PERFORMANCE EVALUATION OF HIGHER ORDER ALAMOUTI SCHEMES WITH DIFFERENT MODULATION FORMATS

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Abstract - In wireless communication fading of channels is the serious cause of the received degraded signals. Orthogonal transmitter diversity such as time diversity and frequency diversity is quite simple to implement and, with optimum signal combining, can take full advantage of fading multipath channels. Receive diversity techniques like maximal ratio receive combining have been popular means of introducing multiple antennas into communication systems. Alamouti proposed a scheme, Space-time block codes which introduces transmit diversity with similar complexity and performance as maximal ratio receive combining. This paper evaluates the performance of Space-time Block Code (STBC), for multiple transmitters and multiple receiver antennas along with different modulation formats like circular, square and rectangular constellation. In this paper a systematic method of designing for arbitrary Multiple Input, Single Output (MISO) system and then extended to MIMO systems with multiple receiving antennas. Maximum likelihood detector was used in the receiver which shows significant reduction in BER for increased values of Eb/N0.

Index terms - Diversity, Flat fading Rayleigh Channels, ML detector, STBC

I. INTRODUCTION

Traditionally, wireless communication entails a sender using a single antenna to transmit a signal, which, after undergoing modification in the communication channel, is then received by a single antenna at the receiver. The significant degradation of transmitted signals is due to fading channels.

One useful method to reduce the adverse effects of fading channels is to employ diversity. Diversity is in general created when the same transmitted information is transmitted on several more or less independently fading channels, and it can be exploited by intelligent combining of the resulting received signals. A lot of attention was received by Multianteena techniques after Foschini [1] and Telatar [2] showed that the capacity of the system increases linearly with the number of uncorrelated transmit and receive antennas. With a restricted number of receive antennas, a part of this capacity increase can be realized using transmit diversity.

In a Multiple-input, Multiple-output (MIMO) scheme, the sender uses multiple antennas for transmission, and the receiver uses multiple antennas for reception, thus making available multiple communication paths (i.e., channels) between the sender and receiver. These multiple channels can be used to increase the data rate by sending different data streams on the different channels. The idea is that the repetition of information, together with an appropriate combining of the received signals in the receiver, will greatly reduce the negative effects of the radio channel fading by effectively stabilizing the channel quality, downplaying the effects of the individual fades on the different independent channels, and thus improving the overall quality of the received signals. Diversity can in general be achieved by creating independent channels in time, frequency, or space. Orthogonal transmit diversity, such as frequency and time diversity, have some properties that are quite attractive in wireless communication as they can provide a diversity gain without the need of multiple transmit/receive antennas. However, this gain comes at a cost of either increased bandwidth or time necessary to transmit the information.

In most scattering environments, antenna diversity is a practical and effective, hence widely used for reducing multipath fading. Now combining antenna or space diversity along with time diversity Alamouti proposed space-time block code scheme, which was later generalized for higher number of transmitter antenna by Tarokh et al.

In this paper, we present a systematic way of designing transmission matrix for arbitrary multiple inputs, single output STBC system which is further extended to multiple input, multiple output with increasing receiving antennas. This schemes being used to with different modulation formats like M-PSK (circular), 4QAM, 16QAM, 64-QAM (square) and 8-QAM (rectangular) and the obtained performance results shows an improvement over space time block code while keeping receiver antenna only one.

The remainder of the paper is organized as follows. In section II we review system model for our proposed system. In section III, we present a method to create transmission matrix of STBC for arbitrary number of transmitter antenna and one receiver antenna. In section IV, we discuss numerical results with the simulation results, and finally we conclude our work.

II. SYSTEM MODEL

The block diagram of the overall system model is presented in Figure 1. The random data source generator generates digital information bits.

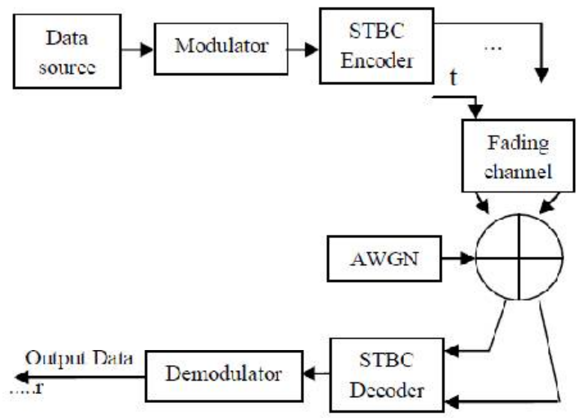

Figure 1: STBC over flat fading channel

This information bits is passed to the different modulation formats, and then the sequences get into the encoder of STBC. From the STBC encoder these are transmitted with t antennas.

