Study and Simulation of Quasi and Rotated Quasi Space Time Block Codes in MIMO systems using Dent Channel model

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ABSTRACT

Multiple Input Multiple Output (MIMO) has become one of the most exciting field in modern engineering.It has become one of the key technologies for wideband wireless communication systems.It is mainly used to increase capacity and data rate of any wireless systems.In this paper,we exploit the space and time diversity to decode the quasi and rotated quasi space time block codes (QOSTBC) based on dent channel model.For doppler shifting and rayleigh distribution we make use of dent channel model.A general Quasi and rotated quasi Space-Time Block Coded (STBC) MIMO structure is presented in this paper. BER analysis is presented in terms of code rate and diversity achieved using Quasi and Rotated quasi STBC methods. Furthermore, simulations are carried out using above two OSTBC methods with various modulation schemes in quasi static dent channel model and then optimum coding method is suggested for 4×2 quasi and rotated quasi Space time block coded MIMO systems.This provide fast decoding and gives better performance of communication system.BER analysis is presented in terms of diversity and code rate.

KEYWORDS

MIMO, QUASI ORTHOGONAL SPACE-TIME BLOCK CODES (QOSTBC), ROTATED QOSTBC,MAXIMUM LIKELIHOOD (ML) DECODING.

1. INTRODUCTION

MIMO technology constitutes a breakthrough in wireless communication system that offers a number of benefits that helps in improving the reliability of link. The advantage of MIMO technology includes improvement in array gain, spatial diversity gain, multiplexing gain and interference reduction. MIMO systems provide diversity to mitigate fading, that is realized by providing the receiver with multiple copies of the transmitted signal in space, frequency or time. By increasing number of signal replicas, the probability of getting least faded signal is increased. The information capacity of a system is increased by employing multiple transmit and receive antennas. An effective and practical way to gain the capacity of the multiple input multiple output (MIMO) is to employ Space Time (ST) Coding. Space-Time (ST) coding schemes combines coding along with transmit diversity to achieve high diversity performance. It can be implemented in two forms ST-Trellis and ST-Block codes.

The main problem with ST-Trellis scheme is that its decoding complexity increases exponentially with diversity and transmission rate. To address this problem Alamouti proposed Orthogonal ST block codes (OSTBC) for 2×1 and 2×2 systems.

Space-time block code designs have recently attractedconsiderable attentions. One attractive approach of space-timeblock codes (STBC) is from orthogonal designs as proposed by Alamouti [5] and Tarokh, Jafarkhani and Calderbank [9].STBC (Space-Time Block Code)[1][2][3] is a coding technique used in MIMO system which has time and space domain correlation among signals transmitted from the multiple antennae. Relative to the non coded system, STBC can provide higher gain of diversity and power with nobandwidth loss.OSTBC (Orthogonal Space-Time Block Code)[4][5][6] is one important subset of linear space time block coding, with its rows and columns keep orthogonal. One basic OSTBC is Alamouti code[7], which as standard, was adopted in third generation mobile telecommunication system[8]. OSTBC had one shortcoming, that is, when utilizing plurality modulation meanwhile the number of transmitting antenna is more than 2,even the OSTBC with full diversity gain obtained by using complex orthogonal, it still cannot obtain full transmissionrate.How to improve the transmission rate is one topic to study.Per above mentioned shorting, Jafarkhani proposed QOSTBC(Quasi-Orthogonal Space-Time Block Code).

These codes achieve full diversity and have fast MaximumLikelihood (ML) decoding at the receiver.It is a modulation schemes for multiple transmit antennas that provide full diversity with simple coding and decoding technique.Alamouti STBC scheme is the first space time block codes to provide full transmit diversity for two transmitting antenna. It is a simple single decoder scheme for 2×2 antennas that provide full rate. It is not possible provide full transmission rate for more than two antennas.Quasi orthogonal codes[8] of full rate have been proposed to overcome the shortcomings of orthogonal codes that cannot achieve full rate. In order to design full transmission rate that provide maximum possible diversity, the decoder performs pairwise symbol decoding instead of single symbol decoding. This is called quasi orthogonal space time block codes (QOSTBC) .Typically, quasi orthogonal space time codes perform best with ML decoding. This technique provide full rate with maximum possible diversity. It is impossible to achieve full diversity if all the symbols are chosen from the same constellation’s ,the solution to this problem is rotation based method, which aims at maximizing the minimum distance in the space time constellation by using different constellation for different transmitted symbols. Using this concept it is possible to provide full diversity. This is called Rotated Quasi Orthogonal Space Time Block Codes.

