Performance Analysis of Space Time Block Coded Spatial Modulation (STBC_SM) under dual diversity Condition

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***Abstract* — STBC_SM is a technique which uses the fundamental of both Spatial modulation and Space time block codes to provide a high rate of spectral efficiency as well as transmit diversity. In this paper we have evaluated the performance of STBC_SM under varying antenna conditions so that to study the effect of receive diversity on STBC_SM. The overall performance is compared under different conventional diversity technique.**

***Keywords* — STBC_SM, Transmit diversity, Receive Diversity**

I. INTRODUCTION

Higher data rate and better spectral efficiency are of paramount importance in next generation cellular communication. MIMO (multiple input multiple output) technology is approach to attain high spectral efficiency by transmitting multiple data streams from multiple antennas. MIMO technology is an effective means to solve the conflict of future high speed wireless communications and the limited spectrum resources can be used [1]. A multiple-input multiple-output (MIMO) system that exploits this potential is the V-BLAST (*Vertical Bell Labs Layered Space-Time*) architecture proposed in [3]. It uses a vertically layered coding structure, where independent code blocks (called layers) are associated with a particular transmit antenna. At the receiver, these layers are detected by a successive interference cancellation technique which nulls the interferers by linearly weighting the received signal vector with a zero-forcing nulling vector (ZF-BLAST). There are two main problems for VBLAST system; one is high inter-channel interference (ICI) at the receiver due to simultaneous transmissions on the same frequency from multiple antennas, which requires a complex receive algorithm. The other is the number of receive antennas must be greater or equal to the number of the transmit antennas. Spatial modulation (SM) technique proposed by Mesleh [4] can overcome the above problems. MIMO Spatial Multiplexing (SM) seems to be the greatest remedy to improve the program potential without demanding extra spectral sources. Recent research have demonstrated that SM is capable of doing a higher capability when compared with multiple–antenna strategies along with comparable decoding complexity, such as Space–Time Block Codes (STBCs). Space–time block codes are designed to get the highest possible variety order for a given number of transmit and receive antennas subject to the restriction of having a simple decoding algorithm. Space-time block codes (STBC's) have received considerable attention in recent open-loop multiple-input-multiple-output (MIMO) wireless communication literature because they allow low complexity maximum-likelihood decoding and guarantee full diversity.

II. RELATED WORK

Researchers from 4G communication fields have targeted their interest on a low complexness implementation of SM along with higher diversity technique to improve quality of service (QoS). Less complex SM is known as Area Move Typing (SSK) modulation [2]. As opposed to SM, in SSK modulation only the spatial–constellation plan is used to regulate the information bits, thus trading–off transmitter and device complexness for the possible details amount [3]. As far receive– and transmit–diversity for SSK modulation is worried, the following contributions are available in the literary works. In [2] and [4], it is shown that SSK modulation can accomplish a receive–diversity gain that improves linearly with the variety of antennas at the device. In [5], it is proven that, regardless of the number of simultaneously–active antennas at the transmitter, SSK modulation is incapable to offer transmit–diversity profits. To get transmit diversity with SM a new scheme was proposed which was called as STBC_SM scheme. In [6], the STBC_SM scheme was presented and analysis shows that it provides better performance in any condition than SM scheme. In [7], an easy technique is presented to get over that limitation. The remedy is appropriate to a transceiver with two transmit–antenna and one receive–antenna, and neither incurs in any spectral performance reduction nor needs multiple simultaneously–active antennas at the transmitter. In [8], transmit–diversity is obtained by delivering repetitive information in non–overlapping time–slots, thus running into in a spectral efficiency reduction. In [9], it is proven that the technique in [7] is incapable to offer full–diversity for an irrelevant variety of antennas at the transmitter and, in common, it allows us to achieve transmit–diversity only similar to two. In [10], the idea in [9] is prolonged and new methods to accomplish transmit–diversity higher than two are suggested. However, all these techniques are mainly worried with SSK modulation, while, to the best of the writers details, the style of transmit–diversity methods for the more common SM concept have never been regarded so far. Only in [12], the writers have studied the possible transmit–diversity of SM and have indicated out that SM cannot accomplish transmit–diversity profits. However, no solutions are offered to deal with this problem and it is shown that the insufficient transmit–diversity may outcome, especially for high associated removal programs, in a significant performance loss of SM with regards to the program. Organization: section III provides the primary STBC_SM system model. Section IV provides some simulation outcomes, and we concluded the paper in section V.