We have assumed that the Channel is a flat fading channel. The channel behaves like a quasi-static fading channel, i.e., it keeps constant during one frame transmission and varies along multiple frames.

At the receiver, the received signals by r receive antennas are sent to STBC Decoder to detect transmitted symbol sequences, the decoding of STBC can achieve by using a Maximum-Likelihood Decoding Algorithm which is based only on Linear Processing.

We have t × r possible channels for the purpose of transmission. The space time block codes are defined in matrix format as shown in (1). The matrix for 2 transmitting antenna block code may be given by $C1$ and may be represented as follows

$$X = \begin{bmatrix} s_1 & -s_2^* \\ s_2 & s_1^* \end{bmatrix} \quad (1)$$

Table 1 indicates that during the first time slot i.e. at time (t), symbol 1 (s_1) and symbol 2 (s_2) will be transmitted from transmitter 1 and 2 respectively whereas during second time slot i.e. at time (t+T) $-s_2^*$ will be transmitted from transmitter 1 and s_1^* will be transmitted from transmitter 2. For the matrix represented in (1), the code rate (R) is defined as follows [3], [5].

$$R = \frac{Number\ of\ symbols\ transmitted}{Number\ of\ time\ slots\ used} \quad (2)$$

We have a coding rate of R = 1 in (1) since we have used two symbols s_1 and s_2 to be transmitted over two time slots (t) and (t+T). In general for a t transmit antenna minimum achievable code rate is

$$R = \frac{2t}{t^2 - t + 2} \quad (3)$$

From the rate formula, it can be seen that if t > 4 (i.e., we transmit more than four symbols as a block), the rate drops to less than ½, and the rate decreases as the number of symbols transmitted per block increases.

III. HIGHER ORDER STBC SCHEME

Consider that a MIMO STBC system with t transmitting antennas and r receiving antennas is to be designed. A MISO STBC system with t transmitting antennas is first developed, and then expanded to a MIMO STBC system with r receiving antennas.

Step 1: In formulating the transmission matrix, we begin with the first column containing t rows (recall that t equals the spatial diversity) as

$$[s_1 \quad s_2 \quad \dots \quad s_t]^T$$

Where [ ]^T represent transpose of matrix. The objective is then to obtain additional columns in such a manner that each row in the final matrix is orthogonal to all others. We fill in the second column, with the purpose of making the first and second row orthogonal, as

$$\begin{bmatrix} s_1 & s_2 & \dots & s_t \\ -s_2^* & s_1^* & \dots & 0 \end{bmatrix}^T$$

Now, we add a third column to make the first and third rows orthogonal, then a fourth column to make the first and fourth rows orthogonal and so on. In total, we add t −1 columns to make the first row orthogonal to all other rows.

Then, we turn our attention to the second row. We add a column to make the second and third rows orthogonal, then another column to make the second and fourth rows orthogonal, and so forth. A total of t −2 columns will be needed to make the second row orthogonal to all others. We continue this process, until we arrive at the point where only a single column must be added to make the (t −1)th row orthogonal to the tth row. A matrix so chosen is of the form

$$S = \begin{bmatrix} s_1 & -s_2^* & -s_3^* & -s_4^* & \dots & 0 \\ s_2 & s_1^* & 0 & 0 & \dots & 0 \\ s_3 & 0 & s_1^* & 0 & \dots & 0 \\ s_4 & 0 & 0 & s_1^* & \dots & 0 \\ \vdots & \vdots & \vdots & \vdots & \dots & s_t^* \\ s_t & 0 & 0 & 0 & \dots & s_{t-1}^* \end{bmatrix} \quad (4)$$

