ISSN (Print) : 2319-5940
ISSN (Online) : 2278-1021

International Journal of Advanced Research in Computer and Communication Engineering
Vol. 2, Issue 6, June 2013

Performance Analysis of Quasi-Orthogonal Space time turbo coded MIMO-OFDM System

Gajanan R. Gaurshetti[1], Prof. Sanjay V. Khobragade[2]

M.Tech, Electronics & Telecommunication Engineering, Dr. Babasaheb Ambedkar Technological University, Lonere, India[1]

Asst. Professor, Electronics & Telecommunication Engineering, Dr. Babasaheb Ambedkar Technological University, Lonere, India[2]

Abstract: In wireless communication Multi Input Multi Output (MIMO) system increases the data rate and gives spacial diversity gain. MIMO in combination with Orthogonal Frequency Division Multiplexing (OFDM) becomes wideband transmission which enhances system capacity by resolving problem of Inter-Symbol Interference. Spacial diversity gain can be achieved by using space time block code without sacrificing bandwidth. In this paper, we proposed a Quasi-Orthogonal Space Time Block Code with Turbo Coding (QO-ST-TC) structure for MIMO-OFDM which gives full rate with coding gain. Also we have analysed QO-ST-TC for MIMO-OFDM over AWGN, Rayleigh and Rician channels and their effect on BER for high data rates have been presented. The simulation result shows QO-ST-TC for MIMO-OFDM system with 4X1 antenna configuration gives better performance in terms of BER.

Keywords: AWGN, Bit Error rate, Diversity, MIMO-OFDM, ML decoding, Q-OSTBC, Rician, Rayleigh, Simulink, Turbo coding, Wireless Metropolitan Area Network (WMAN).

I. INTRODUCTION

Wideband wireless communication system is used for both high data rate and high quality transmission over frequency selective fading channels. Orthogonal Frequency Division Multiplexing (OFDM) has become an attractive technique for wideband communications [1]. By introducing OFDM with multiple antennas to form Multiple-Input Multiple Output (MIMO) OFDM, the transmission capacity expanded much more as the number of spatial communication channels is multiplied [2]. Using OFDM, high data rate information symbol stream are split into low rate stream and transmitted over several parallel independent sub-carriers using the computationally efficient IFFT/FFT modulation/demodulation vectors [3].

The MIMO (Multiple Input, Multiple Output) system is one of several forms of smart antenna technology for wireless communications in which multiple antennas are used at the both side of transceiver. MIMO system is used to increase link capacity by sending different data stream over different transmit antenna or to improve the link reliability by sending the same data stream over different antenna using Space Time Block Code (STBC) [4]. With help of STBC in MIMO-OFDM we can achieve high data rate and full transmit antenna diversity because of their simple decoding algorithm. Without channel state information (CSI) at the transmitter side, the STBCs can effectively combat channel fading in the wireless communication systems [5].

Orthogonal Space-Time Block Codes (OSTB) for two transmit antennas provides full rate and for more than two transmit antennas the OSTBC can provide a rate of at most ¾. To achieve rate one transmission Quasi-Orthogonal Space-Time Block Codes (QOSTBC) structures were first introduced [6]-[7]. Later on rate one can be achieved with complex constellations by this code using three time slots [8]. Quasi-Orthogonal Space-Time Block Codes (QOSTBC) does not have fully diversity but it can be achieved through constellation rotation [9]-[10]. Use of turbo code increases the system performance [11]. In this paper, we propose an approach for high data rate wireless MAN communication systems. Our approach incorporates the turbo and Quasi-Orthogonal Space-Time Block Codes approaches. The proposed QO-ST-TC can achieve high coding and diversity gains. By simulation results, it is observed that this approach improves the BER.

This paper is organized as follows. The MIMO-OFDM system model is presented in Section II. In section III different channels are presented. The Quasi-Orthogonal

ISSN (Print) : 2319-5940
ISSN (Online) : 2278-1021

International Journal of Advanced Research in Computer and Communication Engineering
Vol. 2, Issue 6, June 2013

Space-Time Block Codes and ML decoding is described in Section IV. Simulation results are provided in Section V. Finally, conclusions are given in Section VI.

