Novel QO-STBC Scheme

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ABSTRACT
In order to satisfy the huge communications demands MIMO (Multiple input and Multiple Output) systems is one of the techniques which provide high data rates under the constraints of limited bandwidth and transmit power. Space-Time Block Coding (STBC) is based on MIMO transmission strategy which exploits transmit diversity. STBCs are divided into two main classes i.e. Orthogonal Space-Time Block Codes (OSTBCs) and Non-Orthogonal Space-Time Block Codes (NO-STBCs). The Quasi-Orthogonal Space-Time Block Codes (QO-STBCs) belong to class of NO-STBCs and have been our area of interest. Full data rate and full diversity can only achieved with QSTBCs with a small loss in the diversity gain. The foremost purpose of this work is to provide a unified theory of QSTBCs for four transmit antennas and one receive antennas.

Keywords
MIMO, STBC, OSTBC, QSTBC

1. INTRODUCTION
From the past few years, demand for mobile communication systems with high data rates has increased significantly. In order In order to meet these huge communications demand new methods has been devised that are exploiting the limited resources such as bandwidth and power in an efficient way in order to reduce the system deployment cost. MIMO (Multiple input and Multiple Output) systems is one of the techniques with multiple antenna elements at both the link ends which is an efficient solution to meet the future wireless communications demands as they provide more reliable connection. . STBC is based on MIMO transmission strategy which encodes the data across multiple transmit antennas and time slots, such that multiple redundant copies of data are transmitted through independent fading channel. Alamouti proposed the transmit diversity scheme which is regarded as the first space time coding with two transmit antennas and thus achieved full code rate with full diversity for complex orthogonal design, with simple linear ML decoding. These kinds of space time coding are known as orthogonal space time codes(O-STBC). However we cannot achieve full diversity for complex orthogonal design for more than two antennas. The maximum code rate achieved with 3 or 4 Transmit Antennas was $3/4$ with full diversity. And for more than four transmit antennas, the code rate cannot be achieved more than $1/2$. In order to achieve the advantages of O-STBC schemes with properties close to such optimal codes providing full rate,the so called QO- STBCs were proposed. Here we relax the simple separate decoding property and its orthogonality to achieve higher code rates. A QO-STBC can achieve full rate but it also results in interference from neighbouring signals during This leads to increasing the decoding complexity with respect to O-STBCS. Two ML detectors in parallel are used to decode the pairs of T^Xed symbols in QOSTBC, which results in higher decoding complexity at the receiver. This leads to increase in the modulation level; receiver computes the decision metric over large number of symbols which subsequently increases the decoding complexity and thus transmission delay.

2. CONVENTIONAL QOSTBC
Jafarkhani code for four transmit antenna and one receive antenna, is given by [16]:

$$S = \begin{bmatrix} s_1 & s_2 & s_3 & s_4 \\ -s_2^* & s_1^* & -s_4^* & s_3^* \\ -s_3^* & -s_4^* & s_1^* & s_2^* \\ s_4 & -s_3 & -s_2 & s_1 \end{bmatrix} \quad (3.1)$$

where s_i is input modulated symbols for the QO-STBC encoder. Corresponding equivalent virtual channel matrix (EVCM) of this code is given by

$$H = \begin{bmatrix} h_1 & h_2 & h_3 & h_4 \\ h_2^* & -h_1^* & h_4^* & -h_3^* \\ h_3^* & h_4^* & -h_1^* & -h_2^* \\ h_4 & -h_3 & -h_2 & h_1 \end{bmatrix} \quad (3.2)$$

where h_i is channel coefficient for every transmit and receive antenna pair. Therefore, received signal vector **y** can be written as:

$$y = Hs + \bar{n} \quad (3.3)$$

where $s = [s_1, s_2, s_3, s_4]^T$,

$$\bar{n} = [n_1, n_2^*, n_3^*, n_4]^T$$

and n_i is complex white Gaussian noise added at the i-th time slot. In this case of orthogonal scheme received signals were decoded with the help of detection matrix D defined as $H^H H$. In O-STBC scheme the detection matrix always comes out to be a diagonal matrix and thereby relaxing the decoding complexity at receiver. Although for a QO-STBC scheme, this method cannot be applied because detection matrix is not diagonal. For example, the detection matrix for the above mentioned four transmit antenna QO-STBC scheme is expressed by:

$$D = H^H H = \begin{bmatrix} a & 0 & 0 & b \\ 0 & a & -b & 0 \\ 0 & -b & a & 0 \\ b & 0 & 0 & a \end{bmatrix} \quad (3.4)$$

where, $a = \sum_{i=1}^{4} |h_i|^2$ is channel gain for four transmit antennas.

$b = 2\mathrm{Re}\,(h_1 h_4^* - h_2 h_3^*)$ is interference parameter.