III. SPATIALLY MODULATED SPACE-TIME BLOCK CODE (STBC_SM)

IV.

In the SM_ STBC scheme, both STBC symbols and the indices of the transmit antennas from which these symbols are transmitted, carry information. We choose Alamouti's STBC, which transmits one symbol pcu, as the core STBC due to its advantages in terms of spectral efficiency and simplified ML detection. In Alamouti's STBC, two complex information symbols (x_1 & x_2) drawn from an M-PSK or M-QAM constellation are transmitted from two transmit antennas in two symbol intervals in an orthogonal manner by the codeword.

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

where columns and rows correspond to the transmit antennas and the symbol intervals, respectively. For the STBC-SM scheme we extend the matrix in (1) to the antenna domain.

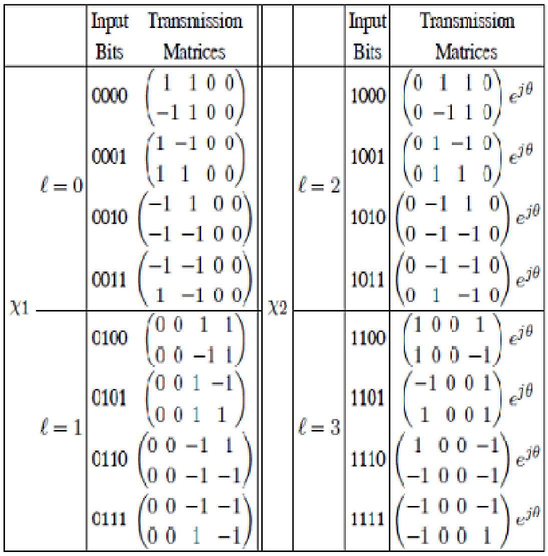
Let us introduce the concept of STBC_SM via the following simple example.

Example (SM_ STBC with four transmit antennas, BPSK modulation): Consider a MIMO system with four transmit antennas which transmits the Alamouti STBC using one of the following four code words:

$$\chi_1 = \{X_{11}, X_{12}\} = \left\{ \begin{pmatrix} x_1 & x_2 & 0 & 0 \\ -x_2^* & x_1^* & 0 & 0 \end{pmatrix} \begin{pmatrix} 0 & 0 & x_1 & x_2 \\ 0 & 0 & -x_2^* & x_1^* \end{pmatrix} \right\} \quad (2)$$

$$\chi_2 = \{X_{21}, X_{22}\} = \left\{ \begin{pmatrix} 0 & x_1 & x_2 & 0 \\ 0 & -x_2^* & x_1^* & 0 \end{pmatrix} \begin{pmatrix} x_2 & 0 & 0 & x_1 \\ x_1^* & 0 & 0 & -x_2^* \end{pmatrix} \right\} e^{j\theta}$$

