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Performance Analysis of a Microwave Link using Space Time Block Code (STBC) with Receiver Diversity

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Abstract— This paper represents the effect of STBC (Space Time Block Coding) over QPSK (Quadrature Phase Shift Keying) on the performance of a microwave link. Space Time Block Coding (STBC) is MIMO (Multiple Input Multiple Output) transmit strategy which exploits transmit diversity and high reliability. The BER (Bit Error Rate) curve for QPSK modulation is obtained and then same number of data is transmitted using STBC. The simulation then finally shows that by doing so the SNR value improves.

Index Terms— Microwave Link, STBC-Space Time Block Code, MIMO-Multiple Input Multiple Output System, BER-Bit Error Rate, QPSK-Quadrature Phase Shift Keying, SNR-Signal to Noise Ratio, Channel Fading.

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1 Introduction

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 environment with 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.

Most work on wireless communications had focused on having an antenna array at only one end of the wireless link — usually at the receiver. Seminal papers by Gerard J. Foschini and Michael J. Gans,[Ref.1] Foschini[Ref.2] and Emre Telatar [Ref.3] enlarged the scope of wireless communication possibilities by showing that for the highly scattering environment substantial capacity gains are enabled when antenna arrays are used at both ends of a link. An alternative approach to utilizing multiple antennas relies on having multiple transmit antennas and only optionally multiple receive antennas. Proposed by Vahid Tarokh, Nambi Seshadri and Robert Calderbank, these space–time codes [Ref.4] (STCs) achieve significant error rate improvements over single-antenna systems.

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Their original scheme was based on trellis codes but the simpler block codes were utilized by Siavash Alamouti, [Ref.5] and later Vahid Tarokh, Hamid Jafarkhani and Robert Calderbank [Ref.6] to develop space–time block-codes (STBCs). STC involves the transmission of multiple redundant copies of data to compensate for fading and thermal noise in the hope that some of them may arrive at the receiver in a better state than others. In the case of STBC in particular, the data stream to be transmitted is encoded in blocks, which are distributed among spaced antennas and across time. While it is necessary to have multiple transmit antennas, it is not necessary to have multiple receive antennas, although to do so improves performance. This process of receiving diverse copies of the data is known as diversity reception and is what was largely studied until Foschini's 1998 paper.

An STBC is usually represented by a matrix. Each row represents a time slot and each column represents one antenna's transmissions over time.

$$\begin{array}{cc} & \xrightarrow{\text{transmit antennas}} \\ \text{time-slots} \big\downarrow & \begin{bmatrix} s_{11} & s_{12} & \cdots & s_{1n_T} \\ s_{21} & s_{22} & \cdots & s_{2n_T} \\ \vdots & \vdots & & \vdots \\ s_{T1} & s_{T2} & \cdots & s_{Tn_T} \end{bmatrix} \end{array}$$

Here, s_{ij} is the modulated symbol to be transmitted in time slot i from antenna j. There are to be T time slots and n_T transmit antennas as well as n_R receive antennas. This block is usually considered to be of 'length' T

The code rate of an STBC measures how many symbols per time slot it transmits on average over the course of one block. [Ref.6] If a block encodes k symbols, the code-rate is

$$r = \frac{k}{T}$$

Only one standard STBC can achieve full-rate (rate 1) — Alamouti's code.

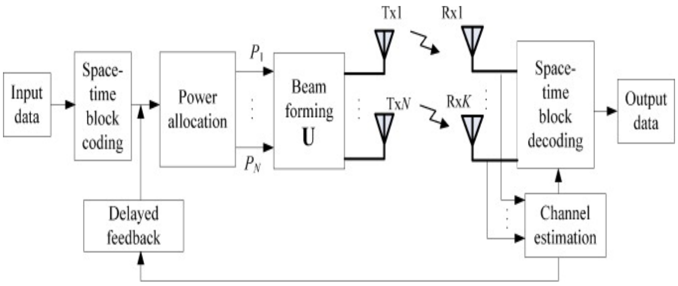

Fig1: Space Time Block Code Diagram

In radio, multiple-input and multiple-output, or MIMO (commonly pronounced my-moh or me-moh), is the use of multiple antennas at both the transmitter and receiver to improve communication performance. MIMO technology has attracted attention in wireless communications, because it offers significant increases in data throughput and link range without additional bandwidth or increased transmit power. It achieves this goal by spreading the same total transmit power over the antennas to achieve an array gain that improves the spectral efficiency (more bits per second per hertz of bandwidth) and/or to achieve a diversity gain that improves the link reliability (reduced fading).Moreover MIMO offers special advantageous features such as Beam Forming, Spatial Diversity, Spatial Multiplexing etc.

