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Orthogonal Space Time Block Code for Four Time Slots for Uplink Transmission

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Abstract: In this paper, a new proposed space-time code for four-time slots and two transmitters for uplink transmission in a mobile system is presented. The mobile system needs three or four-time slots for data transmission. Also, this code is applied for multi-input multi-output (MIMO) fading channel. The proposed orthogonal space-time code achieves the properties of space-time code such as a full rate, full diversity, and non-vanishing minimum determinant value (MDV). The coding gain of this code is high because it achieves the trace or determinant criterion. Also, the proposed code needs a linear maximum likelihood (ML) decoding to decode four real symbols. Simulation results show that the performance of the proposed code is better than the performance of the previously presented schemes that are used in a mobile system for different modulation and diversity.

Keywords: Orthogonal Space-Time Block Code, BER, Maximum Likelihood Decoding, MIMO System

1. Introduction

Orthogonal space- time block code (OSTBC) and quasi-orthogonal (Q-OSTBC) are popular codes for uplink transmission (from the mobile system that has two antennas to the base station that has one or more antennas) in long term evolution-advanced (LTE-A) system. STBC is an open loop system. So, it needs channel state information at the receiver only.

In LTE-A, There are three or four time slots for data transmission. Different STB codes are proposed for data transmission in this system. Orthogonal Alamouti space-time block code (STBC) is for two-time slots and two transmit antennas. So it can't be used in the uplink transmission [1]. 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 [2]. 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 [3]. The maximum likelihood (ML) decoding of this code needs a joint detection of two complex symbols. In [4], a group decodable STBC with three-time slots and two transmit antennas which are suitable for the 3GPP LTE uplink frame structure was constructed. This code achieves full-rate, full diversity for all information symbols and ML detection complexity of order O (M), where M is the size of the symbol constellation. In [5], a novel STBC scheme for three-time slots and two transmit antennas was proposed. It achieves the properties of STBC such as full rate and full diversity, and non-vanishing minimum determinant value (MDV). Also, it has three real symbols decoding complexity. In [6], an efficient STBC that is used for the mobile system was proposed. Its ML decoding required a joint detection of three real symbols and its performance is better than [4, 5] at high signal to noise ratio. The proposed code in [7] is introduced for frame structure of LTE-A system with four-time slots and two antennas, this orthogonal STBC achieves full rate, full diversity, and MDV property of STBC. Its 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. In [8], Quasi-orthogonal STB codes were proposed for three-time slots and two transmitters for uplink transmission. This code achieves full rate and full diversity. Its performance is better than the performance of [2]. In [9], two Quasi-orthogonal STB codes were proposed for a mobile system. These codes achieve full rate and full diversity. This code can save the transmitted power. But, it needs more some operations at the receiver to separate the transmitted symbols to decode them simply. In [10], authors proposed QO-STBC for three and four transit antennas. This QO-STBC doesn't improve the performance over the conventional and previous QO-STBC [11].

In this paper, new proposed OSTBC for MIMO system is presented. The proposed code can transmit four symbols in four-time slots through two transmitters. The code can achieve the properties STBC such as full rate, full diversity, and coding gain [13-14]. Also, this scheme can be used for uplink transmission in the mobile system, where the mobile is equipped with two transmitters and four- time slots. The BER performance of the proposed code is better than the BER performance of previously code [7] and the performance of double Alamout code. This code is an orthogonal code so it uses linear and simple ML decoding to decode four real symbols. Its MDV doesn't vanish by increasing the signal constellation.

The organization of the paper is as followed. In section 2, the system model of the OSTBC is presented. In section 3, the proposed OSTBC scheme is discussed. In section 4, simulation results show the BER performance comparison. Finally, conclusions are given in section 5.

Notations: I_N is N X N identity matrix. Small letters and capital letters denote vectors, matrices respectively. $(.)^*$, $(.)^H$, $(.)^T$ and det (.) stand for conjugate, hermitian, transpose and determinant of a matrix respectively.

