Modulated Data Transmission Using Antenna Indices and Their Combinations

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Abstract- In this study, we propose a transmission scheme Space time block coding which is integrated with spatial modulation to improve the diversity of the system and also to reduce the inter-channel interference. At the transmitter end, for the given number of antennas the data is modulated and antenna indices and combinations are considered for their transmission. At the receiver end a maximum likelihood(ML) decoder, which is a low complexity decoder is considered to recover the original information bits. The simulation results shows the bit error rate performance of the system for various modulation techniques.

Index Terms- Space time block coding, spatial modulation, transmit diversity, maximum likelihood decoding.

I. Introduction

In wireless communications all the diversity schemes focused on improving the data rate, spectral efficiency along with considering the factors such as power ,cost, size of the system. The techniques such as transmit diversity[1] and receiver diversity improves the data rate by using multiple antennas at the transmitter and receiver side. Such MIMO systems offer increase in spectral efficiency only if certain conditions are satisfied: 1.The system operates in rich scattering environment. 2.Appropriate coding structure is used. 3.Error free decisions are available in the interference cancellation schemes ,which in turn assumes Combined use of long error correction codes and perfect decoding. All the conditions led to the development of transmission strategies ,space time coding (STC) and spatial Modulation[4]. In the first multielement antenna system V-BLAST[2] inter-channel interference occurs which inturn increases the complexity of the system. To remove the inter-channel interference of the system led to the development of novel concept called spatial modulation. Spatial modulation is the extension of two dimensional signal constellation to the third dimension, which is the antenna dimension. The main concept of spatial modulation deals with the selection of the position of antenna and their combinations from which the data has to be sent.In this the information bits is mapped to a constellation symbol and a spatial symbol. At the receiver side both the transmitted symbol and the active antenna index are estimated inorder to decode the original information bits. To improve the diversity and coding gain of the system led to the development of space-time coding (STC)) technique. The proposed method will be focused on the integration of space time block coding into Spatial Modulation (SM) for any number of given antennas in order to improve the system performance in terms of BER.In this, space time coding concept will be applied to the antenna constellation points of spatial modulation (SM). SM considers the multiple transmit antennas as additional constellation points and maps the information bits to the transmit antenna indices. The receiver estimates the symbols that are transmitted by using a low complexity maximum likelihood decoder to retrieve the original block of data bits.

The paper is organized as follows: In section II the data transmission at the transmitter end is explained with an example. In Section III, we presented an algorithm for the STBC-SM system design. In section IV we discuss about the data reception at the receiver side and recovering the original data bits. Finally the simulation results are discussed in Section V .In Section VI we discuss about the conclusion of the paper.

STTC-SM (STCM & SM)

II. TRANSMITTER END

Explanation with example:

For the STBC-SM, alamouti's transmission technique is considered.In alamouti's STC two complex symbols x_1 and x_2 drawn from an M-PSK or M-QAM constellation are transmitted from two antennas in two symbol intervals in an orthogonal manner by the codeword

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

The following example gives a brief explanation of STBC-SM concept. Given four transmit antennas A_1, A_2, A_3, A_4 transmitting the one of the below codewords by using the alamouti's STC:

$\chi_1 = \{X_{11}, X_{12}\} =$

$$\left\{\begin{bmatrix} X1 & X2 & 0 & 0 \\ -X2^* & -X1^* & 0 & 0 \end{bmatrix}, \begin{bmatrix} 0 & 0 & X1 & X2 \\ 0 & 0 & -X2^* & X1^* \end{bmatrix}\right\}$$

$\chi_2 = \{X_{21}, X_{22}\} =$

$$\left\{\begin{bmatrix} 0 & X1 & X2 & 0 \\ 0 & -X2^* & -X1^* & 0 \end{bmatrix}, \begin{bmatrix} X2 & 0 & 0 & X1 \\ X1^* & 0 & 0 & -X2^* \end{bmatrix}\right\} e^{-j\theta}$$

where χ_1 , χ_2 denotes the codebooks and $X_{11}, X_{12}, X_{21}, X_{22}$ are the codewords.

