International Journal of Scientific & Engineering Research, Volume 4, Issue 2, February-2013
ISSN 2229-5518

Performance Analysis of Space Time Block Codes over Time Selective Fading Channels

K.Sujatha[1], Dr.S.Varadarajan[2]

Abstract- The last decade we have witnessed an extraordinary growing interest in the field of wireless communications. Wireless industry has recently turned into a technology known as Multiple-Input Multiple-Output (MIMO) to minimize errors and optimize data speed. This is done by using multiple transmit and receive antennas, as well as appropriate space-time block code techniques. Due the fact that time-selective fading channels exist, the assumption that the channel is being static over the length of the codeword does. The channel state varies over the number of signal intervals, and in such case the orthogonality of the space-time block code will be destroyed leading to irreducible error floor. This paper deals with orthogonal space-time block coding schemes where time-selective fading channels arise due to Doppler Effect. A realistic channel model was used, where the channel coherency was considered. Modeling the time-selective channels as random processes, a fast and simple decoding algorithm was derived at the receiver. Using MATLABTM as a simulation tool, we provide simulation results demonstrating the performance of four transmit antennas over time-selective fading channels. We illustrate that using multiple transmit antennas and space-time coding outstanding performance can be obtained, under the impact of channel variation.

Keywords- Space time block codes, MIMO, Fading Channel

1. Introduction

In the last decade, the study of wireless communications with multiple transmit and receive antennas has been conducted expansively in the literature on information theory and communications. It has been known from the information-theoretic results [1], [2], [3], [4], [5] that the application of multiple antennas in wireless systems can significantly improves the channel capacity over the single-antenna systems with the same requirements of power and bandwidth. Based on those results, many communication schemes suitable for data transmission through multiple-antenna wireless channels have been proposed, including Bell Labs Layered Space–Time (BLAST) [1], space–time trellis codes [6], space–time block codes from orthogonal designs [7] and unitary space–time codes [8], [9], among many others. It is well-known that the decoding algorithm must have as low as possible complexity in order to find applications in the real-world of wireless communication systems. Based on this criterion, Alamouti [10] developed a simple and effective transmit technique for two transmit antennas which has remarkably low decoding complexity. Tarokh, Jafarkhani, and Calder bank [7] presented orthogonal designs that can be used as space-time block codes for wireless communications and generalized the Alamouti scheme for more than two transmit antennas. Space–time block coding provides an exceptional link between orthogonal designs and wireless communications.

Since this coding scheme achieves full transmit diversity and has a very simple maximum likelihood decoding algorithm at the receiver, Alamouti's space-time block code has been established as a part of the W-CDMA and CDMA-2000 standards. In this paper we did the analysis of performance results for four transmit antennas and one receive antenna over time-varying channels based on the terminal speeds. In the section II channel calculations are shown. In sectionIII, we present the comparison of performance of Two O-STBC for Four Transmit Antennas.

In section IV, simulation results were built with 1.5 bits per channel use, where in the section V, 2 bits per channel use was considered

.

2. Channel Matrix Calculations

The space-time block code that was used for the simulation of four transmit antennas and one receive antenna for 2 bits per channel use, is shown in Figure 1.

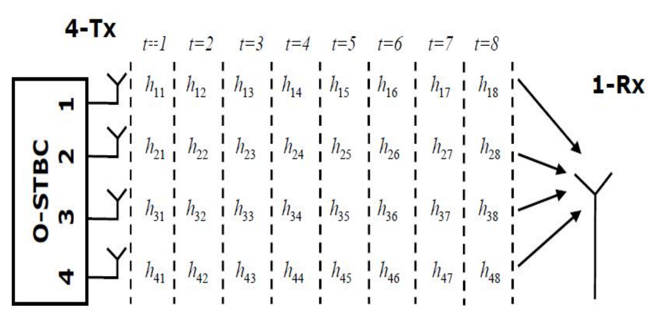


Fig1. Transmission model for 4-Tx antennas, for 2 bits per channel use

At times: (see Figure 1)

t=1 $y_1 = h_{11}.z_1 + h_{21}.0 + h_{31}.z_2 + h_{41}.z_3 + w_1$ (1)

