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Space Time Block Codes With Spatial Modulation

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ABSTRACT:

A new multiple-input multiple-output (MIMO) transmission scheme is proposed and it is called space-time block coded spatial modulation (STBC-SM. This scheme is a combination of both Space Time Block Codes and Spatial modulation. By combining we can avoid the drawbacks of the both systems and make use of the advantages of the system.The transmit information symbols are expanded both in space and time domains and also to the spatial (antenna) domain which corresponds to the on/off status of the transmit antennas available at the space domain.

A general technique is presented for the design of the STBC-SM scheme for any number of transmit antennas. Besides the high spectral efficiency advantage provided by the antenna domain, the proposed scheme is also optimized by deriving its diversity and coding gains to exploit the diversity advantage of STBC. A low-complexity maximum likelihood (ML) decoder is given for the new scheme which profits from the orthogonality of the core STBC. The performance advantages of the STBC-SM over simple SM and over V-BLAST are shown by simulation results for various spectral efficiencies and are supported by the derivation of a closed form expression for the union bound on the bit error probability.

I.INTRODUCTION

Multiple-antenna systems that operate at high rates require simple yet effective space–time transmission schemes to handle the large traffic volume in real time. On the other hand, there are many previously proposed space–time codes that have good fading resistance and simple decoding, but these codes generally have poor performance at high data rates or with many antennas.

We propose a high-rate coding scheme that can handle any configuration of transmit and receive antennas and that subsumes both V-BLAST and many proposed space–time block codes as special cases. The scheme transmits sub streams of data in linear combinations over space and time. The codes are designed to optimize the mutual information between the transmitted and received signals. Because of their linear structure, the codes retain the decoding simplicity of V-BLAST, and because of their information-theoretic optimality, they possess many coding advantages. We give examples of the codes and show that their performance is generally superior to earlier proposed methods over a wide range of rates and signal-to-noise ratios (SNRs).

A new MIMO transmission scheme, called STBC-SM, is proposed, in which information is conveyed with an STBC matrix that is transmitted from combinations of the transmit antennas of the corresponding MIMO system. The Alamouti code [3] is chosen as the target STBC to exploit. As a source of information, we consider not only the two complex information symbols embedded in Alamouti's STBC, but also the indices (positions) of the two transmit antennas employed for the transmission of the Alamouti STBC. · A general technique is presented for constructing the STBC-SM scheme for any number of transmit antennas. Since our scheme relies on STBC, by considering the general STBC performance criteria proposed by Tarokh. Diversity and coding gain analyses are performed for the STBC-SM scheme to benefit the second order transmit diversity advantage of the Alamouti code. · A low complexity ML decoder is derived for the proposed STBC-SM system, to decide on the transmitted symbols as well as on the indices of the two transmit antennas that are used in the STBC transmission.

II.MULTIPLE INPUT MULTIPLE OUTPUT

MIMO (Multiple Inputs, Multiple Outputs) is an Antenna technology for wireless communications in which multiple antennas are used and combined at both the source (transmitter) and the destination (receiver) to minimize errors and optimize data speed. The other forms of smart antenna technology are MISO (multiple inputs, single output) and SIMO (Single Input, Multiple Output). MIMO technology has gained much preference in wireless communication because it provides high data output and range without additional bandwidth. But the problem is extra transmit power is required since multiple transmit antennas are used instead of only one as in SISO systems. MIMO achieves this by higher spectral efficiency (more bits per second per hertz of bandwidth) and link reliability or diversity (reduced fading). MIMO forms an important part of modern wireless communication.

III.EXISTING SYSTEM

In V-BLAST systems, a high level of inter-channel interference (ICI) occurs at the receiver since all antennas transmit their own data streams at the same time. This further increases the complexity of an optimal decoder exponentially, while low-complexity suboptimum linear decoders, such as the minimum mean square error (MMSE) decoder, degrade the error performance of the system significantly.

Disadvantages of existing system:

1) ML decoding complexity grows exponentially with the constellation size
2) Difficult implementation
3) Expensive for future wireless communication system

IV.PROPOSED SYSTEM

SPACE TIME BLOCK CODES WITH SPATIAL MODULATION

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.

