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Preeminence of Space-Time Block Coded Spatial Modulation System Comparing To SM and V-Blast Systems by Evaluating Parameter Bit Error Rate

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Abstract

The Multiple input multiple output (MIMO) Transmission scheme called SPACE BLOCK CODED SPATIAL MODULATION. It is the combination of spatial modulation(SM) and Space time block coding .The transmitted information symbols expanded not only to the space and time domain but also to the spatial (antennas) Domains. As an alternative to existing techniques such as SM and V-BLAST the proposed new transmission scheme employs both APM techniques and antenna indices to convey information and exploits the transmit diversity potential of N 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 performance. It has been shown via computer simulations and also supported by a theoretical upper bound analysis that the STBC_SM offers significant improvements in BER performance compared to SM and V_BLAST systems. The STBC_SM scheme can be useful for high-rate, low complexity, emerging wireless communication systems such as LTE and Wi-MAX.

Index Terms: *A MIMO system, space-time block codes/coding, spatial modulation, V-BLAST, Maximum likelihood, decoding amplitude/phase modulation techniques (APM), WIMAX.*

1. INTRODUCTION

The use of multiple antennas at both transmitter and receiver has been shown to be an effective way to improve capacity and reliability over those achievable with single antenna wireless systems. Consequently, multiple-input multiple-output (MIMO) transmission techniques have been comprehensively studied over the past decade by numerous researchers, and two general MIMO transmission strategies, a **space-time block coding (STBC)** and **spatial multiplexing(SM**), have been proposed. The increasing demand for high data rates and, consequently, high spectral efficiencies has led to the development of spatial multiplexing systems such as V-BLAST. 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. On the other hand, STBCs offer an excellent way to exploit the potential of MIMO systems because of their implementation simplicity as well as their low decoding complexity. A special class of STBCs,

Called orthogonal STBCs (OSTBCs), has attracted attention due to their single-symbol maximum likelihood (ML) receivers with linear decoding complexity. However it has been shown that the symbol rate of an OSTBC is upper bounded by 3/4 symbols per channel use for more than two transmit antennas. Several high rate STBCs have been proposed in the past decade, but their ML decoding complexity grows exponentially with the constellation size, which makes their implementation difficult and expensive for future wireless communication systems.. The basic idea of SM is an extension of two dimensional signal constellations (such as M-ary phase shift keying (M-PSK) and M-ary quadrature amplitude modulation (M-QAM), where M is the constellation size. Therefore, the information is conveyed not only by the amplitude/phase modulation (APM) techniques, but also by the antenna indices. An optimal ML decoder for the SM scheme, which makes an exhaustive search over the aforementioned three dimensional spaces, has been presented. It has been shown in the results that the error performance of the SM scheme can be improved approximately in the amount of 4 dB by the use of the optimal detector under conventional channel assumptions and that SM provides better error performance than V-BLAST and maximal ratio combining (MRC). More recently, a new technique have introduced a so-called space shift keying (SSK) modulation scheme for MIMO channels. In SSK modulation, APM is eliminated and only antenna indices are used to transmit information, to obtain further simplification in system design and reduction in decoding complexity. However, SSK modulation does not provide any performance advantage compared to SM. In both of the SM and SSK modulation systems, only one transmit antenna is active during each transmission interval, and therefore Inter Channel Interference (ICI) is totally eliminated. SSK modulation has been generalized where different combinations of the transmit antenna indices are used to convey information for further design flexibility. Both the SM and SSK modulation systems have been concerned with exploiting the multiplexing gain of multiple transmit antennas, but the potential for transmit diversity of MIMO systems is not exploited by these two systems. This leads to the introduction here of Space-Time Block Coded Spatial Modulation (STBC-SM), designed to take advantage of both SM and STBC.

The main contributions of this paper can be summarized as follows:

- 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's code 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.
- It is shown by computer simulations that the proposed STBC-SM scheme has significant performance advantages over the SM with an optimal decoder, due to its diversity advantage. A closed form expression for the union bound on the bit error probability of the STBC-SM scheme is also derived to support our results. The derived upper bound is shown to become very tight with increasing signal-to-noise (SNR) ratio.