t=2 $y_2 = h_{12}.0 + h_{22}.z_1 + h_{32}.z_4 + h_{42}.z_5 + w_2$ (2)

t=3 $y_3^* = -h_{13}^*.z_2 - h_{23}^*.z_4 + h_{33}^*.z_1 + h_{34}^*.0 + w_3^*$ (3)

t=4 $y_4^* = -h_{14}^*.z_3 - h_{24}^*.z_5 + h_{34}^*.0 + h_{44}^*.z_1 + w_4^*$ (4)

t=5 $y_5 = -h_{15}.z_4 + h_{25}.z_2 + h_{35}.0 + h_{45}.z_6 + w_5$ (5)

t=6 $y_6^* = h_{16}.0 - h_{26}^*.z_5 - h_{36}^*.z_3 + h_{46}^*.z_2 + w_6^*$ (6)

t=7 $y_7 = -h_{17}.z_5 + h_{27}.z_3 - h_{37}.z_6 + h_{47}.0 + w_7$ (7)

t=8 $y_8 = h_{18}^*.z_6 - h_{28}.0 - h_{38}^*.z_5 + h_{48}^*.z_4 + w_8^*$ (8)

$$\begin{bmatrix} y_1 \\ y_2 \\ y_3^* \\ y_4^* \\ y_5 \\ y_6^* \\ y_7 \\ y_8^* \end{bmatrix} = \begin{bmatrix} h_{11} & h_{31} & h_{41} & 0 & 0 & 0 \\ h_{22} & 0 & 0 & h_{32} & h_{42} & 0 \\ h_{33}^* & -h_{13}^* & 0 & -h_{23}^* & 0 & 0 \\ h_{44}^* & 0 & -h_{14}^* & 0 & -h_{24}^* & 0 \\ 0 & h_{25} & 0 & -h_{15} & 0 & h_{45} \\ 0 & h_{46}^* & -h_{36}^* & 0 & 0 & -h_{26}^* \\ 0 & 0 & h_{27} & 0 & -h_{17} & -h_{37} \\ 0 & 0 & 0 & h_{48}^* & -h_{38}^* & h_{18}^* \end{bmatrix} . \begin{bmatrix} z_1 \\ z_2 \\ z_3 \\ z_4 \\ z_5 \\ z_6 \end{bmatrix} + \begin{bmatrix} w_1 \\ w_2 \\ w_3^* \\ w_4^* \\ w_5 \\ w_6^* \\ w_7 \\ w_8^* \end{bmatrix} \quad (9)$$

Where the dimensions of matrix are: $Y_{8\times1} = H_{8\times6} \times S_{6\times1} + W_{8\times1}$

And again the receive signal is given by:

$$\tilde{y} = \tilde{H}.s + w \quad (10)$$

Where s is the signal vector, s= $[z_1 \; z_2 \; z_3 \; z_4 \; z_5 \; z_6]^T$, w is the noise vector, w= $[w_1 \; w_2 \; w_3^* \; w_4^* \; w_5 \; w_6^* \; w_7 \; w_8^*]^T$, and $\tilde{H}$ is the new orthogonal mortified coded channel matrix

$$H_h = \begin{bmatrix} h_{11} & h_{31} & h_{41} & 0 & 0 & 0 \\ h_{22} & 0 & 0 & h_{32} & h_{42} & 0 \\ h_{33}^* & -h_{13}^* & 0 & -h_{23}^* & 0 & 0 \\ h_{44}^* & 0 & -h_{14}^* & 0 & -h_{24}^* & 0 \\ 0 & h_{25} & 0 & -h_{15} & 0 & h_{45} \\ 0 & h_{46}^* & -h_{36}^* & 0 & 0 & -h_{26}^* \\ 0 & 0 & h_{27} & 0 & -h_{17} & -h_{37} \\ 0 & 0 & 0 & h_{48}^* & -h_{38}^* & h_{18}^* \end{bmatrix} \quad (11)$$