It is important to note that each antenna element on a MIMO system operates on the same frequency and therefore does not require extra bandwidth. Also, for fair comparison, the total power through all antenna elements is less than or equal to that of a single antenna system, i.e.

$$\sum_{k=1}^{N} p_k \leq P$$

where N is the total number of antenna elements, p^k is the power allocated through the k^{th} antenna element, and P is the power if the system had a single antenna element[Ref.7]. Effectively, (1) ensures that a MIMO system consumes no extra power due to its multiple antenna elements. As a consequence of their advantages, MIMO wireless systems have captured the attention of international standard organizations.

One of the methodologies for exploiting the capacity in MIMO system consists of using the additional diversity of MIMO systems, namely spatial diversity, to combat channel fading. This can be achieved by transmitting several replicas of the same information through each antenna. By doing this, the probability of losing the information decreases exponentially [Ref.8]. The antennas in a MIMO system are used for supporting a transmission of a SISO system since the targeted rate of is that of a SISO system. The diversity order or diversity gain of a MIMO system is defined as the number of independent receptions of the same signal. A MIMO system with N_t transmit antennas and N_r receive antennas has potentially full diversity (i.e. maximum diversity) gain equal to $N_t N_r$.

The different replicas sent for exploiting diversity are generated by a space-time encoder which encodes a single stream through space using all the transmit antennas and through time by sending each symbol at different times. This form of coding is called Space-Time Coding (STC). Due to their decoding simplicity, form of STCs are the most dominant space-time block codes (STBC)

The paper is organized as follows: section 2 describes system model which includes coding & decoding of higher order STBC. The system analysis is presented in section 3 which also describes the space time coded MIMO channel. In section 4 we discussed about STBC based transmit diversity which is followed by section 5 where the simulation results of improved BER & SNR due to implementation of STBC is shown. Finally we summarized our main results in section 6.

2 System Model

The design of STBCs is based on the so-called diversity criterion derived by Tarokh et al. in their earlier paper on space–time trellis codes.[Ref.4] Orthogonal STBCs can be shown to achieve the maximum diversity allowed by this criterion. Diversity Criterion as follows

Call a codeword

$$\mathbf{c} = c_1^1 c_1^2 \ldots c_1^{n_T} c_2^1 c_2^2 \ldots c_2^{n_T} \ldots c_T^1 c_T^2 \ldots c_T^{n_T}$$

and call an erroneously decoded received codeword

$$\mathbf{e} = e_1^1 e_1^2 \ldots e_1^{n_T} e_2^1 e_2^2 \ldots e_2^{n_T} \ldots e_T^1 e_T^2 \ldots e_T^{n_T}.$$

Then the matrix

$$\mathbf{B}(\mathbf{c},\mathbf{e}) = \begin{bmatrix} e_1^1 - c_1^1 & e_2^1 - c_2^1 & \cdots & e_T^1 - c_T^1 \\ e_1^2 - c_1^2 & e_2^2 - c_2^2 & \cdots & e_T^2 - c_T^2 \\ \vdots & \vdots & \ddots & \vdots \\ e_1^{n_T} - c_1^{n_T} & e_2^{n_T} - c_2^{n_T} & \cdots & e_T^{n_T} - c_T^{n_T} \end{bmatrix}$$

has to be full-rank for any pair of distinct code words $\mathbf{c}$ and $\mathbf{e}$ to give the maximum possible diversity order of $n_T n_R$. If instead, $\mathbf{B}(\mathbf{c},\mathbf{e})$ has minimum rank b over the set of pairs of distinct code words, then the space–time code offers diversity order $b n_R$. An examination of the example STBCs shown below reveals that they all satisfy this criterion for maximum diversity.

