Enhancement of Twice Quasi Orthogonal Space Time Block Coded (QOSTBC) Performance System with Zero Forcing EVCM Decoder

Desy Agustin[1], *Nachwan* Mufti Adriansyah[1,1,], and *Muhsin*[1,]

[1]Electrical Engineering, the School of Engineering, Telkom University.
Jl. Telekomunikasi No. 01, Terusan Buah Batu, Sukapura, Dayeuhkolot, Bandung, Jawa Barat 40257, Indonesia.

Abstract. In today's modern telecommunications systems, makes the number of studies and development of multiple antennas and multiple-input multiple- output (MIMO) systems to achieve high reliability and low complexity. One attractive approach to improve that performance is using technique transmit diversity which is spacetime block coding and receiver diversity i.e. zero forcing EVCM (ZF EVCM). Although some earlier MIMO standards were develop some space-time codes like (O-STBC)and (Q-OSTBC) to provide high reliability but they are limited able to achieve orthogonality. In this research will be proposed a MIMO system scheme which is an improvement of QOSTBC that used a transmission diversity technique. This improvement from QOSTBC is Twice QOSTBC uses a provision in two codeword matrices to be sent are arranged diagonally so as to have higher levels of orthogonality. In this case Twice QOSTBC highly structured (4x1) can be replaced as an equivalent EVCM channel H. The proposed Twice- QOSTBC's results outperform other QOSTBC techniques with a difference around 3 dB for single-input multi-input (MISO) input configuration at 10^{-6} BER and receiver ZF EVCM has a very similar structure as the code matrix S of the underlying Twice QSTBC which can eliminates the system complexity.

1 Introduction

The needs for achieve high performance in modern telecommunication systems today, such as the 5G standard, makes the number of research and development of multiple antennas and multiple-input multiple-output (MIMO) systems [1]. One attractive approach to fulfill high performance is using transmit diversity technique which is spacetime block coding [2] [3]. Full diversity is achieved while we use different orthogonal constellations for different transmitted symbols. In this research, new paradigm uses the theory of orthogonal designs [4] to design twice quasi orthogonal spacetime block codes.

[1] Corresponding author: nachwanma@telkomuniversity.ac.id

Space Time Block Coding (STBC) [3] [5] is one example of a MIMO technique that utilizes antenna time and dimensions to achieve high reliability with minimum error probabilities [5]. Although STBC excel in minimum desired BER but STBC is limited to [3] two receiver antennas Nt=2 as the antenna configuration is not able to achieve orthogonality. This limitation can be overcome by combining specifically the O-STBC to increase the spatial diversity of the scheme [6]. Unfortunately OSTBC can only applied on BPSK modulation when we want to use complex modulation the code is referred to as QO-STBC [7][8]. Standards of QO-STBC scheme that provides Nt>2 and which can be applied on complex modulation, the full diversity can be achieved. Quasi Orthogonal STBC tends to reduce interference by minimizing the non-orthogonality of the symbol.

A few studies were already proposed and developed on methods QOSTBC some of research are ”Two Quasi Orthogonal Space-Time Block Codes with Better Performance and Low Complexity Decoder” [9]. This research trying to exploiting these codes, changed property of the channel from quasi-static fading to block fading and discovered that this alteration improved the proposed code’s performance by up to 4 dB in comparison with [6] and [12]. This research can solve the better performance but the orthogonality still needed to be improved by using different coding method.

In this research, we propose constellations for different transmitted symbols to improve the orthogonality property of the codes. With the existence of good coding techniques for MIMO antennas are increasingly massive expected to improve the quality of service to the user. The proposed codes are designed using orthogonal designs which are transmission matrices with orthogonal columns. It is shown how simple decoding which can separately recover transmit symbols using an possible orthogonal design. The emphasis of our study in was to design codes which provide full diversity by generalizing the theory of orthogonal designs with using Twice QOSTBC. Twice QOSTBC is used in 8,16,64 transmitter antenna which will be obtained coded more orthogonal. The ZF EVCM can also be used to apply a low complexity decoder. It has been shown that the ZF EVCM has the same structure as the corresponding QSTBC [13].

The paper is organized as follows, in section II we study on the proposed system along with Twice QOSTBC and Zero Forcing EVCM decoder. Next, in the section III we explore the evaluated performance of Twice QOSTBC. The main conclusion of this research is summarized in section IV.