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

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:

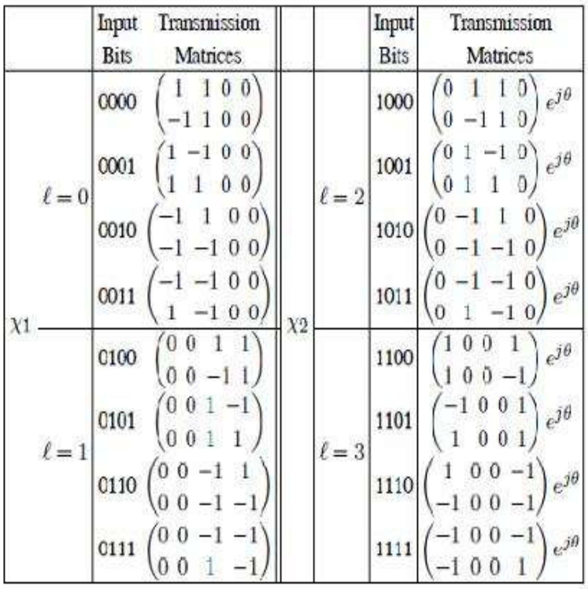
$$\chi_1 = \{X_{11}, X_{12}\} = \left\{ \begin{pmatrix} x_1 & x_2 & 0 & 0 \\ -x_2^* & x_1^* & 0 & 0 \end{pmatrix}, \begin{pmatrix} 0 & 0 & x_1 & x_2 \\ 0 & 0 & -x_2^* & x_1^* \end{pmatrix} \right\}$$

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

--- (2)

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
$\chi 1$	$\ell = 0$	0000	$\begin{pmatrix} 1 & 1 & 0 & 0 \\ -1 & 1 & 0 & 0 \end{pmatrix}$	$\chi 2$	$\ell = 2$	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.

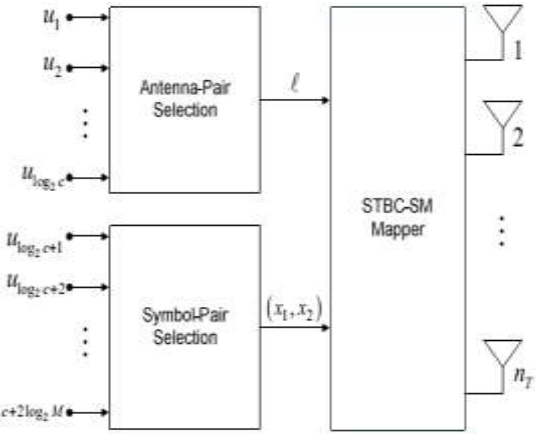
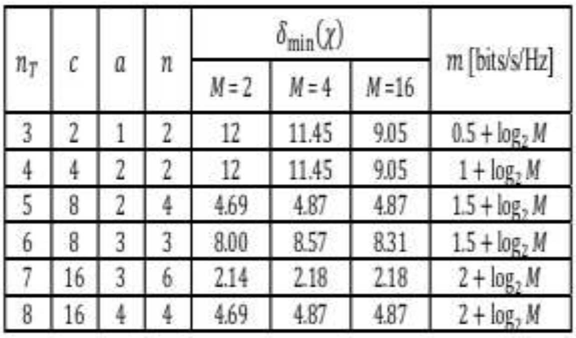


Fig.1 Block diagram of the STBCSM transmitter

During each two consecutive symbol intervals,2mbits,u=(u1,u2,……..,ulog2c,ulog2c+1,……..… ….., ulog2c+2log2M) enter the STBC-SM transmitter, where the first log2c bits determine the antenna-pair positionℓ=u12log2c-1+u22log2c-2+ ……… ..+ulog2c) that is associated with the corresponding antenna pair, while the last 2log2M bits determine the symbol pair (x1,x2,….,γ2). 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

$$Y = \sqrt{\rho / \mu}\ x_x H + N \quad \text{-----(3)}$$

where X_χ є χ 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 nT x nR channel matrix and 2X nR 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 nT transmit antennas are employed, the STBC-SM code has ȯ code words from which cM2 different transmission matrices can be constructed. An ML decoder must make an exhaustive search over all possible cM2 transmission matrices, and decides in favor of the matrix which minimizes the following metric:

$$\hat{\mathbf{X}}_\chi = \arg\min_{\mathbf{X}_\chi \in \chi} \left\| \mathbf{Y} - \sqrt{\frac{\rho}{\mu}} \mathbf{X}_\chi \mathbf{H} \right\|^2. \quad \text{-------(4)}$$