Where X_i, i = 1,2 are called the STBC-SM codebooks each containing two STBC-SM code words $X_{ij,}$ j=1,2 which do not interfere to each other. The resulting STBC-SM code is X = 2i=1, Xi non-interfering codeword group having a elements is defined as a group of codewords satisfying $X_{ij}XH_{ik}$ =2x2 , j,k = 1,2,……….,a,j/k, that is they have no overlapping columns. In (2), θ is a rotation angle to be optimized for a given modulation format to ensure maximum diversity and coding gain at the expense of expansion of the signal constellation. However, if θ is not considered, overlapping columns of codeword pairs from different codebooks would reduce the transmit diversity order to one. Assume now that we have four information bits (u_1,u_2,u_3,u_4) to be transmitted in two consecutive symbol intervals by the STBCSM technique. The mapping rule for 2 bits/s/Hz transmission is given by Table I for the codebooks of (2) and for binary phase-shift keying (BPSK) modulation, where a realization of any codeword is called a transmission matrix. In Table I, the first two information bits (u_1,u_2) are used to determine the antenna-pair position ℓ while the last two (u_3,u_4) determine the BPSK symbol pair. If we generalize this system to M-ary signaling, we have four different codewords each having M2 different realizations. Consequently, the spectral efficiency of the STBC-SM scheme for four transmit antennas becomes m = (1/2) log_2^2 = 1+ log2 , where the factor 1/2 normalizes for the two channel uses spanned by the matrices in (2). For STBCs using larger numbers of symbol



		Input Bits	Transmission Matrices			Input Bits	Transmission Matrices
$\chi1$	$\ell = 0$	0000	$\begin{pmatrix} 1 & 1 & 0 & 0 \\ -1 & 1 & 0 & 0 \end{pmatrix}$	$\chi2$	$\ell = 2$	1000	$\begin{pmatrix} 0 & 1 & 1 & 0 \\ 0 & -1 & 1 & 0 \end{pmatrix} e^{j\theta}$
		0001	$\begin{pmatrix} 1 & -1 & 0 & 0 \\ 1 & 1 & 0 & 0 \end{pmatrix}$			1001	$\begin{pmatrix} 0 & 1 & -1 & 0 \\ 0 & 1 & 1 & 0 \end{pmatrix} e^{j\theta}$
		0010	$\begin{pmatrix} -1 & 1 & 0 & 0 \\ -1 & -1 & 0 & 0 \end{pmatrix}$			1010	$\begin{pmatrix} 0 & -1 & 1 & 0 \\ 0 & -1 & -1 & 0 \end{pmatrix} e^{j\theta}$
		0011	$\begin{pmatrix} -1 & -1 & 0 & 0 \\ 1 & -1 & 0 & 0 \end{pmatrix}$			1011	$\begin{pmatrix} 0 & -1 & -1 & 0 \\ 0 & 1 & -1 & 0 \end{pmatrix} e^{j\theta}$
	$\ell = 1$	0100	$\begin{pmatrix} 0 & 0 & 1 & 1 \\ 0 & 0 & -1 & 1 \end{pmatrix}$		$\ell = 3$	1100	$\begin{pmatrix} 1 & 0 & 0 & 1 \\ 1 & 0 & 0 & -1 \end{pmatrix} e^{j\theta}$
		0101	$\begin{pmatrix} 0 & 0 & 1 & -1 \\ 0 & 0 & 1 & 1 \end{pmatrix}$			1101	$\begin{pmatrix} -1 & 0 & 0 & 1 \\ 1 & 0 & 0 & 1 \end{pmatrix} e^{j\theta}$
		0110	$\begin{pmatrix} 0 & 0 & -1 & 1 \\ 0 & 0 & -1 & -1 \end{pmatrix}$			1110	$\begin{pmatrix} 1 & 0 & 0 & -1 \\ -1 & 0 & 0 & -1 \end{pmatrix} e^{j\theta}$
		0111	$\begin{pmatrix} 0 & 0 & -1 & -1 \\ 0 & 0 & 1 & -1 \end{pmatrix}$			1111	$\begin{pmatrix} -1 & 0 & 0 & -1 \\ -1 & 0 & 0 & 1 \end{pmatrix} e^{j\theta}$

Table I : STBC_SM mapping rule for 2bits/s/Hz Transmission using BPSK, Four transmit antennas and Alamouti's STBC.

The block diagram of the STBC-SM transmitter is shown in Fig. 1.

