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Combined Beamforming with Orthogonal Space Time Block Code for MIMO-OFDM with Simple Feedback

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Abstract

In this paper, we introduce a proposed scheme to enhance the performance of orthogonal space time block code (OSTBC) with four time slots and two antennas by combing OSTBC with random beamforming to can use it in the downlink transmission for a mobile system. Multiple-input multiple-output orthogonal frequency-division multiplexing (MIMO-OFDM) system has been recognized as one of the most promising techniques to achieve a good service and increase data rate in the next generation (4&5G) broadband wireless communications. So, we apply Space time block code (STBC) for MIMO-OFDM system with linear decoding. Also, we perform STBC with beamforming for MIMO-OFDM system to improve the performance of a system. Simulation results show that the beamforming improves bit error rate (BER) performance of OSTBC and STBC-OFDM for different types of modulation and diversity.

Keywords: *space time code, MIMO-OFDM, beamforming, maximum likelihood detection.*

1. Introduction

MIMO communication systems reduce the adverse effect of wireless propagation environment by sending multiple independent replicas of a signal to the receiver. Also, MIMO-OFDM is required to achieve high data rate and to increase the diversity gain where OFDM exploits the frequency selectivity of the channel, frequency diversity. 4G/LTE uses MIMO-OFDM to perform its requirements [1]. In [1], the space time frequency code and space time bock code are presented for MIMO-OFDM.

In the uplink transmission (from mobile to basestation), Orthogonal Alamouti STBC is for two time slots and two transmit antennas, so it can't be used in the uplink transmission [2]. A hybrid scheme has three time slots (two time slots Alamouti code and one time slot repetition transmission), but it doesn't provide full diversity [3]. Quasi orthogonal space time block code that used three time slots and two transmitters and achieved full rate and full diversity has been proposed in [4], to decode this code, maximum likelihood (ML) decoding of this code needs a joint detection of two complex symbols. In [5], a group decodable STBC with three time slots and two-transmit antennas, which are suitable for the 3GPP LTE uplink frame structure, is constructed, the proposed code achieves full-rate, full diversity and symbol-wise decoding complexity. In [6], a novel STBC scheme for three time slots and two transmit antennas was proposed, this scheme achieves the properties of STBC such as full rate and full diversity, and non-vanishing minimum determinant value (MDV), also, it has a joint three real symbols decoding complexity. In [7], an efficient STBC that is suitable for LTE-A system was proposed, it can achieve the properties of STBC and its ML decoding requires a joint detection of three real symbols. The proposed code in [8] is introduced for frame structure of LTE-A system with four time slots and two antennas, this code achieves full rate, full diversity, and MDV property of STBC, also, it's ML decoding needs a joint detection of four real symbols, this code shows that its BER performance is better than BER performance of double Alamouti code for different modulations. So, the code in [8] can be used also in the downlink transmission (from base station to mobile).

Beamforming is a closed loop MIMO system where the channel estimation is available at the receiver and the transmitter (i. e., it is a signal processing technique that is used to increase the radiated power in the desired direction). In [9], the BER performance of orthogonal

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STBC with perfect channel state information at the transmitter. In [10], the quasi orthogonal STBC with mean feedback channel is proposed. For all cases, the BER performance of STBC with beamforming is better than the BER performance of STBC without beamforming. In [11], combined random beamforming (RBF) with space time frequency code (STFC) for MIMO-OFDM has been proposed for mobile system; they exploit orthogonality conditions of user with reduced feedback in the cellular system to use random beamforming. Although, random beamforming is poorer than the orthogonal beamforming that uses channel information at the transmitter, it is simpler and lower feedback. They used Alamouti code to compare the BER performance of STFC with respect to STFC and beamforming to maximize the diversity gain and enhance the overall performance of the system. But, its ML decoding is complex. In [12], they use space time block code (Alamouti code) for MIMO-OFDM to improve the reliability of the WIMAX systems and to keep the conventional decoding algorithm.

In this paper, we apply random beamforming on orthogonal STBC with four time slots and two transmitters [8] to enhance the performance of the code and to show that this code can be used in the downlink transmission for the mobile system. Also, the performance analysis of MIMO-OFDM system using ST coding is applied and the performance analysis of MIMO-OFDM system using ST coding with random beamforming is performed to use the conventional decoding algorithm, it is observed that the combination of ST with beamforming gives an enhancement over the performance of ST for MIMO-OFDM system. We use linear ML decoding to obtain a simple design which is required for the future wireless communication. So, the proposed code [8] can be used for MIMO-OFDM system to serve the cellular system.

The organization of this paper is as followed. In section 2, the system model of the MIMO-OFDM system and Space time block code are presented. In section 3, the proposed scheme is discussed. In section 4, simulation results show the BER performance comparison. Finally, conclusions are given in section 5.