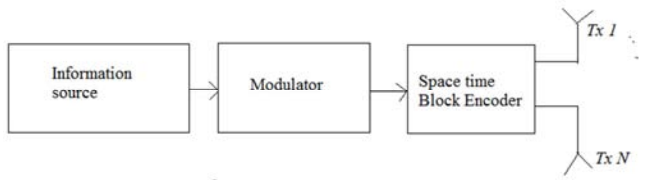

Fig. 1. *Block diagram of space-time coding at transmitter (mobile device) [14].*

2. System Model

Figure 1 shows the block diagram of space-time coding at the transmitter that has N transmit antennas, mobile device. The base-station represents the receiver in the wireless communication with contains M receive antennas. As shown in fig 1, the input of modulator box is the information source. The selected symbols from the modulator are the input of the space-time encoder. In this paper, we use two types of modulations, m-QAM and M-PSK. It is assumed that each element of the modulation constellation is scaled by factor $\sqrt{E_s}$ so the average energy is one. The size of space-time coding through time periods, T, is N x T.

The received signal at time slot t in the i^{th} receiver is

$$\boldsymbol{r}_t^i = \sum_{g=1}^{N} \boldsymbol{h}_{ig}^t * \boldsymbol{s}_t^g + \boldsymbol{n}_t^i \quad (1)$$

Where, $\boldsymbol{s}_t^g$ is the transmitted symbol from the g^{th} transmit antenna at t, $\boldsymbol{n}_t^i$ is a complex additive white Gaussian noise with zero mean and unit variance at the receiver antenna i at time t, and $\boldsymbol{h}_{ig}^t$ is the channel between the g^{th} transmitter and i^{th} receiver at time t and modeled as a Rayleigh fading channel.

3. The Proposed OSTBC Scheme

We propose a rate one and full diversity orthogonal STBC code for four-time slots and two transmit antennas. This code can be applied for LTE-A system. To design a good code, we should satisfy the properties of OSTBC such as full rate, full diversity, non-vanishing minimum determinant value (MDV), trace criteria, and simple decoding.

Our design code is obtained as follows

$$X = \begin{bmatrix} s_1+s_2 & -s_3^*-s_4^* & -s_1+s_2 & -s_3^*+s_4^* \\ s_3+s_4 & s_1^*+s_2^* & s_3-s_4 & -s_1^*+s_2^* \end{bmatrix} \quad (2)$$

This code is full rate because of the number of transmitted symbols from each antenna, $k = 4$ and the number of symbols at the input of the STBC encoder $p=4$, a number of time slots. The rate, R, is

$$R = \frac{k}{p} = 1 \quad (3)$$

This code achieves full rate.

The orthogonality of the proposed code is satisfied if we show that $X * X^H = \alpha I_N$;

$$X * X^H = \begin{bmatrix} s_1+s_2 & -s_3^*-s_4^* & -s_1+s_2 & -s_3^*+s_4^* \\ s_3+s_4 & s_1^*+s_2^* & s_3-s_4 & -s_1^*+s_2^* \end{bmatrix} * \begin{bmatrix} s_1^*+s_2^* & s_3^*+s_4^* \\ -s_3-s_4 & s_1+s_2 \\ -s_1^*+s_2^* & s_3^*-s_4^* \\ -s_3+s_4 & -s_1+s_2 \end{bmatrix} =$$

$$= ((s_1+s_2)^2 + (s_3+s_4)^2 + (-s_1+s_2)^2 + (s_4-s_3)^2).\begin{bmatrix} 1 & 0 \\ 0 & 1 \end{bmatrix} \quad (4)$$

The trace of the code is

$$\text{trace } (\bar{X}^H \bar{X}) = 2 * ((\bar{s_1}+\bar{s_2})^2 + (\bar{s_3}+\bar{s_4})^2 + (-\bar{s_1}+\bar{s_2})^2 + (\bar{s_4}-\bar{s_3})^2) \quad (5)$$

Where $\bar{X} = X - \hat{X}$, where X *and* $\hat{X}$ are transmitted code matrix and detected code matrix. $\bar{s_l} = s_l - \hat{s_l}$, where s_l *and* $\hat{s}_l$ are transmitted signal and detected signal.