To detect the original information symbols, we take advantage the orthogonal structure of $\tilde{H}$, so the retrieve symbols can be found by:

$$\tilde{s} = \tilde{H}^H . \tilde{y} \quad (12)$$

3. Comparison of Performance of Two O-STBC for Four Transmit Antennas

Orthogonal designs have been used as space–time block codes for wireless communications with multiple transmit antennas (*n*). This section presents a comparison of performance of two orthogonal space-time block codes with different rates, $R1 = \frac{4}{8}$ and $R2 = \frac{6}{8}$, for four transmit antennas over time-selective fading channels. It is shown that under time-selectiveness and once the vehicle speed rises above a certain value, the code with rate of $\frac{6}{8}$ is much more efficient than the code with rate $\frac{4}{8}$

3.1. Orthogonal Designs

The aim of this section is to introduce a new orthogonal space-time code design, which minimizes the floor error that arises due to the terminal speed. The orthogonal designs that will be presented in this section have a special structure. Each row has either only complex symbols or only conjugate (*) complex symbols (Figure 2 and Figure 3). This structure gives the flexibility to manipulate the complex number properties in order to demodulate the receive signals. The new orthogonal design

3.2. The Conventional O-STBC

This space-time block code, (Figure 2) can find application for 4 transmit antennas (*n*) to send 4 information symbols (*k*) in a block of 8 channel uses (p). The rate of this orthogonal code is therefore, $R = \frac{k}{p} = \frac{4}{8} = \frac{1}{2}$

$$\begin{bmatrix} z_1 & z_2 & z_3 & z_4 \\ -z_2 & z_1 & -z_4 & z_3 \\ -z_3 & z_4 & z_1 & -z_2 \\ -z_4 & -z_3 & z_2 & z_1 \\ z_1^* & z_2^* & z_3^* & z_4^* \\ -z_2^* & z_1^* & -z_4^* & z_3^* \\ -z_3^* & z_4^* & z_1^* & -z_2^* \\ -z_4^* & -z_3^* & z_2^* & z_1^* \end{bmatrix}$$

Fig2. The conventional code [p, n, k] = [8, 4, 4]

3.3. The New High-Rate O-STBC

The new design of transmission matrix for 4 transmit antennas of size 8× 4 is given in Figure 3. This matrix is clearly an orthogonal space-time block code and sends k = 6 information symbols in a block of p = 8 channel uses. The rate of this Orthogonal code is therefore, R= $\frac{k}{p} = \frac{6}{8} = \frac{3}{4}$ [12].

$$\begin{bmatrix} z_1 & 0 & z_2 & z_3 \\ 0 & z_1 & z_4 & z_5 \\ -z_2^* & -z_4^* & z_1^* & 0 \\ -z_3^* & -z_5 & 0 & z_1^* \\ -z_4 & z_2 & 0 & z_6 \\ 0 & -z_6^* & -z_3^* & z_2^* \\ -z_5 & z_3 & -z_6 & 0 \\ -z_6^* & 0 & -z_5^* & z_4^* \end{bmatrix}$$

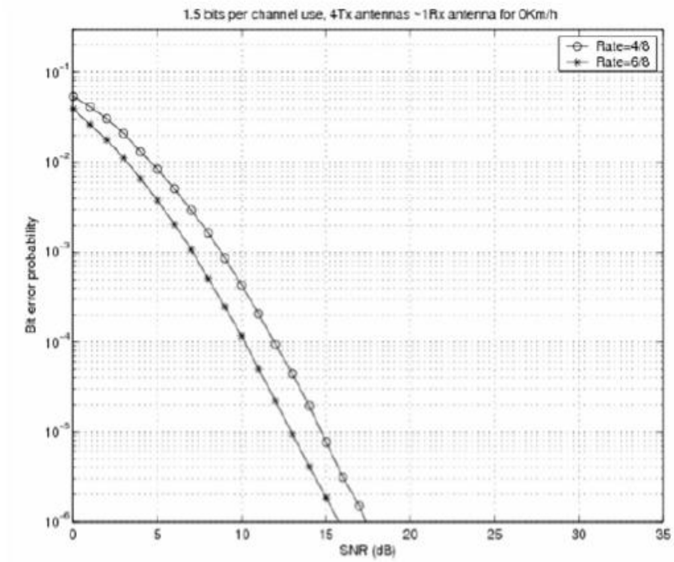
Fig3. The new High-Rate O-STBC [p, n, k] = [8, 4, 6]