II. MIMO-OFDM SYSTEM MODEL

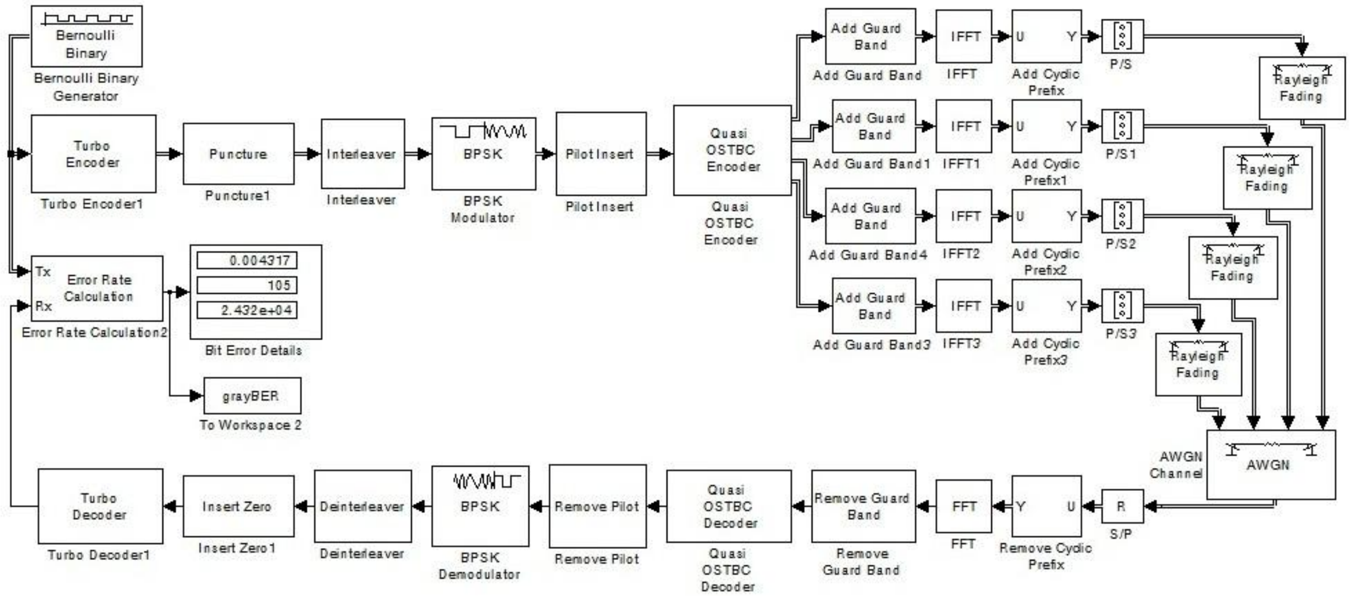

Fig. 1. Quasi-Orthogonal MIMO-OFDM System

Consider a MIMO-OFDM system with N_m X N_n where N_n is the number of transmitters and N_m is the number of receivers, OFDM is employed with N subcarriers at each transmit antennas. There are L numbers of frequency selective fading independent delay path between any transmit antenna and receive antenna. The MIMO-OFDM system is implemented with the help of MATLAB Simulink as shown in the Fig. 1.

The system process is binary frame based data that is passed to the turbo code. A turbo encoder consists of two identical Recursive Systematic Convolutional codes. They are of constraint length K. Data stream coming from information source is fed to turbo encoder in which convolution encoder CE1 generate coded bit stream, same data stream from source is also given to second convolution encoder CE2 through interleaver, interleaver rearranges the source data stream and CE2 encodes that interleaved data stream. These two parallel coded bit streams are reordered and then twelve tail bits are added to them. This output of turbo encoder is given to constellation mapper.

