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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 fields in modern engineering. It is mainly used to increase data rate and capacity of wireless communication system. 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. This provides 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, which 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. 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 to provide full transmission rate for more than two antennas. Quasi orthogonal codes 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 pair wise 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 constellations for different transmitted symbols. Using this concept it is possible to provide full diversity. This is called Rotated Quasi Orthogonal Space Time Block Codes.

2. MIMO CHANNEL MODEL

Let us consider a communication system with 'N' number of transmitting antennas and 'M' number of receiving antennas in an i.i.d Rayleigh Flat Fading channel shown in Fig. 1.

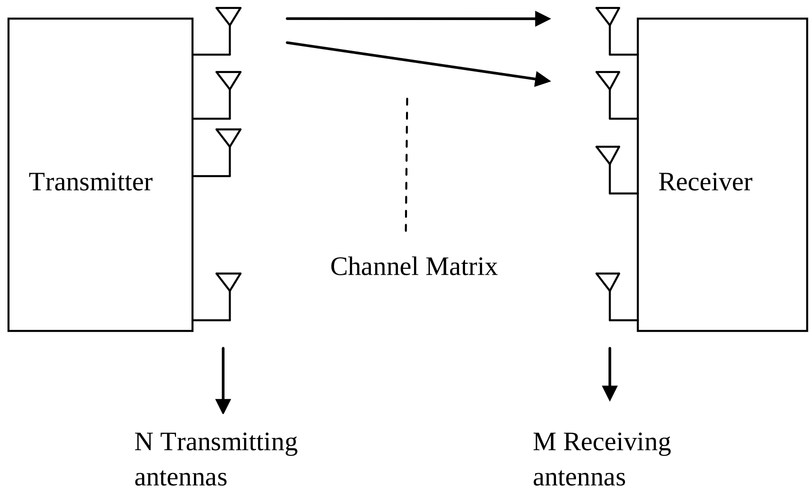

Figure1. MIMO Block Diagram

The sampled baseband representation of signal is given by

$$y = Hx + n \tag{1}$$

And the complex baseband representation of signal [15] is given by

$$y = \sqrt{\frac{P}{M}} Hx + n \tag{2}$$

where $y \in C^{N\times 1}$ is the received signal vector, $x \in C^{M\times 1}$ is the transmitted signal vector with zero mean and unit variance, P is the total transmit power, $H \in C^{N\times M}$ is the channel response matrix with possibly correlated fading coefficients. In order to access the performance of V-BLAST in correlated channel, we adopted a correlation-based channel model which is expressed as

$$H \sim R_{Rx}^{\frac{1}{2}} H_w \left(R_{Tx}^{1\backslash 2}\right)^T \tag{3}$$

Where x ~ y denotes that x and y are identical in distribution, R_{Rx} and T_{Tx} are the normal correlation distribution matrices at the Rx and transmitter (Tx) respectively, and $H_W \in C^{N\times M}$ contains i.i.d complex Gaussian entries with zero mean and unit variance.

3. RAYLEIGH CHANNEL

The fading effect is usually described statistically using the Rayleigh distribution. The amplitude of two quadrature Gaussian signals follows the Rayleigh distribution whereas the phase follows a uniform distribution. The probability distribution function (PDF) of a Rayleigh distribution is given by

$$p(r) = \begin{cases} \frac{r}{\sigma^2} exp\left(\frac{-r^2}{2\sigma^2}\right) & (0 \le r \le \infty \\ 0 & (r < 0) \end{cases}$$

Where σ is the RMS (amplitude) value of the received signal and σ^2 is the average power.

4. 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 sub streams. Within each sub stream, bits are mapped to signal waveforms, which are then emitted from the antenna corresponding to that sub stream. Signals transmitted simultaneously over each antenna interfere with each other as they propagate through 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.