2. System Model

In MIMO-OFDM system, we have M transmitters, N receivers, and M_s OFDM subcarriers. The max diversity gain of STC is MN. But, the max diversity gain of ST-OFDM is MNJ. J is independent channel taps.

h_{ig}^{t} is a frequency-selective channel between i^{th} receive antenna and g^{th} transmit antenna during t^{th} symbol interval defined as

$$h_{ig}^{t}(0), h_{ig}^{t}(1), h_{ig}^{t}(2), \ldots.. h_{ig}^{t}(J-1).$$

$$H_{ig}^{t}(k) = \sum_{l=0}^{J-1} h_{ig}^{t}\,(l) e^{-j2\pi lk/M_s} \quad (1)$$

Where $H_{ig}^{t}(k)$ is channel gain of the kth subcarrier from ith receive antenna and gth transmit antenna during tth symbol interval.

We assume that the MIMO channel is constant over each OFDM symbol which consists of M_x number of transmitted symbols. The STBC is achieved by transmitting symbols through different antennas (M), different frequencies (M_s), and (M_x) symbols. ST code word contains MM_sM_x transmitted symbols. So, the general codeword matrix with four time slot and two transmitters is

$$X = \begin{pmatrix} x_1^1(k) & x_1^2(k) \\ x_2^1(k) & x_2^2(k) \\ x_3^1(k) & x_3^2(k) \\ x_4^1(k) & x_4^2(k) \end{pmatrix} \quad (2)$$

X is an orthogonal space time block code with four time slots and two transmit antennas.

The condition of full diversity is: $M_x \geq M$. $x_t^g(k)$ is the symbol transmitted on the k^{th} subcarrier through the t^{th} symbol interval from g^{th} transmit antenna. At the receiver, the received signal at i^{th} receive antenna during t^{th} OFDM symbol is $r_t^i(k)$ of the k^{th} subcarrier. Here, we assume that the Inverse Fast Fourier Transform is applied and cyclic prefix is added before transmission the codeword. At the receiver, the cyclic prefix is removed then Fast Fourier Transform is applied. H(k) model is the equivalent channel in the frequency domain.

$$r_t^i(k)= \sum_{g=1}^{M} H_{ig}^t(k) * x_t^g(k) + n_t^i(k) \quad (3)$$

$n_t^i(k)$ is additive white Gaussian noise at the receive antenna i^{th} at time t^{th} of the k^{th} subcarrier.

3. Proposed Scheme

3.1. Combining STBC with Random Beamforming

The space time block code with time slots Mx=4 and number of transmitter M=2 is required. The goal of this code is to achieve orthogonal STBC, XHX=αIn, full rate, full diversity= 2 M, and high coding gain [8].

This code is

$$\text{Xnew}=\begin{bmatrix} x_1+x_2 & -x_3^* & -x_1+x_2 & -x_4^* \\ x_3 & x_1^*+x_2^* & x_4 & -x_1^*+x_2^* \end{bmatrix} \quad (4)$$

To improve the BER performance of the code (4), we use RBM. To perform beamforming, the channel estimation should be sent from the receiver to transmitter. When the channel estimation is perfect known at the transmitter, the best performance can be achieved. But, in some application, the feedback information from receiver to transmitter is difficult to apply. In beamforming, STBC of each user is independently multiplied by a beamforming weight factor for transmission on MIMO system to improve signal to interference and noise ratio at the receiver. Random beamforming is used due to its simplicity and lower feedback [11].

Let W_j random orthogonal beams (M x 1) ∊ $C^{M\times M}$ are generated according to an isotropic distribution [12-13].

The size of weight beamforming is M_x M.

So, the received signal at the i^{th} receive antenna is

$$r_t^i=\sum_{g=1}^{M} H_{ig} x_t^g w_g + n_t^i \quad (5)$$

To decode by using the Euclidian distance based on ML to estimate transmitted signal from received signal is

$$\hat{x} = \text{arg}_x\text{min}\left\| r_t^i - \sum_{g=1}^{M} H_{ig}\hat{x}_t^g\, w_g \right\|^2 \quad (6)$$

The linear decoding is preferred in wireless communication due to its simplicity.

3.2. Combining STC with Random Beamforming for MIMO-OFDM System.

The STC with four times, two antennas and M_s subcarrier is

$$X(k)=\begin{bmatrix} x_1(k)+x_2(k) & -x_3^*(k) & -x_1(k)+x_2(k) & -x_4^*(k) \\ x_3(k) & x_1^*(k)+x_2^*(k) & x_4(k) & -x_1^*(k)+x_2^*(k) \end{bmatrix} \quad (7)$$

The size of weight beamforming is $M_x M_s$ M.