This fulfils the orthogonality requirement for the transmission matrix. The number of columns indicates the number of symbol intervals needed to transmit t symbols. As noted, we start with the left column, then add j −1 columns to make the first row orthogonal to rows 2 through j, then add j − 2 columns to make the second row orthogonal to row 3 through j, and so forth. Thus, the total number of columns in the completed transmission matrix is

$$1+\sum_{j=1}^{t-1} j = 1+\frac{t(t-1)}{2} = \frac{t^2-t+2}{2}$$

Step 2: The input-output relationship using the designed S matrix is thus given by

$$\underline{y} = \underline{h}S + \underline{n}$$

$$\boldsymbol{y} = \begin{bmatrix} y_1 & y_2 & y_3 & y_4 & \cdots & y_{\frac{t^2-t+2}{2}} \end{bmatrix}$$

$$= \begin{bmatrix} h_1 & h_2 & h_3 & h_4 & \dots & h_t \end{bmatrix} \begin{bmatrix} s_1 & -s_2^* & -s_3^* \\ s_2 & s_1^* & 0 \\ s_3 & 0 & s_1^* \\ s_4 & 0 & 0 \\ \vdots & \vdots & \vdots \\ s_t & 0 & 0 \end{bmatrix} \quad (5)$$

$$+ \begin{bmatrix} \eta_1 & \eta_2 & \eta_3 & \eta_4 & \cdots & \eta_{\frac{t^2-t+2}{2}} \end{bmatrix}$$

where $\underline{y}$ is a $1 \times \frac{t^2-t+2}{2}$ vector of received signals, $\underline{h}$ is a t ×1 channel vector , S is a $t \times \frac{t^2-t+2}{2}$ transmission matrix of input symbols, and $\underline{n}$ is a $1\times \frac{t^2-t+2}{2}$ vector of noise.

Step 3: By writing the matrix as a system of linear equations, it can readily be seen which symbols should be transmitted during any specific symbol interval. Which is also derived from transmission matrix as every row shows the respective antenna transmission and every column will show at which interval or time slot the symbol is transmitted.

Step 4: The estimated received symbol vector $\widetilde{S}$ is obtained by ML detector. ML decoding of any space–time block code can be achieved using only linear processing at the receiver.ML detection amounts to minimizing the decision matrix

$$C = min\left(\sum_{j=1}^{\frac{t^2-t+2}{2}} \left|y_j - \sum_{i=1}^{t} h_i S\right|^2\right) \quad (6)$$

Note that due to the quasi-static nature of the channel, the path gains are constant over transmissions. The minimizing values are the receiver estimation of $s_1, s_2, s_3 \ldots\ldots s_t$ respectively.

Step 5: We can show that each estimated symbol s_1, s_2, s_3 .... s_t respectively is given by

$$|\tilde{s}_1 - s_1|^2 + \xi|s_1|^2$$
$$|\tilde{s}_2 - s_2|^2 + \xi|s_2|^2 \quad (7)$$
$$\vdots$$
$$|\tilde{s}_t - s_t|^2 + \xi|s_t|^2$$

where

$$\xi = \left(-1+\sum_{i=1}^{t}|h_i|^2\right) \quad (8)$$

The above steps were used for MISO STBC system. We have to repeat above steps for r receiving antennas in order to have a MIMO STBC system.

IV. SIMULATION RESULTS

For the purpose of simulation, Matlab-2010 edition has been used. The information source contains 5 thousands packets having frame size of 128 bits. The wireless multipath channel is assumed to be slowly Rayleigh flat fading and no correlation between different branches.

Simulation results for the circular constellation such as QPSK and 8-PSK system employing arbitrary transmit antennas and arbitrary receive antennas but less than or equal transmit antenna are depicted in Fig. 2 and Fig. 3 respectively. The obtained results show an improvement on average BER when receive diversity is added with transmit diversity