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:

$$Y = \sqrt{\rho / \mu}\ H_x \begin{pmatrix} x_1 \\ x_2 \end{pmatrix} + N \quad \text{-------(5)}$$

whereHχ is the 2nR x 2 equivalent channel matrix which has c different realizations, according to the STBC-SM codewords; y and n represent the 2nR x 1 equivalent received signal and noise vectors, respectively. Due to the orthogonality, the

columns of Hχ are orthogonal to each other for all cases, and, consequently no ICI occurs in this scheme as in SM. Since c >n_T for nT>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.2.

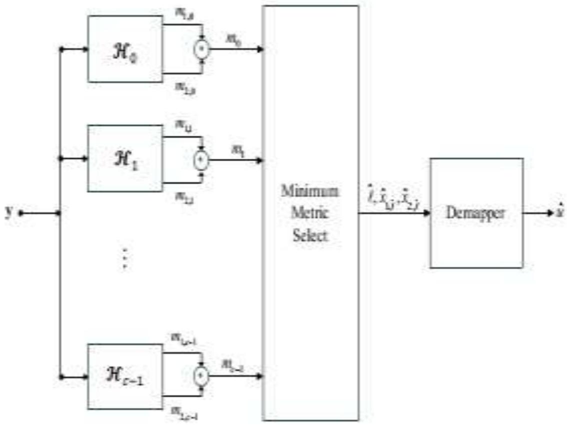


Fig.2. Block diagram of the STBC-SM with ML decoder

V.SIMULATION RESULTS

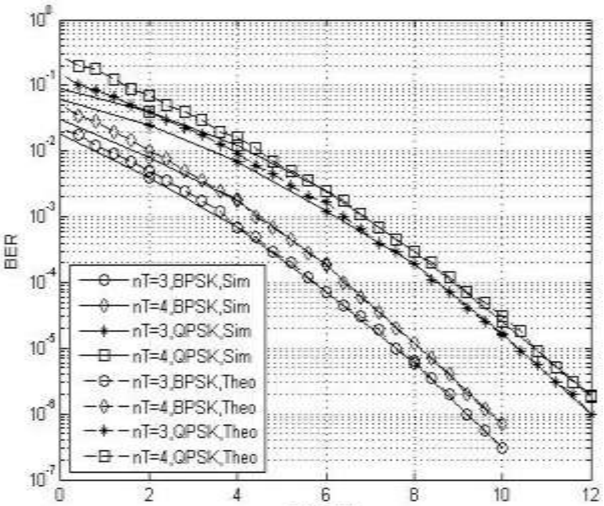


Fig 3: BER performance of STBC-SM Scheme for BPSK and QPSK compared with theoretical upper bounds.

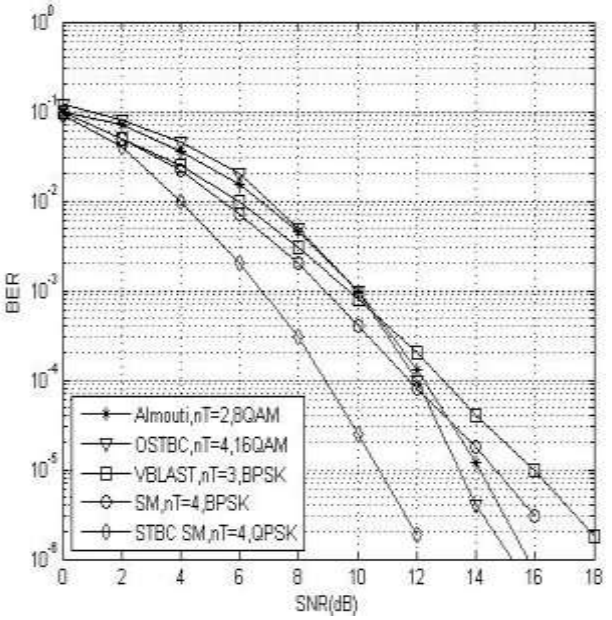


Fig 4:BER performance at 3 bits/s/Hz for STBC-SM,SM, V-BLAST,OSTBC and Alamouti STBC schemes