The rest of the paper is organized as follows. In section 2, we introduce MIMO space time block code transceiver model and briefly review the ST code design criteria. In section 3,space time block codes is discussed with its two methods. In section 4, ML decoding method is discussed. The simulation results are presented in section 5, and some conclusions are drawn in section 6.

2. SYSTEM MODEL

A typical MIMO communication system consists of transmitter, channel and receiver. Space Time coding involves use of multiple transmit and receive antennas. Figure.1 shows the transceiver of MIMO in space time code. Bits entering to the system are mapped into the symbol mapper using different modulation techniques like BPSK, QPSK and 16-QAM.Bits entering the quasi and rotated quasi space time block code encoder serially are distributed to parallel substreams.Within each substream, bits are mapped to signal waveforms, which are then emitted from the antenna corresponding to that substream.Signals transmitted simultaneously over each antenna interfere with each other as they propagate through then wireless channel. The receiver collects the signal at the output of receiver antenna element and reverses the transmitter operation in order to decode the data with quasi and rotated quasi space time decoder.

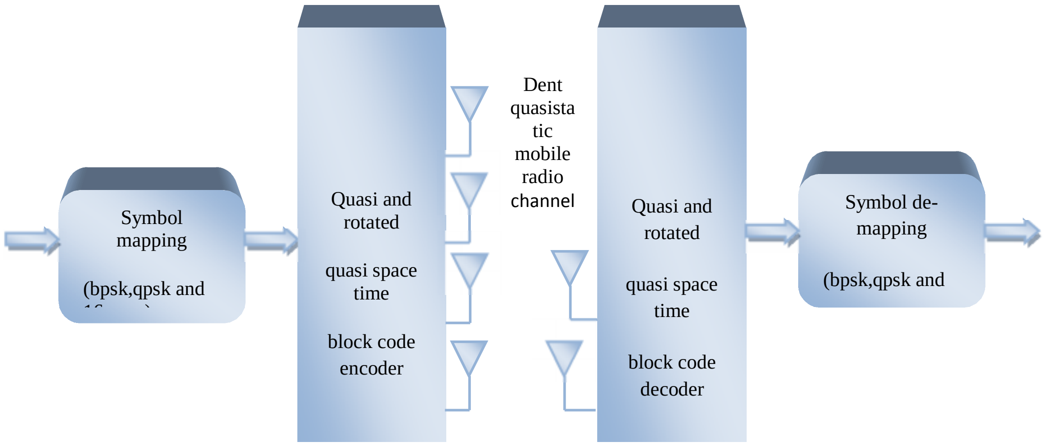

Figure 1. Quasi and rotated quasi Space Time Block Coded 4x2 MIMO transceiver structure

3. SPACE TIME BLOCK CODES (STBC)

Space time block codes(STBCs) [3] have been proposed to realize the enhanced reliability of multi-antenna systems.It is a transmit diversity scheme in which full diversity is achived while a very simple ML decoding algorithm is used at the decoder.This new paradigm uses the theory of orthogonal designs to design space time block codes [4].When transmitter has two antennas,Alaomuti codes [3] achieve the full diversity performance with a symbol rate of 1(rate-one) and simple linear processing under the assumption of no channel data information at the transmitter (CSIT) but perfect channel state information at the receiver (CSIR). Alamouti code provides the full diversity of 2 with 2 transmitting antenna with a rate of 1. For more reliable communication, Alamouti code can be further generalized for more than two transmitting antenna using the concept of orthogonal designs. But unfortunately it neither provide any coding gain nor achieve a rate larger than ¾ [3].

