

4. Simulation Results

We let the multipath coefficients for each transmit-receive pair of each user be invariant within one slot period. In the deployment of MIMO systems a major limiting factor is the cost of multiple analog chains (such as low noise amplifiers, mixers and analog-to-digital converters) at the receiver end. Antenna selection is a powerful technique that reduces the number of analog chains required, whilst preserving the diversity benefits obtained from the full MIMO system [12]. In this paper, according to the maximum receiver SNR, we will select the corresponding receive antenna.

We consider EO-STBC and QO-STBC WCDMA systems with four transmit antennas and four receive antennas combined with receive antenna selection. The same parameters: spread gain=32, symbols=100, slotsize=320, delay=[0,23], two users, channel length $L_h=3$ have been used in Fig.3, and the five active users' case as shown in Fig.4. These two sets of results allows one to quantify the performance advantage attained using full-rate STBC with four transmit antennas in a WCDMA system, the QO-STBC is better than the EO-STBC, e.g. in fig.4, at BER 10^{-3} , there is more than 3dB improvement. In addition, our scheme can get increase the performance with receive antenna selection.

5. Conclusion

In this article, two full-rate STBCs for four transmit antennas have been adopted in long code WCDMA systems which exploit the subspace structure of the long code WCDMA transmission. A receive antenna selection technique is also adopted to achieve the additional performance gain. The proposed STBCs combined with the receive antenna selection technique in long code WCDMA system is evaluated through simulation and is compared with other schemes. The simulation results demonstrate the additional gain attained by the proposed method.

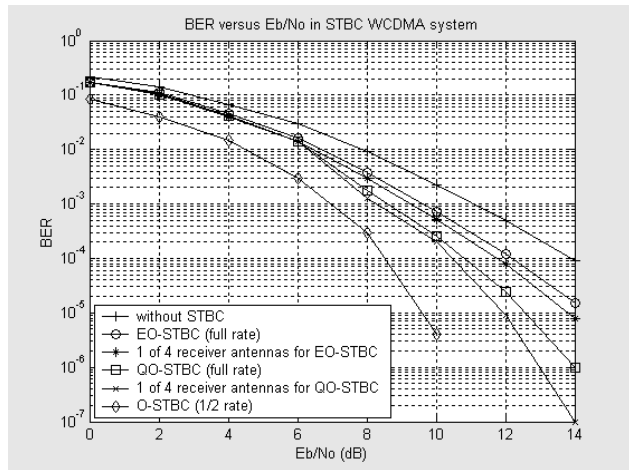


Fig. 3 Performance of the BER Versus SNR in a STBC- WCDMA system (two users).

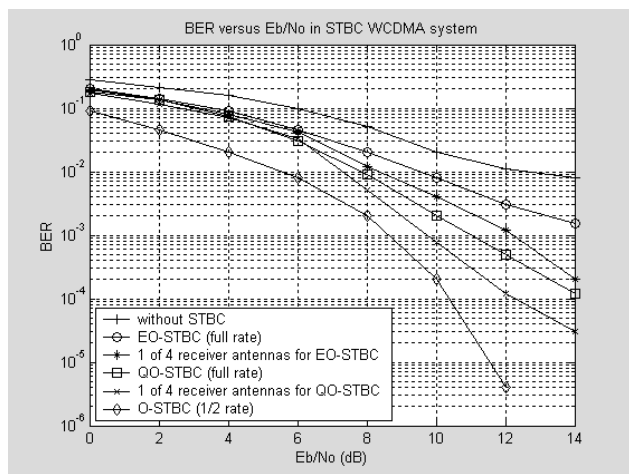


Fig.4 Performance of the BER Versus SNR in a STBC-WCDMA system (five users)

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