3.4. Comparison of the Orthogonal Designs

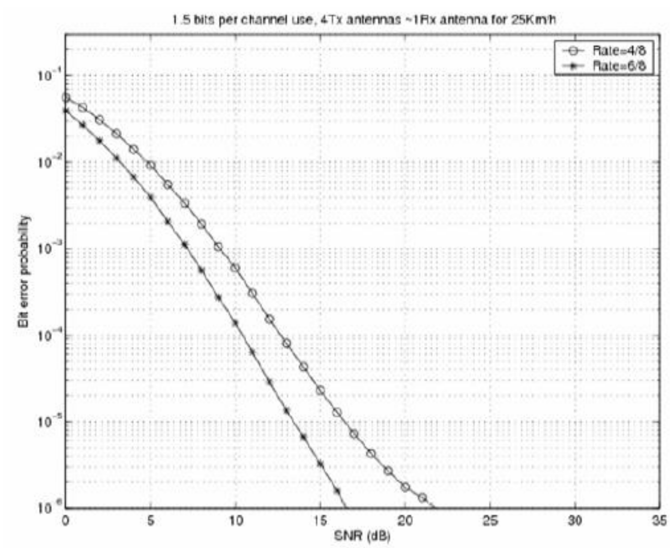
Clearly, the new orthogonal design has a greater rate than the conventional code. Consequently, the new high rate orthogonal design can achieve bigger diversity gain by transmitting additional two more information symbols. Another big advantage of the new orthogonal design is that in eight symbol periods (*Ts)* transmits zero (nothing), which saves power consumption to the transmitter. The simulations show that the new orthogonal design can efficiently reduce the error floor at the high signal to- noise ratio (SNR) region. In addition, it provides better performance in high vehicle speed values.

4. Simulation Results for 1.5 Bits per Channel Use

The following section provides simulation results for the performance of the above orthogonal space-time block codes. The new orthogonal design code with rate $\frac{3}{4}$ is compared with the conventional code, which has rate $\frac{1}{2}$. The receiver estimates the transmitted bits by using the signals of the receive antennas (coherent case). Figure 5 and Figure 6 show bit error rates (BER), for transmission of 1.5 bits per channel use for four transmit antennas and one receive antenna, with rates $\frac{4}{8}$ and $\frac{6}{8}$ respectively. In order to achieve a transmission with 1.5 bits per channel use, 8-PSK constellation for the conventional orthogonal design and 4-PSK constellation for the new orthogonal design were used. Each graph in Figure 4 presents the performance results for terminal speeds 0, 25, 50, and 75km/h*.* The bit error rate at each SNR (*Eb* / *N*0) point is averaged over 5×106 channel realizations.

