PERFORMANCE ANALYSIS OF SPACE TIME BLOCK CODES IN LTE ADVANCED SYSTEM

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ABSTRACT

The primary purpose of this paper is to present the space time block code for wireless networks that uses multiple numbers of antennas at both transmitter and receiver. LTE aims to provide enhanced service quality over 3G systems in terms of throughput, spectral efficiency, latency, peak data rate, and the MIMO techniques. Among several operational modes of MIMO, MU-MIMO, the base station transmits multiple streams to multiple users, has received much attention as a way of achieving improvement in performance. Space time wireless technology uses, multiple antennas along with appropriate signaling and receiver techniques offer a powerful tool for improving wireless performance. Space time block coding has been trying to incorporate in the fourth generation of mobile communications, which aims to deliver true multimedia capability. Simulation results have been shown that the STBC which includes the alamouti scheme as well as an orthogonal STBC for 4, 8 transmit antenna case has been simulated and studied. With orthogonal STBC, we have developed an 8 array antenna, which effectively handles large amount of data during transmission.

Keywords: mobile broadband, MIMO, 3GPP, 4G, LTE-Advanced, OSTBC.

1. INTRODUCTION

Now a days the multimedia communications become increasingly popular, and mobile communications support high data rate transmissions. 3GPP (3rd Generation Partnership Project) has so many technologies, the most recent technology is OFDM called Evolved Universal Terrestrial Radio Access (E-UTRA) or LTE support broadband data services. It meets the requirement of spectrum flexibility and enables cost efficient solutions for wide carriers and peak rates. To achieve all these requirements it uses MIMO transmission techniques which include transmit diversity, beam-forming, SU-MIMO (Single User-MIMO) and MU- MIMO (Multi User-MIMO), to improve cell coverage and throughput in both uplink and downlink. Space time code explains, what is transmitted by the array of transmitter in a MIMO communication link. These codes use advanced coding concepts along with sophisticated iterative receivers. However many technical challenges remain in designing robust wireless networks that deliver the performance necessary to support emerging applications. STBC along with MIMO had tremendous potential for link reliability in physical layer. This work depicts that the combination of multiple antennas at either transmitter or receiver, increase in number of antennas give rise to bit error rate which is one of the important measure of link reliability. In this paper the focus is given to spatial diversity, MIMO systems concepts to achieve throughput explained in section II, space time block codes with generalized versions of alamouti scheme and Orthogonal Space Time Block Codes discussed in section III, the simulation results have been shown in section IV, and finally section V provides the conclusion for this paper. [1-5]

2. MIMO FOR LTE

MIMO system forms an essential part of LTE in order to accomplish the ambitious requirements for throughput and spectral efficiency. By using multiple antennas, the transmitter and receiver along with some complex digital signal processing enables the system to set up multiple data streams on the same channel, thereby increasing the data capacity of a channel. LTE introduces higher order downlink MIMO upto 4×4 and MIMO in the uplink further increases peak rate and performance. [10] Multidimensional MIMO channel can be exploited to increase the diversity of system to provide parallel spatial channels which is known as spatial multiplexing. Diversity increases robustness of the system by eliminating fades and also increasing average signal to noise ratio. Advanced MIMO schemes are subdivided into Transmit diversity, Spatial Multiplexing (including both SU-MIMO and MU-MIMO). [14]

2.1. Transmit Diversity in LTE

The transmit diversity provides source of diversity for averaging out the channel variation either for operation at higher UE speeds (300Kmph) or for delay sensitive services at both low (15 Kmph), and medium (15-120Kmph) UE speeds. Each transmit antenna transmits the same stream of data so the receiver gets replicas of the same signal. This increase the signal to noise ratio at the receiver side thus the robustness of data transmission especially in fading scenarios. Instead of increasing data rate or capacity, MIMO can be used to exploit diversity and increase the robustness of data transmission. [7]

For LTE downlink, the transmit diversity schemes can be applied to all the physical channels such as Physical Downlink Shared Channel (PDSCH), Physical Broadcast Channel (PBCH), Physical Control Format