A complex decoding method to find the estimate $\hat{C}$ was introduced which has the high decoding complexity due to process of the inverse of the matrix. This method is called as zero forcing decoding, and given by [37]:

$$\hat{C} = (H^H H)^{-1} H^H R_n \quad (3.5)$$

3. PROPOSED QOSTBC

As the detection matrix D is symmetric, so using the property of symmetric matrix, we can express D as:

$$D = QD_nQ^T \qquad (4.1)$$

where Q and D_n are orthogonal and diagonal matrix respectively where diagonal elements of D_n are eigen value of D. Equation (4.1) can also be rewritten as

$$Q^TDQ = D_n \qquad (4.2)$$

by pre multiplying detection matrix D with Q^T and post multiplying the detection matrix D with Q, the diagonal matrix D_n is obtained which is interference free. In Z.Q.Taha *et al.* [22], they used similar concept of symmetry for detection matrix but for constructing their code the value of Q was taken as general unitary matrix. But in this proposed scheme SVD is used to derive the value of Q. So Q is given by:

$$Q = \begin{bmatrix} 0.5 & 0.5 & 0.5 & -0.5 \\ 0.5 & -0.5 & 0.5 & 0.5 \\ -0.5 & 0.5 & 0.5 & 0.5 \\ 0.5 & 0.5 & -0.5 & 0.5 \end{bmatrix} \qquad (4.3)$$

In matrix notation, D_n can be written as:

$$D_n = \begin{bmatrix} 0.5 & 0.5 & -0.5 & 0.5 \\ 0.5 & -0.5 & 0.5 & 0.5 \\ 0.5 & 0.5 & 0.5 & -0.5 \\ -0.5 & 0.5 & 0.5 & 0.5 \end{bmatrix} \begin{bmatrix} a & 0 & 0 & b \\ 0 & a & -b & 0 \\ 0 & -b & a & 0 \\ b & 0 & 0 & a \end{bmatrix} \begin{bmatrix} 0.5 & 0.5 & 0.5 & -0.5 \\ 0.5 & -0.5 & 0.5 & 0.5 \\ -0.5 & 0.5 & 0.5 & 0.5 \\ 0.5 & 0.5 & -0.5 & 0.5 \end{bmatrix} \qquad (4.4)$$

So the new interference free detection matrix D_n becomes

$$D_n = \begin{bmatrix} a+b & 0 & 0 & 0 \\ 0 & a+b & 0 & 0 \\ 0 & 0 & a-b & 0 \\ 0 & 0 & 0 & a-b \end{bmatrix} \qquad (4.5)$$

New channel matrix is derived from D_n as:

$$D_n = Q^TDQ = Q^HDQ = Q^HH^HHQ \qquad (4.6)$$

$$= (HQ)^H \,.\, (HQ)$$

So, new channel matrix is defined as

$H_n = HQ$, where:

$$H_n = \begin{bmatrix} (h_1+h_2-h_3+h_4)/2 & (h_1-h_2+h_3+h_4)/2 & (h_1+h_2+h_3-h_4)/2 & (-h_1+h_2+h_2+h_4)/2 \\ (h_2^*-h_1^*-h_4^*-h_3^*)/2 & (h_2^*+h_1^*+h_4^*-h_3^*)/2 & (h_2^*-h_1^*+h_4^*+h_3^*)/2 & (-h_2^*-h_1^*+h_4^*-h_3^*)/2 \\ (h_3^*+h_4^*+h_1^*-h_2^*)/2 & (h_3^*-h_4^*-h_1^*-h_2^*)/2 & (h_3^*+h_4^*-h_1^*+h_2^*)/2 & (-h_3^*+h_4^*-h_1^*-h_2^*)/2 \\ (h_4-h_3+h_2+h_1)/2 & (h_4+h_3-h_2+h_1)/2 & (h_4-h_3-h_2-h_1)/2 & (-h_4-h_3-h_2+h_1)/2 \end{bmatrix} \qquad (4.7)$$

Now using the property of EVCM new encoding matrix is expressed as:

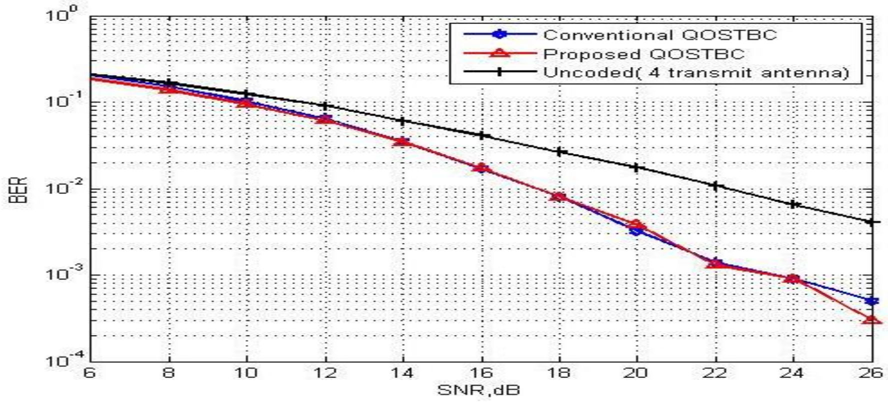
$$S_n = \begin{bmatrix} (s_1+s_2+s_3-s_4)/2 & (s_1-s_2+s_3+s_4)/2 & (-s_1+s_2+s_3+s_4)/2 & (s_1+s_2-s_3+s_4)/2 \\ (-s_1^*+s_2^*-s_3^*-s_4^*)/2 & (s_1^*+s_2^*+s_3^*-s_4^*)/2 & (-s_1^*-s_2^*+s_3^*-s_4^*)/2 & (-s_1^*+s_2^*+s_3^*+s_4^*)/2 \\ (s_1^*-s_2^*-s_3^*-s_4^*)/2 & (-s_1^*-s_2^*+s_3^*-s_4^*)/2 & (s_1^*+s_2^*+s_3^*-s_4^*)/2 & (s_1^*-s_2^*+s_3^*+s_4^*)/2 \\ (s_1+s_2-s_3+s_4)/2 & (s_1-s_2-s_3-s_4)/2 & (-s_1+s_2-s_3-s_4)/2 & (s_1+s_2+s_3-s_4)/2 \end{bmatrix} \qquad (4.8)$$

