EFFICIENT STBC FOR THE DATA RATE OF MIMO-OFDMA

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ABSTRACT: *Multicarrier modulation can be implemented by using Orthogonal Frequency Division Multiplexing (OFDM) to achieve utmost bandwidth exploitation and soaring alleviation attributes profile besides multipath fading. To support delay sensitive and band bandwidth demanding multimedia applications and internet services, MIMO in addition with other techniques can be used to achieve high capacity and reliability. To obtain high spatial rate by transmitting data on several antennas by using MIMO with OFDM results in reducing error recovery features and the equalization complexities arise by sending data on varying frequency levels. Three parameters frequency OFDM, Spatial (MIMO) and time (STC) can be used to achieve diversity in MIMO-OFDM. This technique is dynamic and well-known for services of wireless broadband access. MIMO if used with OFDM is highly beneficial for each scheme and provides high throughput. There are several space time block codes to exploit MIMO OFDM; one of the techniques is called Alamouti Codes. The paper investigates adaptive Alamouti Codes and their application in IEEE 802.11n.*

Keywords: MIMO-OFDM, STBC, SNR, Line of Sight, QoS, Frequency Division Multiplexing, Fourier transform, discrete Fourier transform, inter-leaving, carrier

I. INTRODUCTION

The demand of the next generation communication networks is to support a wide range of services which includes high quality voice, data, still pictures, streaming videos, and services which require several megabits per second of data rate. When data is transmitted at high data rates over radio channel CIR (channel impulse response) can expand to several symbol periods because of multipath signals and resulting ISI (Inter symbol interference). Different objects reflect signals traveling through several paths and signals taking less direct path arrive at receiver later and are often attenuated. A common strategy to deal with multipath signals is to ignore weaker signals by the energy which they contain is wasted. Traditional systems employ some improvement techniques to deal with multipath signals; one technique is to use various antennas to capture the strongest signal at each moment of time, whereas there is another technique that adds delays to back align the signals. Whatever technique is used, it's very much clear that multipath signals are harmful and wasteful. MIMO (Multiple Input Multiple Output) seize the benefits of multipath propagation signals as compared to the other conventional systems. MIMO set multipath signals to work instead of implementing various techniques to manage multipath signals. It is likely to be done by sending over one data signal at the same time in the same frequency band by exploiting multiple transmitting and multiple receiving antennas. OFDM (Orthogonal frequency division multiplexing) is also shining candidate to handle the effect of ISI and ICI (Inter carrier interference). OFDM converts frequency selective wide band signal into frequency flat multiple orthogonally spaced narrow band signals also resulting in high bandwidth efficiency. There are three most essential parameters that completely define the quality and effectiveness of any wireless communication system Speed, Range and Reliability. In traditional system speed can only be improved at a cost of range and reliability, Range could be increased at cost of speed and reliability and Reliability could be increased at the expense of range and speed. MIMO-OFDM systems have altered the trends by clearly representing that it can boost up all the three basic parameters simultaneously. The detailed overview and analysis of OFDM, MIMO and their combination with space time coding is discussed. Simulation results provided shows that Alamouti scheme can be best exploited with MIMO. Alamouti scheme with MIMO produce highe order of diversity and considerable improvement in BER as number of antennas increased. Simulation results are almost identical to theoretical results which give an approach to design MIMO systems with Alamouti Scheme of coding. It was simulated in MATLAB. Space Time coding with MIMO is deployed to attain transmit diversity and allows secure means of propagation of data in a scenario where mobility is needed. If there is perfect channel state information (knowledge of response of the channel) it can achieve maximum gain in capacity and high SNR at the receiver. From the simulation result perform on different order of MIMO systems.

II. LITERATURE REVIEW

2.1 A Road to Future Broadband Wireless Access: MIMO-OFDM-Based Air Interface --- Hongwei Yang and Alcatel Shanghai Bell

OFDM is an eminent technique to achieve high data rates. An epigrammatic methodological overview of MIMO-OFDM is examined in this paper, including several research topics spatial channel modeling, space-time techniques, Air interface, channel estimation and transceiver design of MIMO-OFDM [2]. There are many advantages of exploiting OFDM systems in future broadband wireless access which are listed below

a. Less complications at receiver end
b. inflated spectral efficiency
c. Suitability for high-data-rate transmission over a multipath fading channel.

d. Easy implementations by Fast Fourier transform (FFT) [2].

The major drawback of OFDM systems is exaggerated peak-to-average power ratio (PAPR) in contrast with single-carrier modulation [2].

2.2 Use of Space Time Block Codes and Spatial Multiplexing using TDLS Channel Estimation to Enhance the Throughput of OFDM based WLANs ------ Angela Doufexi, Arantxa Prado Miguelez, Simon Armour, Andrew Nix and Mark Beach

In this paper a technique "Hadamard Design" [8] is used to enhance the performance and efficiency of COFDM WLANs by exploiting space-time block coding and spatial multiplexing MIMO techniques.

The proposed system characteristics/features are:

a. Need for high data rates.
b. Interference avoidance from other users.
c. By using multiple antennas as compared to single antenna performance will improve.
d. Improved spectral efficiency.