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Indicator channel (PCFICH), Physical Down Link control channel (PDCCH), and Physical Hybrid ARQ Indicator cannel (PHICH). UE recognizes the number of transmitting antennas at the base station by blindly decoding PBCH. Once these antennas detected a specific Transmit diversity technique, applicable to other physical channel is determined. Transmit diversity schemes defined for LTE down link. The Space-frequency block code (SFBC) scheme as shown in Figure-1 is used if the enodeB has two transmit antennas. For enodeB with 4 transmit antennas, a combination of the SFBC and the frequency-switched transmit diversity (FSTD) scheme is used to provide robustness against correlation between channels from different transmit antennas and for easier UE receiver implementation.

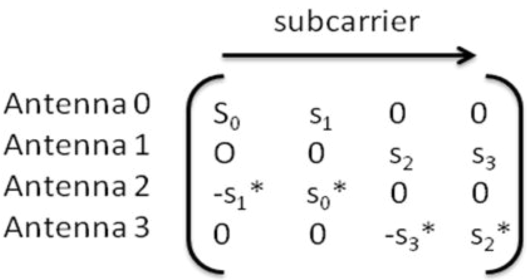

Figure-1. SFBC with two transmit antennas on downlink.

2.2. SU-MIMO in LTE

In SU- MIMO all the spatial layers within allocated resource blocks are addressed to the same UE, hence this improves both UE peak data rates as well as cell capacity. There are two operating modes in SU-MIMO spatial multiplexing; those are open-loop spatial multiplexing and closed-loop multiplexing. In closed-loop spatial multiplexing mode, the base station applies the precoding on the transmitted signal taking into account the precoding matrix indicator (PMI) reported by the UE.

To support the closed-loop spatial multiplexing in the downlink, the UE needs to feedback the rank indicator (RI), the PMI and the channel quality indicator (CQI) in the uplink. The RI indicates the number of spatial layers that can be supported by the current channel experienced at the UE. The enodeB may decide, the transmission rank $N_{L,}$ taking into account the RI reported by the UE as well as other factors such as traffic pattern, available transmission power. The precoding operation on transmitter side is used to support closed-loop spatial multiplexing is defined by Y = Wk, where $y=[y_0....y_{N-1}]^T$, y_n denotes the complex symbol transmitted on the nth antenna, $x= [xo,...x_{M-1}]^T$ denotes the modulation symbol transmitted on the m^{th} layer, and W denotes the N×M precoding matrix is selected from a predefined codebook which is known at enode B and UE side. For transmission on two antennas, the precoding matrix W is selected from Table-1 where each column vector is in the form of $[1e^{j(\theta+k\pi)})]^T$ multiplied by a scaling factor. For transmission on four antennas the precoding matrix W is selected from [6] Table-2, where $Wi^{\{c_1..c_m\}}$ denotes the matrix defined by the columns $c_1...c_m$ of the matrix $W_i=I_{4\times4} - 2u_i u_i^H/ u_i^H u_i$.

Table-1. Precoding codebook for transmission on two antenna.

Code book index	Number of layers *M*	
	1	**2**
0	$\frac{1}{\sqrt{2}}\begin{pmatrix}1\\1\end{pmatrix}$	-
1	$\frac{1}{\sqrt{2}}\begin{pmatrix}1\\-1\end{pmatrix}$	$\frac{1}{2}\begin{pmatrix}1 & 1\\1 & -1\end{pmatrix}$
2	$\frac{1}{\sqrt{2}}\begin{pmatrix}1\\j\end{pmatrix}$	$\frac{1}{2}\begin{pmatrix}1 & 1\\j & -j\end{pmatrix}$
3	$\frac{1}{\sqrt{2}}\begin{pmatrix}1\\-j\end{pmatrix}$	-

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Table-2. Precoding codebook for transmission on four antennas.