To obtain high coding gain, the minimum trace of STBC should be large according to the trace criteria. The trace of this code consists of square terms and it is non-zero among all $s_l \neq \hat{s}_l$.

To check the full diversity of the proposed code, we calculate the rank of all possible difference matrices, $\bar{X}$.

$$\det(\bar{X}^H \bar{X}) = ((\bar{s_1} + \bar{s_2})^2 + (\bar{s_3} + \bar{s_4})^2 + (-\bar{s_1} + \bar{s_2})^2 + (\bar{s_4} - \bar{s_3})^2)^2 \quad (6)$$

If $s_l = \hat{s_l}$ is achieved, the determinant of difference matrix is zero. So, the difference matrix is full rank when $X \neq \hat{X}$. So, the proposed code is full diversity code and it provides a diversity of *NM*. If *N=2*, the diversity is *2M*. Also, the new code achieves the determinant criterion that is required to achieve coding gain. The MDV does not vanish by increasing the signal constellation.

The received signals of space time block code are

$$r_1^i = (s_1 + s_2)h_{i,1} + (s_3 + s_4)h_{i,2} + n_1^i \quad (7)$$

$$r_2^i = -(s_3^* + s_4^*)h_{i,1} + (s_1^* + s_2^*)h_{i,2} + n_2^i$$

$$r_3^i = (-s_1 + s_2)h_{i,1} + (s_3 - s_4)h_{i,2} + n_3^i$$

$$r_4^i = (-s_3^* + s_4^*)h_{i,1} + (-s_1^* + s_2^*)h_{i,2} + n_4^i$$

To decode the transmitted signal, ML decoding to minimize the following equation

$$\sum_{i=1}^{M} \left| r_1^i - (\hat{s_1} + \hat{s_2})h_{i,1} - (\hat{s_3} + \hat{s_4})h_{i,2} \right|^2 + \left| r_2^i + (\hat{s_3}^* + \hat{s_4}^*)h_{i,1} - (\hat{s_1}^* + \hat{s_2}^*)h_{i,2} \right|^2 + \left| r_3^i - (-\hat{s_1} + \hat{s_2})h_{i,1} - (\hat{s_3} - \hat{s_4})h_{i,2} \right|^2 + \left| r_4^i - (-\hat{s_3}^* + \hat{s_4}^*)h_{i,1} - (-\hat{s_1}^* + \hat{s_2}^*)h_{i,2} \right|^2 \quad (8)$$

The decision symbols would be

$$\bar{s_1} = \sum_{i=1}^{M} r_1^i h_{i,1}^* + (r_2^i)^* h_{i,2} - r_3^i h_{i,1}^* - (r_4^i)^* h_{i,2}$$

$$\bar{s_2} = \sum_{i=1}^{M} r_1^i h_{i,1}^* + (r_2^i)^* h_{i,2} + r_3^i h_{i,1}^* + (r_4^i)^* h_{i,2}$$

$$\bar{s_3} = \sum_{i=1}^{M} r_1^i h_{i,2}^* - (r_2^i)^* h_{i,1} + r_3^i h_{i,2}^* - (r_4^i)^* h_{i,2}$$

$$\bar{s_4} = \sum_{i=1}^{M} r_1^i h_{i,2}^* - (r_2^i)^* h_{i,1} - r_3^i h_{i,2}^* + (r_4^i)^* h_{i,2} \quad (9)$$

If we call the previous space time code for four time slots and two transmitters [7]

$$X = \begin{bmatrix} s_1 + s_2 & -s_3^* & -s_1 + s_2 & -s_4^* \\ s_3 & s_1^* + s_2^* & s_4 & -s_1^* + s_2^* \end{bmatrix} \quad (10)$$

And also, if we call the double Alamouti code matrix [7]

$$X = \begin{bmatrix} s_1 & -s_2^* & s_3 & -s_4^* \\ s_2 & s_1^* & s_4 & s_3^* \end{bmatrix} \quad (11)$$

The two OSTB codes achieve full rate, full diversity, and coding gain. Also, they need a linear decoder to decode four transmitted symbols.