Modulation is the process of mapping digital data to analog form so we can transmit it over channel. The digital modulation scheme will transmit the data in parallel by assigning symbols to each sub-channel and the modulation scheme will determine the phase mapping of sub-channels by a complex I-Q mapping vector. Now this constellation mapped signal goes to the OSTBC encoder. To obtain the transmit diversity we use OSTBC encoder. The OSTBC encoder maps the input symbols block-wise and concatenates the output code-word matrices in the time domain. Consider n_N complex symbols $\{X_1, X_2, X_3, \dots X_N\}$ are generated from the circular QPSK or rectangular QAM constellations, OSTBC encoder maps them onto a matrix S of dimension $n_t \times N$, and matrix S is given by

$$S = \begin{bmatrix} X_1 & X_2 & X_3 & X_4 \\ -X_2^* & X_1^* & -X_4^* & X_3^* \\ -X_3^* & -X_4^* & X_1^* & X_2^* \\ X_4 & -X_3 & -X_2 & X_1 \end{bmatrix} \quad (1)$$

The i^{th} row of S corresponds to the symbols transmitted from the i^{th} transmit antenna in N transmission periods, while the j^{th} column of S represents the symbols transmitted simultaneously through N_n transmit antennas at time j. These transmitted symbols are Inverse-Fast-Fourier-Transformed (IFFT) and by inserting cyclic prefix (CP) transmitted with each transmit antenna.

Let $X_n^p(k)$ be symbol transmitted from n^{th} transmit antenna on k^{th} subcarrier during p^{th} OFDM symbol interval. In MIMO-OFDM system there is frequency selective channel between n^{th} transmit antenna and m^{th} receive antenna having L independent delay paths. Each path have channel coefficient, defined as

ISSN (Print) : 2319-5940
ISSN (Online) : 2278-1021

International Journal of Advanced Research in Computer and Communication Engineering
Vol. 2, Issue 6, June 2013

$$H_{n,m} = [h_{n,m}(0), h_{n,m}(1), h_{n,m}(2) \dots h_{n,m}(L-1)]^T \quad (2)$$

At the receiver, the signal is subjected to an additive white Gaussian noise. The received signal at m^{th} receive antenna is given as

$$Y_m^p(k) = \sum_{m=1}^{N_m}[H_{nm}(k) * S_n(k) + N_{nm}(k)] \quad (3)$$

Where $H_{nm}(k)$ is the channel gain of the k^{th} subcarrier during p^{th} symbol interval from n^{th} transmit antenna to m^{th} receive antenna and $N_{nm}(k)$ is the complex additive white Gaussian noise having zero mean and unit variance.

III. COMMUNICATION CHANNELS

Space is medium for the wireless communication. The signal propagation in space medium is not smooth as in wired medium, in space medium signal received not only from direct path but also from reflected, diffracted, and scattered path. Reflected signal is signal that hits a surface giving some part of energy to surface. Therefor the reflection coefficient is the ratio of reflected signal to transmitted signal. Diffracted signal is the signal that passes through another medium by changing some of its properties. Scattered signals are those deviated from the non-uniform objects. Wireless communication is multipath propagation environment, which means depending on the lengths and depending on distances and depending upon attenuation of each path, signals that are arriving from the different paths either adds constructively or destructively at the receiver which is a multipath fading.

A. AWGN Channel

AWGN channel is universal channel that adds white Gaussian noise in the signal. This noise has a uniform spectral density & a Gaussian distribution in amplitude. AWGN has flat amplitude frequency response and linear phase frequency response so the signal passing through AWGN channel is without amplitude and phase distortion in other words there is no fading present.
Output of the AWGN channel is given by

$$Y_t(t) = S_n(t) + N_{nm}(t) \quad (4)$$

Where N_{nm} is the AWGN signal noise with zero mean.