STBCs offer only diversity gain (compared to single-antenna schemes) and not coding gain. There is no coding scheme included here — the redundancy purely provides diversity in space and time. This is contrast with space–time trellis codes which provide both diversity and coding gain since they spread a conventional trellis code over space and time.

2.1 Coding

Alamouti invented the simplest of all the STBCs in 1998,[Ref.5]although he did not coin the term "space–time block code" himself. It was designed for a two-transmit antenna system and has the coding matrix:

$$C_2 = \begin{bmatrix} c_1 & c_2 \\ -c_2^* & c_1^* \end{bmatrix},$$

where * denotes complex conjugate.
It is readily apparent that this is a rate-1 code. It takes two time-slots to transmit two symbols. Using the optimal decoding scheme discussed below, the bit-error rate (BER) of this STBC is equivalent to $2n_R$-branch maximal ratio combining (MRC). This is a result of the perfect orthogonality between the symbols after receive processing — there are two copies of each symbol transmitted and n_R copies received.

2.2 Higher order STBCs

Tarokh et al. discovered a set of STBCs [Ref.6][Ref.9] that are particularly straightforward, and coined the scheme's name. They also proved that no code for more than 2 transmit antennas could achieve full-rate. Their codes have since been improved upon (both by the original authors and by many others). Nevertheless, they serve as clear examples of why the rate cannot reach 1, and what other problems must be solved to produce 'good' STBCs. They also demonstrated the simple, linear decoding scheme that goes with their codes under perfect channel state information assumption

2.3 3 Transmit Antennas

Two straightforward codes for 3 transmit antennas are:

$$C_{3,1/2} = \begin{bmatrix} c_1 & c_2 & c_3 \\ -c_2 & c_1 & -c_4 \\ -c_3 & c_4 & c_1 \\ -c_4 & -c_3 & c_2 \\ c_1^* & c_2^* & c_3^* \\ -c_2^* & c_1^* & -c_4^* \\ -c_3^* & c_4^* & c_1^* \\ -c_4^* & -c_3^* & c_2^* \end{bmatrix} \quad \text{and} \quad C_{3,3/4} = \begin{bmatrix} c_1 & c_2 & \frac{c_3}{\sqrt{2}} \\ -c_2^* & c_1^* & \frac{c_3}{\sqrt{2}} \\ \frac{c_3^*}{\sqrt{2}} & \frac{c_3^*}{\sqrt{2}} & \frac{(-c_1-c_1^*+c_2-c_2^*)}{2} \\ \frac{c_3^*}{\sqrt{2}} & -\frac{c_3^*}{\sqrt{2}} & \frac{(c_2+c_2^*+c_1-c_1^*)}{2} \end{bmatrix}$$

These codes achieve rate-1/2 and rate-3/4 respectively. These two matrices give examples of why codes for more than two antennas must sacrifice rate — it is the only way to achieve orthogonality. One particular problem with $C_{3,3/4}$ is that it has uneven power among the symbols it transmits. This means that the signal does not have a constant envelope and that the power each antenna must transmit has to vary, both of which are undesirable. Modified versions of this code that overcome this problem have since been designed.

2.4 4 Transmit Antennas

Two straightforward codes for 4 transmit antennas are:

$$C_{4,1/2} = \begin{bmatrix} c_1 & c_2 & c_3 & c_4 \\ -c_2 & c_1 & -c_4 & c_3 \\ -c_3 & c_4 & c_1 & -c_2 \\ -c_4 & -c_3 & c_2 & c_1 \\ c_1^* & c_2^* & c_3^* & c_4^* \\ -c_2^* & c_1^* & -c_4^* & c_3^* \\ -c_3^* & c_4^* & c_1^* & -c_2^* \\ -c_4^* & -c_3^* & c_2^* & c_1^* \end{bmatrix}$$

$$C_{4,3/4} = \begin{bmatrix} c_1 & c_2 & \frac{c_3}{\sqrt{2}} & \frac{c_3}{\sqrt{2}} \\ -c_2^* & c_1^* & \frac{c_3}{\sqrt{2}} & -\frac{c_3}{\sqrt{2}} \\ \frac{c_3^*}{\sqrt{2}} & \frac{c_3^*}{\sqrt{2}} & \frac{(-c_1-c_1^*+c_2-c_2^*)}{2} & \frac{(-c_2-c_2^*+c_1-c_1^*)}{2} \\ \frac{c_3^*}{\sqrt{2}} & -\frac{c_3^*}{\sqrt{2}} & \frac{(c_2+c_2^*+c_1-c_1^*)}{2} & -\frac{(c_1+c_1^*+c_2-c_2^*)}{2} \end{bmatrix}$$