It is proved in [4] that a complex orthogonal design and corresponding Space Time Block code which provide full diversity and full transmission rate is not possible for more than two antennas.

3.1. QUASI ORTHOGONAL SPACE TIME BLOCK CODES (QOSTBC)

Full- rate orthogonal designs with complex elements in its transmission matrix are impossible for more than two transmit antennas[8].The only example of a full-rate full-diversity complex space-time block code using orthogonal designs is Alamouti schemes [8].The generator matrix [8] of Alamouti code is given as,

$$G(x_1, \quad x_2) = \begin{pmatrix} x_1 & x_2 \\ -x_2^* & x_1^* \end{pmatrix} \qquad (1)$$

to design full rate codes, we co(1)sider codes with decoding pair of symbols [8].

$$G = \begin{pmatrix} G(x_1, x_2) & G(x_3, x_4) \\ -G^*(x_3, x_4) & G^*(x_1, x_2) \end{pmatrix} \qquad (2)$$

$$= \begin{pmatrix} x_1 & x_2 & x_3 & x_4 \\ -x_2^* & x_1^* & -x_4^* & x_3^* \\ -x_3^* & -x_4^* & x_1^* & x_2^* \\ x_4 & -x_3 & -x_2 & x_1 \end{pmatrix} \quad (3)$$

we denote the ith column of above matrix by v_i, then for any intermediate variable x_1, x_2, x_3, x_4 , we have,

$$(v_1, v_2) = (v_1, v_3) = (v_2, v_4) = 0 \quad (4)$$

where, the above symbols are inner product of eachother independently.

3.2. ROTATED QUASI SPACE TIME BLOCK CODES (RQOSTBC)

Sometimes, it is impossible to achieve code rate 1 for the complex orthogonal codes.To provide full diversity, different constellations are send through different transmitted symbols.This is done by rotating the symbols before transmission.This provide full-diversity with code rate 1 and these pairing of symbols gives good performance as compared to QOSTBC.

For *M* receive antennas, a diversity of 2*M* is achieved while the rate of the code is one. The maximum diversity of 4*M* for a rate one complex orthogonal code is impossible in this case if all symbols are chosen from the same constellation. By using same constellation for all symbols in the subset reduces the minimum distance for such codes. As a remedy to this problem, rotation based method is used that aims in maximizing the minimum distance in the space time constellation. To provide full diversity, we use different constellations for different transmitted symbols.

For example, we may rotate symbols x_3 and x_4 before transmission. Let us denote x'_3 and x'_4 as the rotated versions of x_3 and x_4, respectively. We show that it is possible to provide full-diversity QOSTBCs by replacing (x_3, x_4) with (x'_3,x'_4).The resulting code is very powerful since it provides full diversity, rate one, and simple pair wise decoding with good performance. Different modulation techniques use different rotation. In this paper, we are using bpsk, qpsk and 16-qam.The optimum rotation is given in table 1.

Table 1.Optimum rotation for different modulation techniques

Modulation techniques	**Optimum rotation**
BPSK	$\pi/2$
QPSK	$\pi/4$
16-QAM	$\pi/4$

3.3. DENT CHANNEL MODEL

A Rayleigh fading channel constitutes Dopplers spectrum is produced by synthesizing the complex sinusoids.The complex output of the jakes model [18], is given as,

$$h(t) = \frac{E_0}{\sqrt{2N_0 + 1}} \left\{ h_1(t) + jh_Q(t) \right\} \quad (5)$$

The real and imaginary parts [7],is given as,

$$h(t)=2\sum_{n=1}^{N_0}(\cos\varphi_n \cos w_n t)+\sqrt{2}\cos\varphi_N \cos w_d t$$
$$h_Q(t)=2\sum_{n=1}^{N_0}(\sin\varphi_n \cos w_n t)+\sqrt{2}\sin\varphi_N \cos w_d t \qquad (6)$$