B. Rayleigh Channel

When the information is sent over the environment where more no of obstacles are present then there are many scattered signals arrives at receiver with different delay and phase factor. Rayleigh distribution is used to approximate these received signals. The received signal is given by

$$Y_t(t) = h_{nm}(t,\tau) * S_n(t) + N_{nm}(t) \quad (5)$$

Where $h_{nm}(t,\tau)$ is channel coefficient matrix having Rayleigh distribution and $N_{nm}(t)$ is additive white Gaussian noise. The Rayleigh distribution is sum of independent orthogonal Gaussian random variables and density function is given by

$$p(x) = \frac{x}{\sigma^2} e^{-x^2/2\sigma^2} \qquad 0 \le x \le \infty \quad (6)$$

Where σ^2 is the avg power of the received signal.

C. Rician Channel

Due to multiple paths in wireless communication receiver experiences superposition of multiple copies of the transmitted signal and this result in constrictive or destructive interference. If there is strong destructive interference then it is called as Deep Fading. Rician distribution is used to approximate these deep fading signals. The output signal of Rician channel is then given by

$$Y_t(t) = h_{nm}(t,\tau) * S_n(t) + N_{nm}(t) \quad (7)$$

Where $h_{nm}(t,\tau)$ is channel coefficient matrix having Rician distribution and $N_{nm}(t)$ is additive white Gaussian noise. The Rician distribution is nothing but magnitude of a circular bivariate normal random variable with potentially non-zero mean and this distribution is

$$p(x) = \frac{x}{\sigma^2} e^{-(x^2+A^2)/2\sigma^2} \; I_0\left(\frac{Ax}{\sigma^2}\right) \qquad x \ge 0, A \ge 0 \quad (8)$$

Where $I_0(.)$ is Bessel function of order zero and A is the peak amplitude of signal.

IV. PROPOSED SYSTEM MODEL

A convolutional code (CC) is described by three parameters n, k and K and it is denoted as CC (n; k; K). At each instant, a CC (n; k; K) encoder accepts k input bits and outputs n coded bits. The constraint length of the code is K and the number of encoder states is equal to2^{K-1}. The channel code rate is given by

$$R = k/n \quad (9)$$

However, different code rates can be obtained by suitable puncturing. We denote a turbo convolutional code as TC (n; k; K), where n is number of output coded bits, k is the number of input bits and K is the constraint length. The output code-word of turbo encoder is fed to the different constellations.

A. Constellation Rotation

It is not possible to achieve code rate 1 for the complex orthogonal codes, to achieve this we use Constellation Rotation. This is done by rotating the symbols during the constellation mapping. This provides full diversity with code rate 1 and gives good performance.
The optimal angle of rotation is determined such that the coding gain is maximized while the code is full-diversity. Thus the optimal angle of rotation for MPSK constellation is π/M (for M even) and π/2M (for M odd) and for QAM is π/4. The optimal angle of rotation for four transmit antennas

ISSN (Print) : 2319-5940
ISSN (Online) : 2278-1021

International Journal of Advanced Research in Computer and Communication Engineering
Vol. 2, Issue 6, June 2013

is listed in Table.1. After the constellation rotation process these symbols are given to QO-STBC block.

TABLE I
OPTIMAL ANGLE OF ROTATION

Modulation	Angle of rotation
BPSK	π/2
QPSK	π/4
16-QAM	π/4
64-QAM	π/4

B. Quasi-Orthogonal Space-Time Block Code

The full-rate full-diversity space-time block code using orthogonal designs is Alamouti schemes and it is given by

$$S(X_1, X_2) = \begin{bmatrix} X_1 & X_2 \\ -X_2^* & X_1^* \end{bmatrix} \quad (10)$$

We can design full rate code for four transmit antennas using this STBC code and pair of symbols as

$$S = \begin{bmatrix} S(X_1, X_2) & S(X_3, X_4) \\ -S^*(X_3, X_4) & S^*(X_1, X_2) \end{bmatrix} \quad (11)$$

On simplifying and considering rotated constellation symbols we get

$$S = \begin{bmatrix} S_1 & S_2 & S_3 & S_4 \\ -S_2^* & S_1^* & -S_4^* & S_3^* \\ -S_3^* & -S_4^* & S_1^* & S_2^* \\ S_4 & -S_3 & -S_2 & S_1 \end{bmatrix} \quad (12)$$