'θ' , the rotation angle should be considered to avoid overlapping columns of codewords in different codebooks. Including 'θ' would provide transmit diversity to the system.

A non-interfering codeword group with b elements is a set of codewords satisfying the condition $X_{ij}X_{ik}^H=0, j,k=1,2,\ldots..b, j\neq k$.Consider the transmission of four bits

S_1,S_2,S_3,S_4 in two consecutive symbol intervals by the STBC-SM.The bits S_1, S_2 represents the selection of antennas and the next two bits S_3,S_4 represents the BPSK the symbol pair.

For the design of the system, the Rayleigh fading channel is considered.The minimum coding distance between two codewords i.e transmitted X_{ij} and the erroneously detected $\hat{X}_{ij}$,is given as

$$\delta(X_{ij},\hat{X}_{ij}) = \min_{X_{ij},\hat{X}_{ij}} \det(X_{ij} - \hat{X}_{ij})(X_{ij} - \hat{X}_{ij})^H$$

The minimum CGD[4] between two codebooks $\mathbf{X_i}$ and $\mathbf{x_j}$ is defined as

$$\delta(X_i,X_j) = \min_{k,l} \delta_{min}(X_{ik} - \hat{X}_{jl})$$

III. DESIGN ALGORITHM FOR STBC-SM

1.Consider T_t be the number of transmit antennas, determine the codewords that are formed by using the number of antenna combinations for STBC transmission.The total number of codewords be $w=2T_t$.

2.Codewords together form a codebook χ_i,i=1,2…n-1.The maximum number of codewords that can be fit in a codebook is determined by b=[$T_t/2$] and the number of codebooks is given by n=[w/b]. The codebook χ_n which is present at the last does not need to have b codeword's.

3.Construct the codebook χ_1 which contains a non-interfering codewords as

χ_1 ={ $(X\ 0_{2*(nT-2)})$
$(0_{2*2}\ X\ 0_{2*(nT-4)})$
$(0_{2*4}\ X\ 0_{2*(nT-6)})$
…….
………..
$(0_{2*2(a-1)}\ X\ 0_{2*(nT-2a)})$}

Where X is the orthogonal manner of the codeword

4.By considering the following conditions Construct χ_i for $2\le i\le n$

- The codeword's in every codebook should be non-interfering codeword's, chosen from combinations of available transmit antennas T_t.
- The codeword's in one codebook should not coincide with the codeword's of another codebook.

5.The rotation angle θ_i is determined for each χ_i ,$2\le i\le n$ where $\theta=(\theta_2, \theta_3,\ldots\ldots\theta_n)$. Based on the constructing the STTC-SM codewords based on the above algorithm the spectral efficiency can be calculated as

$m=1/2\log_2 w+\log_2 M$ [bits/s/Hz].

The codewords designed are predefined and these codebooks are considered as lookup table inorder to get the desired codeword.

IV. RECEIVER SIDE

The design of the system is considered in rayleigh flat fading channel.The received signal $2R_r$ matrix Z can be given as