2 The Proposed System Model

2.1 Twice QOSTBC Encoding

MIMO schemes with full rate and full diversity are met if modulation is in binary. If the complex modulastion used, OSTBC with full rate and diversity cannot be achieved [2]. Another alternative that can be used is QOSTBC which can increase the data rate and maintain the level of diversity of the system [10] [11][12]. QOSTBC tends to decrease interference by reducing the non-orthogonality of symbols. This paper proposed a scheme code word that has better orthogonality to achieve full diversity and full orthogonal. For the proposed Twice QOSTBC scheme can be seen in the following Figure 1.

In [9] a novel QO-STBC scheme for three and four transmit antennas was proposed by reforming the detection matrix of the conventional QO-STBC by using two QOSTBC technique where data matrix of symbol that will be send transformed into a scheme introduce by Tirkkonen, Boariu and Hottinen. This scheme used Alamouti scheme to construct matrix symbol pattern that will be derivative into 4x1, 8x1, 16x1 matrix antenna. We will start sending a code word with $C \in C^{TxM_T}$ where T is time slot and received signal is $Y \in C^{TxM_R}$,

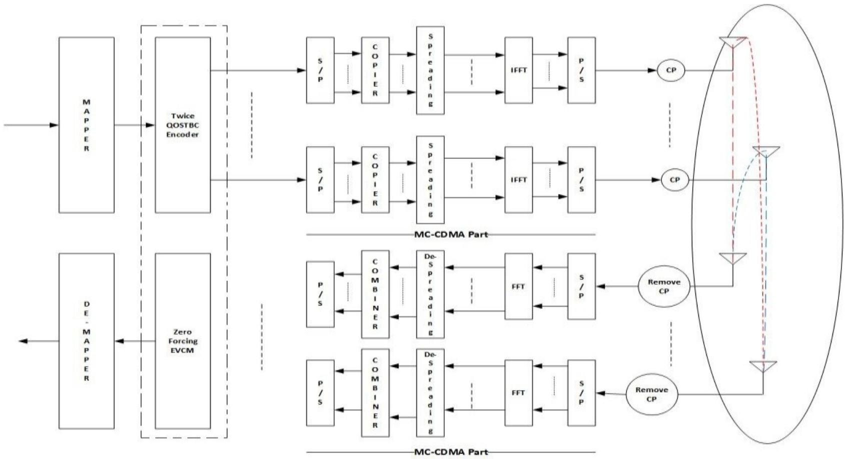

Fig 1. The Proposed Methode Twice QOSTBC transmitter

$H \in C^{T\, xM_R}$ is a fading matrix and $N \in C^{T\, xM_R}$ is Additve White Gaussian Noise (AWGN). For a system that has been designed for two blocks fading the following expression can be written as follows

$$\begin{bmatrix} Y_1 \\ Y_2 \end{bmatrix} = \begin{bmatrix} C_1 & 0 \\ 0 & C_2 \end{bmatrix} \begin{bmatrix} H_1 \\ H_2 \end{bmatrix} + \begin{bmatrix} N_1 \\ N_2 \end{bmatrix} \tag{1}$$

By using Alamouti scheme we can define as matrix generator

$$(x_1, x_2) = \begin{bmatrix} x_1 & x_2 \\ -x_2^* & x_1^* \end{bmatrix} \tag{2}$$

In this paper, a new approach is proposed for the Twice QOSTBC scheme by re-forming the matrix generator using a different technique. The main properties of different technique orthogonal design are simple separate encoding and full diversity. In order to full-diversity codes, we relax the derivation of matrix with better orthogonality. The derivation of matrix Twice-QOSTBC is explained below :

$$S_{4x4} = \begin{bmatrix} U_1 & U_2 & 0 & 0 \\ -U_2^* & U_1^* & 0 & 0 \\ 0 & 0 & U_3 & U_4 \\ 0 & 0 & -U_4^* & U_3^* \end{bmatrix} \tag{3}$$

The aforementioned codewords are the outcome of a case where the careful combination of the two symbols result in the best possible performance to achieve full diversity. In this case, as Eq. (3) is showing we combine S_k and S_{k+4}, where k = 1,2,...4, and replacing U matrix in Eq(4),as follows:

$$C = \begin{bmatrix} S_1 + jS_2 & S_3 + jS_4 & 0 & 0 \\ -(S_3 + jS_4)^* & (S_1 + jS_2)^* & 0 & 0 \\ 0 & 0 & S_1 + jS_2 & S_3 + jS_4 \\ 0 & 0 & -(S_3 + jS_4)^* & (S_1 + jS_2)^* \end{bmatrix} \tag{4}$$