Alamouti proposed a simple transmit diversity scheme which was generalized by Tarokh to form the class of Space-Time Block Codes (STBC) [8]. Space time block codes can be represented as:

$$X=\begin{bmatrix} S_1 & -S_2^* \\ S_2 & S_1^* \end{bmatrix} \quad (1)$$

2.3 MIMO Space-Time Block Coding (STBC): Simulations and Results ---Luis Miguel Cort´es-Pe˜na

Wireless networks, including Wireless LANs and mobile phone networks have been emerging very vastly and now becomes the part of our everyday life. Despite the fact that wireless devices are the data rate and range limited and becoming the greatest challenge day by day, the researchers have splurged efforts to triumph over these limitations. Beam foaming is a signal processing technique to maximize the signal received at the receiver end, which contains the transmission of the same signals with varying gain and phase called weights [3].

Diversity is the phenomenon in which a signal with single space time coded stream is transmitted through all antennas.

To increase network capacity a high signal is divided into several lower streams by using spatial multiplexing and sending them through multiple antennas. By using this technique every stream can be effectively decoded at receiver provided that the receiver has sufficient antennas to split the streams and signals received have enough spatial signatures. The range can be extended and high data rates will be achieved by using these techniques without entailing transmits power or extra bandwidth. Diversity coding for MIMO systems is examined in detail as well as Space-time block coding techniques comprising of Alamouti's STBC for dual antenna and also for orthogonal STBC for 3 and 4 transmit antennas are investigated. Results of performance are evaluated and examined by implementing these techniques in MATLAB according to their bit rates using different modulation techniques.

2.4 System Model

There are three main components of a MIMO system, Transmitter, Receiver and the Channel. N_t represents the multiple antennas at the transmitter side and N_r symbolize the multiple antennas at the receiver side. Block diagram of MIMO system is depicted in Figure 3.3. The MIMO system is illustrated with regard to the channel, as depicted in the figure multiple inputs to the channel are situated at the output of the Transmitter and the outputs of channel are situated at the input of Receiver [11].

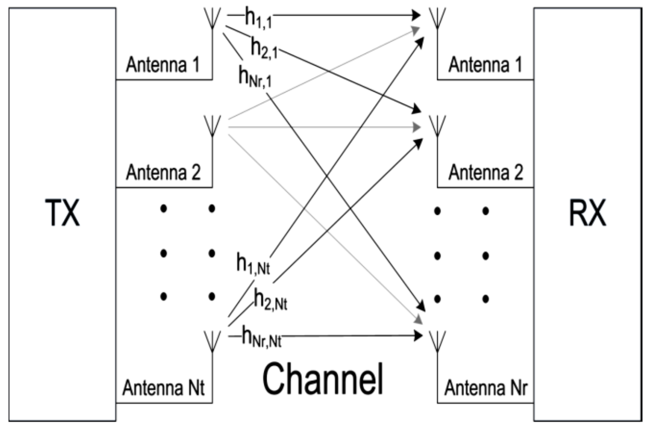

Fig. 1. MIMO system block diagram.

2.5 MIMO Advantages: There are numerous benefits of using MIMO in wireless broadband services some of its advantages are listed below.

a. **Spatial multiplexing:** Multiple streams of signals can be sent in parallel, every stream uses a different transmit antenna element. Appropriate signal processing can be carried out at the receiver end to split the signals [11].
b. **Spatial diversity:** Transmit antennas can code a signal thus creating redundancy this reduces the outage probability [11].
c. **Beam forming**: The receiving power of the receiver and the SNR can be increased by getting more streams, this is done by making a transmitter receiver pair that can achieve beam forming and send their beams at each other [11].

2.6 Space Time Block Coding: Spatial Diversity is the methodology used to combat channel fading by exploiting the redundant diversity of MIMO systems and transmitting a number of copy of similar data through every antenna. As a result of using spatial diversity the possibility of losing information reduces exponentially. Transmission over SISO systems is also supported by antennas in MIMO systems as the required rate of is that of a SISO system. [11]

III. METHODOLOGY

The main flow of the system designed will work as given in the following fig. 2:

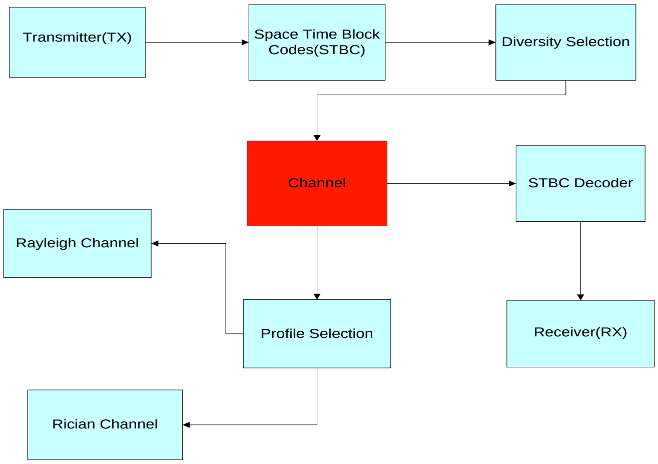

Fig. 2. Block Diagram of MIMO-OFDM System

3.1 2×1 Alamouti Scheme

Symbols represented as S1 and S2 is sent by antenna1 and antenna 2 at time T1 and at time T2 .Symbol S2*(complex conjugate of symbol 2) and S1* (negative complex conjugate of symbol 1) is sent by antenna 1 and 2 respectively to fulfill orthogonality, Where h1 and h2 are channel parameter (h1 and h2 are the channel path response to signal from antenna 1 and antenna 2 respectively). Whereas r1 and r2 is receiving vector at one receiver for time T1 transaction and for time T2 transaction, at receiver received information is [11].