2. SPACE – TIME BLOCK CODED SPATIAL MODULATION (STBC-SM)

Space–time block coding is a technique used in wireless communications to transmit multiple copies of a data stream across a number of antennas and to exploit the various received versions of the data to improve the reliability of data-transfer. The fact that the transmitted signal must traverse a potentially difficult with environment scattering, reflection, refraction and so on and may then be further corrupted by thermal noise in the receiver means that some of the received copies of the data will be 'better' than others. This redundancy results in a higher chance of being able to use one or more of the received copies to correctly decode the received signal. In fact, space-time coding combines all the copies of the received signal in an optimal way to extract as much information from each of them as possible performance of the system significantly. On the other hand, STBCs offer an excellent way to exploit the potential of MIMO systems because of their implementation simplicity as well as their low decoding complexity. A special class of STBCs, called orthogonal STBCs (OSTBCs), has attracted attention due to their single-symbol maxi mum likelihood (ML) receivers with linear decoding complexity. However it has been shown that the symbol rate of an OSTBC is upper bounded by ¾ symbols per channel use (PCU) for more than two transmit antennas. Several high rate STBCs have been proposed in the past decade but their ML decoding complexity grows exponentially with the constellation size, which makes their implementation difficult and expensive for future wireless communication systems. Recently, a novel concept known as spatial modulation (SM) has been introduced by Mesleh to remove the ICI completely between the transmit antennas of a MIMO link. The basic idea of SM is an extension of two dimensional signal constellations (such as M-ary phase shift keying (-PSK) and M-ary quadrature amplitude modulation (-QAM), where is the constellation size) to a third dimension, which is the spatial (antenna) dimension. Therefore, the information is conveyed not only by the amplitude/phase modulation (APM) techniques, but also by the antenna indices. An optimal ML decoder for the SM scheme, which makes an exhaustive search over the aforementioned three dimensional spaces, has been presented. It has been shown in

$$\max \delta \min(x) = \max \min_{i,j,i\neq j} \delta \min\left(x_i, x_j\right)$$
$$= \max \min_{i,j,i\neq j} M$$

that the error performance of the SM scheme can be improved approximately in the amount of 4 dB by the use of the optimal detector under conventional channel assumptions and that SM provides better error performance than V-BLAST and maximal ratio combining (MRC). More recently, Jeganatha net al. have introduced a so-called space shift keying (SSK) modulation scheme for MIMO channels. In SSK modulation, APM is eliminated and only antenna indices are used to transmit information, to obtain further simplification in system design and reduction in decoding complexity. However, SSK modulation does not provide any performance advantage compared to SM. In both of the SM and SSK modulation systems, only one transmit antenna is active during each transmission interval, and therefore ICI is totally eliminated.SSK modulation, where different combinations of the transmit antenna indices are used to convey information for further design flexibility. Both the SM and SSK modulation systems have been concerned with exploiting the multiplexing gain of multiple transmit antennas, but the potential for transmit diversity of MIMO systems is not exploited by these two systems. This leads to the introduction here of Space-Time Block Coded Spatial Modulation (STBC-SM), designed to take advantage of both SM and STBC.

In the STBC-SM scheme, both STBC symbols and the indices of the transmit antennas from which these symbols are transmitted, carry information. We choose Altamonte's STBC, which transmits one symbol pcu, as the core STBC due to its advantages in terms of spectral efficiency and simplifies ML detection. In Alamouti's STBC, two complex information symbols (1and2) 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 code word

$$X = (X_1\ X_2) = \begin{pmatrix} x_1 & x_1 \\ -x_2^* & -x_1^* \end{pmatrix} \qquad (1)$$

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

$$\chi_1 = \{X_{11}, X_{22}\} = \left\{ \begin{pmatrix} x_1 & x_2 & 0 & 0 \\ -x_2^* & x_1^* & 0 & 0 \end{pmatrix}, \begin{pmatrix} 0 & 0 & x_1 & x_2 \\ 0 & 0 & -x_2^* & x_1^* \end{pmatrix} \right\}$$

$$\chi_2 = \{X_{21}, X_{22}\} = \left\{ \begin{pmatrix} 0 & x_1 & x_2 & 0 \\ 0 & -x_2^* & x_1^* & 0 \end{pmatrix}, \begin{pmatrix} x_2 & 0 & 0 & x_1 \\ x_1^* & 0 & 0 - x_2^* \end{pmatrix} \right\} e^{j\theta} \qquad (2)$$