$C_{4,3/4}$ exhibits the same uneven power problems as $C_{3,3/4}$. An improved version of $C_{4,3/4}$ is [Ref 10]

$$C_{4,3/4} = \begin{bmatrix} c_1 & c_2 & c_3 & 0 \\ -c_2^* & c_1^* & 0 & c_3 \\ -c_3^* & 0 & c_1^* & -c_2 \\ 0 & -c_3^* & c_2^* & c_1 \end{bmatrix},$$

which has equal power from all antennas in all time-slots.

2.5 Decoding

One particularly attractive feature of orthogonal STBCs is that maximum likelihood decoding can be achieved at the receiver with only linear processing. In order to consider a decoding method, a model of the wireless communications system is needed.

At time t, the signal r_t^j received at antenna j is:

$$r_t^j = \sum_{i=1}^{n_T} \alpha_{ij} s_t^i + n_t^j,$$

where α_{ij} is the path gain from transmit antenna i to receive antenna j, s_t^i is the signal transmitted by transmit antenna i and n_t^j is a sample of additive white Gaussian noise (AWGN).
The maximum-likelihood detection rule [Ref.9] is to form the decision variables

$$R_i = \sum_{t=1}^{n_T} \sum_{j=1}^{n_R} r_t^j \alpha_{\epsilon_t(i)j} \delta_t(i)$$

where $\delta_k(i)$ is the sign of s_i in the k^th row of the coding matrix, $\epsilon_k(p) = q$ denotes that s_p is (up to a sign difference), the (k, q) element of the coding matrix, for $i = 1, 2 \ldots n_T$ and then decide on constellation symbol s_i that satisfies

$$s_i = \arg\min_{s \in \mathcal{A}} \left(|R_i - s|^2 + \left(-1 + \sum_{k,l} |\alpha_{kl}|^2 \right) |s|^2 \right)$$

With $\mathcal{A}$ the constellation alphabet. Despite its appearance, this is a simple, linear decoding scheme that provides maximal diversity.

3 System Analysis

MIMO systems are composed of three main elements, namely the transmitter (TX), the channel (H), and the

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receiver (RX). 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. For example, the Multiple-Inputs are located at the output of the TX (the input to the channel), and similarly, the Multiple-Outputs are located at the input of the RX (the output of the channel).

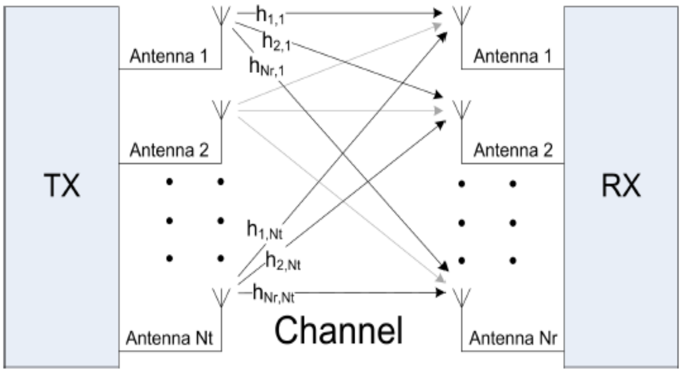

Fig2: Multiple-Input Multiple-Output system block diagram.

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

$$\boldsymbol{H} = \begin{pmatrix} h_{1,1} & h_{1,2} & \cdots & h_{1,N_t} \\ h_{2,1} & h_{2,2} & \cdots & h_{2,N_t} \\ \vdots & \vdots & \ddots & \vdots \\ h_{N_r,1} & h_{N_r,2} & \cdots & h_{N_r,N_t} \end{pmatrix} \qquad (2)$$

where each entry h^{ij} denotes the attenuation and phase shift (transfer function) between the jth transmitter and the ith 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 [Ref.11].