$r = Sh + n$ (2)

Whereas "n" shows noise (could be white Gaussian Noise, Rayleigh fading, flat fading channel etc)

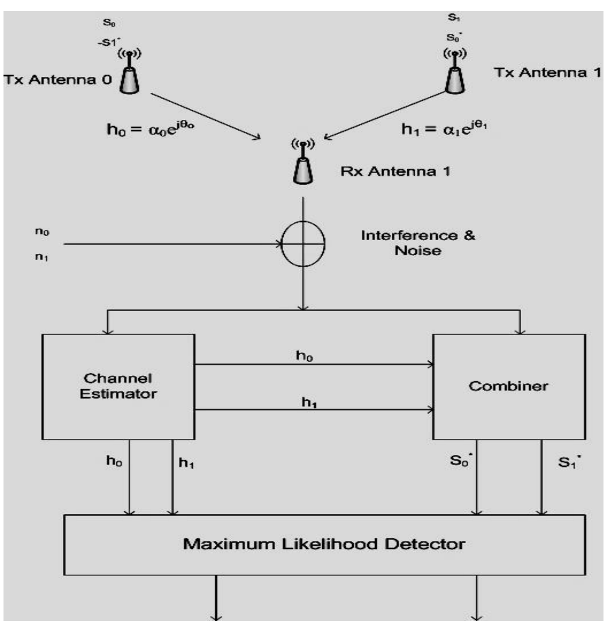

Fig. 3. 2×1 Alamouti Scheme

From figure it is cleared that channel matrix is" h" is repressed as h= [h1, h2] ^{T,} (in figure _h1=h0, h2=h1, and S1=s0, S2=s1)

Receive matrix can be written as

$$r = Sh + v \quad (3)$$

$$\begin{pmatrix} r_1 \\ r_2 \end{pmatrix} = \begin{pmatrix} S_1 & S_2 \\ S_2^* & -S_1^* \end{pmatrix} * \begin{pmatrix} h_1 \\ h_2 \end{pmatrix} + \begin{pmatrix} v_1 \\ v_2 \end{pmatrix} \quad (4)$$

In equation form it is written as :

$$r_1 = h_1 s_{1+} h_2 s_2 + v_1 \quad (5)$$

$$r_2 = -h_2 s_1^{*}{}_{+} h_1 s_2^{*} + v_2 \quad (6)$$

After taking complex, conjugate of equation (6)

$$r_1 = h_1 s_{1+} h_2 s_2 + v_1 \quad (7)$$

$$r_2^{*} = -h_2^{*} s_{1+} h_1^{*} s_2 + v_2 \quad (8)$$

In Matrix form it can be written as :

$$\begin{pmatrix} r_1 \\ r_2^* \end{pmatrix} = \begin{pmatrix} h_1 & h_2 \\ -h_2^* & h_1^* \end{pmatrix} * \begin{pmatrix} s_1 \\ s_2 \end{pmatrix} + \begin{pmatrix} v_1 \\ v_2^* \end{pmatrix} \quad (9)$$

Now channel matrix with symbols takes new mathematical shape i.e. $Y = Hs+v$

Where the rearrange channel matrix H is orthogonal, mathematically it can verified as

$$H^H H = H H^H = h^2 I_2$$

I is identity matrix of order 2× 2 and gain is h2= │h1│2 + │h2│2, (all this manipulation is provided using symbol tool box in this report). [5], [7]

3.2 Rayleigh Channel

In wireless channel, mostly behaviour of channel is unpredictable because of time varying properties of channel. Signal propagate through medium from different path suffer different level of attenuation and impairment. At receiver signal is received with superposition of multi signals coming from multipath is termed s multipath fading. If there is no line of sight path between the sender and receiver, Attenuation coefficient to each path (multipath) is considered to be IID (independent identical distribution) and central limit theorem applies. Resulting path become complex Gaussian random variable, Channel is said to **be Rayleigh** .In Rayleigh fading LOS path does not exist .While signal travelling through a wireless link, its power alters due to channel response. [4, 10]

3.3 Rician Channel

In Rician fading line of sight (LOS) exist i.e. one of the path to receiver is much stronger than other one. A signal or symbol of delay version have change in phase or differ in phase with line of sight signal phase. Crust and trough of both these signals cause resultant signal to be high average power or attenuated. So in result we may get distorted signal at receiver end. Rician fading occurs when one of the paths, typically a line of sight signal, is much stronger than the others. [6]

Fig. 4 depicts the behavior of the Transmitter and Fig.5 depicts the behavior of the Receiver.