In (2), 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 is not considered, over-lapping columns of codeword pairs from different codebooks would reduce the transmit diversity order to one. Assume now that we have four information bits ($_1,\ _2,\ _3,\ _4$) to be transmitted in two consecutive symbol intervals by the STBC-SM 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 ($_1,\ _2$) are used to determine the antenna-pair position ℓ while the last two ($_3,\ _4$) determine the BPSK symbol pair. If we generalize this system to M-ary signaling, we have four different codeword's each having two different realizations. Consequently, the spectral efficiency of the STBC-SM scheme for four transmit antennas becomes = $(1/2)\log_2 4^2 = 1 + \log_2$bits/s/Hz, where the factor ½ normalizes for the two channel uses spanned by the matrices in (2). For STBCs using larger numbers of symbol intervals such as the quasi-orthogonal STBC for four transmit antennas which employs four symbol intervals, the spectral efficiency will be degraded substantially due to this normalization term since the number of bits carried by the antenna modulation ($\log_2$), is normalized by the number of channel uses of the corresponding STBC.

		Input Bits	Transmission Matrices			Input Bits	Transmission Matrices
χ_1	$\ell = 0$	0000	$\begin{pmatrix} 1 & 1 & 0 & 0 \\ -1 & 1 & 0 & 0 \end{pmatrix}$	χ_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	$\begin{pmatrix} -1 & 0 & 0 & -1 \\ -1 & 0 & 0 & 1 \end{pmatrix} e^{j\theta}$

TABEL 1: **STBC-SM MAPPING RULE FOR 2 BITS/Hz TRANSMISSION USING BPSK FOUR ANTENNAS AND ALAMOUTI'S STBC**

3. STBC-SM System Design and Optimization

In this subsection, I generalize the STBC-SM scheme for MIMO systems using Alamouti's STBC to transmit antennas by giving a general design technique. An important design parameter for quasi-static Rayleigh fading channels is the minimum coding gain distance (CGD) between two STBC-SM code words X_{ij} and $\widehat{X}_{ij}$, where X_{ij} is transmitted and $\widehat{X}_{ij}$ is erroneously detected, is de fined as,

$$\delta \min(X_{ij}, \widehat{X}_{ij}) = \min_{X_{ij}, \widehat{X}_{ij}} \det(X_{ij} - \widehat{X}_{ij})(X_{ij} - \widehat{X}_{ij})^H \qquad (3)$$

The minimum CGD between two codebooks x_i and x_j is defined as,

$$\delta \min(x_i, x_j) = \min_{k,l} \delta\min(X_{ik} - X_{il}) \qquad (4)$$

And the minimum CGD of an STBC-SM code is defined by,

$$\delta \min(x) = \min_{i,j,i \neq j} \delta\min(x_i - x_j) \qquad (5)$$

Note that, min corresponds to the determinant criterion given since the minimum CGD between non-interfering code words of the same codebook is always greater than or equal to the right hand side .

Unlike in the SM scheme, the number of transmit antennas in the STBC-SM scheme need not be an integer power of 2, since the pair wise combinations are chosen from nT available transmit antennas for STBC transmission. This provides design flexibility. However, the total number of codeword combinations considered should be an integer power of 2.

Given the total number of transmit antennas; calculate the number of possible antenna combinations for the transmission of Altamonte's STBC, i.e., the total number of STBC-SM code words from $c = \lfloor \binom{nT}{2} \rfloor_{2P}$ where p is a positive integer.