The MIMO signal model is described as

$$\vec{r} = \boldsymbol{H}\vec{s} + \vec{n} \qquad (3)$$

where $\vec{r}$ is the received vector of size $N_r \times 1$, H is the channel matrix of size $N_r \times N_t$, $\vec{s}$ is the transmitted vector of size $N_t \times 1$, and $\vec{n}$ 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 [Ref.110], [Ref.7] with variance $N_t/(2 \cdot SNR)$ [Ref.12]. An explanation for this model is as follows. 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 (3) as a system of linear equations [Ref.8]. If the channel H is correlated, the system of linear equations will have more unknowns than equations. One reason correlation between signals can occur is due to the spacing between antennas. To prevent correlation due to the pacing, they are typically spaced at least $\lambda_c/2$, where λ_c is the wavelength of the carrier frequency [Ref.13]. The second reason correlation can occur is due to lack of multipath components. It is for this reason that rich multipath is desirable in MIMO systems. The multipath effect can be interpreted by each receive antenna being in a different channel. For this reason, he rank of a MIMO channel is defined as the number of independent equations offered. It is important to note that,

$$rank(\boldsymbol{H}) \leq min(N_r, N_t)$$

and therefore the maximum number of streams that a MIMO system can support is upper-bounded by min $(N_r; N_t)$. Since the performance of MIMO systems depends highly on the channel matrix, it is important to model the channel matrix realistically

The Space-Time Coded MIMO Channel

The transmitted symbols over the MIMO channel are affected by severe magnitude fluctuations and phase rotations.

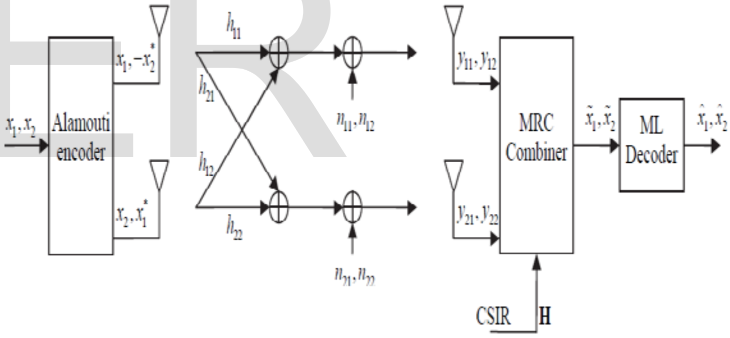

Fig3: A particular MIMO 2x2 system with Alamouti coding and MRC&ML decoding

For two receive antennas, the received symbols are:

$$y_{11} = h_{11}x_1 + h_{12}x_2 + n_{11}, \quad y_{12} = -h_{11}x_2^* + h_{12}x_1^* + n_{12},$$
$$y_{21} = h_{21}x_1 + h_{22}x_2 + n_{21}, \quad y_{22} = -h_{21}x_2^* + h_{22}x_1^* + n_{22}, \qquad (2)$$

where h_{ij} is the path gain between the jth transmit antenna and the ith receive antenna. The term n_{ij} is the additive noise for the ith receive antenna at the jth time slot, modeled as independent complex Gaussian random variables with zero-mean and variance 1/(2SNR) per complex dimension, where SNR is the signal to noise ratio of the channel. We assume a quasi-static flat fading Rayleigh channel, with coherence time T_c. For a flat fading channel, the fading coefficients h_{ij} remain constant within a frame of length T_c time slots and change into new ones from frame to frame. Also, we assume uncorrelated path gains (the distance between two antennas is more than that half of the wavelength) which vary independently from one frame to another. For a quasi-static channel, the path gains are constant over a frame of length multiple of T_c. For a Rayleigh channel, the path gains are independent complex Gaussian random variables, with zero mean and variance 0.5 per real dimension. If the symbols y_{12} and y_{22} from equations (2) are complex conjugated, then we have:

$$y_{11} = h_{11}x_1 + h_{12}x_2 + n_{11}, \quad y_{12}^* = h_{12}^*x_1 - h_{11}^*x_2 + n_{12}^*, \quad (3)$$
$$y_{21} = h_{21}x_1 + h_{22}x_2 + n_{21}, \quad y_{22}^* = h_{22}^*x_1 - h_{21}^*x_2 + n_{22}^*,$$