Code book index	u_i	Number of layers *M*			
		1	2	3	4
	$u_0=[1\ -1\ -1\ -1]^T$	$W_0^{\{1\}}$	$W_0^{\{14\}}/\sqrt{2}$	$W_0^{\{124\}}/\sqrt{3}$	$W_0^{\{1234\}}/2$
	$u_1=[1\ -j\ 1\ j]^T$	$W_1^{\{1\}}$	$W_1^{\{12\}}/\sqrt{2}$	$W_1^{\{123\}}/\sqrt{3}$	$W_1^{\{1234\}}/2$
	$u_2=[1\ 1\ -1\ 1]^T$	$W_2^{\{1\}}$	$W_2^{\{12\}}/\sqrt{2}$	$W_2^{\{123\}}/\sqrt{3}$	$W_2^{\{3214\}}/2$
	$u_3=[1\ j\ 1\ -j]^T$	$W_3^{\{1\}}$	$W_3^{\{12\}}/\sqrt{2}$	$W_3^{\{123\}}/\sqrt{3}$	$W_3^{\{3214\}}/2$
	$u_4=[1(-1-j)/\sqrt{2}-j(1-j)/\sqrt{2}]^T$	$W_4^{\{1\}}$	$W_4^{\{14\}}/\sqrt{2}$	$W_4^{\{124\}}/\sqrt{3}$	$W_4^{\{1234\}}/2$
	$u_5=[1(1-j)/\sqrt{2}j(-1-j)/\sqrt{2}]^T$	$W_5^{\{1\}}$	$W_5^{\{14\}}/\sqrt{2}$	$W_5^{\{124\}}/\sqrt{3}$	$W_5^{\{1234\}}/2$
	$u_6=[1(1+j)/\sqrt{2}-j(-1+j)/\sqrt{2}]^T$	$W_6^{\{1\}}$	$W^{6\{13\}}/\sqrt{2}$	$W_6^{\{134\}}/\sqrt{3}$	$W_6^{\{1324\}}/2$
	$u_7=[1(-1+j)/\sqrt{2}j(1+j)/\sqrt{2}]^T$	$W_7^{\{1\}}$	$W_7^{\{13\}}/\sqrt{2}$	$W_7^{\{134\}}/\sqrt{3}$	$W_7^{\{1324\}}/2$
	$u_8=[1\ -1\ 1\ 1]^T$	$W_8^{\{1\}}$	$W_8^{\{12\}}/\sqrt{2}$	$W_8^{\{124\}}/\sqrt{3}$	$W_8^{\{1234\}}/2$
	$u_9=[1\ -j\ -1\ -j]^T$	$W_9^{\{1\}}$	$W_9^{\{14\}}/\sqrt{2}$	$W_9^{\{134\}}/\sqrt{3}$	$W_{9\{1234\}}/2$
	$u_{10}=[1\ 1\ 1\ -1]^T$	$W_{10}^{\{1\}}$	$W_{10}^{\{13\}}/\sqrt{2}$	$W_{10}^{\{123\}}/\sqrt{3}$	$W_{10}^{\{1324\}}/2$
	$u_{11}=[1\ j\ -1\ j]^T$	$W_{11}^{\{1\}}$	$W_{11}^{\{13\}}/\sqrt{2}$	$W_{11}^{\{134\}}/\sqrt{3}$	$W_{11}^{\{1324\}}/2$
	$u_{12}=[1\ -1\ -1\ 1]^T$	$W_{12}^{\{1\}}$	$W_{12}^{\{12\}}/\sqrt{2}$	$W_{12}^{\{123\}}/\sqrt{3}$	$W_{12}^{\{1234\}}/2$
	$u_{13}=[1\ -1\ 1\ -1]^T$	$W_{13}^{\{1\}}$	$W_{13}^{\{13\}}/\sqrt{2}$	$W_{13}^{\{123\}}/\sqrt{3}$	$W_{13}^{\{1324\}}/2$
	$u_{14}=[1\ 1\ -1\ -1]^T$	$W_{14}^{\{1\}}$	$W_{14}^{\{13\}}/\sqrt{2}$	$W_{14}^{\{123\}}/\sqrt{3}$	$W_{14}^{\{3214\}}/2$
	$u_{15}=[1\ 1\ 1\ 1]^T$	$W_{15}^{\{1\}}$	$W_{15}^{\{12\}}/\sqrt{2}$	$W_{15}^{\{123\}}/\sqrt{3}$	$W_{15}^{\{1234\}}/2$