1) Calculate the number of code words in each codebookxi, i = 1, 2, . . ., $n-1$ from $a = \lfloor nT / 2 \rfloor$ and the total number of codebooks from $n = \lceil c/a \rceil$. Note that the last codebook χ_n does not need to have a code words, i.e., its cardinality is $a' = c-(n-1)$.
2) Start with the construction of χ_1 which contains a non-interfering.
3) Code words as

$$\chi_1 = \{(X\ 0_{2\times(nT-2)}),\ (0_{2\times2}\ X\ 0_{2\times(nT-4)}),\ (0_{2\times4}\ X\ 0_{2\times(nT-6)}),\ \ldots,\ (0_{2\times2(a-1)}\ X\ 0_{2\times(nT-2a)})\} \quad (6)$$

Where X is defined in (1).

4) Using a similar approach, construct χ_i for $2 \le i \le n$ by considering the following two important facts: Every codebook must contain non-interfering code words chosen from pair wise combinations of n_T available transmit antennas. Each codebook must be composed of code words with antenna combinations that were never used in the construction of a previous codebook.

5) Determine the rotation angles θ_i for each $x_i, 2 \le i \le ns$, that maximize δmin(x) in (5) for a given signal constellation and antenna configuration; i.e.,

$$\theta\, opt = \arg\max_{\theta} \delta \min(x) \quad (7)$$

Where $\theta = (\theta_2, \theta_3 \ldots \theta_n)$.

As long as the STBC-SM code words are generated by the algorithm described above, the choice of other antenna combinations is also possible but this would not improve the overall system performance for uncorrelated channels Since we have antenna combinations, the resulting spectral efficiency of the STBC-SM scheme can be calculated as efficiency of the STBC-SM scheme can be calculated as

$$m = \frac{1}{2}\log_2 c + \log_2 M \text{ [bits/s/Hz]}$$

3. Optimal ML Decoder for the STBC-SM System

In this subsection, I formulate the ML decoder for the STBC-SM scheme. The system with nT transmit and nR receive antennas is considered in the presence of a quasi-static Rayleigh flat fading MIMO channel.

The received 2 × nR signal matrix Y can be expressed as

$$Y = \sqrt{\frac{\rho}{\mu}} X_x H + N \quad (8)$$

Where $X_x \epsilon_x$ is the 2×nT STBC-SM transmission matrix, transmitted over two channel uses μ and is a normalization factor to ensure that ρ is the average SNR at each receive antenna. H and N denote the nT * nR channel matrix and 2 × 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. We further assume that H is known at the receiver, but not at the transmitter.

Assuming nT transmit antennas are employed, the STBC-SM code has code words, from which cM^2 different trans-mission 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 that minimizes the following metric:

$$\hat{X}_x = \arg\min_{X_x, \epsilon_x} \left\| Y - \sqrt{\frac{\rho}{\mu}} X_x H \right\|^2 \quad (9)$$

The minimization in (9) can be simplified due to the orthogonality of Alamouti's STBC as follows. The decoder can e extracts the embedded information symbol vector from (8), and obtains the following equivalent channel model:

$$Y = \sqrt{\frac{\rho}{\mu}} H_x \begin{bmatrix} x_1 \\ x_2 \end{bmatrix} + n \quad (10)$$

Where $\mathcal{H}x$ is the 2 nR × 2 equivalent channel matrix of the Altamonte coded SM scheme, which has different realizations according to the STBC-SM code words. In (10), y and n represent the 2 nR × 1 equivalent received signal and noise vectors, respectively. Due to the orthogonality of Alamouti's STBC, the columns of $\mathcal{H}x$ are orthogonal to each other for all cases and, consequently, no ICI occurs in our scheme as in the case of SM. Consider the STBC-SM transmission model as described in Table I for four transmit antennas. Since there are c=4 STBC-SM code words, as seen from Table II, I have four different realizations for $\mathcal{H}x$, which are given for receive antennas as

$$H_0 = \begin{bmatrix} h_{1.1} & h_{1.2} \\ h^*_{1,2} & -h^*_{1,1} \\ & \vdots \\ h_{nR,1} & h_{nR,2} \\ h^*_{nR,2} & -h^*_{nR,1} \end{bmatrix} \quad H_1 = \begin{bmatrix} h_{1.3} & h_{1.4} \\ h^*_{1,4} & -h^*_{1,3} \\ & \vdots \\ h_{nR,3} & h_{nR,4} \\ h^*_{nR,4} & -h^*_{nR,3} \end{bmatrix}$$