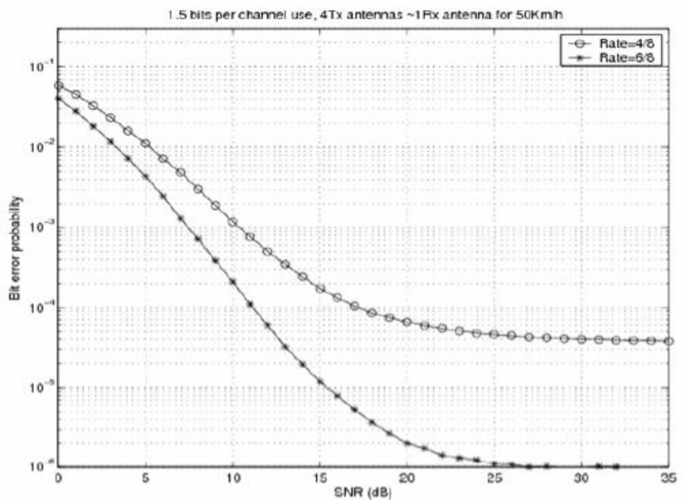


(a) 0km/h

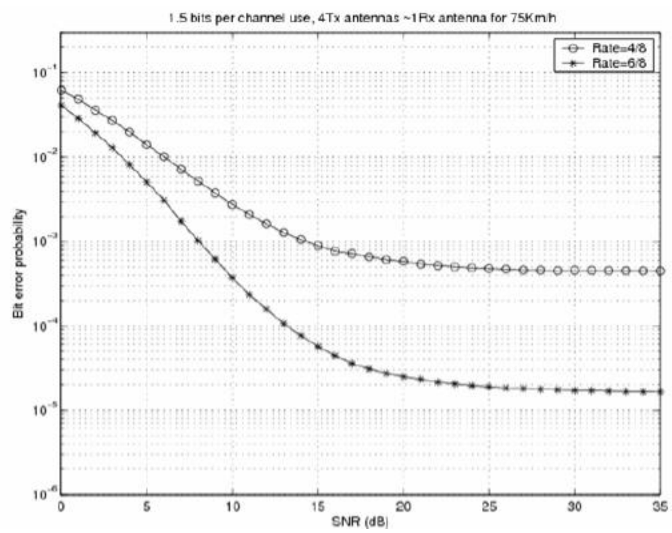


(b) 25km/h

International Journal of Scientific & Engineering Research, Volume 4, Issue 2, February-2013
ISSN 2229-5518



(c) 50 km/h



(d) 75km/h

Figure 4: The BER vs. SNR performance between the two orthogonal designs for terminal speeds 0, 25, 50, and 75 km/h respectively

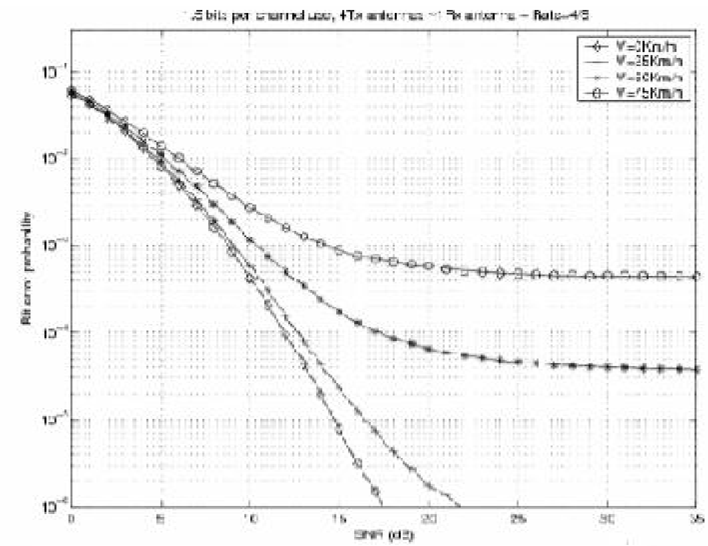


Fig5: The BER performance of the O-STBC with rate = $\frac{4}{8}$

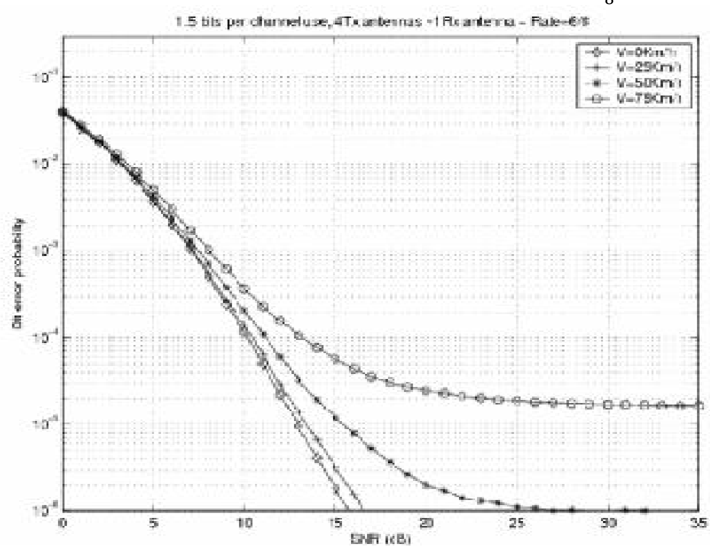
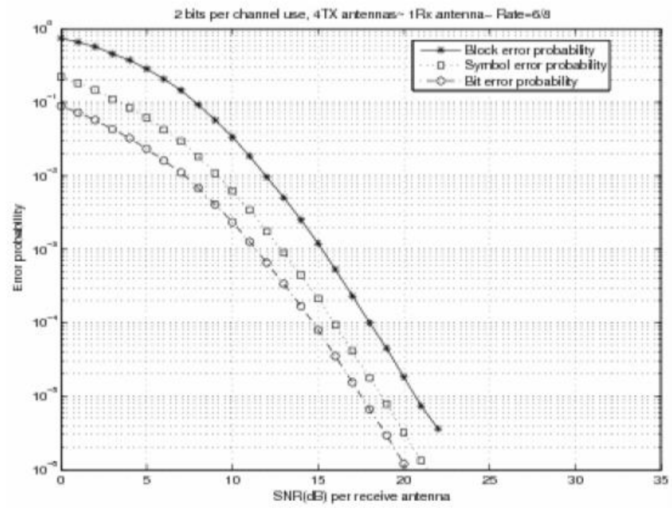