And output of transmitter at time t is given by

$$Y_t(t) = \sum_{m=1}^{N_m} [h_{nm}(t,\tau) * S_n(t) + N_{nm}(t)] \quad (13)$$

C. ML Decoding

Assuming perfect channel knowledge at the receiver, it computes the following decision metric

$$\sum_{n=1}^{N} \sum_{t=1}^{T} \left| Y_{t,n} - \sum_{m=1}^{M} h_{nm} S'_{tm} \right|^2 \quad (14)$$

Where S'_{tm} is the complex space-time block coded transmission matrix with time t and the transmitting antenna m for all possible X ϵ S that minimize the sum in maximum-likelihood decoding scheme. Using the orthogonality, the maximum-likelihood decision metric (9) can be calculated as the sum of two terms $f_{14}(X_1, X_4) + f_{23}(X_2, X_3)$ where f_{14} is independent of X_2, X_3 and f_{23} is independent of X_1, X_4. Thus, the minimization of (9) is equivalent to minimizing these two terms independently, i.e. decoder first finds the pair (S_1, S_4) that minimizes $f_{14}(X_1, X_4)$ among all possible pair of (X_1, X_4). Then, the decoder selects the pair (S_2, S_3) which minimizes $f_{23}(X_2, X_3)$. This reduces the complexity of decoding without sacrificing the performance.

The manipulation of equation (9) for $f_{14}(X_1, X_4)$ and $f_{23}(X_2, X_3)$ is given as

$f_{14}(X_1, X_4) = \sum_{n=1}^{N} \left[\left(\sum_{n=1}^{4} |h_{nm}|^2 \right) (|X_1|^2 + |X_4|^2) + \right.$
2 Re−h1,nY1,n∗−h2,n∗Y2,n−h3,n∗Y3,n−h4,nY4,n∗X1+−h4,nY1,n∗−h3,n∗Y2,n−h2,n∗Y3,n−h1,nY4,n∗X4+h1,nh4,n∗−h2,n∗h3,n−h2,nh3,n∗+h1,n∗h4,nX1X4∗ (15)

$f_{23}(X_2, X_3) = \sum_{n=1}^{N} \left[\left(\sum_{n=1}^{4} |h_{nm}|^2 \right) (|X_2|^2 + |X_3|^2) + \right.$
2 Re−h2,nY1,n∗+h1,n∗Y2,n−h4,n∗Y3,n+h3,nY4,n∗X2+−h3,nY1,n∗−h4,n∗Y2,n+h1,n∗Y3,n+h2,nY4,n∗X3+h2,nh3,n∗−h1,n∗h4,n− h1,nh4,n∗+h2,n∗h3,nX2X3∗ (16)

Where Re is the real part of h.

V. SIMULATION RESULT

The proposed system is implemented with the help of MATLAB Simulink. In this system we have used different modulation schemes such as BPSK, QPSK, 16 QAM and 64 QAM. The system is implemented for three different channel conditions and these channels are AWGN channel, Rayleigh channel and Rician channel. The simulation parameters to analyse this system for three different channels are given in Table.2 [12] and Table.3.

TABLE III
INTERLEAVER PARAMETERS

mod \ Sub-Channels	16	8	4	2	1
BPSK	192	96	48	24	12
QPSK	384	192	96	48	24
16-QAM	768	384	192	96	48
64-QAM	1152	576	288	144	72

TABLE IIII
SIMULATION PARAMETERS

Parameters	Values
Sample Time	8.334e-08
No. of Sub-channels	16
No. of Sub-carriers	256
N_{cpc}	1
Channel Coding /Decoding	Turbo/Log-MAP
Modulation	BPSK, QPSK, 16 & 64QAM
IFFT/FFT SIZE	256
CP	64
Ts	7.20e-05
Delay (ms)	(0, 0.3, 0.15, 0.31, 0.37)
power gain	(0, -1.5, -1.4, -3.6, -0.6)
K factor	0.5
Doppler shift	0.5

The performance of proposed system is plotted in terms of BER vs. SNR with four modulation schemes for three wireless channels. Figure.2 shows the BER graph for AWGN channel, it is clear that BER is very low as AWGN channel is simple.