$$H_2 = \begin{bmatrix} h_{1.2}\varphi & h_{1.3}\varphi \\ h^*_{1,3}\varphi^* & -h^*_{1,2}\varphi^* \\ & \vdots \\ h_{nR,2}\varphi & h_{nR,3}\varphi \\ h^*_{nR,3}\varphi^* & -h^*_{nR,2}\varphi^* \end{bmatrix}$$

$$H_3 = \begin{bmatrix} h_{1.4}\varphi & h_{1.1}\varphi \\ h^*_{1,1}\varphi^* & -h^*_{1,4}\varphi^* \\ & \vdots \\ h_{nR,4}\varphi & h_{nR,1}\varphi \\ h^*_{nR,1}\varphi^* & -h^*_{nR,4}\varphi^* \end{bmatrix} \quad (11)$$

Where hi, jis the channel fading coefficient between transmit antenna j and receive antenna i and $\varphi = e^{j\theta}$ Generally, we have equivalent channel matrices $\mathcal{H}\ell$, $0 \leq \ell \leq \ - 1$,and for the ℓ the combination, the receiver determines the ML estimates of x1 and x2 using the decomposition as follows [11], resulting from the orthogonality of hℓ, 1and hℓ,2

$$\hat{x}_{1.l} = \arg \min_{x_1 \epsilon_\gamma} \left\| Y - \sqrt{\frac{\rho}{\mu}} h_{l,1}\chi_1 \right\|^2$$

$$\hat{x}_{2.l} = \arg \min_{x_2 \epsilon_\gamma} \left\| Y - \sqrt{\frac{\rho}{\mu}} h_{l,2}\chi_2 \right\|^2 \quad (12)$$

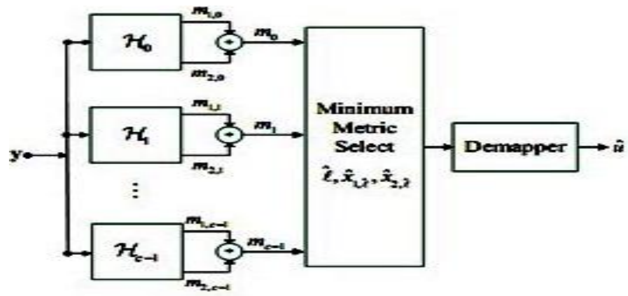
Where $\mathcal{H}\ell$ = [h ℓ, 1 h ℓ, 2], $0 \leq \ell \leq - 1$, and hℓ, =1, 2, is a 2 nR × 1 column vector. The associated minimum ML metrics m1, ℓ and m2, ℓ for x1 and x2 are

$$m_{1,l} = \min_{x_1 \epsilon_\gamma} \left\| Y - \sqrt{\frac{\rho}{\mu}} h_{\ell,1}\ \chi_1 \right\|^2$$

$$m_{2,l} = \min_{x_2 \epsilon_\gamma} \left\| Y - \sqrt{\frac{\rho}{\mu}} h_{\ell,2}\chi_2 \right\|^2 \quad (13)$$

respectively. Since m1, ℓ and m 2, ℓ are calculated by the ML decoder for the ℓth combination, their summation m ℓ =m1, ℓ +m 2, ℓ, $0 \leq \ell \leq c - 1$ gives the total ML metric for the ℓ th combination. Finally, the receiver makes a decision by choosing the minimum antenna combination met $\hat{\ell} = \arg\min m_\ell$ for which$(\hat{x}_1, \hat{x}_2) = (\hat{x}_{1,\hat{\ell}}, \hat{x}_{2,\hat{\ell}})$.

As a result, the total number of ML metric calculations in (15) is reduced from $cM^2$to 2cM, yielding a linear decoding complexity as is also true for the SM scheme, whose optimal decoder requires metric calculations. Obviously, 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 rewarded with significant performance improvement provided by the STBC-SM over SM.



Block diagram of the STBC-SM ML receiver

Step of the decoding process is the de-mapping operation based on the look-up table used at the transmitter, to recover the input bits

$$\hat{u} = (\hat{u}_1, \dots, \hat{u}_{\log_2 c}, \hat{u}_{\log_2 c+1}, \dots \hat{u}_{\log_2 c+\log_2 M})$$

from the determined spatial position (combination) $\hat{\ell}$ and the information symbols $\hat{x}_1$ and $\hat{x}_2$. The block diagram of the ML decoder described above is given in Fig. 6.1.