Equation (4) is valid for single rate. Because of the use of zeros in (3), the code has a high peak-to-average power ratio that may increase its cost of implementation. A similar idea can be used to combine transmission matrices (4x1) to build a transmission matrix (8x1) and so on. An example of an 8x1 matrix which provides a rate one code

$$S_{8x8} = \begin{bmatrix} U_1 & U_2 & U_3 & U_4 & 0 & 0 & 0 & 0 \\ -U_2^* & U_1^* & -U_4^* & U_3^* & 0 & 0 & 0 & 0 \\ U_3^* & U_4^* & -U_1^* & -U_2^* & 0 & 0 & 0 & 0 \\ -U_4 & U_3 & U_2 & -U_1 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & U_5 & U_6 & U_7 & U_8 \\ 0 & 0 & 0 & 0 & -U_6^* & U_5^* & -U_8^* & U_7^* \\ 0 & 0 & 0 & 0 & U_7^* & U_8^* & -U_5^* & -U_6^* \\ 0 & 0 & 0 & 0 & -U_8 & U_7 & U_6 & -U_5 \end{bmatrix} \quad (5)$$

For the OSTBC scheme the detection matrix is always diagonal this enables the use of simple linear decoding, but in the two-QOSTBC previous scheme this cannot be done due to the non-orthogonal detection matrix [9]

$$v = \begin{bmatrix} \alpha & 0 & \beta & \beta \\ 0 & \alpha & 0 & 0 \\ \beta & 0 & \alpha & 0 \\ \beta & 0 & 0 & \alpha \end{bmatrix} \quad (6)$$

Where the diagonal elements α represent the channel gains and β represent the interference from the neighbouring signals, for eight transmit antennas. The interference in the detection matrix will cause performance degradation. Now, the encoding matrix codeword Twice QOSTBC result in a free interference detection matrix be given as

$$\begin{matrix} < v_1, v_i >= 0, i \neq 1 & < v_2, v_i >= 0, i \neq 2 \\ < v_3, v_i >= 0, i \neq 3 & < v_4, v_i >= 0, i \neq 4 \\ < v_5, v_i >= 0, i \neq 5 & < v_6, v_i >= 0, i \neq 6 \\ < v_7, v_i >= 0, i \neq 7 & < v_8, v_i >= 0, i \neq 8 \end{matrix} \quad (7)$$

The orthogonality between some columns can help to simplify our ZF EVCM decoder. As mentioned before, this type of coding creates block fading channels [13].

2.2 Zero Forcing Equivalent Channel Matrix (ZF EVCM)

For detection, the interference caused by symbols on each other, related to the non-orthonormality, has to be cancelled [14]. The simple structure of the non-orthonormality matrix results in an easily implementable ZF EVCM decoder [13]. EVCM offers simple detection by ZF in EVCM domain which have better performance compared to conventional ZF, estimation using Zero Forcing EVCM (ZF-EVCM) applied by

$$y(t) = \begin{pmatrix} y_1 \\ y_2 \\ \cdots \\ y_N \end{pmatrix} = H_N \begin{pmatrix} x_1 \\ x_2 \\ \cdots \\ x_N \end{pmatrix} + \begin{pmatrix} n_1 \\ n_2 \\ \cdots \\ n_N \end{pmatrix} \quad (8)$$

The channel coefficients are denoted by $\mathrm{h} = [\mathrm{h}_1, \mathrm{h}_2, \mathrm{h}_3, \mathrm{h}_4]$ and $\mathrm{n} = [\mathrm{n}_1, \mathrm{n}_2, \mathrm{n}_3, \mathrm{n}_4]$ is the noise vector. Zero forcing EVCM has a very similar structure as the code matrix S of the underlying Twice QSTBC which can eliminates the system by

$$\tilde{x} = \left(H_{N_t}^H H_{N_T}\right)^{-1} H_{N_t}^H y \quad (9)$$

with mean value of $x^{\sim}$ are simply taken from each receive antennas as final result of QOSTBC decoding.