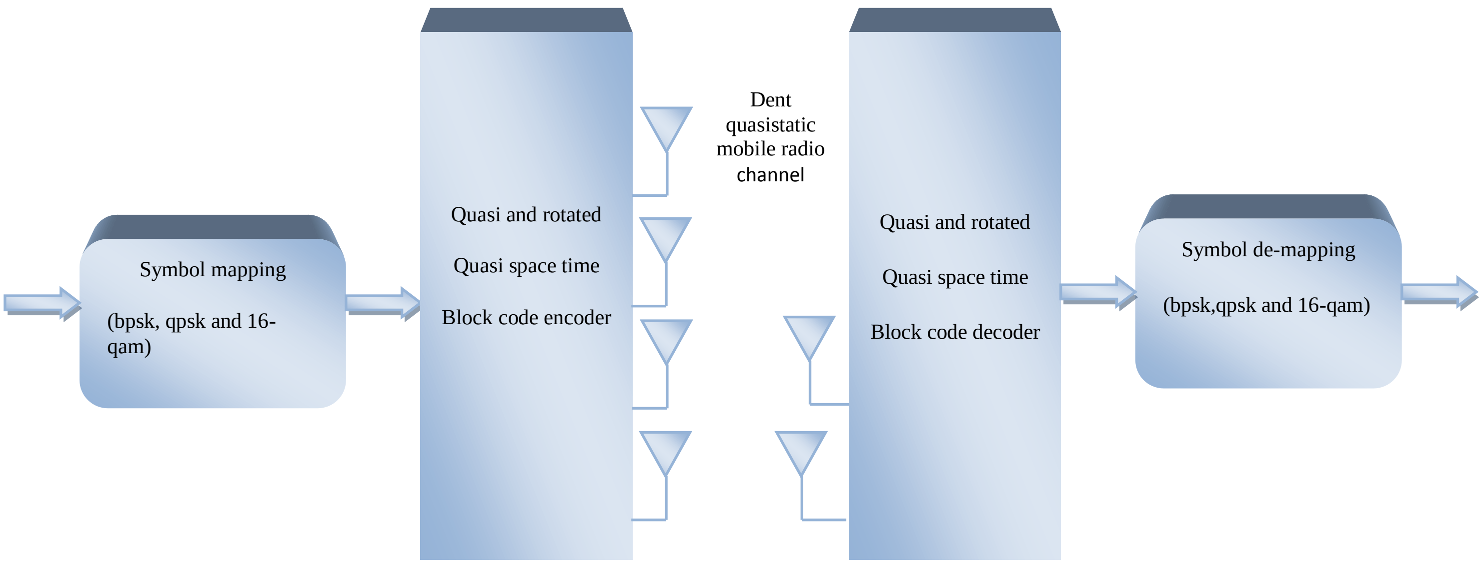

Figure2. Quasi and rotated quasi Space Time Block Coded 4x2 MIMO transceiver structure

5. 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 achieved 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 [5] 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 [6].

It is proved in [3] 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.

5.1. 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[4].The only example of a full-rate full-diversity complex space-time block code using orthogonal designs is Alamouti schemes [4].The generator matrix [4] of Alamouti code is given as,

$$G(x_1, \quad x_2) = \begin{pmatrix} x_1 & x_2 \\ -x_2^* & x_1^* \end{pmatrix} \tag{4}$$

To design full rate codes, we consider codes with decoding pair of symbols [4].

$$G = \begin{pmatrix} G(x_1, x_2) & G(x_3, x_4) \\ -G^*(x_3, x_4) & G^*(x_1, x_2) \end{pmatrix} \tag{5}$$

$$= \begin{pmatrix} x_1 & x_2 & x_3 & x_4 \\ -x_2^* & x_1^* & -x_4^* & x_3^* \\ -x_3^* & -x_4^* & x_1^* & x_2^* \\ x_4 & -x_3 & -x_2 & x_1 \end{pmatrix} \tag{6}$$

We denote the ith column of above matrix by $v_{i,}$ then for any intermediate variable x_1, x2, x3, x4 we have,

$$(v_1, v_2) = (v_1, v_3) = (v_2, v_4) = 0 \tag{7}$$

Where, the above symbols are inner product of each other independently.

5.2. 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 sending through different transmitted symbols. This is done by rotating the symbols before transmission. This provides full-diversity with code rate 1 and these pairing of symbols give good performance as compared to QOSTBC.