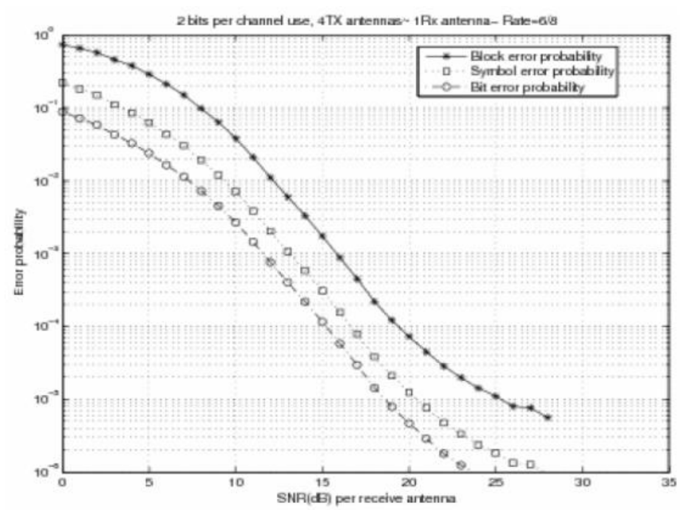
Fig6: The BER performance of the O-STBC with rate = $\frac{6}{8}$

5. Simulation Results for 2 Bits per Channel Use

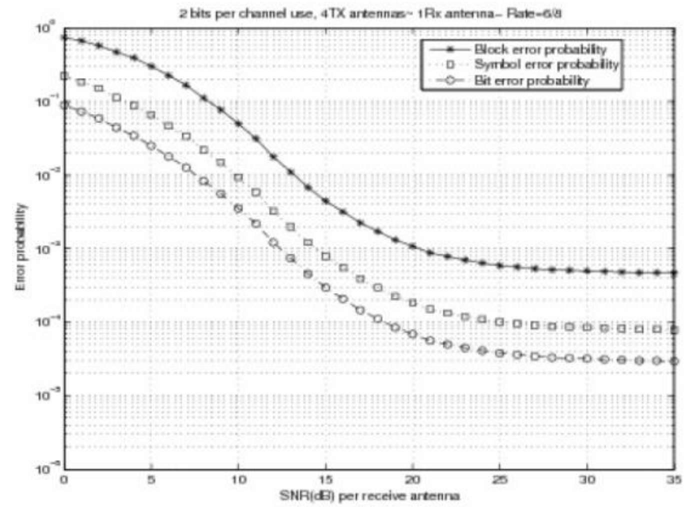
The graphs in Figure 7 illustrate simulation results in terms of bit, symbol, and block error probability versus signal-to-noise ratio (SNR) for four transmit antennas and one receive antenna base on four different vehicle speeds 0, 25, 50, and 75km/h for transmission of 2 bits per channel use. The orthogonal transmission matrix that was used is the one that was demonstrated in Figure 3. It's important to mention, that in order to achieve a transmission rate of 2 bits per channel use, 4-PSK and 8-PSK constellations where used. Therefore, two symbols where selected from 4-PSK constellation and four symbols from 8-PSK constellation since the orthogonal design has rate of R= $\frac{k}{p}$ = $\frac{6}{8}$ .The analysis and simulations, for four transmit antennas and one receive antenna have shown that for vehicle speeds above 25km/h, a significant amount of error floor appears at high regions of SNR, as shown in Figure 8