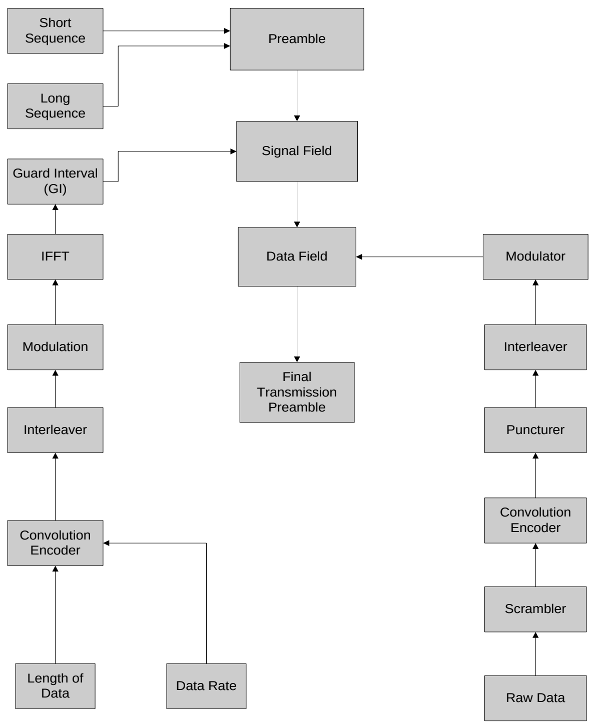

Fig. 4. Transmitter (Tx)

Receiver (Rx)

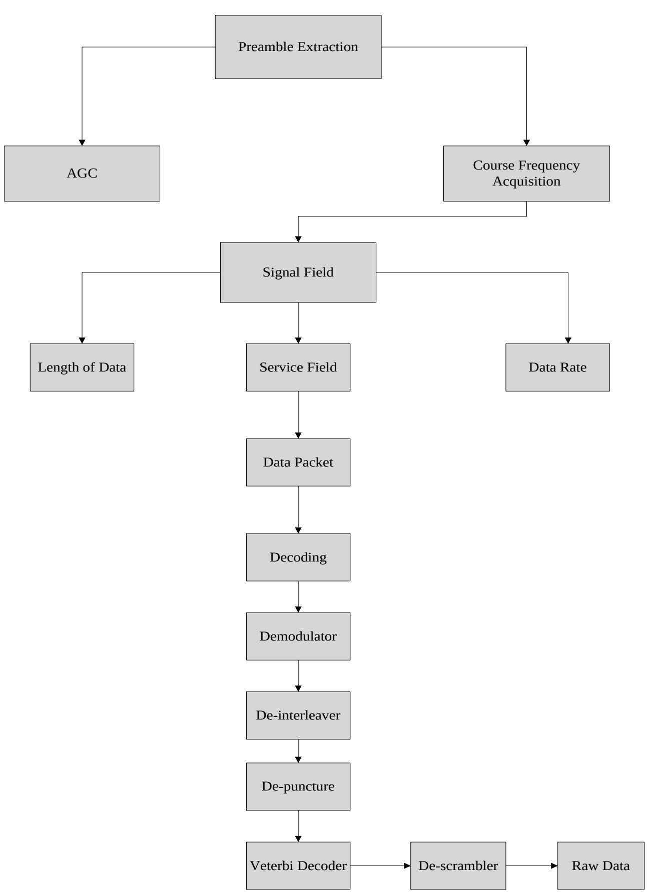

Fig. 5. Receiver (Rx)

3.4 IFFT/FFT

The Fourier transformation is generally needed to transform a Signal from the special dimension into the frequency dimension. Using the inverse Fourier transformation the converted signal can be restored from frequency dimension..

3.5 Viterbi decoder

The Viterbi algorithm offers an efficient way of finding Viterbi path which is basically a string of veiled states. This algorithm can be used as an error correction scheme for noisy channels. It can also be used to mark out the widespread function in decoding the convolution codes exploited in GSM as well as CDMA, satellite communications, dial up modems, and deep space communications. Furthermore this algorithm is employed in speech recognition, bioinformatics and keyword spotting. In case of Speech to text conversion the acoustic signal is considered to be the observed sequence of events on the other side a text string is treated as hidden cause.

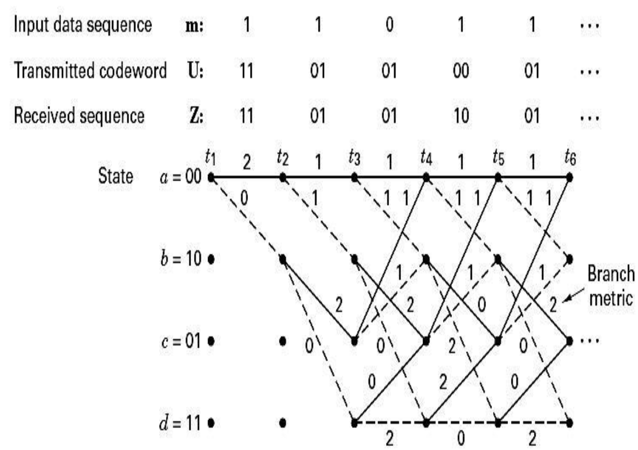

Fig. 6. Trellis diagram

IV. IMPLEMENTATION

The implementation phase composed of two basic elements which are: Transmitter (Tx), Receiver (Rx).

4.1 Design and Simulations using MATLAB

MATLAB is strong mathematical tool provide help to engineers to solve, model, simulate the problems ,and find solutions assuming environment in to mathematical equations. It is standard engineering tool as perform many different tasks using different tool box relevant to different particular cases e.g. Control systems, signal processing, image processing, communication systems, and support complex matrix manipulation, simulink etc .In field and research and universities it provide platform for learning and comparison of theatrical hypothesis and simulated values. It even provide support to nonlinear system calculations and result.

4.2 Simulation and Procedure

In this report MATLAB R2011b [13] is used to simulate and models the problems for analysis and results. Different features of symbolic toolbox is use in simulation for Alamouti scheme of coding which are not supported by older version of MATLAB in order to simulate the provided code MATLAB R2011b is
Appropriate software package to get results.