BER performance of QO-ST-TC system for Rayleigh and Rician channel is shown in Figure.3 and Figure.4 respectively. Here it is clearly seen that BER increases as we go from fast selective fading Rayleigh to Rician channel. The BER is less in M-PSK modulated signal, because of the spacing of the constellation points.

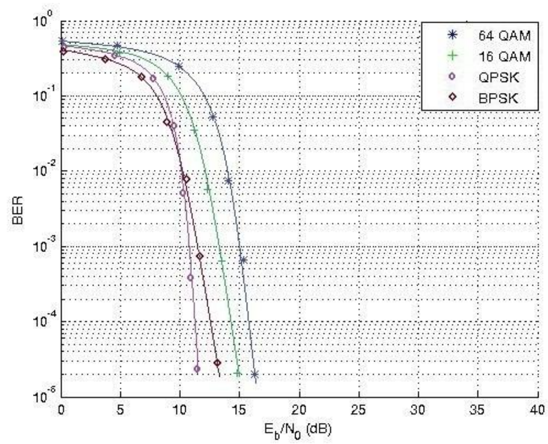

Fig. 2. BER plot of Q0-ST-TC MIMO-OFDM for AWGN Channel

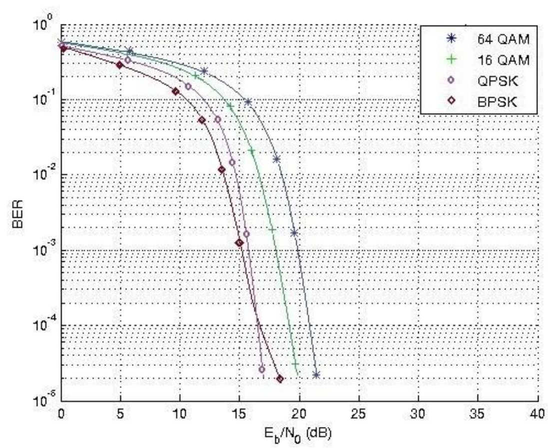

Fig. 3. BER plot of Q0-ST-TC MIMO-OFDM for Rayleigh Channel

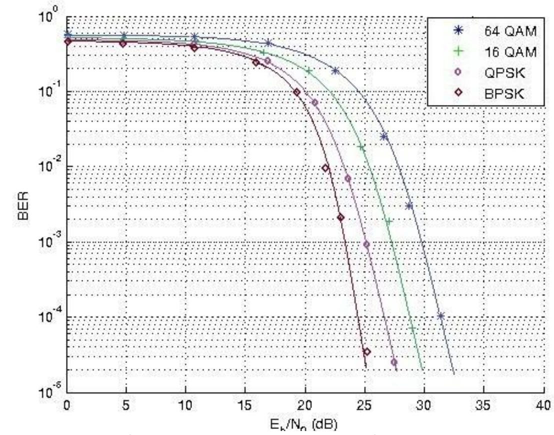

Fig. 4. BER plot of Q0-ST-TC MIMO-OFDM for Rician Channel

VI. CONCLUSION

New approach is presented in this paper for high data rate communication channel. This approach is consisting of Quasi-Orthogonal Space Time Block Code with high performance Turbo code for MIMO-OFDM system. With the help of QO-STBC and Turbo code we achieved full diversity and full code rate. The proposed QO-ST-TC MIMO-OFDM system improves the performance significantly in terms of BER. The system has been verified in AWGN channel, Rayleigh channel and Rician channel and it is observed that to maintain the required BER we need more SNR as we go from AWGN channel to Rician Channel.

REFERENCES

[1] Lin Chin-Hsien, Lin Yi-Hsien Wu Chih-Feng, Wang Chorng-Kuang Kuang. “A MIMO-OFDM digital baseband receiver design with adaptive equalization technique for IEEE 802.16 WMAN”, IEEE International Conference on Acoustics, Speech and Signal Processing, pp. 617 – 620, April 2009.