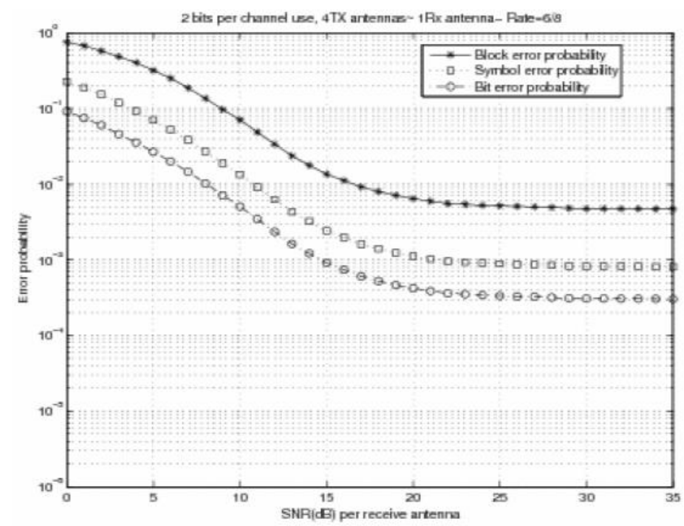
(a) 0 km/h



(b) 25 km/h



(c) 50 km/h



(d) 75 km/h

Figure 7: Bit, symbol, and block error probability versus signal-to-noise ratio (SNR) for 4-Tx antennas base on vehicle speeds 0, 25, 50, and 75 km/h, respectively.

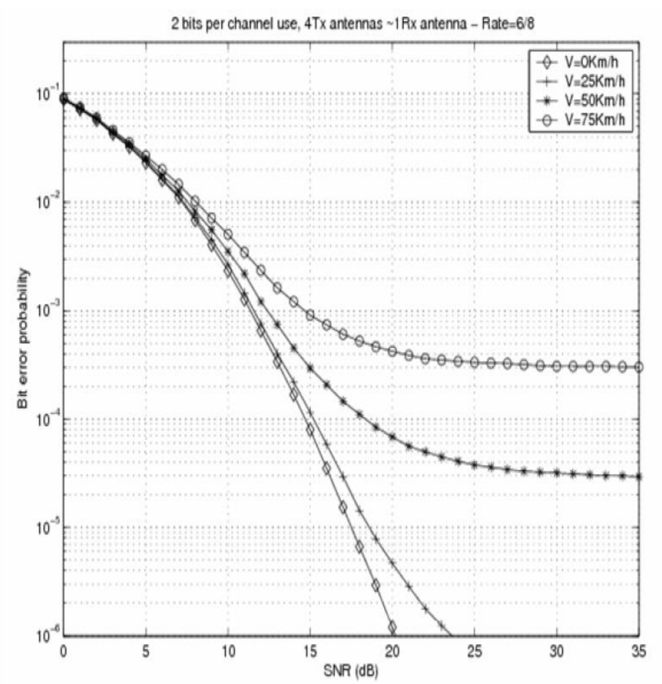


Figure 8: BER comparisons between different values of speeds, for 4-Tx Antennas

6. Conclusions

The section 4 has shown simulation results for the performance of the new orthogonal space-time block code. It is clearly shown that the new orthogonal design (Figure 6) has better performance compared with the conventional orthogonal design (Figure 5). It reduces efficiently the error floor at the high signal-to-noise ratio region, especially when the terminal speed is 50km/h (Figure 4c). On the other hand, the scheme performance below 25km/h *is* excellent and shows no error floor at all, under the presence of channel variation. Consequently, when the terminals speeds are kept below 25km/h, a very good performance appears where the bit error probability is very low at low signal-to-noise ratio areas. The performance of his scheme has shown that it can find real applications

REFERENCES:

[1] G. J. Foschini, "Layered space-time architecture for wireless communication in fading environment when using multi-element antennas," *Bell Labs Tech.J.*, vol. 1, No. 2, pp. 41-59, 1996.
[2] G. J. Foschini and M. J. Gans, "On limitis of wireless communications in fading environment when using multiple antennas," *Wireless Personal Commun,* pp. 311-355, 1998.
[3] T. L. Marzetta and B. M. Hochwald, "Capacity of a mobile multiple-antenna communication link in Rayleigh flat fading " *IEEE Trans. Inform. Theory*, vol. 45, pp. 139-157, Jan. 1999.
[4] I. E. Telatar, "Capacity of multi-antenna Gaussian channels," *AT&T Bell Labs, Internal Tech. Memo, 1995. See also, European Trans. Telecommun.*, vol. 10, no. 6, pp. 585-595, 1999.
[5] L. Zheng and D. N. C. Tse, "Communication on the Grassmann manifold: A geometric approach to the noncoherent multiple-antenna channel," *IEEE Trans. Inform. Theory*, vol. 48, pp. 359-383, Feb. 2002.
[6] V. Tarokh, N. Seshadri, and A. R. Calderbank, "Space-time codes for high data rate wireless communications: Performance criterion and code construction," *IEEE Trans. Inform. Theory*, vol. 44, pp. 744-765, Mar. 1998.
[7] V. Tarokh, H. Jafarkhani, and A. R. Calderbank, "Space-time block codes from orthogonal designs," *IEEE Trans. Inform. Theory*, vol. 45, pp. 1456- 1467, July 1999.
[8] B. M. Hochwald and T. L. Marzetta, "Unitary space-time modulation for multiple-antenna communication in Rayleigh flat fading," *IEEE Trans. Inform. Theory*, vol. 46, pp. 543-564, Mar. 2000.
[9] A. Shokrollahi, B. Hassibi, B. M. Hochwald, and W. Sweldens, "Representation theory for high-rate multiple-antenna code design," *IEEE Trans. Commun.*, vol. 47, pp. 2335-2367, Sept. 2001.
[10] S. M. Alamouti, "A simple transmit diversity technique for wireless communications," *IEEE J. Select. Areas Commun.* , vol. 16, pp. 1451-1458,Oct. 1998.
[11] V. Tarokh, H. Jafarkhani, and A. R. Calderbank, "Space-Time Block Coding for Wireless Communications: Performance Results," *IEEE J. Select. Areas Commun.*, vol. 17, No.3, pp. 451-460, March 1999.
[18] "http://mathworld.wolfram.com/."
[12] "Digital Cellular Telecommunications System (Phase2+); Enhanced Data rates for GSM Evolution (EDGE); European Telecommunications StandardsIstitute. [Online] http:// www.etsi.org ".
[13] J. F. Adams, P. D. Lax, and R. S. Philips, "On matrices whose real linear combinations are nonsingular," *Proc. Amer. Math. Soc.*, vol. 16, pp. 318-322, 1965.
[14] F.-C. Zheng and A. G. Burr, "Receiver Design for Orthogonal Space-Time Block Coding for Four Transmit Antennas over Time Selective-Fading Channels," in *Proc. IEEE Globecom*. San Francisco, CA, 2003, pp. 128-132.
[15] Z. Liu, X. Ma, and G. B. Giannakis, "Space-Time Coding and Kalman Filtering for Time-Selective Fading Channels," *IEEE Trans. Commun.*, vol. 50, No. 2, pp. 183-186, Feb. 2002.
[16] X. B. Liang, "A High-Rate Orthogonal Space-Time Block Code," *IEEE Communications Letters*, vol. 7, pp. 222-223, May 2003

Author's Profile

K. Sujatha, received the B.Tech degree in Electronics and Communication Engineering from Kuppam Engineering College in 2005 and M.Tech from Dr.M.G.R university in 2008.Currently pursuing PhD from Jawaharlal Nehru Technological University, India. Research interests include wireless Communications and Wireless Networks

Dr. S. Varadarajan received the B.Tech degree in Electronics and Communication Engineering from Sri Venkateswara University in 1987 and M.Tech from NIT, Warangal He did his PhD in the area of Radar Signal Processing. He is fellow of Institute of Electronics and Communication Engineers (IETE) and member of IEEE. Currently working as Professor in the department of ECE, Sri Venkateswara University, Tirupati, Andhra Pradesh India