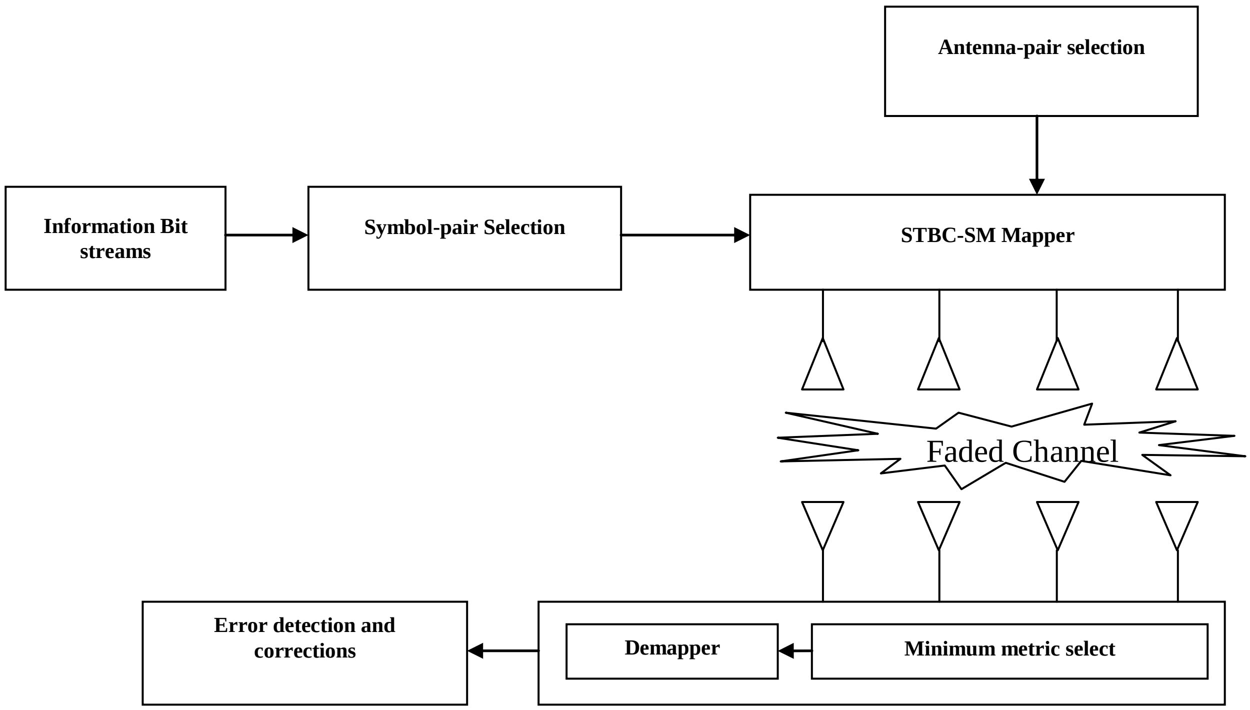

FIGURE -1 BLOCK DIAGRAM OF STBC-SM

$$\mathbf{Y} = \sqrt{\frac{\rho}{\mu}}\ \mathbf{X}_\chi\mathbf{H}+\mathbf{N} \qquad (2)$$

H is the channel matrix ,N is the noise matrix .$X_x \epsilon \chi$,μ is a normalization factor and ρ is the average SNR present at all the receiving antennas.The H and N contains independent and identically distributed(i.i.d) complex Gaussian random variables with zero mean and unit variance.The value of H will be constant while transmitting a codeword and the values are independent from one codeword to other codeword. The receiver knows about the channel H and at the transmit end the channel is unknown. For T_t transmit antennas employed ,wM^2 different transmission matrices are obtained from w codeword's using STBC-SM technique. The ML decoder performs its searching operation over all the wM^2 matrices and finds the matrix that minimizes the following equation

$$\hat{X}_\chi = \arg \min_{X_\chi \in \chi} \left\| Y - \sqrt{\frac{\rho}{\mu}} X_\chi \mathrm{H} \right\|^2 \qquad (3)$$

Thus the wM^2 realizations are reduced to 2wM.The last operation at the receiver is demapping operation which is based on the lookup table present at the transmitter to recover the input bits. For 2m bits transmitted during two consecutive symbol intervals using one of the $wM^2=2^{2m}$ different STBC-SM transmission matrices, the error performance of the STBC-SM system ,is given by X_1 X_1 X_2 ……… $X_{2^{2m}}$.