In the simulation part, we compare BER performance of STB codes (2), (10) and (11) for different modulation and diversity.

4. Performance Analysis and Simulation Results

In this section, the performance of the proposed code is simulated and evaluated by MATLAB program. In order to evaluate the performance of the code, we should calculate the pairwise error probability for MIMO fading channel [14-15].

The pairwise error probability for MIMO fading channel is

$$p(X, \hat{X}) \leq \frac{1}{\prod_{n=1}^{N} \left[1 + \gamma \frac{\lambda_n}{4}\right]^M} \quad (12)$$

Where, X is transmitted codeword, $\hat{X}$ is detecting codeword, γ is a signal to noise ratio per symbol, and λ_n ' s is eigenvalues of the difference matrix $X = X - \hat{X}$. The probability of error is decreased with increasing the diversity and coding gain of the STBC.

The simulation results of the performance of the proposed code are shown. In the simulation, we assumed that the receiver has perfect channel state information and the channel is Rayleigh fading channel. We use two types of modulation, m-PSK, and m-QAM.

In figure 2, a comparison of proposed STBC and other previous codes have been done for two transmit antennas and one receiver. The BER performance of the new proposed STB codes gives a gain of approximately 2 dB over the previous STBC [7], for the BER of 10-3. Also, the gain of the new code is approximately 2.8 dB over the double Alamouti code for the BER of 10-3. The same comparison is performed for QAM modulation and PSK modulation as shown in fig. 3 and fig. 4 respectively.

The new code is applied also in a MIMO system as shown in fig. 5 and fig.6. In figure 5, the performance of new OSTBC is better than the performance of the previous code [7] and double Alamouti code for two transmitters and two receivers for two different types of modulations.

Figure 6 shows the performances of new code and the previous codes for two transmit antennas and four receive antennas for different modulations. The new OSTBC gives better performance than the previous codes.

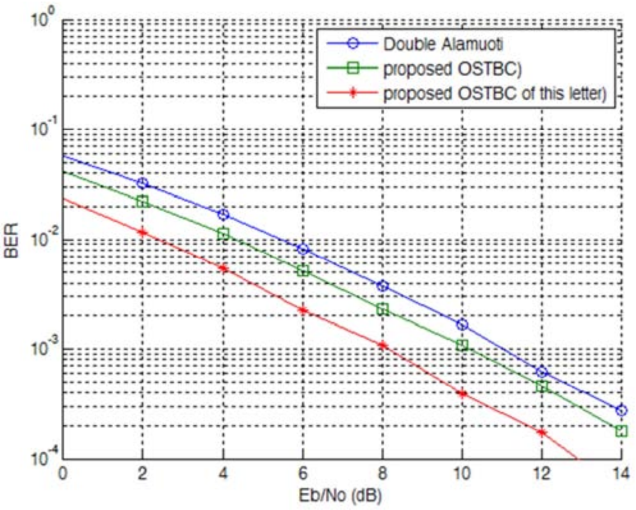

Fig. 2. BER performance of the proposed code and BER performance of previous and double for BPSK modulation for $N = 2$ *and* $M = 1$.

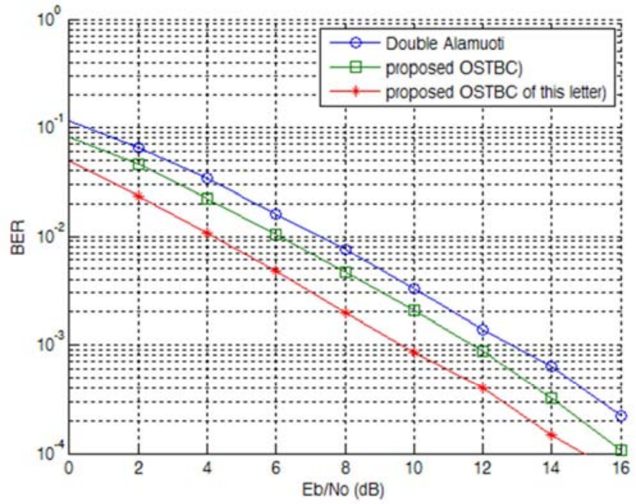

Fig. 3. BER performance of the proposed code and BER performance of previous STBC and double Alamouti for QAM modulation (2 bit/sec /Hz) for $N = 2$ *and* $M = 1$.