4.3 Software Simulations and Results

This section includes the analysis on OFDM transceiver along with channel estimation effects. Following simulations show the results of application of STBC followed by the graphical interface as well as simulations have been done on MATLAB R2011b.

4.4 Implementation and Testing

Finally, simulation performed on MIMO using Alamouti scheme by considering a different antenna arrangement. MIMO system is tested by both types of Space time block codes which are Alamouti Scheme and Orthogonal space time block codes with coding rates of ½ and ¾. Values are assumed in order get BER.

EbNo ratio Eb/No range is define it is taken from 0 to 40 if taken larger ,it takes more time to produce results

Random data is generated for 40 times (length of Eb/N0) ,it is considered as x-axis for BER graph .on y-axis BER is taken from a range of 10^{-5} to 0.9.

Number of receivers are taken 1, 2, 3,4 and 6 with variation in the transmitter, different BER graphs are defined for each case respectively.

It can be seen in the figures presented in Annexure-A that simulated result is identical to theoretical and expected result. A series of tests were conducted and the results are shared in Annexure-A. Simulation results conclude that it's quite evident from the results that as number of antennas are increasing on receiver side BER is largely improve, for increment in the number of antennas at transmitter also play role in improvement of BER which can be easily viewed by compared 1×1 system with 2× 1 etc. Further Almouti 2x1, 2x2 and 2x3 system has been implemented and results compared in Fig 7. Simulation result it is concluded that: BER performance of 2×3 system is better than BER performance of 2×2 system which is better than BER performance of 1×2.

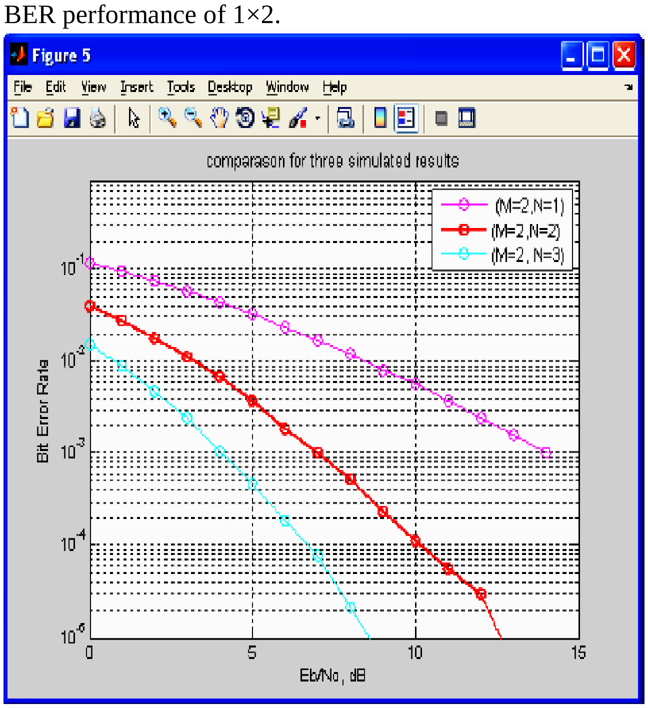

Fig. 7. Comparison result for simulations

V. CONCLUSION

Space time coding (STC) was implemented on MIMO system and its Bit Error Rate was checked. For the simulation purpose MATLAB was used. MIMO system uses OFDM. OFDM modulator was designed and simulated. The data is encoded using space time block codes to keep multiple data symbols orthogonal. Space–Time Block Codes (STBCs) are the simplest types of spatial temporal codes that exploit the diversity offered in systems with several transmit antennas. The combined use of MIMO architecture, OFDM modulation, and STBC coding, creates a highly flexible communication system. The designed system is tested by using various Space time block codes such as first with Alamouti codes and then with the Orthogonal space time block codes with coding rates of ½ and ¾.

New solutions must be developed in order to cope with the scarcity of spectrum.

MIMO-OFDM system is a solution and a future technology that can exploit the available spectrum with greater efficiency to support high data rates, reduces the carrier cost, carries a smaller carrier cost through to end user and supports many users within individual cells enhancing the user experience.

The concept of MIMO system is its motivation to achieve higher throughputs within a given bandwidth. MIMO-OFDM is communication system using multiple antennas (transmit & receive) with OFDM modulation at each antenna, is a promising candidate for 4G systems. [1]

Future work can be done on this system, by combining OFDM and STBC for MIMO, OFDM demodulator and channel effects with different noise models can be simulated. There could be many experiments performed considering this approach in a different environment indoors and outdoor, to make system adaptive and develop feedback approach. There are various approaches in coding structures, but the approach used in this project is Space-time block codes (STBC), and anyone can use other coding techniques in order to investigate the MIMO-OFDM systems such as space-time trellis codes (STTC), space-time turbo trellis codes and layered space-time (LST) codes etc.

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ANNEXURE-A

1. When nRx=1

1.1 Alamouti STBC with 2x1 Diversity

When Alamouti STBC with 2x1 Diversity is tested it is seen that the BER and Eb/no with BPSK is high from all the other modulation schemes.