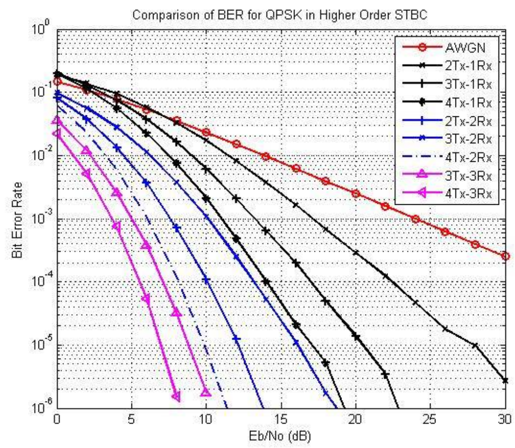

Fig. 2 Comparison of BER for QPSK in higher order STBC

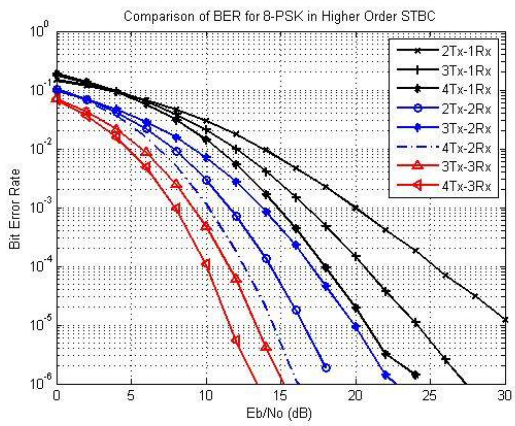

Fig. 3 Comparison of BER for 8-PSK in higher order STBC

Simulation results for the rectangular constellation such as 8QAM and square constellation 4QAM and

16QAM system employing arbitrary transmit antennas and arbitrary receive antennas but less than or equal transmit antenna are depicted in Fig. 5 and Fig. 4, Fig. 6 respectively. The obtained results show an improvement on average BER when receive diversity is added with transmit diversity.

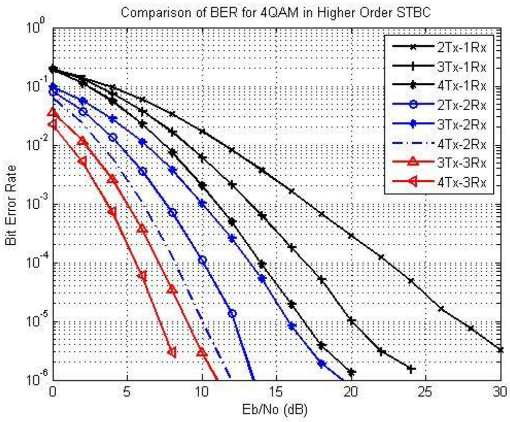

Fig. 4 Comparison of BER for 4QAM in higher order STBC

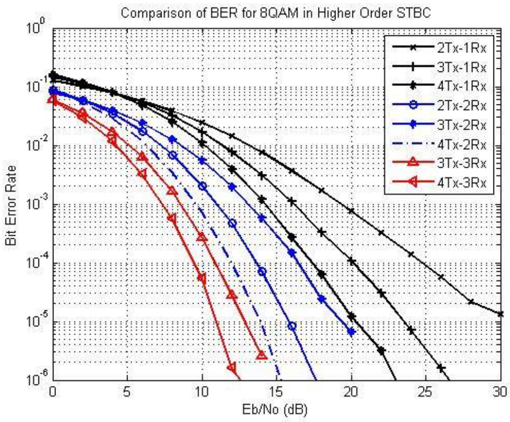

Fig. 5 Comparison of BER for 8QAM in higher order STBC

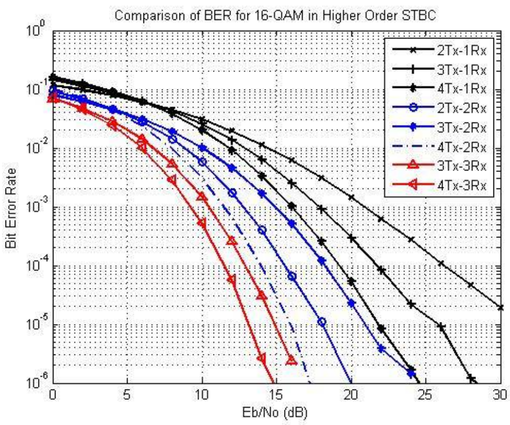

Fig. 6 Comparison of BER for 16QAM in higher order STBC

CONCLUSIONS

Receiver diversity can be used in digital communication system to decrease BER in spite of slightly increase in computational complexity and cost of system. In this paper we have discussed the application of receiver diversity in conjunction with space-time block code system as opposed to single receiver. Simulation results clearly showed improvements of proposed method.

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