3. Simulation Result

This study focused on the performance of the downlink transmission system. The goal is to address the problem of high reliability with full orthogonality. The purpose of this simulation is to demonstrate the superiority of the proposed system compared with QOSTBC system which has higher orthogonolatias value so it can achieve full diversity coding scheme and full orthogonality. The matlab script performs the following : First, generate random binary sequence of +1+j,+1-j,-1+j,-1-j and then group them into pair of four symbols and send four symbols in one time slot (Twice QOSTBC), multiply the Twice QOSTBC with the channel and then add white Gaussian noise. The received symbols will perform zero forcing EVCM and count the bit errors. Repeat for multiple values of SNR and plot the simulation and theoritical results.

Figure 2 shows the result of Twice QOSTBC simulation compared to QOSTBC system in Rayleigh channel for four transmitter antennas. As it is shown from the Figure 2 that the proposed results outperform other QOSTBC techniques with a difference around 3 dB for 10^{-6} BER This is because the Twice QOSTBC coding technique sends two symbols at once which are repeated with the second codeword and the orthogonality of this coding technique is also smaller so the possibility of smaller interference and the reliability of the transmitted data will be more efficient. The simulation results also show the correct data because it does not exceed the predetermined BER result based on diversity order = 4.

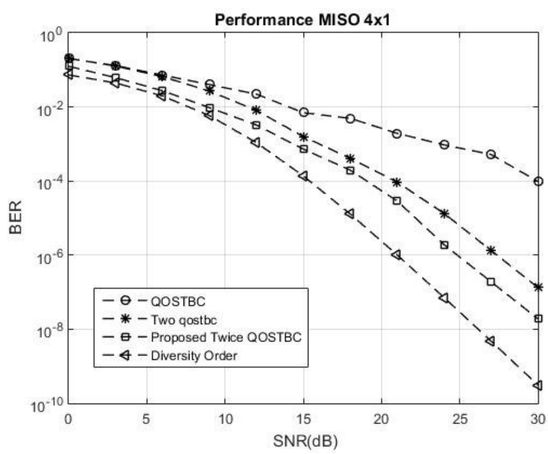

Fig 2. The comparison analysis between MISO 4x1 QOSTBC Scheme, Twice QOSTBC Scheme, and diversity order Scheme

Figure 3 shows the performances of the proposed Twice QOSTBC and the conventional QOSTBC for eight transmit antennas. It is clearly indicated that the proposed scheme achieves better performance than the conventional scheme.We can shown that by carefully choosing the coding scheme, the non-orthogonality can be minimized, and accordingly the performance can be maximized. The simulation results also show the correct data because it does not exceed the predetermined BER result based on diversity order = 8.

Figure 4 shows MIMO 16x16 has a better performance than MIMO 2x2. On the use of 16 antennas, to achieve the BER target of 10^{-5}, the Twice QOSTBC system requires SNR $\pm 3, 5$ dB, while on the use of 2 antennas, SNR larger ± 22 dB, so the improvement performance provided by the number of antennas used is $\pm 18, 5$ dB. It can be concluded,

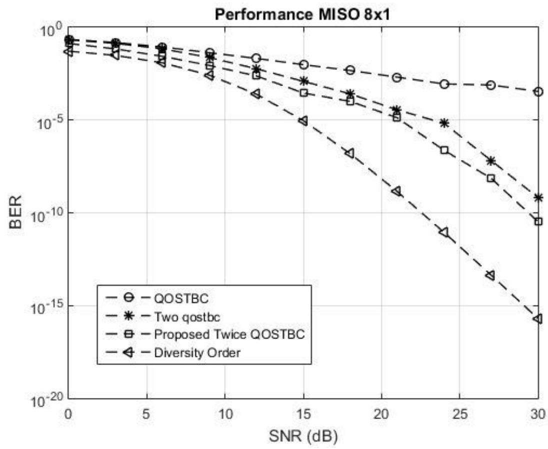

Fig 3. The comparison analysis between MISO 8x1 QOSTBC Scheme, Twice QOSTBC Scheme, and diversity order Scheme

higher number of antennas provides lower BER. In addition, the 16x16 MIMO used the Twice Orthogonal Space Time Block Code (OSTBC) scheme. It was observed that by reforming the detection matrix of the original QO-STBC to eliminate the interference terms, it was able to derive the orthogonal channel matrix that results in simple decoding scheme as in OSTBC. In addition, the more number of antennas used, the faster the process of coding and transmitting data.