Design of the precoding for four transmit antennas is based on the Householder transformation, to reduce the computational complexity at the UE as well as the design complexity for finding out suitable precoding matrices due to its structure. The UE receives the information from the base station on what precoding matrix is used, which is utilized by the UE for demodulating the data. The downlink reference signal is common for all UEs belonging to the cell and hence is not precoded by W. Each precoding matrix in a higher rank sub codebook, can find at least one precoding matrix in a lower rank sub codebook, which is a submatrix of the higher rank precoding matrix. For example, in Table-2 for the precoding matrix with codebook index 0 in M = 3 sub codebook, $W_o^{[124]}/\sqrt{3}$we can find a precoding matrix with codebook index 0 in M = 2 sub codebook, $W_o^{[12]}/\sqrt{2}$, which is a submatrix of $W_o^{[124]}/\sqrt{3}$. In SU- MIMO, all the spatial layers within allocated resource blocks are addressed to the same UE, hence this improves both UE peak data rates as well as cell capacity. [11]

2.3.MU-MIMO in LTE

Multiuser MIMO is supported in both the uplink and the downlink of the LTE. MU-MIMO forms when the base station can always schedule more than one UEs to transmit in the same time-frequency resource in the uplink. The enodeB needs to assign orthogonal reference signals to UE's, which are scheduled for MU-MIMO transmission, to correctly demodulate and differentiating of UEs by base stations.

The LTE system supports multi-user MIMO for the correlated channel conditions, with single layer transmission to a UE. The single-user MIMO codebooks for two and four antenna ports are reused for multi-user MIMO. The first release of the LTE system does not support single-user MIMO, spatial multiplexing in the uplink. However, multi-user MIMO operation where two UEs are scheduled on the same resource blocks in the same subframe is permitted. The multi-user MIMO operation in the uplink can improve the cell capacity but does not help to improve the UE peak data rates. [15]

3. ALAMOUTI'S STBC

Space Time Block Codes (STBC) is generalized versions of Alamouti scheme. These codes are orthogonal and can attain full transmit diversity specified by the number of transmitting antennas. In this coding the data are constructed as a matrix, which has its columns equal to the number of transmit antennas and its rows equal to the number of time slots required to transmit the data. [12]

At the receiver side, the signals which are received first combined and then sent to the maximum likelihood detector. Space time block codes were intended to achieve the maximum diversity order for the given number of transmit and receive antennas, subject to the constraint of having a simple linear decoding algorithm. Alamouti scheme is the source of the space time coding technique. Using two transmit antennas and one receive antenna scheme provides, the same diversity order as maximal ratio receiver combining with one transmit antenna and two receive antennas. At the transmitter side, a block of two symbols is taken from the source data and sent to the modulator. The alamouti space time encoder takes two symbols called S_1 and S_2 creates encoding matrix S. The encoding matrix is given by, [8]

$$S=\begin{bmatrix} S_1 & S_2 \\ -S_2* & S_1* \end{bmatrix}$$

The alamouti encoder and decoder schemes are shown in [13], the increment of the number of antennas of the alamouti scheme results space time block code.