or in matrix form:

$$\begin{bmatrix} y_{11} \\ y_{21} \\ y_{12}^* \\ y_{22}^* \end{bmatrix} = \begin{bmatrix} h_{11} & h_{12} \\ h_{21} & h_{22} \\ h_{12}^* & -h_{11}^* \\ h_{22}^* & -h_{21}^* \end{bmatrix} \begin{bmatrix} x_1 \\ x_2 \end{bmatrix} + \begin{bmatrix} n_{11} \\ n_{21} \\ n_{12}^* \\ n_{22}^* \end{bmatrix}, \quad (4)$$

which can be rewritten:

$$\mathbf{y} = \mathbf{H}_{ef}\mathbf{x} + \mathbf{n}. \quad (5)$$

This relation represents the transfer function between the input x of the STBC encoder and the output y of the MIMO channel, where H_{ef} is the matrix of the equivalent channel formed by the ST encoder and the MIMO channel. Moreover, H_{ef} is an orthogonal matrix over all channel realizations because $\mathbf{H}_{ef}^H\mathbf{H}_{ef} = \|\mathbf{H}\|_F^2\,\mathbf{I}_2$, where $\mathbf{H} = [h_{ij}]$ is the channel matrix and $\|\cdot\|_F$ is the Frobenius norm.

4 STBC BASED TRANSMIT DIVERSITY

Space-time block coding based transmit diversity (STTD) is a method of transmit diversity used in UMTS third-generation cellular systems. STTD is optional in the UTRAN air interface but mandatory for user equipment (UE). STTD utilizes space-time block code (STBC) in order to exploit redundancy in multiply transmitted versions of a signal.

STTD is one of numerous open loop transmit diversity schemes which also include Phase Switched Transmit Diversity (PSTD), Time Switched Diversity (TSTD), Orthogonal Transmit Diversity (OTD) and Space Time Spreading (STS) [15]. The aim of all of these schemes is to smooth the fading and drop out effects observed when using only a single antenna at both ends of a radio link in a Multipath propagation environment.

STTD can be applied to single symbols in QAM, CDMA code words, or subcarrier symbols in OFDM and the transmit method has become standardized, especially in 3G cellular wireless [14]as described below. The transmitter coder takes consecutive pairs of data symbols {S1, S2}, normally sent directly from one antenna. For two transmit antennas the symbols {S1, S2} are transmitted unchanged from antenna #1 while simultaneously from antenna #2 is sent the sequence {-S2*, S1*}. At the receiver some linear algebra is needed for decoding. Consider the complex channel gains between the TX elements and the single RX element are already known at the receiver. The received signals in the two time slots are

$$\{h_1S_1 - h_2S_2^*, \quad h_1S_2 + h_2S_1^*\}$$

with some added noise . By conjugating the second received symbol within the receiver, we can write the matrix equation

$$\begin{bmatrix} x_1 \\ x_2^* \end{bmatrix} = \begin{bmatrix} h_1 & -h_2 \\ h_2^* & h_1^* \end{bmatrix} \begin{bmatrix} S_1 \\ S_2^* \end{bmatrix} + \begin{bmatrix} n_1 \\ n_2^* \end{bmatrix}$$

and the least squares solution is to solve for S1 and S2 by matrix inversion:

$$\begin{bmatrix} \hat{S}_1 \\ \hat{S}_2^* \end{bmatrix} = \begin{bmatrix} h_1 & -h_2 \\ h_2^* & h_1^* \end{bmatrix}^{-1} \begin{bmatrix} x_1 \\ x_2^* \end{bmatrix} = \frac{1}{h_1h_1^* + h_2h_2^*} \begin{bmatrix} h_1^* & h_2 \\ -h_2^* & h_1 \end{bmatrix} \begin{bmatrix} x_1 \\ x_2^* \end{bmatrix}$$

This is called the zero forcing solution. It attempts to drive interference between the symbols to zero by a process of weighting linear combinations of the received signals at the two time samples and works perfectly in the absence of errors and noise.