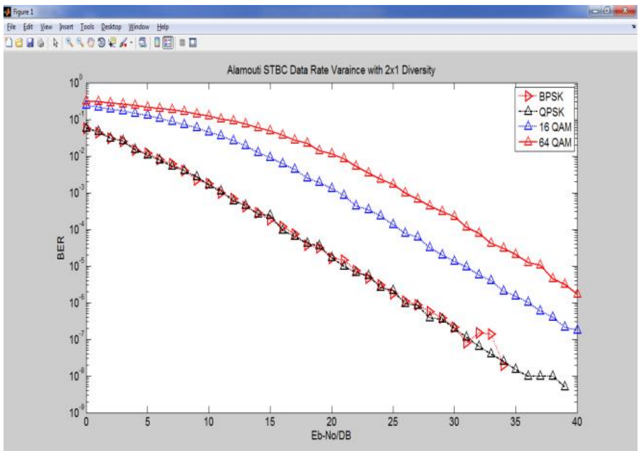

Fig. 8. Alamouti STBC with 2x1 Diversity

1.2 Orthogonal STBC with 3x1 Diversity

Orthogonal STBC with 3x1 Diversity is tested with ½ coding rate. The BER value is 0.25. This means that Data rate in this combination is high as compared to Orthogonal STBC with 3x1 Diversity because large BER is appalling.

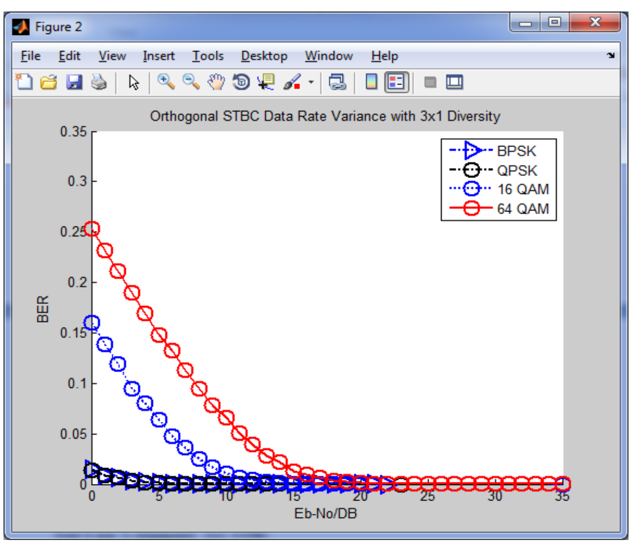

Fig. 9. Orthogonal STBC with 3x1 Diversity

1.3 Orthogonal STBC with 3x1 Diversity

Orthogonal STBC with 3x1 Diversity is tested with ¾ coding rate. The BER value is 0.31.This means that Data rate in this combination is low as compared to Orthogonal STBC with 3x1 Diversity with coding rate ½ because large BER is not good.

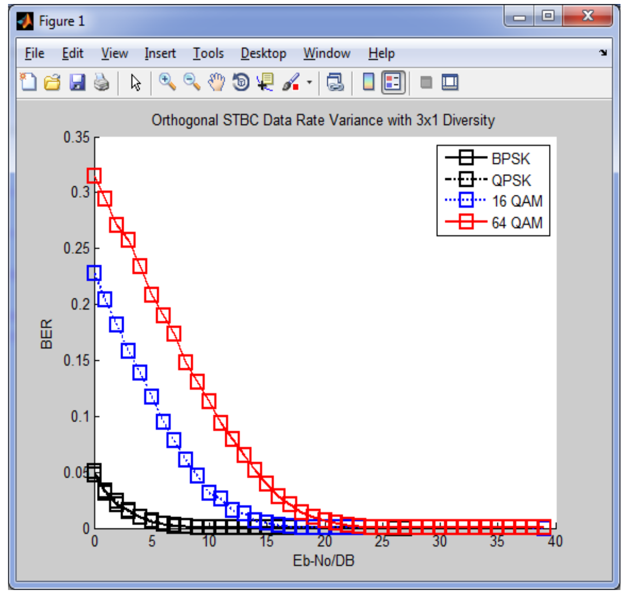

Fig. 10. Orthogonal STBC with 3x1 Diversity

1.4 Orthogonal STBC with 4x1 Diversity

Orthogonal STBC with 4x1 Diversity is tested with ½ coding rate.