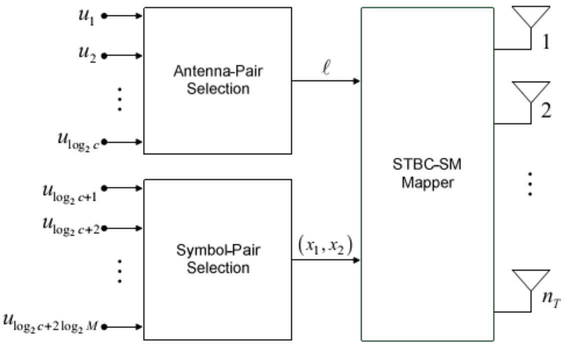


Fig.1 Block diagram of the STBC-SM transmitter.

During each two consecutive symbol intervals, 2mbits,u=(u_1,u_2,……..,ulog2c,ulog2c+1,…….……..., ulog2c +2log2M) enter the STBC-SM transmitter, where the first log2c bits determine the antenna-pair positionℓ=$u_1$2log2c-1+ $u_2$2log2c-2+ ………..+ulog2c) that is associated with the corresponding antenna pair, while the last 2log2M bits determine the symbol pair (x_1,$x_{2,}$….,γ_2). If we compare the spectral efficiency (7) of the STBC-SM scheme with that of Alamouti's scheme (log2Mbits/s/Hz), we observe an increment of 1/2log2c bits/s/Hz provided by the antenna modulation. We consider two different cases for the optimization of the STBC-SM scheme.

n_T	c	a	n	$\delta_{\min}(\chi)$			m [bits/s/Hz]
				$M=2$	$M=4$	$M=16$	
3	2	1	2	12	11.45	9.05	$0.5+\log_2 M$
4	4	2	2	12	11.45	9.05	$1+\log_2 M$
5	8	2	4	4.69	4.87	4.87	$1.5+\log_2 M$
6	8	3	3	8.00	8.57	8.31	$1.5+\log_2 M$
7	16	3	6	2.14	2.18	2.18	$2+\log_2 M$
8	16	4	4	4.69	4.87	4.87	$2+\log_2 M$

Table II: Basic Parameters of the STBC_SM system for different number of Transmit antennas

Optimal ML Decoder for the STBC-SM Scheme

The system with n_T transmit and n_R receive antennas is considered in the presence of a quasi-static Rayleigh fading MIMO channel. The received 2 X n_R signal matrix Y can be expressed as

$$Y = \sqrt{\rho/\mu}\ X_\chi H+N \qquad (3)$$

where $X\chi \in \chi$ the 2 X n_T STBC-SM transmission matrix, transmitted over two channel uses and μ is the normalization factor to ensure that ρ is the average signal-to-noise ratio (SNR) at each receive antenna. H and N denote the n_T x n_R channel matrix and 2X n_R noise matrix, respectively. The entries of H and N are assumed to be independent and identically distributed (i.i.d.) complex Gaussian random variables with zero means and unit variances. We assume that H remains constant during the transmission of a codeword and takes independent values from one codeword to another as well as being known at the receiver, but not at the transmitter. Assuming n_T transmit antennas are employed, the STBC-SM code has ◌ code words from which cM^2 different transmission matrices can be constructed. An ML decoder must make an exhaustive search over all possible cM^2 transmission matrices, and decides in favor of the matrix which minimizes the following metric:

$$\widehat{X_\chi} = argmin_{X_\chi \in \chi} \left\| Y - \sqrt{\rho/\mu}\ X_\chi H \right\|_2 \qquad (4)$$

The minimization in (4) can be simplified as follows. The decoder can extract the embedded information symbol vector from (3), and obtain the following equivalent channel model:

$$y = \sqrt{\rho/\mu}\ H_\chi \begin{bmatrix} x_1 \\ x_2 \end{bmatrix} +n \qquad (5)$$

where H_χ is the 2n_R x 2 equivalent channel matrix which has c different realizations, according to the STBC-SM codewords; y and n represent the 2n_R x 1 equivalent received signal and noise vectors, respectively. Due to the orthogonality, the columns of H_χ are orthogonal to each other for all cases, and, consequently no ICI occurs in this scheme as in SM. Since $c \geq n_T$ for $n_T \geq 4$, there will be a linear increase in ML decoding complexity with STBC-SM as compared to the SM scheme. However, as we will show in the next section, this insignificant increase in decoding complexity is compensated by significant performance improvement provided by the STBC-SM over SM. The last step of the decoding process is the demapping operation based on the look-up table used at the transmitter, the block diagram of the ML decoder described above is given in Fig. 3.