4. PERFORMANCE ANALYSIS OF THE STBC - SM SYSTEM

In this section, I analyze the error performance of the STBC-SM system, in which 2 bits are transmitted during two consecutive symbol intervals using one of the $cM^2 = 2^2m$ different STBC-SM transmission matrices, denoted by $X_1, X_2, \ldots, X_{2^2m}$ here for convenience. An upper bound other average bit error probability (BEP) is given by the well-known union bound:

$$P_b \leq \frac{1}{2^{2m}} \sum_{i=1}^{2^{2m}} \sum_{j=1}^{2^{2m}} \frac{P(X_i \to X_j) n_{i,j}}{2m} \quad (14)$$

Where (X→X) is the pair wise error probability (PEP) of deciding STBC-SM matrix Xj given that the STBC-SM, matrix is transmitted, and ni,is the number of bits in error between the matrices X$i$and Xj . Under the normalizationμ= 1 and {tr (X$H\chi$Xχ)}= 2 in (14), the conditional PEP of the STBC-SM system is calculated as

$$P(X_i \to X_j \mid H = Q(\sqrt{\frac{\rho}{2}} \|(X_j - X_i)H\| \quad (15)$$

Where $Q(x) = (1/\sqrt{2\pi}) \int_x^\infty e^{-y^2/2} dy\ldots$ Averaging (15) over the channel matrix H and using the moment generating function (MGF) approach [12], the unconditional PEP is obtained As

$$p(X_i \to X_j) = \frac{1}{\pi} \int_0^{\frac{\pi}{2}} \left(\frac{1}{1 + \frac{\rho \lambda_{i,j,1}}{4 \sin^2 \phi}} \right)^{nR} \left(\frac{1}{1 + \frac{\rho \lambda_{i,j,2}}{4 \sin^2 \phi}} \right)^{nR} dt \quad (16)$$

whereλ_i, 1 and $\lambda_{i,}$, 2are the Eigen values of the distance matrix (Xi−Xj)(Xi−Xj).

If λi,1= $\lambda i,j$,2 = $\lambda i,j$, (16) simplifies to

$$p\left(X_i \to X_j\right) = \frac{1}{\pi}\int_0^{\frac{\pi}{2}}\left(\frac{1}{1+\frac{\rho\lambda_{i,j}}{4\sin^2\emptyset}}\right)^{2n_R} d\emptyset \qquad (17)$$

Which is the PEP of the conventional Alamouti STBC. Closed form expressions can be obtained for the integrals in (16) and (17) using the general formulas.

In case of c= an, for nT=3and for an even number of transmit antennas when ≥ 4, it is observed that all transmission matrices have the uniform error property due to the symmetry of STBC-SM codebooks, i.e., have the same PEP as that ofX1. Thus, we obtain a BEP upper bound for STBC-SM as follows:

$$P_b \le \sum_{j=2}^{2^{2m}} \frac{P(X_1 \to X_j)n_{1,j}}{2m} \qquad (18)$$

Applying the natural mapping to transmission matrices.$n1$, can be directly calculated as$n1$, = [(j−1)2], where [x] and (x) 2 are the Hamming weight and the binary representation of , respectively. Consequently, from (24), we obtain the union bound on the BEP as

$$\sum_{j=2}^{2^{2m}} \frac{\omega[(j-1)_2]}{2m\pi}\int_0^{\pi/2}\left(\frac{1}{1+\frac{\rho\lambda_{i,j,1}}{4\sin^2\emptyset}}\right)^{n_R}\left(\frac{1}{1+\frac{\rho\lambda_{i,j,2}}{4\sin^2\emptyset}}\right)^{n_R} d\emptyset \qquad (19)$$

This will be evaluated in the next section for different system parameters.