5.3. DENT CHANNEL MODEL

A Rayleigh fading channel constitutes Doppler's spectrum is produced by synthesizing the complex sinusoids. The complex output of the jakes model [7], is given as,

$$\mathrm{h(t)} = \frac{\mathrm{E_0}}{\sqrt{2\mathrm{N_0}+1}} \{\mathrm{h_1(t) + jh_Q(t)}\} \tag{8}$$

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

$$h(t) = 2\sum_{n=1}^{N_0} (\cos\phi_n \cos w_n t) + \sqrt{2}\cos\phi_N \cos w_d t$$

$$h_Q(t) = 2\sum_{n=1}^{N_0} (\sin\phi_n \cos w_n t) + \sqrt{2}\sin\phi_N \cos w_d t \tag{9}$$

The unwanted correlation of Jake's model is removed in a modification by Dent model. The unwanted correlation can be corrected by using orthogonal functions generated by Walsh-Hadamard codewords to weigh the oscillator values before summing so that each wave has equal power [11]. The weighting is achieved by adjusting the Jake's model so that the incoming waves have slightly different arrival angles α_n .The modified Jakes model is given by

$$T(t) = \sqrt{(2/N_0)} \sum_{n=1}^{N_0} [\cos(\beta_n) + i\sin(\beta_n)] \cos(\omega_n t + \theta_n) \tag{10}$$

Where, the normalization factor $\sqrt{(2/N_0)}$ gives rise to $E\{T(t)T^*(t)\} = 1,\ N_o = N/4,$

$i = \sqrt{(-1)}, \beta_n = \Pi * n / N_o$ is phase, θ is initial phase 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 fading waveforms thereby simulating a Rayleigh multi-path air channel.

6. MAXIMUM LIKELIHOOD (ML) DECODING

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

$$C = G(s_1, s_2, s_3, s_4) \tag{11}$$

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,

$$\min_{S_1,S_2,S_3,S_4} \{H^H.C^H.C.H - H^H.C^H.r - r^{H.}C.H \tag{12}$$

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

$$f_{14}(s_1, s_4) + f_{23}(s_2, s_3) \tag{13}$$

Where,

$$\begin{aligned} f_{14}(s_1,s_4) = \sum_{m=1}^{M} \Bigg[& \left(|s_1|^2 + |s_4|^2\right) + \left(\sum_{n=1}^{4} |\alpha_{n,m}|^2\right) \\ & + 2R\{\left(-\alpha_{1,m} r_{1,m}^{*} - \alpha_{2,m}^{*} r_{2,m} - \alpha_{3,m}^{*} r_{3,m} - \alpha_{4,m} r_{4,m}^{*}\right) s_1 \\ & + \left(-\alpha_{4,m} r_{1,m}^{*} + \alpha_{3,m}^{*} r_{2,m} + \alpha_{2,m}^{*} r_{3,m} - \alpha_{1,m} r_{4,m}^{*}\right) s_4 \} \\ & + 4R\{\alpha_{1,m} \alpha_{4,m}^{*} - \alpha_{2,m}^{*} \alpha_{3,m}\} R\{s_1 s_4^{*}\} \Bigg] \end{aligned} \tag{14}$$

And,

$$\begin{aligned} f_{23}(s_2,s_3) = \sum_{m=1}^{M} \Bigg[& \left(|s_2|^2 + |s_3|^2\right) \left(\sum_{n=1}^{4} |\alpha_{n,m}|^2\right) \\ & + 2R\{\left(-\alpha_{2,m} r_{1,m}^{*} + \alpha_{1,m}^{*} r_{2,m} - \alpha_{4,m}^{*} r_{3,m} + \alpha_{3,m} r_{4,m}^{*}\right) s_2 \\ & + \left(-\alpha_{3,m} r_{1,m}^{*} - \alpha_{4,m}^{*} r_{2,m} + \alpha_{1,m}^{*} r_{3,m} + \alpha_{2,m} r_{4,m}^{*}\right) s_3 \} \\ & + 4R\{\alpha_{2,m} \alpha_{3,m}^{*} - \alpha_{1,m}^{*} \alpha_{4,m}\} R\{s_2 s_3^{*}\} \Bigg] \end{aligned} \tag{15}$$

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

7. SIMULATION RESULTS

The simulation parameters used throughout in this work are listed out in Table 1. Results are then plotted and discussed using these simulation parameters.