The received signal after applying RBF is

$$r_t^i(k)=\sum_{g=1}^{M} H_{ig}(k)\, x_t^g(k)\, w_g + n_t^i(k) \quad (8)$$

Simple ML decoding to decode the transmitted symbol is used.

$$\hat{x} = \text{argxmin}\left\| r_t^i(k) - \sum_{g=1}^{M} H_{ig}(k)\hat{x}_t^g(k) w_g) \right\|^2 \quad (9)$$

4. Performance Evaluation

The simulation has been done using MATLAB 14.a. In the simulation, it is assumed that the receiver has perfect channel state information and the weight of beamforming. The number of subcarriers is 100 and the number of the paths is assumed to be 4.

In Figure 1, comparison of double Alamouti, new STBC [8], and the proposed of combined new STBC with beamforming has been done. The BER performance of STBC with beamforming over the independent and quasi-static channel for 2 x1 systems is better than STBC [8]. The proposed beamforming with STBC scheme gives a gain of approximately 2.4 dB over STBC, for the BER of 10-3. The same comparison has been done in Figure 2 and 3 for different types of modulations, QAM and PSK.

In Figure 4 and 5, the BER performance of STC scheme and STC with beamforming for different modulation and different diversity has been performed for MIMO-OFDM system. The STC without beamforming achieves lower diversity gain than STC with beamforming.

Figure 6 shows that the BER performance of combined STC-OFDM with beamforming is better than the BER performance of the STBC-OFDM for MIMO system.

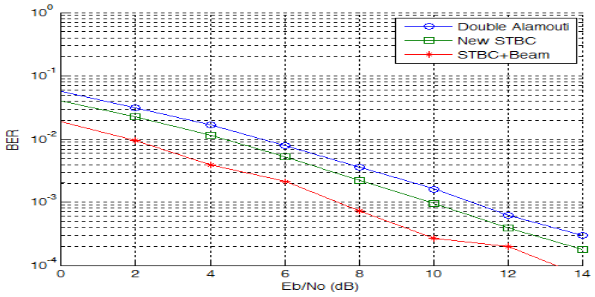

Figure 1. BER Performance of New STBC [8] and Combined Beamforming with STBC for BPSK Modulation (2 bit/Sec/Hertz) for $\mathrm{M} = 2$ and $\mathrm{N} = 1$

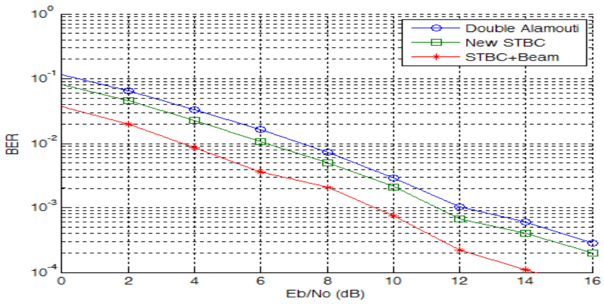

Figure 2. BER Performance of new STBC [8] and Combined Beamforming with STBC for 4QAM Modulation (2 bit/Sec/Hertz) for $\mathrm{M} = 2$ and $\mathrm{N} = 1$

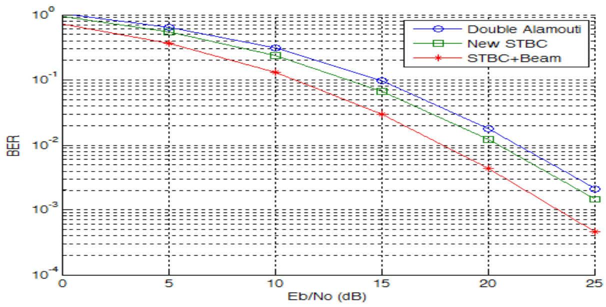

Figure 3. BER performance of new STBC [8] and Combined Beamforming with STBC for 16 PSK modulation (4 bit/Sec/Hertz) for $\mathrm{M} = 2$ and $\mathrm{N} = 1$

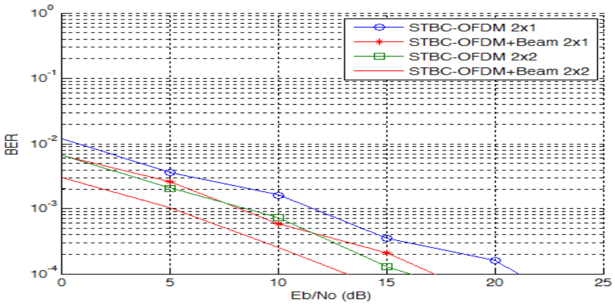

Figure 4. BER performance of STC and Combined Beamforming with STC for 4 QAM modulation (2 bit/Sec/Hertz) and for MIMO-OFDM System