The unwanted correlation of Jake's model is removed ina modification by Dent model. The unwanted correlation canbe corrected by using orthogonal functions generated byWalsh-Hadamard codewords to weigh the oscillator valuesbefore summing so that each wave has equal power [11]. Theweighting is achieved by adjusting the Jake's model so thatthe incoming waves have slightly different arrival angles α_n .The modified Jakes model is given by

$$T(t) = \sqrt{(2/N_0)}\sum_{n=1}^{N_0}[\cos(\beta_n) + i\sin(\beta_n)]\cos(\omega_n t + \theta_n) \qquad (7)$$

where,the normalization factor $\sqrt{(2/N_0)}$ gives rise to $E\{T(t)T^*(t)\} = 1,\ N_0 = N/4,$ $i = \sqrt{(-1)},\ \beta_n = \prod * n / N_0$ is phase, θ is initialphase that can be randomized to provide different waveform realizations and $w_n = w_M \cos(\alpha_n)$ is the doppler shift. Dent's model successfully generates uncorrelated fadingwaveforms thereby simulating a Rayleigh multi-path air channel.

4. MAXIMUM LIKELIHOOD (ML) DECODING

At time T,four elements in the t_{th} rowof C are transmitted from the four transmit antenna.The codeword matrix is given as

$$C = G(s_1, s_2, s_3, s_4) \qquad (8)$$

Since,the four given symbols are transmitted in four time slots,this gives the code rate of 1.The ML decoding matrix for QOSTBC is given as,

$$\min_{S_1,S_2,S_3,S_4}\{H^H.C^H.C.H - H^H.C^H.r - r^H.C.H \qquad (9)$$

After simple calculations, ML decoding amounts to minimizing the given sum [4],

$$f_{14}(s_1, s_4) + f_{23}(s_2, s_3) \qquad (10)$$

where,

$$f_{14}(s_1, s_4) = \sum_{m=1}^{M}\left[\left(|s_1|^2 + |s_4|^2\right) + \left(\sum_{n=1}^{4}|\alpha_{n,m}|^2\right)\right.$$
$$+2R\{(-\alpha_{1,m}r_{1,m}^* - \alpha_{2,m}^* r_{2,m} - \alpha_{3,m}^* r_{3,m} - \alpha_{4,m} r_{4,m}^*)s_1$$

$$+\left(-\alpha_{4,m} r_{1,m}^{*} + \alpha_{3,m}^{*} r_{2,m} + \alpha_{2,m}^{*} r_{3,m} - \alpha_{1,m} r_{4,m}^{*}\right) s_4 \}$$

$$+ 4R\{\alpha_{1,m}\alpha_{4,m}^{*} - \alpha_{2,m}^{*}\alpha_{3,m}\} R\{s_1 s_4^{*}\}] \tag{11}$$

and,

$$f_{23}(s_2, s_3) = \sum_{m=1}^{M}\left[\left(|s_2|^2 + |s_3|^2\right)\left(\sum_{n=1}^{4}|\alpha_{n,m}|^2\right)\right.$$

$$+2R\{\left(-\alpha_{2,m} r_{1,m}^{*} + \alpha_{1,m}^{*} r_{2,m} - \alpha_{4,m}^{*} r_{3,m} + \alpha_{3,m} r_{4,m}^{*}\right) s_2$$

$$+\left(-\alpha_{3,m} r_{1,m}^{*} - \alpha_{4,m}^{*} r_{2,m} + \alpha_{1,m}^{*} r_{3,m} + \alpha_{2,m} r_{4,m}^{*}\right) s_3 \}$$

$$+ 4R\{\alpha_{2,m}\alpha_{3,m}^{*} - \alpha_{1,m}^{*}\alpha_{4,m}\} R\{s_2 s_3^{*}\}] \tag{12}$$

From, the above calculations symbols are independent and ML decoders decode the symbols separately.

5. SIMULATION RESULTS

In this paper,the simulation parameters used throughout in this work are listed out in Table 2. Results are then plotted and discussed using these simulation parameters.

5.1. SIMULATION PARAMETERS

Simulation parameters are shown MIMO space time block coding system given in figure 1. are listed in table 1.