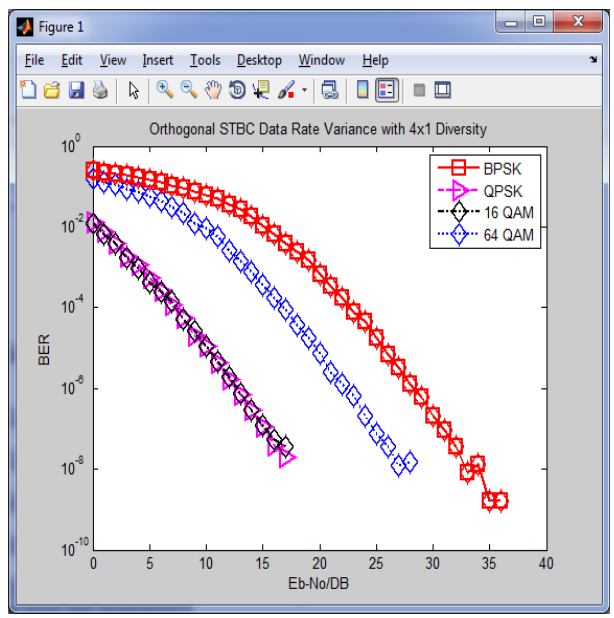

Fig. 11. Orthogonal STBC with 4x1 Diversity

1.5 Orthogonal STBC with 4x1 Diversity

Orthogonal STBC with 4x1 Diversity is tested with ¾ coding rate

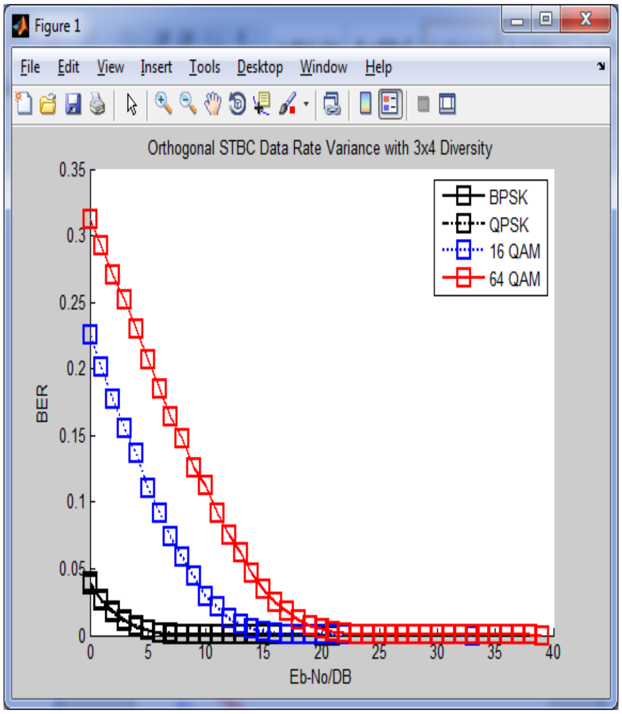

Fig. 12. Orthogonal STBC Data rate variance with 3x4 Diversity

2. When nRx=2

2.1 Orthogonal STBC with 4x2 Diversity

Orthogonal STBC with 4x2 Diversity is tested with ½ coding rate.

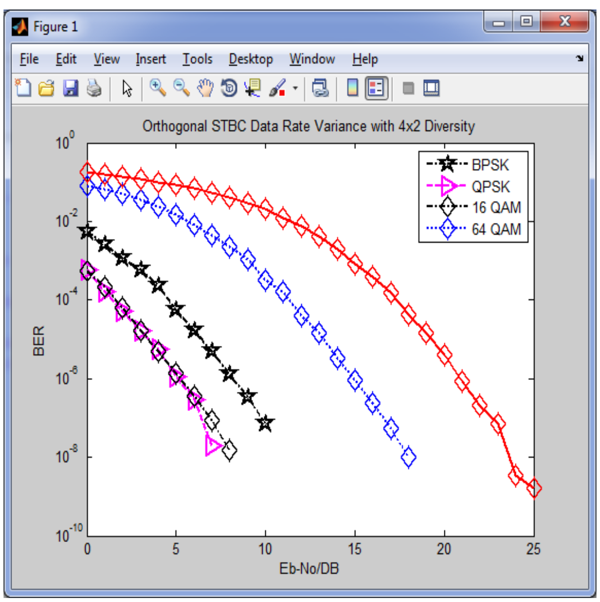

Fig. 13. Orthogonal STBC with 4x2 Diversity

2.2 Orthogonal STBC with 4x2 Diversity

Orthogonal STBC with 4x2 Diversity is tested with ¾ coding rate.

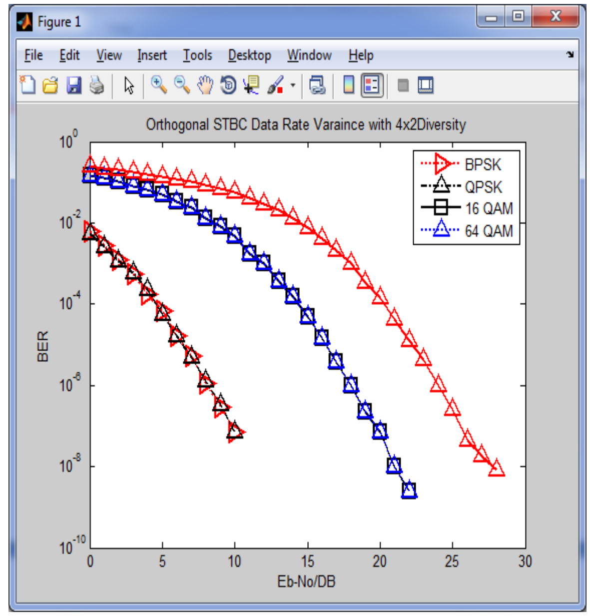

Fig. 14. Orthogonal STBC with 4x2 Diversity

2.3 Orthogonal STBC with 3x2 Diversity

Orthogonal STBC with 3x2 Diversity is tested with ½ coding rate.