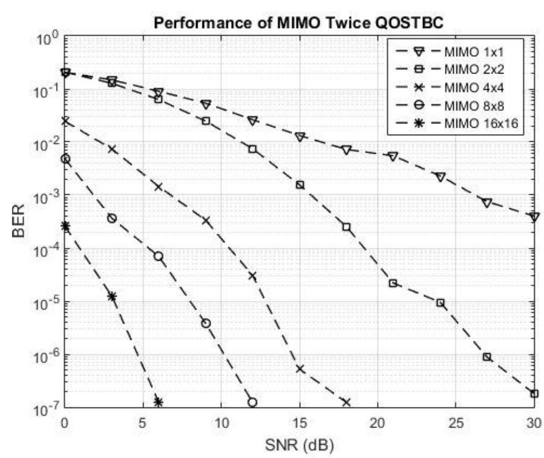

Fig 4. MIMO Twice QOSTBC system

3 Conclusion

From the research results, we can concluded that in general the proposed sytem maintained a better performance compared to other Space Time Coding scheme. Previous research QOSTBC does not have really orthogonal behavior. This non orthogonal behavior leads to increasing error. It has been evaluated in this research using twice qostbc technique coding. Orthogonality rate of full rate Twice-Qostbc by experiment is

$$k = \frac{1}{2} + \frac{2}{n}$$

with n is number of antennas (4,8,16,...). Orthogonality rate is decreasing close to 0,5 by increasing number of antennas. The value of orthogonality of transmitt antenna 4 can provides better SNR at 24 dB to reach the value of BER = $1,617x10^{-6}$.

From the point of view of decoding, the minimal nonorthogonality code presented here may run into trouble in slowly fading channels, when the worst case scenario where all channels are the same may persist for a long time. Alternatively, to prevent this may be applied with algorithm ZF EVCM known to the receiver.

References

1. G. O. Kelvin Anoh and S. Jones, " Full diversity qo-stbc technique for large antenna mimo systems Internet Technologies and Applications",(ITA)Wrexham,UK, (2015)
2. S. Alamouti, “A Simple Transmitter Diversity Technique for Wireless Communications. IEEE Journal on Selected Areas of Communications, Special Issue on Signal Processing for Wireless Communications”, vol.16, no.8, pp.1451-1458, Oct. (1998).
3. C. Tarokh.V, Jafarkhani, "Space-time block coding for wireless communications : Performance results" IEEE J.Select Areas COmmun, 17:451460, Mar (1999).
4. V. Geramita and J.Seberry, "Orthogonal designs,quadratic forms and hadamard matrices" ser.Lecture Notes in Pure and Applied Mathematics, 43, (1979).
5. C. Okorafor, Rodriguez, "Performance evaluation of spatial modulation and qostbc for mimo systems" EAI Endorsed Trans.Mobb Commun Appl J.Select Areas COmmun, 44:15, Mar (2015).
6. S. Proakis, J.G. "Digital communications". Mc Graw-Hill:New York,NY,USA,(2008).
7. S. Larsson. "Space time block coding for wireless communications" Cambridge University Press,Cambridge,UK, (2008).
8. H. Jafarkhani. "Space-time coding:theory and practice", Cambridge University Press,Cambridge,UK, (2005)
9. Ali Lotfi-Rezaabad1, Siamak Taleb,"Two Quasi Orthogonal Space-Time Block Codes with Better Performance and Low Complexity Decoder" harif University of Technology (SUT), Tehran, IRAN, (2016)
10. H. Jafarkhani, “A quasi orthogonal space-time block code”, IEEE Trans. Comm., vol. 49, pp. 1-4, January, (2001).
11. O. Tirkkonen, A. Boariu, A. Hottinen, “Minimal nonorthogonality rate one space-time block codes for 3+ Tx antennas”, IEE International Symposium on Spread Spectrum Tech- niques and Applications (ISSSTA), vol. 2, New Jersey, USA, pp. 429-432, September, (2000).
12. C. B. Papadias and G. J. Foschini,“Capacity-approaching space-time codes for systems employing four transmitter antennas”, IEEE Trans. on Information Theory, vol. 49, pp. 726-733, March (2003)
13. Badic, Biljana. "Space-Time Block Coding for Multiple Antenna Systems",November (2005)
14. Patrick Marsch et al., "Quasi-Orthogonal STBC using Streched Constellations for Low Detection Complexity", IEEE Wireless Communications and Networking Conference, (2007)