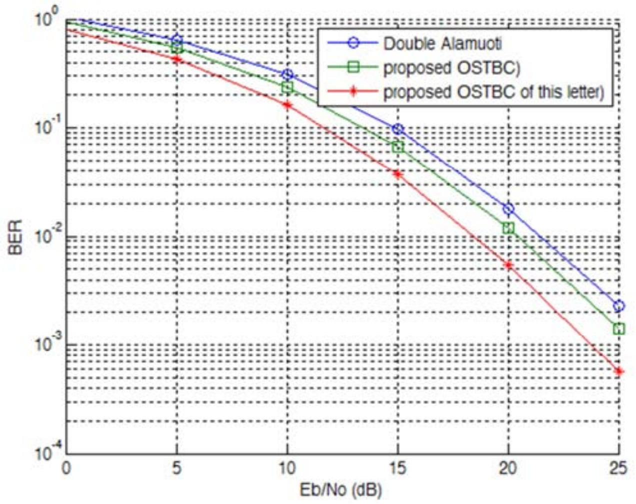

Fig. 4. BER performance of the proposed code and BER performance of previous STBC and double Alamouti for 16PSK modulation for $N = 2$ *and* $M = 1$.

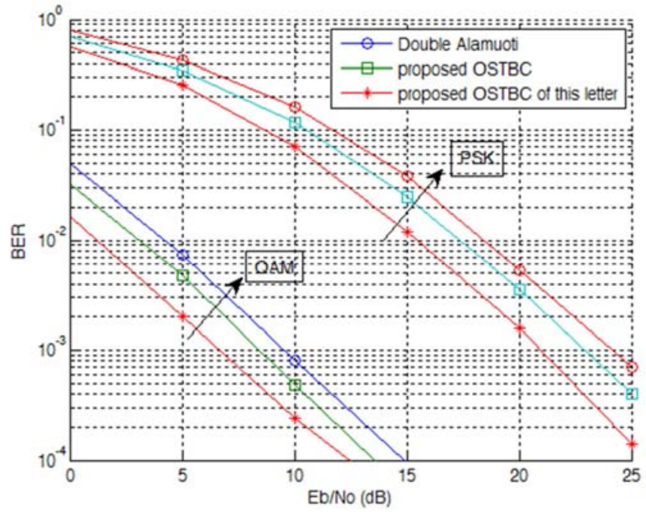

Fig. 5. BER performance of proposed code and BER performance of previous STBC and double Alamouti for 16PSK and 4-QAM modulation for $N = 2$ *and* $M = 2$.

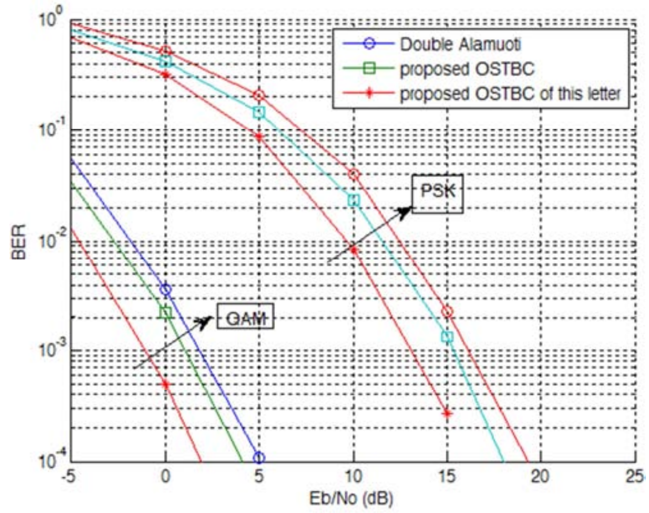

Fig. 6. BER performance of proposed code and BER performance of previous STBC and double Alamouti for 16PSK and 4-QAM modulation for $N = 2$ *and* $M = 4$.