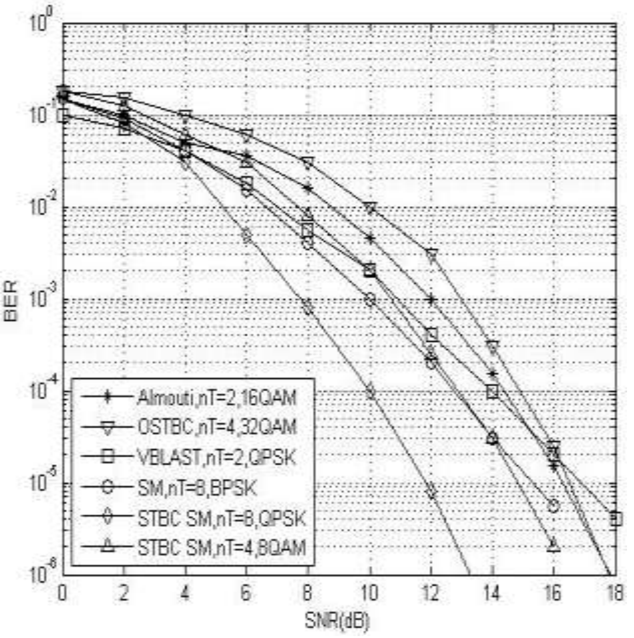


Fig 5: BER performance at 4 bits/s/Hz for STBC-SM,SM, V-BLAST,OSTBC and Alamouti STBC schemes

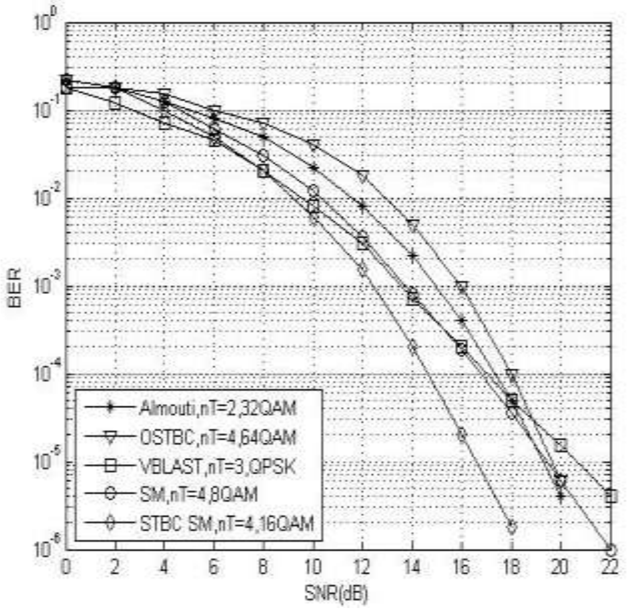


Fig 6: BER performance at 5 bits/s/Hz for STBC-SM,SM, V-BLAST,OSTBC and Alamouti STBC schemes

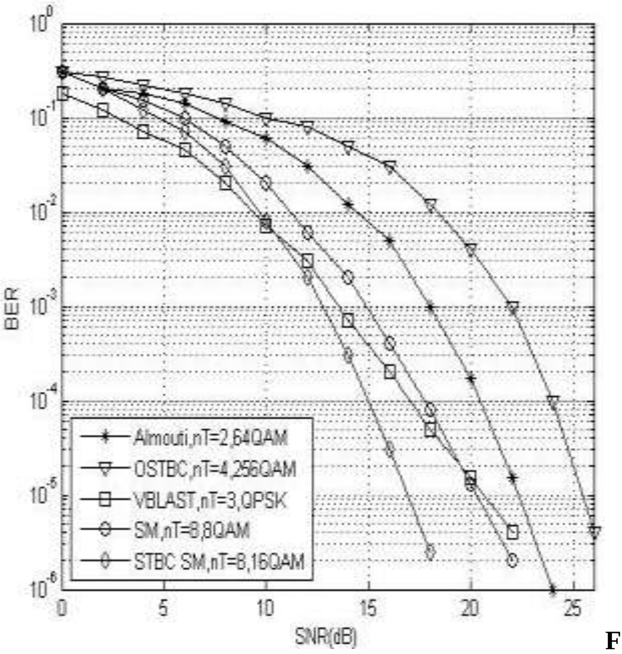


Fig 7: BER performance at 5 bits/s/Hz for STBC-SM,SM, V-BLAST,OSTBC and Alamouti STBC schemes