An upper bound on the average bit error probability (BEP) is given by the union bound.

$$P_b = \frac{1}{2^{2m}} \sum_{i=1}^{2^{2m}} \sum_{j=1}^{2^{2m}} \frac{P(X_i \rightarrow X_j) n_{i,j}}{2m} \qquad (4)$$

$P(\mathbf{X}i \rightarrow \mathbf{X}j)$ is the pair wise error probability (PEP)

The conditional PEP of the STBC-SM system is given as

$$P(X_i \rightarrow X_j \mid H) = Q\left(\sqrt{\frac{\rho}{2}} \left\| (X_i \rightarrow X_j \mid H) \right\| \right)$$ where $(x) = (1/\sqrt{2\pi}) \int_x^\infty e^{-y^2/2} dy$

The unconditional PEP is obtained as

$$P(X_i \rightarrow X_j) = \frac{1}{\pi} \int_0^{\pi/2} \left(\frac{1}{1+\frac{\rho\lambda_{i,j,1}}{4\sin^2\phi}} \right)^{n_R} \left(\frac{1}{1+\frac{\rho\lambda_{i,j,2}}{4\sin^2\phi}} \right)^{n_R} d\phi$$

V. SIMULATION RESULTS

In this section, we present simulation results for the STBCSM system with different numbers of transmit antennas. All performance comparisons are made for a BER value of 10^{-5}. We first present the BEP upper bound curves of the STBC-SM scheme are evaluated from and depicted in the following Figures. The derived upper bound becomes very tight with increasing SNR values for all cases and can be used as a helpful tool to estimate the error performance behaviour of the STBC-SM scheme with different setups.

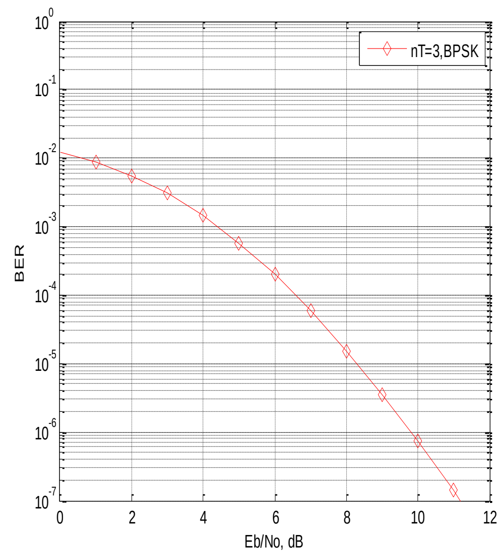

Figure 2: BER performance of STBC-SM for BPSK

In the above figure the bit error rate performance is analysed for a system with number of transmitting antennas n_T=3,and the modulation used is BPSK.

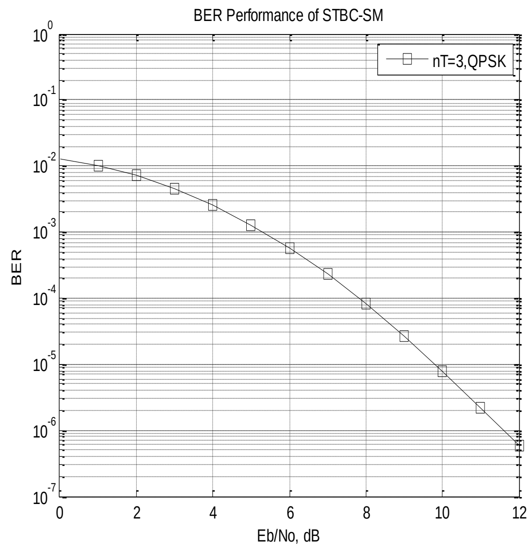

Figure 3: BER performance of STBC-SM for QPSK

The above figure shows the bit error rate performance of the STBC-SM system with number of transmitting antennas n_T=4,and the modulation used is QPSK.