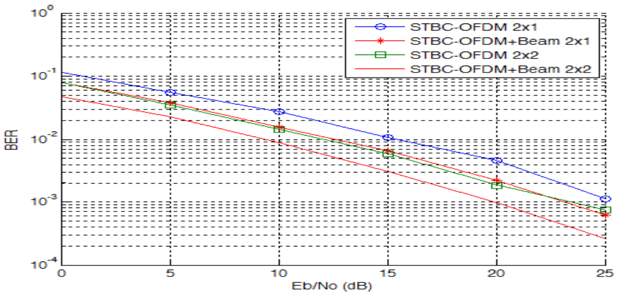

Figure 5. BER performance of STC and Combined Beamforming with STC for 16 PSK modulation (4 bit/Sec/Hertz) and for MIMO-OFDM System

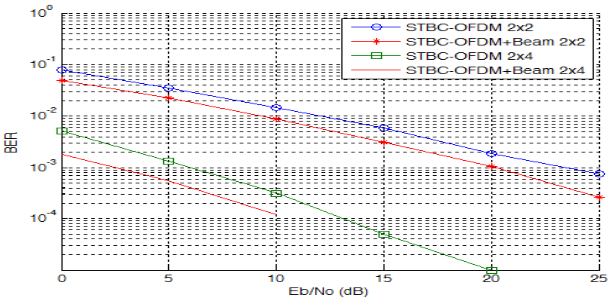

Figure 6. BER performance of STBC and Combined Beamforming with STBC for 16 PSK modulation and for MIMO-OFDM

5. Conclusion

In this paper, we proposed an enhancement in the BER performance of the proposed code [8] by applying random beamforming on the STBC with simple channel estimation at the transmitter. So it can be used in the downlink transmission. Due to MIMO-OFDM system is used in the wireless communication. We apply STBC, four time slots and two transmitters, in MIMO-OFDM system. Also, STBC with beamforming is performed in MIMO-OFDM to achieve the best output performance of the whole system with simple ML decoding at the receiver. This scheme gives performance is close to 3.2dB over the performance of STC-OFDM without beamforming for different types of modulations and different diversity.

References

[1] W Zhang W, X Xia K Letief. Space-time/frequency coding for MIMO–OFDM in next generation broadband wireless systems. *IEEE Wireless Communication*. 2007.

[2] SM Alamouti. A simple transmit diversity technique for wireless communications. *IEEE J. Sel. Areas Communication*. 1998; 16(8): 1451–1458.

[3] Alcatel Shanghai Bell, Alcatel-Lucent. *STBC-II scheme with non paired symbols for LTE-Advanced uplink transmit diversity*. 3GPP TSG RAN WG 1 Meeting 55 bis. 2009, R1-090058.
[4] Z Lei, C Yuen, F Chin. Quasi-orthogonal space-time block codes for two transmit antennas and three time slots. *IEEE Trans. Wireless Communication*. 2011; 10(6): 1983-1991.
[5] TP Ren, C Yuen, YL Guan, KH Wang. 3-Time-Slot Group- Decodable STBC with Full Rate and Full Diversity. *IEEE Communications Letter*. 2012; 16(1).
[6] M Ahmadi, VT Vakily. A novel space time block code scheme for three time slots and two transmit antennas. *IEEE Communication Letter*. 2013; 17(3): 455–458.
[7] V Abbasi, MG Shayesteh, M Ahmadi. *An Efficient Space Time Block Code for LTE-A System.* IEEE Signal Processing Letters. 2014; 21(12).
[8] M Norouzi, E Attang, Y Wu, RB Ellis, GE Atkin. *Space Time Coding for Four Time Slots and Two Transmit Antennas.* IEEE International Conference on Electro/Information Technology. 2015.
[9] G Jöngren, M Skoglund, B Ottersten. Combining Beamforming and Orthogonal Space–Time Block Coding. *IEEE Transactions on Information Theory*. 2002; 48 (3).
[10] L Liu, H Jafarkhani. *Combining Beamforming and Quasi-Orthogonal Space-Time Block Coding Using Channel Mean Feedback*. IEEE Global Telecommunications Conference. 2003.
[11] N Shrivastava, A Trivedi. Combined beamforming with space-time- frequency coding for MIMO-OFDM systems. *International Journal of Electronics and Communications*. 2015.
[12] S Chouhan, A sharma. Performance analysis of STBC Coded MIMO-OFDM System for WIMAX (IEEE 802.16) Systems. *IEEE* Sponsored 2nd International Embedded and communication Systems. 2015.
[13] B Hassibi, T Marzetta. Multiple-antennas and isotropically random unitary inputs: the received signal density in closed form. *IEEE Transactions Information Theory*. 2002; 48(6).
[14] TL Marzetta, BM Hochwald. Capacity of a mobile multiple-antenna communication link in Rayleigh flat fading. *IEEE Transactions Information Theory*. 1999; 45(1): 138-157.