Note that in the inscrutable 3G specifications, for example TS125.211, a consecutive pair of transmitted QPSK symbols, after coding, interleaving etc., is defined by a logical binary string of four bits: , representing in-phase and quadrature components and .

$$\{S_1 = (2b_0 - 1) + i(2b_1 - 1), \; S_2 = (2b_2 - 1) + i(2b_3 - 1)\}$$

Here

$$-S_1^* = (2\overline{b_0} - 1) + i(2b_1 - 1), \; S_2^* = (2b_2 - 1) + i(2\overline{b_3} - 1)\}$$

where over bar means logical inversion.

For CDMA, STTD is applied to whole code words rather than consecutive chips. In OFDM applications such as Long Term Evolution (LTE) two transmit element STTD is optionally applied just as above while there is also a 4-element option.

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5 PERFORMANCE ANALYSIS OF MICROWAVE LINK USING STBC

•In data communication, only QPSK coded data gives a higher amount of bit error rate

•If data rate is increased, the performance rate increases and there is a visible reduction in the bit error rate

•If the QPSK data and STBC data is compared, it is clearly visible that after introducing STBC, the error rate decreased to a satisfactory level

The simulation presented here compares the results of QPSK coded data before and after introduction of STBC. The simulation has been done with MATLAB. At first QPSK is used and Gaussian channel is used.

Fig:4 and Fig:5 show QPSK coded modulation with increasing number of data. It shows that with the increasing number of data the performance improves with less distortion.

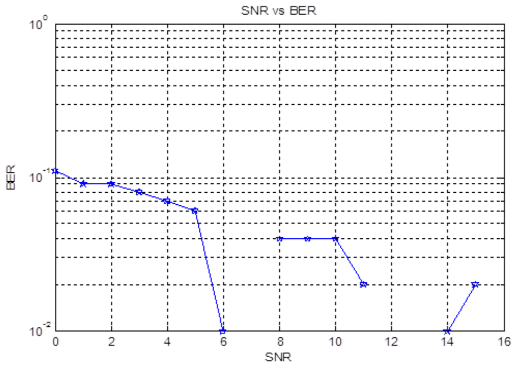

Fig4: QPSK has been done with less number of data (data=10^2)

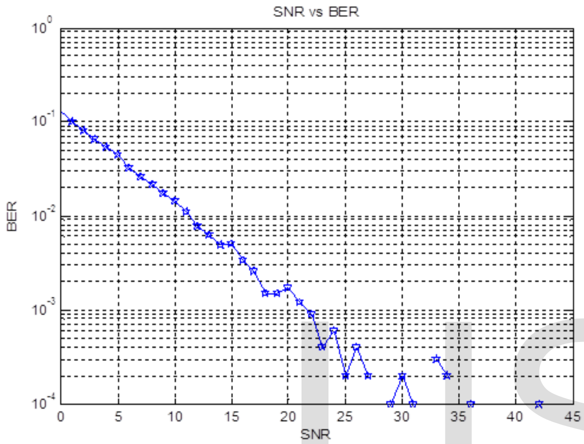

Fig5: QPSK has been done by increasing the number of data (data N= 10^4,)

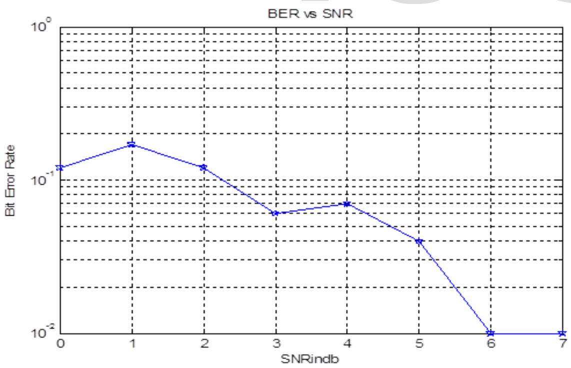

Fig6: STBC has been introduced to the QPSK coded data and the noise has been visibly reduced. After the introduction of STBC with the same number of data (N=10^4) the SNR has been reduced to almost 8db.