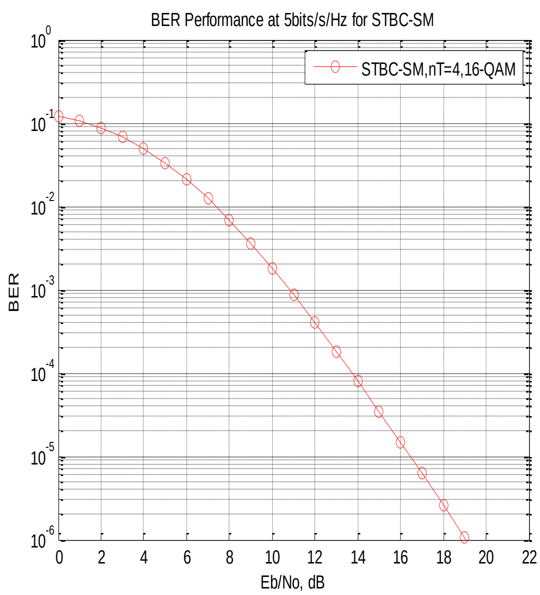

Figure 4: BER performance of STBC-SM for QAM

In following figure the BER curves of STBC-SM with n_T = 4, 8 and QPSK, QAM is evaluated for data transmission.

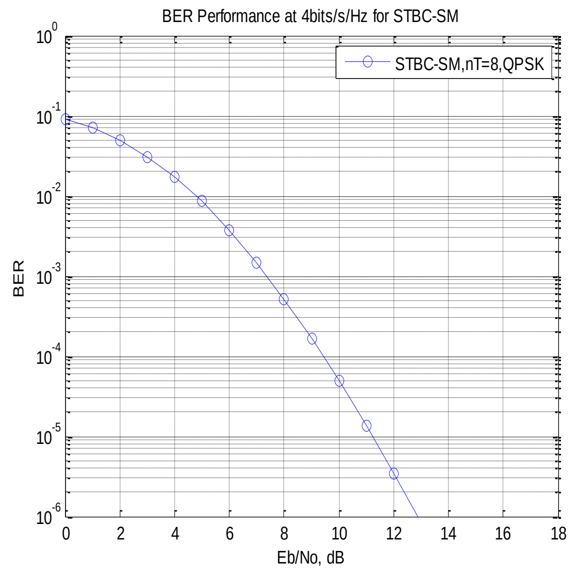

Figure 5: BER performance of STBC-SM for QPSK

In following figure the BER curves of STBC-SM with n_T = 8, QPSK, QAM is evaluated for data transmission.

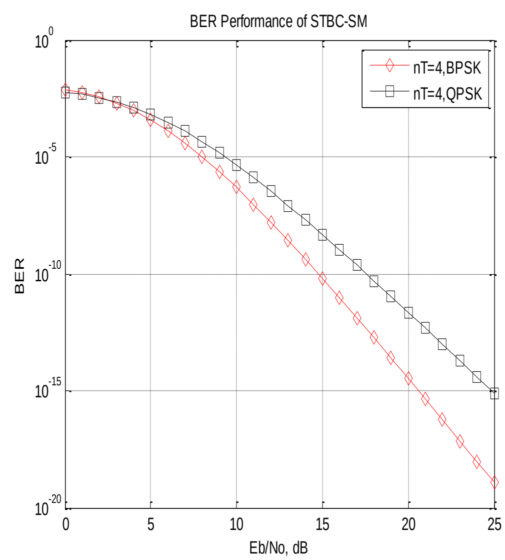

Figure 6: BER performance of STBC-SM for QPSK

The above figure shows the comparision of bit error rate performance of STBC-SM system with BPSK modulation and QPSK modulation where the number of transmitting antennas n_T=4.

For n_T=3,4 and BPSK, QPSK modulations are shifted to the right while their slope remains unchanged and equal to 2nR, with increasing spectral efficiency.

VI. CONCLUSION

In this paper an algorithm has been presented for construction of STBC-SM technique for the given number of transmit antennas to exploit the transmit diversity and coding gain of the system. Synchronization of all the transmitters is not required in STBC-SM as incase of other transmission techniques. Considering the number of transmitters 3 and 4,the bit error rate performance was analysed for various modulation techniques BPSK,QPSK.

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