5. Conclusion

In this paper, we proposed an efficient OSTBC for four-time slots and two transmitters for uplink transmission in LTE-A system. This system needs three or four-time slots for data transmission. The proposed code satisfies full rate and full diversity. This code achieves high coding gain and the minimum determinant value does not vanish by increasing the signal constellation. Also, it needs linear ML decoding to decode four real symbols. The results show that the proposed code gives approximately 2 dB over the previous code. This new OSTBC has lower BER than the proposed code of [7] and double Alamouti code for different modulation and diversity. For the future work, this code can be applied to other types of channels such as Rican channel.

References

[1] S. M. Alamouti, “A simple transmit diversity technique for wireless communications”, IEEE J. Sel. Areas Communication, Vol. 16, No. 8, pp. 1451–1458, Oct. 1998.

[2] Alcatel Shanghai Bell, Alcatel-Lucent, “STBC-II scheme with non paired symbols for LTE-Advanced uplink transmit diversity”, R1-090058, 3GPP TSG RAN WG 1 Meeting 55 bis, Jan. 2009.

[3] Z. Lei, C. Yuen, and F. Chin, “Quasi-orthogonal space-time block codes for two transmit antennas and three time slots”, IEEE Trans. Wireless Communication, Vol.10, No.6, pp. 1983–1991, June 2011.

[4] T. P. Ren, C. Yuen, Y. L. Guan, K. H. Wang, “3-Time-Slot Group- Decodable STBC with Full Rate and Full Diversity”, IEEE Communications Letter Vol.16, No.1, Jan. 2012.

[5] M. Ahmadi and V. T. Vakily, “A novel space time block code scheme for three time slots and two transmit antennas”, IEEE Communication Letter, Vol. 17, No. 3, pp.455–458, Mar. 2013.

[6] V. Abbasi, M. G. Shayesteh, M. Ahmadi, “An Efficient Space Time Block Code for LTE-A System,” IEEE Signal Processing Letters, Vol. 21, No.12, Dec. 2014.

[7] M. Norouzi, E. Attang, Y. Wu, R. B. Ellis, G. E Atkin, “Space Time Coding for Four Time Slots and Two Transmit Antennas”, IEEE International Conference on Electro/Information Technology, May 2015.

[8] R. Chauhan, R. Singhal, N. S. Thakur, S. S. Thakur, “Few more Quasi-Orthogonal Space-Time Block Codes with 3-Time Slots for Wireless Communication”, IEEE Conference, pp. 431–434, 2013.

[9] N. S. Thakur, R. Bhatia, S. S. Thakur, “Two New Quasi-Orthogonal Space-Time Block Codes with 3-Time Slots for LTE-Advanced”, IEEE conference (CODEC), pp. 1-4, 2012.

[10] Y. Lee, M. Uh, S. Chang, “Comments and Corrections an A novel QO-STBC Scheme with Linear Decoding for Three and Four Transmit Antennas”, IEEE communications letters, pp. 1908-1909, 2016.

[11] U. Park, S. Kim, K. Lim, J. li, “A novel QO-STBC scheme with linear decoding for three and four transmit antennas”, IEEE communications, Lett. vol. 12, pp. 868-870, Dec. 2008.

[12] D. M. Ionescu, “New results on space time code design criteria,” in Proc. IEEE WCNC, pp. 684–687, 1999.

[13] D. M. Ionescu, “On space-time code design,” IEEE Trans. Wireless Communications, vol. 2, no. 1, pp. 20–28, Jan. 2003.

[14] B. Vucetic, J. Yuan, “Space-Time Coding,” John Wiley & Sons Ltd., ISBN 0-470-84757-3, 2003.

[15] Y. S. Cho, J. Kim, W. Y. Yang, C-G. Kang, “MIMO–OFDM wireless communications with MATLAB,” John Wiley & Sons (Asia) Ltd.; 2010.