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7.1. SIMULATION PARAMETERS

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

Table1. 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

7.2. RESULTS

The simulation parameters used throughout in this work are listed in Table 1.Results are then plotted and discussed using these simulation parameters. The simulation result is conducted in MATLAB. In this we will make comparison of performance of QOSTBC with rotated QOSTBC using Dent model. Results with different modulation techniques are 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.3 and figure.4,BER performance is better using BPSK as compared to QPSK and 16-QAM.Figure.5 shows the comparison 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.

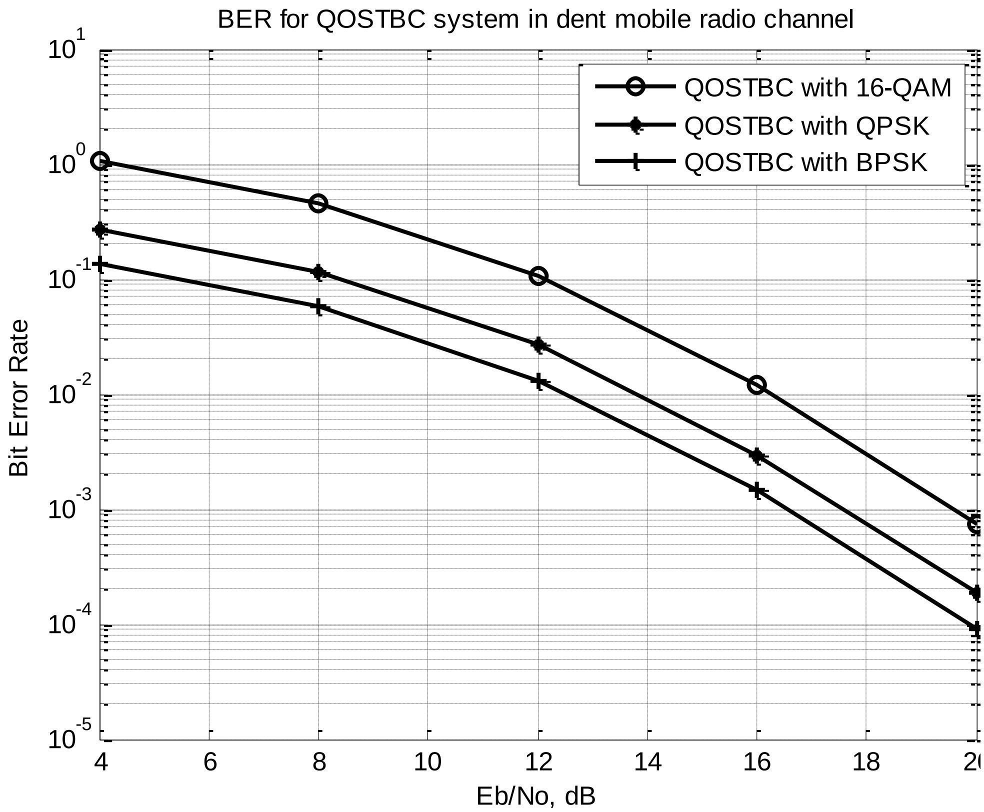

Figure3. BER for Quasi-OSTBC system with Dent channel model

From Table.2, At SNR=12dB, 4X2 antenna configuration BPSK modulation has 0.0019 BER have minimum BER than another modulation schemes like QPSK, 16-QAM in Quasi- OSTBC MIMO System. So we can say that in this configuration BPSK modulation gives better BER performance.

Table2. Simulation Parameters for Quasi-OSTBC MIMO STBC System

Modulation	**BER**
BPSK	.0019
QPSK	0.0032
16-QAM	0.0158

8. 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. 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.