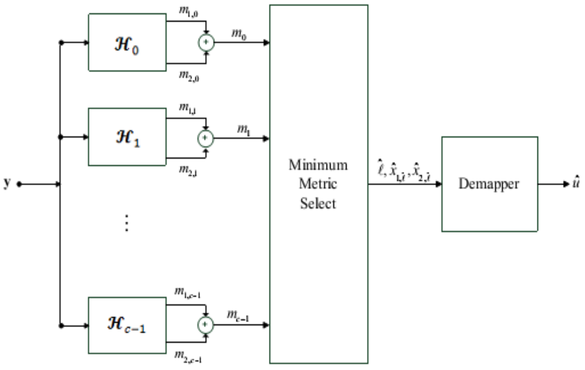


Fig. 3 Block Diagram of the STBC_SM ML Decoder.

V. SIMULATION RESULTS

In this section, we present simulation results for the STBC-SM system with different numbers of transmit and receive antennas. Two types of modulation scheme has been used to analyze the effect of conventional diversity scheme also, so dual diversity scheme. The bit error rate (BER) performance of these systems was evaluated by Monte Carlo simulations for various spectral efficiencies as a function of the average SNR per receive antenna (ρ) All performance comparisons are made for a SNR of the range from 0-7 db. The performance comparison is made on the BER and SER scale of up to 10^{-4}. The comparison shows that with the use of both Transmit and Receive Diversity along with SM we can get maximum data rate with lesser BER and SER when both transmit as well as Receive side uses same number of antenna, whatever modulation technique is used.