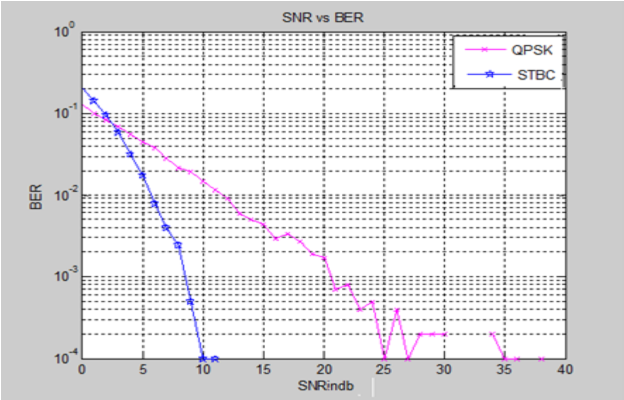

Fig7: The figure shows the comparison between QPSK coded data with STBC and without STBC. It is visible from the graph that after the introduction of STBC the SNR has been decreased which is actually the objective of data communication system.

6 Conclusion

In this paper, a visualization has been introduced which has compared the performance analysis of microwave link using QPSK Coded data before and after the introduction of STBC. The simulation has been done using MATLAB programming by varying the data rate in the QPSK coded data. After that, the data rate has been increased and then STBC is introduced. Simulation result shows that after introducing STBC the performance has been improved.

References

1. Gerard J. Foschini and Michael. J. Gans (January 1998). "On limits of wireless communications in a fading environment when using multiple antennas". Wireless Personal Communications 6 (3): 311–335. doi:10.1023/A:1008889222784
2. Gerard J. Foschini (autumn 1996). "Layered space-time architecture for wireless communications in a fading environment when using multi-element antennas". Bell Labs Technical Journal 1 (2): 41–59. doi:10.1002/bltj.2015.
3. I. Emre Telatar (November 1999). "Capacity of multi-antenna gaussian channels". European Transactions on Telecommunications, 10 (6): 585-595. doi:10.1002/ett.4460100604.
4. Vahid Tarokh, Nambi Seshadri, and A. R. Calderbank (March 1998). "Spacetime codes for high data rate wireless communication: Performance analysis and code construction". IEEE Transactions on Information Theory 44 (2): 744–765. doi:10.1109/18.661517
5. S.M. Alamouti (October 1998). "A simple transmit diversity technique for wireless communications". IEEE Journal on Selected Areas in Communications 16 (8): 1451–1458.doi:10.1109/49.730453
6 . Vahid Tarokh, Hamid Jafarkhani, and A. R. Calderbank (July 1999). "Space–time block codes from orthogonal designs" (PDF). IEEE Transactions on Information Theory 45 (5): 744–765. doi:10.1109/18.771146
7. Tsoulos, MIMO system technology for wireless communications.
8. D. Gesbert, M. Shafi, D. Shiu, P. Smith, and A. Naguib, "From theoryto practice: an overview of MIMO space-time coded wireless systems," IEEE Journal on selected areas in Communications, vol. 21, no. 3, pp.281–302, 2003
9. Vahid Tarokh, Hamid Jafarkhani, and A. Robert Calderbank (March 1999). "Space–time block coding for wireless communications: performance results" (PDF). IEEE Journal on Selected Areas in Communications 17 (3): 451–460. doi:10.1109/49.753730
10. G. Ganesan and P. Stoica (May 2001). "Space–time block codes: A maximum SNR approach". IEEE Transactions on Information Theory 47 (4): 1650–1656.doi:10.1109/18.923754.

11. V. Tarokh, H. Jafarkhani, and A. Calderbank, “Space-time block coding for wireless communications: performance results,” IEEE Journal on selected areas in communications, vol. 17, no. 3, pp. 451–460, 1999.
12. G. Foschini and M. Gans, “On limits of wireless communications in a fading environment when using multiple antennas,” Wireless personal communications, vol. 6, no. 3, pp. 311–335, 1998
13. A. Molisch, Wireless Communications. Wiley-IEEE Press, 2005.
14. 24. Maturana, H. R., and F. J. Varela (1988). The Tree of Knowledge. Boston: New Science Library.
15. R. Thomas Derryberry et al. Nokia Research Center, "Transmit Diversity in CDMA Systems"
http://users.ece.utexas.edu/~jandrews/ee381k/EE381KTA/td_cdma.pdf