# Performance Evaluation of STBC Codes With Increased Order Of Pseudo-random Number Generator

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**Abstract—** Wireless network devices have quickly become a part of everyday life. Wireless LANs, cell phone networks and personal area networks are few examples of widely used wireless networks. However, wireless devices are range and data rate limited. To overcome these limitations, Multiple-Input Multiple Output (MIMO ) links are used, wherein data is encoded using higher order space–time block code, which is then split into n streams and simultaneously transmitted using n transmitting antennas. The received signal is a linear superposition of the n transmitted signals perturbed by noise. Maximum likelihood decoding is achieved in a simple way through decoupling of the signals transmitted from different antennas rather than joint detection. In this paper, we have evaluated the performance of space time block codes with increased order of pseudo random number generator and derived an analytical expression for the SNR and Bit Error Rate , showing that higher order STBC scheme provides full diversity and effective BER for particular values of SNR gain, for which the results have been verified through Matlab simulations.

***Keywords*—**Space time codes, Transmit diversity, Rayleigh fading channel, Higher order STBC codes, MIMO.

## I. INTRODUCTION

With the increase in demand for the wireless multimedia, current wireless broadband services fall short in terms of the quality of service (QoS), data rate, coverage and the number of users which can be supported. Multiple antennas [1] at both the transmit ($T_x$) and receiver ($R_x$) sites seem to meet these demands through improved higher data rate due to spatial multiplexing and link reliability due to diversity. The multiple antennas in MIMO systems can be exploited in two different ways. One is the creation of a highly effective antenna diversity system,the other is the use of the multiple antennas for the transmission of several parallel data streams to increase the capacity of the system. Antenna diversity is used in wireless systems to combat the effects of fading [2],[3]. Open loop full rate system enables full diversity with linear processing at the receiver, without need for feedback information [2] If multiple, independent copies of the same signal are available, we can combine them into a total signal with high quality—even if some of the copies exhibit low quality. The different signal copies are linearly combined, i.e., weighted and added. The resulting signal at the combiner output can then be demodulated and decoded in the usual way. The optimum weights for this combining are matched to the wireless channel [maximum ratio combining (MRC)]. If we have N receiving antenna elements, the diversity order, which describes the effectiveness of diversity in avoiding deep fades is N. In other words the diversity order is related to the slope of the signal-to-noise ratio (SNR) distribution at the combiner output. The multiple antennas also increase the average SNR seen at the combiner output. When the channel is known to the transmitter, we can again "match" the multiple transmitted signal copies to the channel, resulting in the same gains as for receiver diversity. If the channel is unknown at the transmitter other strategies like delay diversity or space-time-coding have to be used. In that case we can gain high diversity order but not improvement of average SNR. The logical next step is the combination of transmit and receive diversity. It has been demonstrated that with $N_t$ transmit and $N_r$ receive antennas, a diversity order of $N_tN_r$ can be achieved.

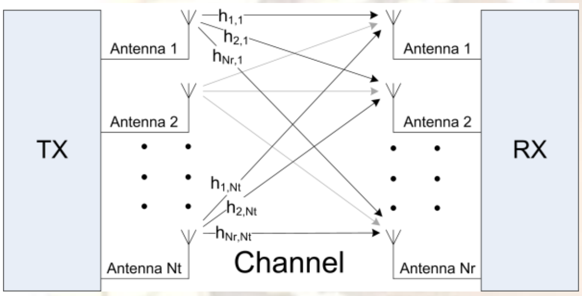
An alternative way of exploiting the multiple antenna elements is the so-called "spatial multiplexing" or "BLAST" approach. Different data streams are transmitted (in parallel) from the different transmit antennas. The multiple receive antenna elements are used for separating the different data streams at the receiver. We have $N_r$ combinations of the $N_t$ transmit signals. If the channel is well-behaved so that the $N_r$ received signals represent linearly independent combinations, we can recover the transmit signals as long as $N_t \leq N_r$. The advantage of this method is that the data rate can be increased by a factor $N_t$ without requiring more spectrum

Regardless of the use as diversity or spatial multiplexing system, the main drawback of any MIMO system is the increased complexity and thus cost [4].MIMO systems with $N_t$ transmit and $N_r$ receive antennas require $N_t$ ($N_r$) complete RF chains at the transmitter and the receiver respectively including low-noise amplifiers, down converters, and analog-to-digital converters [4].The Antenna subset selection is low cost, low-complexity technique. This reduces the hardware cost in the radio frequency (RF) chain and captures many of the advantages of the MIMO systems [4] – [7]. It was shown in [8] that a $T_x$ AnSS scheme based on STBC with emphasis on the Alamouti code [2] achieves both the coding and diversity gain over the non-AnSS STBC scheme. Higher order STBC codes are used for decreasing the BER for particular SNR. By increasing the order channel parameters are changed and hence improves the system.