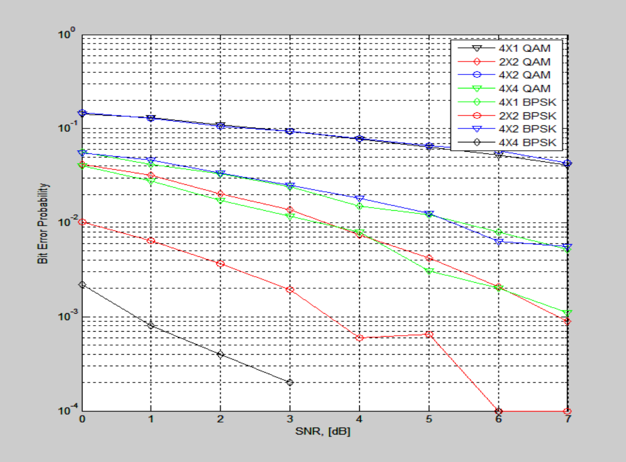


Fig.4 BER comparison of STBC_SM under different antenna configuration

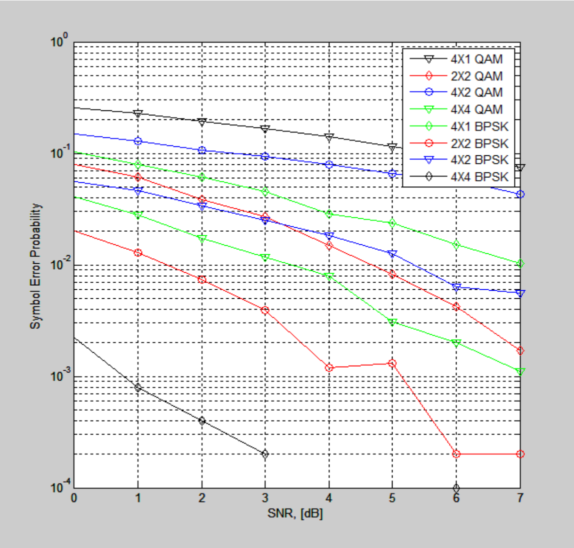


Fig.5 SER comparison of STBC_SM under different antenna configuration

VI. CONCLUSION

STBC_SM system produce full transmit diversity along with spectral efficiency. We have compared the performance of this system. When Receive diversity is also induced along with the STBC_SM we have found better BER and SER performance as compared to STBC_SM. We named it STBC_SM with dual diversity.

VII. REFERENCES

[1] J. Mietzner, R. Schober, L. Lampe, W. H. Gerstacker, and P. A. Hoeher, “Multiple–antenna techniques for wireless communications – A comprehensive literature survey”, IEEE Commun. Surveys Tuts., vol. 11, pp. 87–105, 2nd quarter 2009.

[2] J. Jeganathan, A. Ghrayeb, L. Szczecinski, and A. Ceron, “Space shift keying modulation for MIMO channels”, IEEE Trans. Wireless Commun., vol. 8, no. 7, pp. 3692–3703, July 2009.

[3] M. Di Renzo and H. Haas, “Performance analysis of spatial modulation”, IEEE Int. Conf. Commun. Networking in China, pp. 1–7, Aug. 2010 (invited paper).

[4] M. Di Renzo and H. Haas, “On the performance of space shift keying MIMO systems over correlated Rician fading channels”, IEEE/ITG Int. Workshop on Smart Antennas, pp. 72–79, Feb. 2010.

[5] J. Jeganathan, A. Ghrayeb, and L. Szczecinski, “Generalized space shift keying modulation for MIMO channels”, IEEE Int. Symp. Personal, Indoor, Mobile Radio Commun., pp. 1–5, Sept. 2008.

[6] M. Di Renzo and H. Haas, “Performance comparison of different spatial modulation schemes in correlated fading channels”, IEEE Int. Conf. Commun., pp. 1–6, May 2010.

[7] E.Basar, U. Aygolu, E. Panayirci and H.Vinent Poor,” Space-Time Block Coding for Spatial Modulation” IEEE 21^{st} international symposium on personal indoor and mobile radio communication, 2010

[8] S. Sugiura, S. Chen, and L. Hanzo, “A unified MIMO architecture subsuming space shift keying, OSTBC, BLAST and LDC”, IEEE Veh. Technol. Conf. – all, pp. 1–5, Sept. 2010.

[9] M. Di Renzo and H. Haas, “Space shift keying (SSK–) MIMO over correlated Rician fading channels: Performance analysis and a new method for transmit–diversity”, IEEE Trans. Commun., vol. 59, no. 1, pp. 116–129, Jan. 2011.

[10] M. Di Renzo and H. Haas, “Space shift keying (SSK) modulation: On the transmit–diversity/multiplexing trade–off”, IEEE Int. Conf. Commun., Japan, June 2011.

[11] E. Basar, U. Aygolu, E. Panayirci, and H. V. Poor, “Space–time block coding for spatial modulation”, IEEE Int. Symp. Personal, Indoor, Mobile Radio Commun., pp. 803–808, Sep. 2010.

[12] T. Handte, A. Muller, and J. Speidel, “BER analysis and optimization of generalized spatial modulation in correlated fading channels”, IEEE Veh Technol. Conf.–Fall, pp. 1–5, Sep. 2009.

[13] Donghun Lee, Saeid Nooshabadi, Kiseon Kim,”Dual-Mode SM/STBC system with antenna subset selection employing ML detection”, International journal of electronics and communication vol.64 page 1128-1136, 2010.

[14] Jayesh Dabi and Kamelsh Gupta, “Performance analysis of STBC Spatial Modulation under Transmit diversity and Multiplexing gain”, International Journal of Engineering Sciences & Management, Dabi, Vol 3(1): April- June 2012.