5. Results and comparison

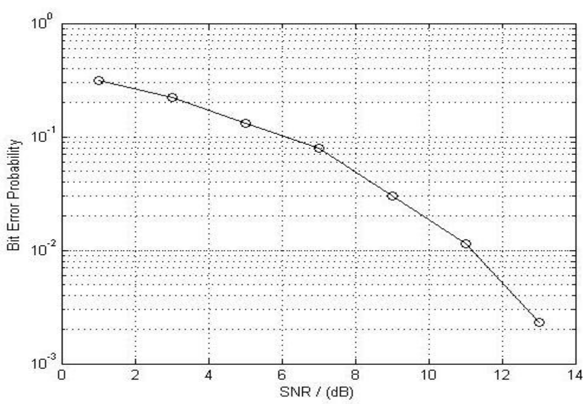


FIG: STBC

The above graph shows the representation of the STBC Using different no of transmitting antenna in different cases as per the requirement for p=1, p=2, p=4, p=8 as p represents the no of transmitting antenna. And the modulation technique used here is phase shift keying (psk) Modulation. By plotting the graph between BER on x-axis and SNR on y-axis.

The below graph shows the representation of the VBLAST in this technique using the four transmitting antennas and four receiving antennas.

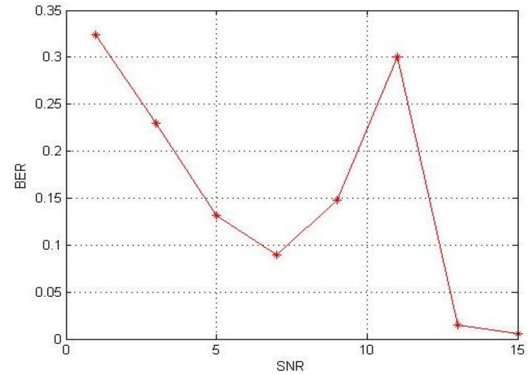


Fig. V-BLAST

The V-BLAST system uses MMSE detection with ordered successive interference cancellation (SIC) decoding where the layer with the highest post detection SNR is detected first, then mulled and the process is repeated for all layers. We employ ML decoders for both the Golden code and the DSTTD scheme.

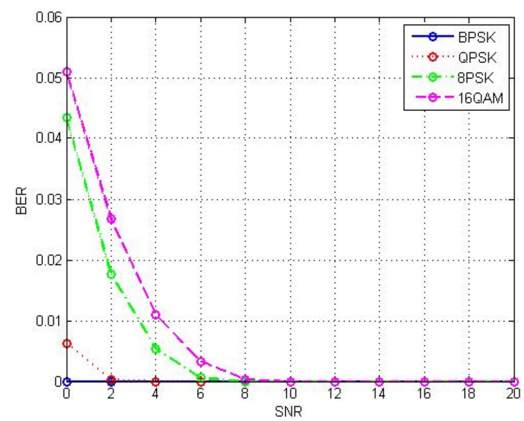


Fig. Representation of STBC different digital modulation techniques

The above graph shows the representation of the STBC-SM. Using four transmitting antennas four receiving antennas. In this the data is divided into frames and packets and we have used different modulation techniques like BPSK, QPSK, 8PSK, 16QAM. By plotting the graph between BER on x-axis and SNR on y-axis

7. COMPARISION STBC – SM WITH EXISTING SCHEMES

Space–time block coding is a technique used in wireless communications to transmit multiple copies of a data stream across a number of antennas . Graphical representation of STBC over other existing techniques is as shown below.

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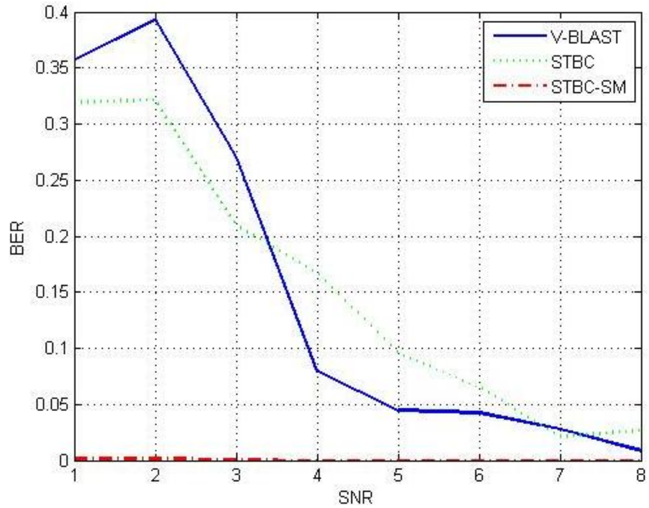