Table 2.SIMULATION PARAMETERS FOR MIMO STBC

S.No.	Parameters	Values
1	No. of transmitters	4
2	No. of receivers	2
3	Max. Doppler shift(fm)	200Hz
4	Sampling frequency(fs)	8000Hz
5	Career modulation	BPSK,QPSK,16QAM
6	Bandwidth	20 MHz
7	Sampling time(ts)	1/fs
8	No. of Doppler shift(N)	8

5.2. RESULTS

The simulation parameters used throughout in this work are listed in Table 1 and 2.Results are then plotted and discussed using these simulation parameters.The simulation result is conducted in MATLAB.In this we will make comparision of performance of roatated QOSTBC with roatated QOSTBC using dent model.Results with different modulation techniques is plotted for

BER with SNR.The modulation technique used is BPSK,QPSK and 16-QAM with rotation of Π/2,Π/4 and Π/4 respectively for transmission of 1.5 bits/s/Hz.In figure.2 and figure.3,BER performance is better using BPSK as compared to QPSK and 16-QAM.Figure.4 shows the comparision of quasi and rotated quasi OSTBC with BPSK modulation,it is clearly observed that rotated quasi OSTBC gives better result when compared to quasi OSTBC.As it is clear from the figure by employing 4 transmitting antennas system performance is enhanced.

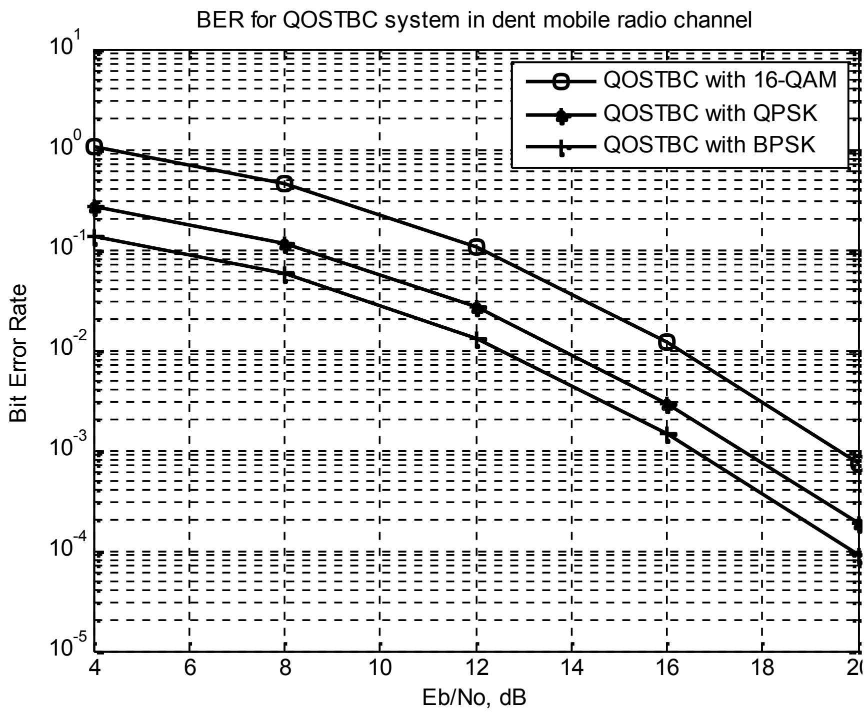

Figure 2.BER for Quasi-OSTBC system with dent channel model

6. CONCLUSION

In this paper, we studied MIMO system performance under mobile radio channel using dent model.Further,system performance is compared with three different modulation techniques and system with BPSK modulation gives better result as compared to oher modulation techniques.Quasi orthogonal space time block coding provide code rate of 1 and rotated quasi orthogonal space time block coding provide full rate and full diverty system with simple decoding technique.Maximum likelihood (ML) decoding reduces the decoding complexity of the system and enhances the system performance.it is clearly observed that the system performance enhances using dent channel model.