[2] G. J. Foschini and M. J. Gans. “On limits of wireless communications in a fading environment when using multiple antennas”, Wireless Personal Communications, vol. 6, pp. 311–335, 1998.

[3] Cortes, Velez, Sevillano, Irizar,"An approach to simplify the design of IFFT/FFT cores for OFDM systems", IEEE Transactions on Consumer Electronics, Vol.52,pp.26-32, Feb. 2006

[4] V. Tarokh, A. Naguib, N. Seshadri, and A. Calderbank. “Space-time codes for high data rate wireless communication: performance criteria in the presence of channel estimation errors, mobility, and multiple paths”, IEEE Transactions on Communications, vol. 47, no. 2, pp. 199 –207, feb 1999.

[5] Chen,H-Y. Chang, W.-K. Jou, S.-J,"A Low-Overhead Interference Canceller for High-Mobility STBC-OFDM Systems",IEEE Transactions on Circuits and Systems I,Vol.PP,pp.1-11, March 2013

[6] H. Jafakani, “A quasi-orthogonal space-time block codes,” IEEE Trans. Commun., vol. 49, no.1, Jan. 2001.

[7] W. Su and X. Xia, “Quasi-orthogonal space-time block codes with full diversity,” in Proc. Global Telecom. Conf., vol. 2, pp. 1098-1102, Nov. 2002

[8] Zhongding Lei, Chau Yuen, and Francois P.S. Chin, “Quasi-Orthogonal Space-Time Block Codes for Two Transmit Antennas and

ISSN (Print) : 2319-5940
ISSN (Online) : 2278-1021

International Journal of Advanced Research in Computer and Communication Engineering
Vol. 2, Issue 6, June 2013

Three Time Slots”, IEEE Transactions on Wireless Communications, Vol. 10, No. 6,pp.1983-1991. JUNE 2011

[9] N. Sharma and C. B. Papadias, “Improved qusi-orthogonal codes through constellation rotation,” IEEE Trans. Commun., Oct. 2001.

[10] F. Fazel and H. Jafarkani, “Quasi-orthogonal space-frequency and space-time-frequency block codes for MIMO-OFDM channels,” IEEE Trans. Wireless Commun., vol. 7, no. 1, pp. 184-192, jan. 2008.

[11] H. Chen, X. Deng, and A. Haimovich, “Layered turbo space-time coded mimo-ofdm systems for time varying channels,” in Global Telecommunications Conference, 2003. GLOBECOM’03. IEEE, vol. 4. IEEE, 2003, pp. 2003. GLOBECOM’03. IEEE, vol. 4. IEEE, 2003, pp. 1831–1836.

[12] IEEE Standard for Local and Metropolitan Area Networks – Part 16: Air Interface for Broadband Wireless Access Systems, IEEE Std. 802.16-2009, May 2009.

BIOGRAPHY

Gajanan R. Gaurshetti was born in Maharashtra, India, on Augest 10, 1986. He received the B.E degree in Electronics and Telecommunications engineering from Dr. Babasaheb Ambedkar Marathawada University, Maharashtra, India, in 2008 and pursuing the M.Tech degree in Electronics and Telecommunications engineering from Dr. Babasaheb Ambedkar Technological University, Lonere, Maharashtra, India.

Prof. Sanjay V. Khobragade has been working as Assistant Professor in Dr. B.A. Technological University Lonere, Maharashtra, India from last 13 years. He is graduated from Nagpur University in 1996 and post graduated in Electronics Engineering from Mumbai University in 2008 and pursuing PhD form Rayalaseema University Kurnool, Andhra Pradesh. He has been involved in teaching a Microwave, Antenna & Wave Propagation and Electromagnetic Field. He has received Young Scientist Award in URSI 2004 in Pisa Italy, and Consolation Prize for best paper in ICMARS Jodhpur, 2008 and best Technical teacher award by ISTE sponsored by Maharashtra and Goa in 2010. He has around 70 papers at national and International conferences in his credit.