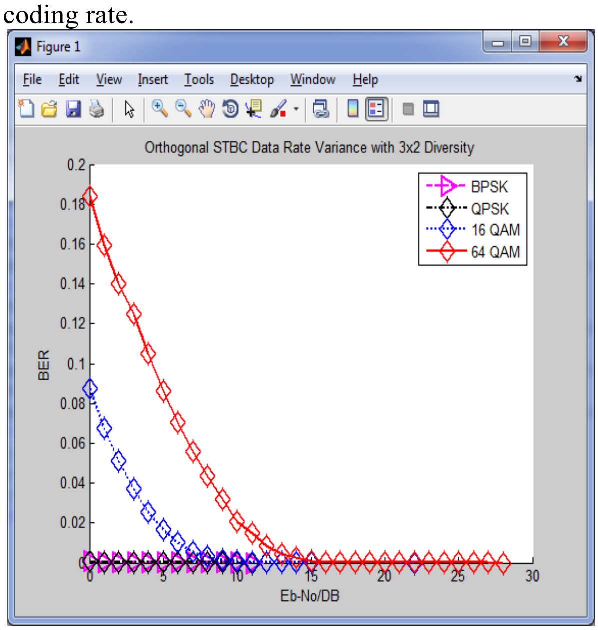

Fig. 15. Orthogonal STBC with 3x2 Diversity

2.4 Orthogonal STBC with 3x2 Diversity

Orthogonal STBC with 3x2 Diversity is tested with ¾ coding rate.

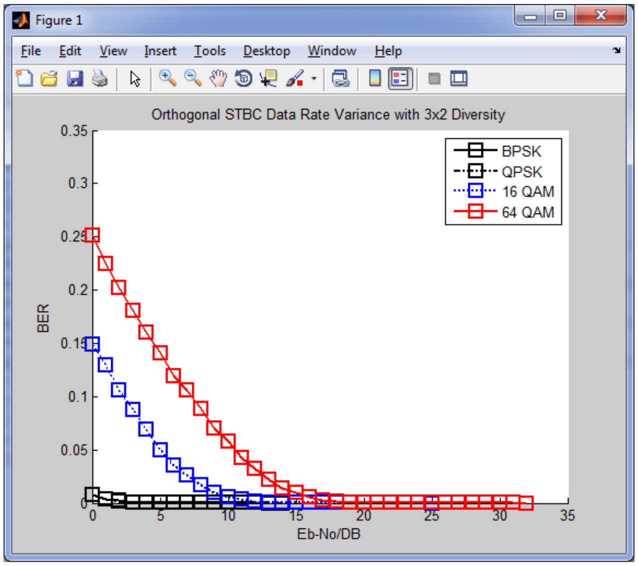

Fig. 16. Orthogonal STBC with 3x2 Diversity

3. WHEN nRX=3

3.1 Orthogonal STBC with 4x3 Diversity

Orthogonal STBC with 4x1 Diversity is tested with ½ coding rate.

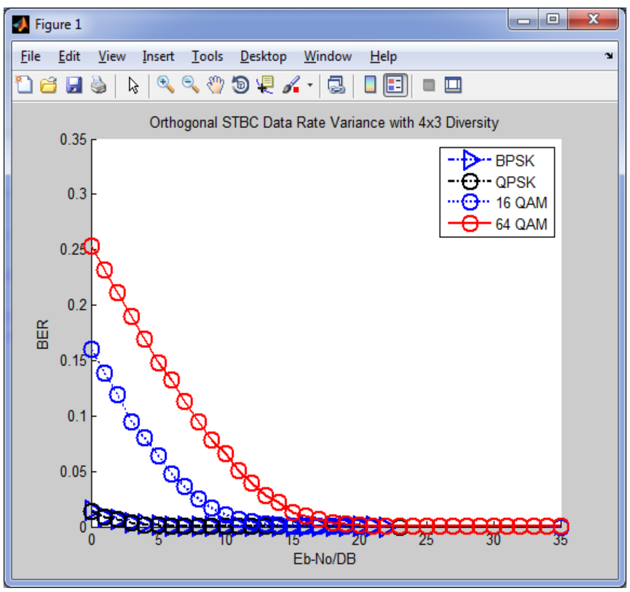

Fig. 17. Orthogonal STBC with 4x3 Diversity

3.2 Orthogonal STBC with 4x3 Diversity

Orthogonal STBC with 4x1 Diversity is tested with ¾ coding rate.

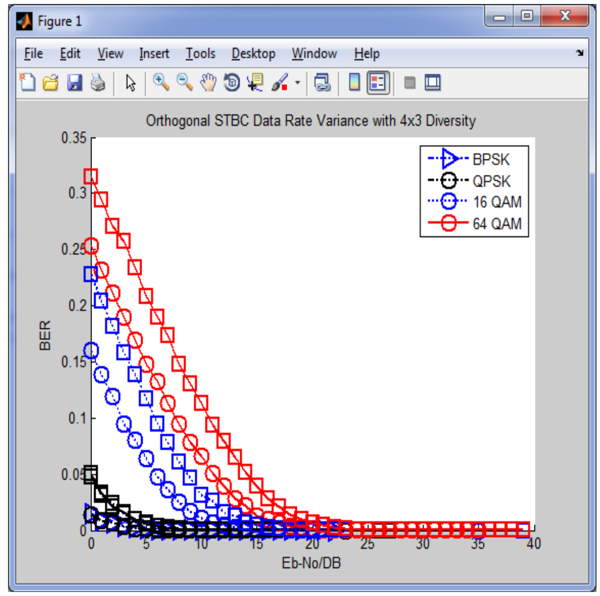

Fig.18. Orthogonal STBC with 4x3 Diversity

When Alamouti STBC with 2x4 Diversity is tested it is seen that the BER and Eb/no with BPSK is high from all the other modulation schemes.