Fig. Comparison of STBC-SM over other techniques

The above graph represents the comparison of all the above techniques the blue line indicates the V-BLAST and the green lines indicates the STBC and the red line indicates the STBC-SM and comparing the all the values by plotting the graph between BER on x-axis and SNR on y-axis.

STBC is used to exploit the various received versions of the data to improve the reliability of data-transfer. The fact that the transmitted signal must traverse with environment scattering, reflection, refraction and so on and may then be further corrupted by thermal noise in the receiver means that some of the received copies of the data will be 'better' than others. This redundancy results in a higher chance of being able to use one or more of the received copies to correctly decode the received signal. In fact, space–time coding combines all the copies of the received signal in an optimal way to extract as much information from each of them as possible performance of the system significantly. On the other hand, STBCs offer an excellent way to exploit the potential of MIMO systems because of their implementation simplicity as well as their low decoding complexity. A special class of STBCs, called orthogonal STBCs (OSTBCs), has attracted attention due to their single-symbol maxi mum likelihood (ML) receivers with linear decoding complexity. However it has been shown that the symbol rate of an OSTBC is upper bounded by 3 / 4 symbols per channel use (PCU) for more than two transmit antennas [5]. Several high rate STBCs have been proposed in the past decade but their ML decoding complexity grows exponentially with the constellation size, which makes their implementation difficult and expensive for future wireless communication systems. Recently, a novel concept known as spatial modulation (SM) has been introduced by Mesleh to remove the ICI completely between the transmit antennas of a MIMO link. The basic idea of SM is an extension of two dimensional signal constellations (such as M-ary phase shift keying (-PSK) and M-ary quadrature amplitude modulation (-QAM), where M is the constellation size) to a third dimension, which is the spatial (antenna) dimension. Therefore, the information is conveyed not only by the amplitude/phase modulation (APM) techniques, but also by the antenna indices. An optimal ML decoder for the SM scheme, which makes an exhaustive search over the aforementioned three dimensional spaces, has been presented. It has been shown in

$$\max \delta \min(\mathrm{x}) = \max \min_{\mathrm{i,j,i\neq j}} \delta \min(\mathrm{x_i}, \mathrm{x_j})$$
$$= \max \min_{\mathrm{i,j,i\neq j}} ƒ_{\mathrm{M}}$$

That the error performance of the SM scheme can be improved approximately in the amount of 4 dB by the use of the optimal detector under conventional channel assumptions and that SM provides better error performance than V-BLAST and maximal ratio combining (MRC). More recently, Jeganatha net al. have introduced a so-called space shift keying (SSK) modulation scheme for MIMO channels. In SSK modulation, APM is eliminated and only antenna indices are used to transmit information, to obtain further simplification in system design and reduction in decoding complexity. However, SSK modulation does not provide any performance advantage compared to SM. In both of the SM and SSK modulation systems, only one transmit antenna is active during each transmission interval, and therefore ICI is totally eliminated.SSK modulation, where different combinations of the transmit antenna indices are used to convey information for further design flexibility. Both the SM and SSK modulation systems have been concerned with exploiting the multiplexing gain of multiple transmit antennas, but the potential for transmit diversity of MIMO systems is not exploited by these two systems. This leads to the introduction here of Space-Time Block Coded Spatial Modulation (STBC-SM), designed to take advantage of both SM and STBC.

Conclusion

In this paper I 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. STBC-SM offers significant improvements in BER performance compared to SM and V-BLAST systems with an acceptable linear increase in decoding complexity. From a practical implementation point of view, the RF (radio frequency) front-end of the system should be able to switch between different transmit antennas similar to the classical SM scheme. I conclude that the STBC-SM scheme can be useful for high-rate, low complexity, emerging wireless communication systems such as LTE and WiMAX.

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