The purpose of this paper is to evaluate the performance **of space time block codes with increased order of pseudo random number generator** and to provide the details of the encoding and decoding procedures. In Section II, we have explained MIMO system model. Section III analyzes the performance of the space–time block code and enhancement of its performance by using **space time block codes with increased order of pseudo random number generator**. Section IV provides simulation results by demonstrating the performance of these codes. In last section we have concluded higher order Space Time Block Codes improves the BER in comparison to conventional Space Time Block Codes.

II. MIMO System Model

MIMO systems are composed of three main elements namely the transmitter ($T_X$), the channel (H) and the receiver ($R_X$). $N_t$ is denoted as the number of antenna elements at the transmitter and $N_r$ is denoted as the number of elements at the receiver. Figure 1 depicts such MIMO system block diagram. It is worth noting that system is described in terms of the channel.




The channel with $N_r$ outputs and $N_t$ inputs is denoted as a $N_r \times N_t$ matrix:

$$H = \begin{pmatrix} h_{1,1} & h_{1,2} & \ldots\ldots & h_{1,N_t} \\ h_{2,1} & h_{2,2} & \ldots\ldots & h_{2,N_t} \\ \ldots\ldots & \ldots\ldots & \ldots\ldots & \ldots\ldots \\ h_{Nr,1} & h_{Nr,2} & \ldots\ldots & h_{Nr,Nt} \end{pmatrix}$$

Where each entry $h_{i,j}$ denotes the attenuation and phase shift (transfer function) between the $j^{th}$ transmitter and the $i^{th}$ receiver. It is assumed that the MIMO channel behaves in a "quasi-static" fashion i.e. the Channel varies randomly between burst to burst but fixed within a transmission. This is a reasonable and commonly used assumption as it represents an indoor channel where the time of change is constant and negligible compared to the time of a burst of data [9].

The MIMO signal model is described as

$$r = Hs + n \qquad (1)$$

where r is the received vector of size $N_r \times 1$, H is the channel matrix of size $N_r \times N_t$ , s is the transmitted vector of size $N_t \times 1$ and n is the noise vector of size $N_r \times 1$. Each noise element is typically modeled as independent identically distributed (i.i.d.) white Gaussian noise with variance Nt/(2×SNR). The transmitted signals are mixed in the channel since they use the same carrier Frequency. At the receiver side the received signal is composed of a linear combination of each transmitted signal plus noise. The receiver can solve for the transmitted signals by treating as a system of linear equations (1).

III: Space time block codes

In [11], Alamouti published his technique on transmit diversity. Alamouti STBC scheme uses two transmit antennas and $N_r$ receive antennas and can accomplish a maximum diversity order of $2N_r$ [2]. Moreover the Alamouti scheme has full rate (i.e. a rate of 1) since it transmits 2 symbols every 2 time intervals. The encoding operation is given by (2). In this the rows of each coding scheme repr2 respectively. Assuming that each symbol has duration T then at time (t + T) the symbols $-S_2^*$ and $S_1^*$ are transmitted from antenna 1and 2 respectively.

$$S = \begin{pmatrix} S_1 & S_2 \\ -S_2^* & S_1^* \end{pmatrix} \qquad (2)$$

The reception and decoding of the signal depends on the number of receive antennas available. For the case of one receive antenna the received signals are [2]:

$$r_1^{(1)} = r_1(t) = h_{1,1}s_1 + h_{1,2}s_2 + n_1^{(1)}$$
$$r_1^{(2)} = r_1(t+T) = -h_{1,1}s_2^* + h_{1,2}s_1^* + n_1^{(2)} \qquad (3)$$

where $r_1$ is the received signal at antenna 1, $h_{i,j}$ is the channel transfer function from the $j^{th}$ transmit antenna and the $i^{th}$ receive antenna , $n_1$ is a complex random variable representing noise at antenna 1. $x^{(k)}$ denotes x at time instant k (i.e. at time t + ( k-1)T). Before the received signals are sent to the decoder they are combined as follows [2]

$$\tilde{S}_1 = h_{1,1}^* r_1^{(1)} + h_{1,2} r_1^{*(2)}$$
$$\tilde{S}_2 = h_{1,2}^* r_1^{(1)} + h_{1,1} r_1^{*(2)} \qquad (4)$$

.