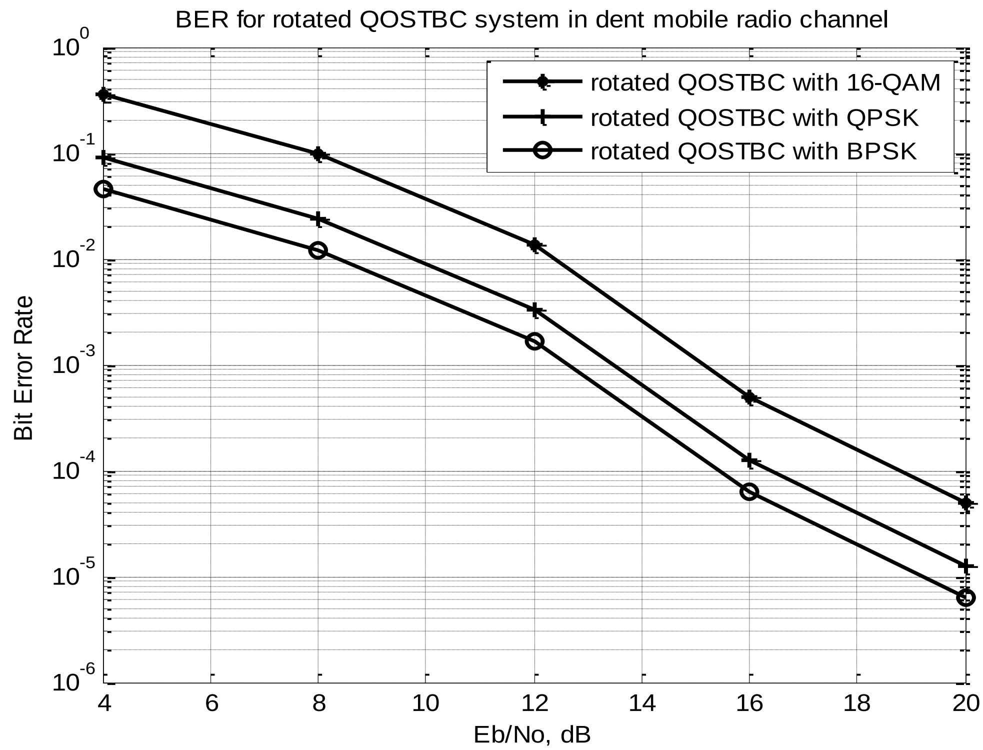

Figure4. BER for rotated quasi-OSTBC system with Dent channel model

From Table.3, At SNR=12dB, 4X2 antenna configuration BPSK modulation has 0.000003162 BER have minimum than another modulation schemes like QPSK, 16-QAM. in rotated Quasi- OSTBC MIMO System. So we can say that in this configuration gives BPSK modulation gives better BER performance and by using 16-QAM modulation technique Rotated Quasi – OSTBC gives worst result.

Table3. Simulation Parameters for Rotated Quasi-OSTBC MIMO STBC System

Modulation	BER
BPSK	.000003162
QPSK	0.0001
16-QAM	0.000063

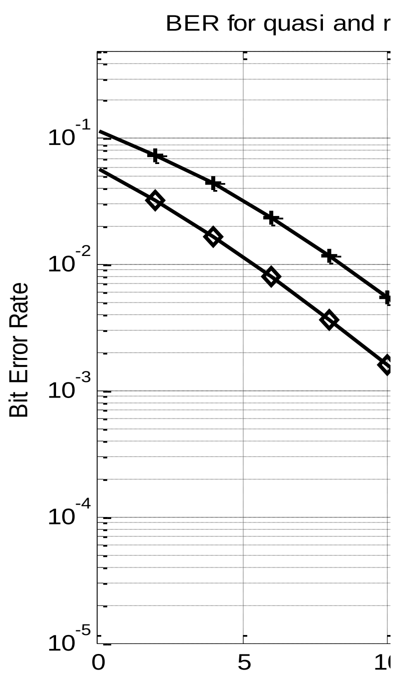

Figure5. BER for rotated quasi and quasi OSTBC system with Dent channel model

From Table.4, At SNR=15dB, 4X2 antenna configuration, for Rotated Quasi OSTBC BER is 0.000063 and for Quasi-OSTBC MIMO System BER is 0.0000251 in BPSK modulation So we can say that Rotated Quasi OSTBC have better performance than Quasi-OSTBC MIMO System,.

Table4. Simulation Parameters for comparison between Rotated Quasi-OSTBC and Quasi-OSTBC MIMO System using BPSK Modulation

Modulation	**BER**
Rotated Quasi-OSTBC	.00000632
Quasi-OSTBC	0.0000251

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