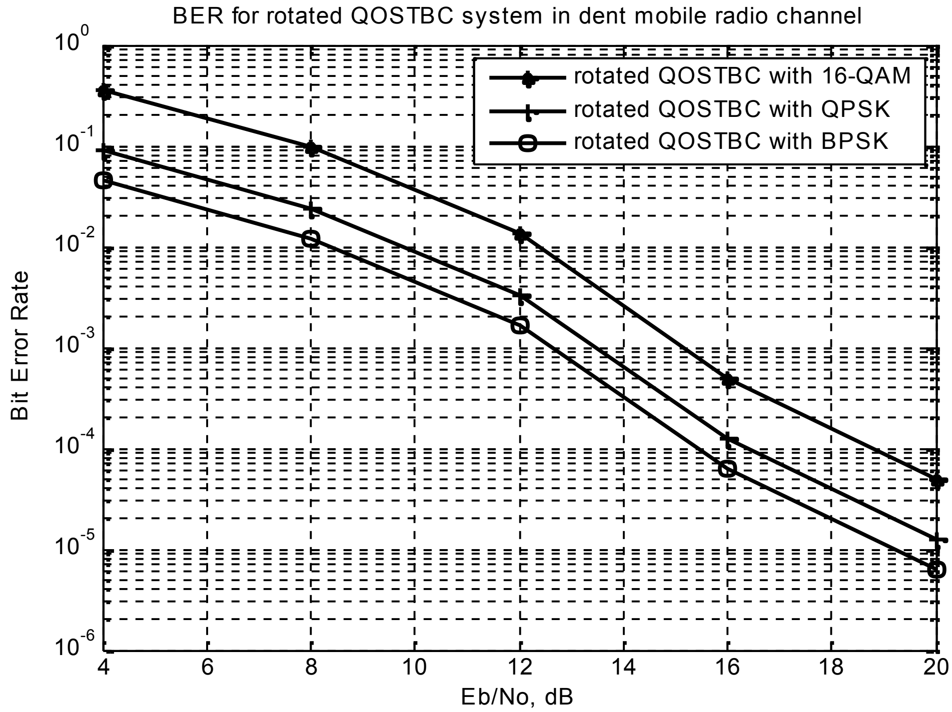

Figure 3.BER for rotaed quasi-OSTBC system with dent channel model

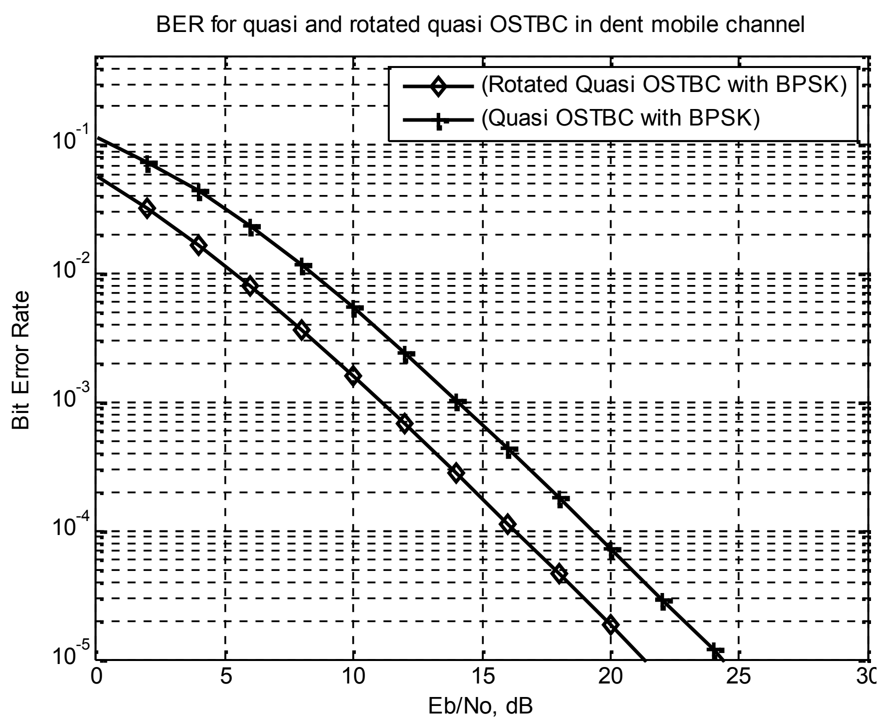

Figure 4.BER for rotaed quasi and quasi OSTBC system with dent channel model

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