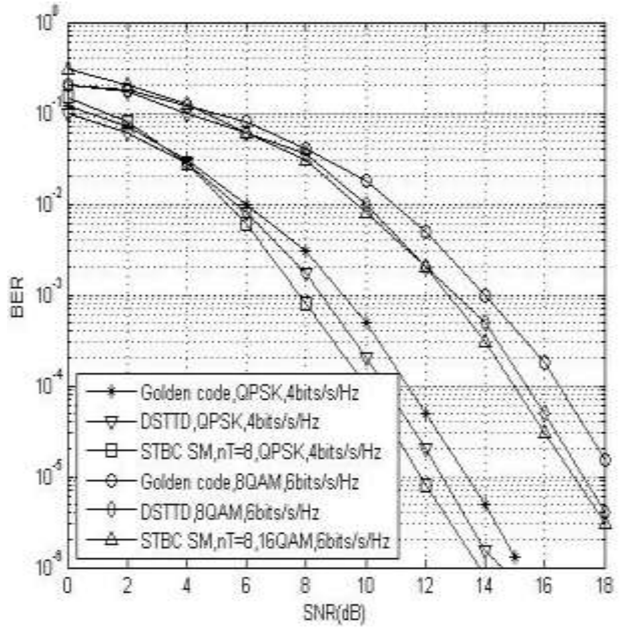


Fig 8: BER performance of STBC-SM, the golden code and DSTTD schemes at 4 and 6 bits/Hz spectral efficiencies

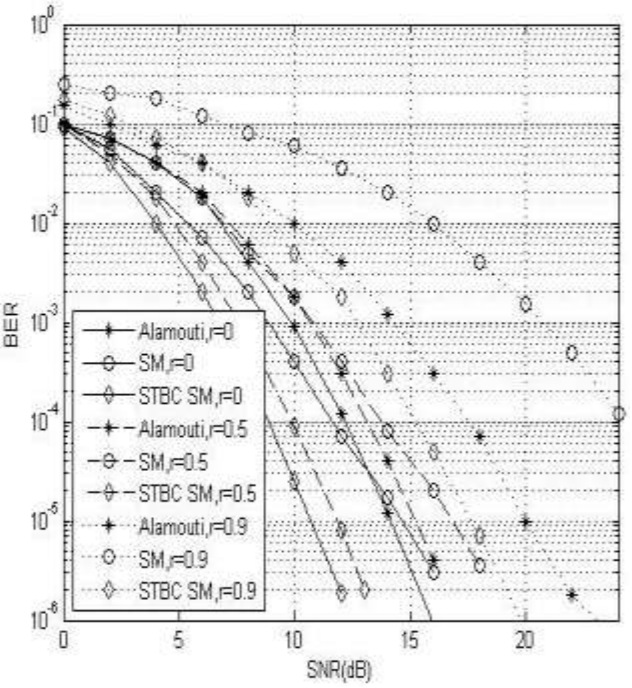


Fig 9: BER performance at 3bitsHz for STBC-SM, SM, and Alamouti's STBC schemes for SC channel with r=0,0.5 and 0.9

VI.CONCLUSION

In this paper, we have introduced a novel high-rate, low complexity MIMO transmission scheme, called STBC-SM, as an alternative to existing techniques such as SM and VBLAST. The proposed new transmission scheme employs both APM techniques and antenna indices to convey information and exploits the transmit diversity potential of MIMO channels. A general technique has been presented for the construction of the STBC-SM scheme for any number of transmit antennas in which the STBC-SM system was optimized by deriving its diversity and coding gains to reach optimum performance. We conclude that the STBC-SM scheme can be useful for high-rate, low complexity, emerging wireless communication systems such as LTE and WiMAX. Our future work will be focused on the integration of trellis coding into the proposed STBC-SM scheme.

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