The new encoding matrix S_n is Quasi-orthogonal, but its channel matrix H_n is orthogonal matrix, so it enables simple linear decoding at the receiver thereby reducing decoding complexity without sacrificing in terms of bit error rate. The decoding matrix is given by:

$$\hat{C} = H_n^H H_n C_n + H_n^H \bar{n} \qquad (4.9)$$

$C_n = [s_1\ s_2\ s_3\ s_4]^T$, $\bar{n} = [n_1\ n_2^*\ n_3^*\ n_4]^T$

4. SIMULATION RESULTS



Graph 4.1: Performance of conventional and proposed QO-STBC scheme.

5. CONCLUSION

A new QO-STBC is developed which has very low decoding complexity than the maximum likelihood decoder and zero forcing decoder. The proposed scheme is developed by using symmetry property of the grammian matrix. The encoding matrix S_n is Quasi-Orthogonal but the virtual channel matrix H_n is Orthogonal which results in simple linear decoding thereby reducing the transmission delay which in turn reduces the decoding complexity without any degradation in BER performance. It is well known that transmission strategy can be improved using the closed loop system in which the transmitter have aces to the channel state information. The proposed QO-STBC provides more power gain in comparison to the conventional QO-STBC thereby reducing decoding complexity and increased BER performance.

6. REFERENCES

[1] V. Tarokh, H. Jafarkhani and A. R. Calderbank, "Space-time block codes from orthogonal designs", IEEE Transactions on Information Theory, vol. 45, pp. 1456-1467, July 1999.

[2] Z. Chen, B. Vucetic, J. Yuan and K. L. Lo, "Space-time trellis codes with two three and four transmit antennas in quasi-static flat channels", IEEE International Conference on Communications, vol. 3, no. 2, pp. 1589-1595, February 2002

[3] H. Jafarkhani, "A quasi orthogonal space-time block code", IEEE Transactions on Communications, vol. 49, pp. 1-4, January 2001.

[4] V. Tarokh, H. Jafarkhani and A.R. Calderbank, "Space-time block coding for wireless communications: Performance results", IEEE Journal on Selected Areas in Communication, vol.17, no. 3, pp. 451-460, March 1999.

[5] I. Choi, J. K. Kim, H. Lee and I. Lee, "Alamouti-Codes based Four-Antenna Transmission Schemes with Phase Feedback", IEEE Communications Letters, vol. 13, no. 10, pp. 749-751, October 2009.

[6] U. Park, S. Kim, K. Lim and J. Li, "A Novel QO-STBC Scheme with Linear Decoding for Three and Four Transmit Antennas", IEEE Communications Letters, vol. 12, no. 12, pp. 868-870, December 2008.

[7] C. Yuen, Y. L. Guan and T. T. Tjhung, "Quasi-Orthogonal STBC With Minimum Decoding Complexity", IEEE Transactions on Wireless Communications, vol. 4, no. 5, pp. 2089-2094, September 2005.

[8] W. Su and X. G. Xia, "Signal Constellations for Quasi-Orthogonal Space-Time Block Codes with Full Diversity", IEEE Transactions on Information Theory, vol. 50, no. 10, pp. 2331-2347, October 2004.

[9] Y. Yu, S. Kerouedan and J. Yuan, "Transmit Antenna Shuffling for Quasi-Orthogonal Space-Time Block Codes with Linear Receivers", IEEE Communications Letters, vol. 10, no. 8, pp. 596-598, August 2006.

[10] C. M. Li and Y. C. Chen, "A Simple One-Constant Feedback Quasi-Orthogonal Space-Time Block Code Transmission Scheme", International Conference on Computing, Communication and Applications, Hongkong, pp. 167-169, 2012.

[11] H. K. Shah, R. K. Dana and K. S. Dasgupta, "Performance Evaluation of QO-STBC and CR-QO-STBC over Correlated Channel", International Conference on Communication Systems and Network Technologies, Rajkot, pp. 207-210, 2012.