Substituting (3) in (4) yields:

$$\tilde{s}_1 = (\alpha_{1,1}^2 + \alpha_{1,2}^2)s_1 + h_{1,1}^* n_1^{(1)} + h_{1,2} n_1^{*(2)}$$
$$\tilde{s}_2 = (\alpha_{1,1}^2 + \alpha_{1,2}^2)s_2 - h_{1,1} n_1^{*(2)} + h_{1,2}^* n_1^{(1)} \qquad (5)$$

The calculated $\tilde{S}_1$ and $\tilde{S}_2$ are then sent to a Maximum Likelihood (ML) decoder to estimate the transmitted symbols $s_1$ and $s_2$ respectively. The ML decoder decision statistic decodes in favor of $s_1$ and $s_2$ over all possible values of $s_1$ and $s_2$ such that (4) is minimized.

$$\hat{s}_{ML} = \arg\min_{\hat{s}\in S}\left(\left\|Y - H\tilde{s}\right\|^2\right)$$

System block diagram for ***of space time block codes with increased order of pseudo random number generator*** is shown in fig 2. Channel coefficients are changed by changing the order of the system Pseudorandom values drawn from the standard normal distribution are generated as channel coefficients. Number of the channel coefficients is increased by increasing the order of the system. These values are then arranged in descending order. First two values from these are picked up and used as channel coefficients

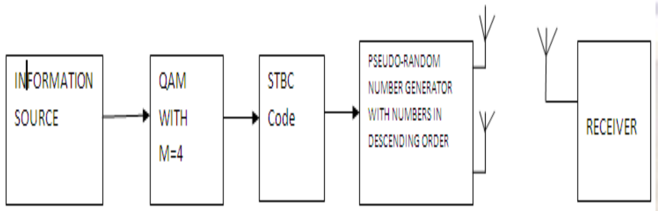



*Fig 2: System Block Diagram*

## IV: SIMULATION RESULTS

The information source is encoded using a space–time block code, and the constellation symbols are transmitted from different antennas. The receiver estimates the transmitted bits by using the signals of the received antennas.

Table 1 describes the performance parameters taken to study the STBC codes. Simulation results in Fig. 4 shows the BER with different values of SNRs. It shows the simulation of higher order space time block codes using Quadrature Amplitude Modulation with M=4. Simulation is done for second order , third order and fourth order space time block codes.

**TABLE -1**
PERFORMANCE PARAMETERS

| **Parameters** | |
|---|---|
| No. of transmitting antennas | 2 |
| No. of receiving antennas | 1 |
| Diversity order | 2 |
| Modulation technique used | QAM |
| Order used | Second, third and fourth |

Table 2 clearly evaluates that by increasing the order of the system, BER starts decreasing. If we increase SNR, then the performance of higher order STBC also increases in terms of BER.

**TABLE 2**
PERFORMANCE ANALYSIS

| **Order of the system** | **BER** | |
|---|---|---|
| | **At SNR = 8 dB** | **At SNR= 10 dB** |
| Second | 0.015 | 0.006 |
| Third | 0.005 | 0.0085 |
| Fourth | 0.0008 | 0.00002 |

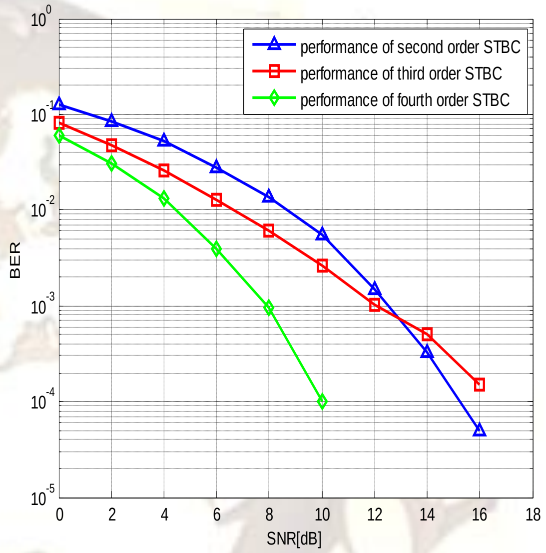



**Fig 4:** Improved BER using STBC code by increased order of random number generator

## V: CONCLUSIONS

This paper evaluates the ***space time block codes with increased order of pseudo random number generator*** in MIMO system. We have presented the BER performance of higher order STBC. The simulation results show that by increasing the order of random number generator in space time block codes, BER of the system is improved. We also derived an analytical expression for the SNR and Bit Error Rate which shows that the higher order STBC scheme provide full diversity. The analytical results conclude that the higher order STBC scheme provides effective BER for particular values of SNR gain.

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