3.1 Orthogonal Space Time Block Code

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 pick up the reliability of data-transfer. The systems with multiple antennas at both the transmitter and the receiver can have very large capacities. Several coding and modulation techniques have been projected to exploit this potential increase in the capacity of the multiple antenna systems. Among all the schemes, one scheme of particular interest is the orthogonal space-time block codes (OSTBCs), first presented for two transmit antennas, and generalized for an arbitrary number of transmit antennas. [9]

OSTBC is a significant technique which can give full diversity gain with a very simple decoding process. It is also revealed that OSTBCs are optimal in terms of the signal-to-noise ratio (SNR). OSTBCs can be applied to systems with an arbitrary number of transmit and receive antennas. Combined with the fact that OSTBCs provide a simple technique to upgrade current wireless systems to multiple antenna systems, while keeping a full diversity gain. They assure to be an alternative and attractive solution for future high data rate wireless communication systems. The pioneering work of Alamouti has been bases to generate OSTBC for more than two transmit antennas. OSTBC are vital subclass of linear STBC that guarantee that, the ML detection of different symbols $\{c_n\}$ is decoupled. The main drawback of OSTBC is for more than two transmit antennas and for complex valued signals OSTBC exist for code rates smaller than one symbol per time slot. In this paper we discuss four transmit and multiple receive antennas for different types of modulation schemes and observe the BER performance. An OSTBC is a linear time block code that has the following unitary property. [13]

$$c^H c = \sum_{j=1}^{N_t} |c_j|_2$$

The orthogonality enable us to achieve full transmit diversity allows a maximum likelihood decoding, decouple the signals transmitted from different antennas. For any arbitrary signal constellation there are OSTBC's that can achieve the rate of 1/2, transmitted via three transmitting antennas in eight time slots for any given transmitting antennas with code matrix c3 four complex symbols are taken at a time. The symbol rate for this constellation is 1/2, with the code matrix c4 four symbols are taken at a time and transmitted via four transmit antennas in eight time slot resulting in a transmission rate of 1/2.

The code matrices and complex generalized designs for OSTBC with rate 3/4 for three and four transmit antennas are shown in [10]. Obviously, some transmitted signal samples are scaled the linear combinations of the original symbols. For simulation purpose four transmit and variable receive antennas are consider, code matrix defined in above equation is used for simulation process. In OSTBC encoder and decoding technique first input symbols are modulated, in this simulation QPSK and 16 QAM modulation scheme are consider. Then modulated symbols are applied to OSTBC converter, the symbols are encoded in space and time. The four symbols are transmitted in eight time slot from four transmit antennas. Received symbol matrix for four transmit single received antennas shown in [13] at the receiver side combiner will combine the signals transmitted from four transmit antennas and receive at particular receive antennas. After this process ML decoder will decode the symbols ($C_1C_2C_3C_4$), demapping gives demodulated symbols that are information symbols and finally BER is calculated.

4. Simulation Results

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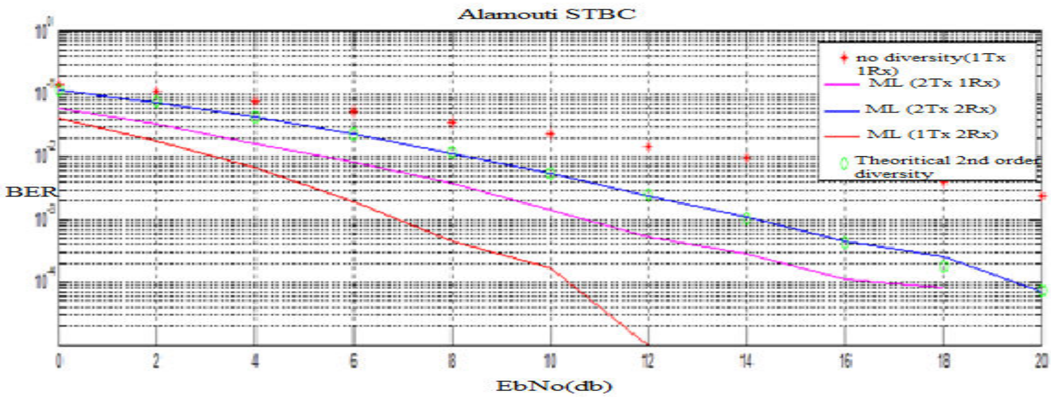

Figure-2. Alamouti STBC for 2nd order diversity.

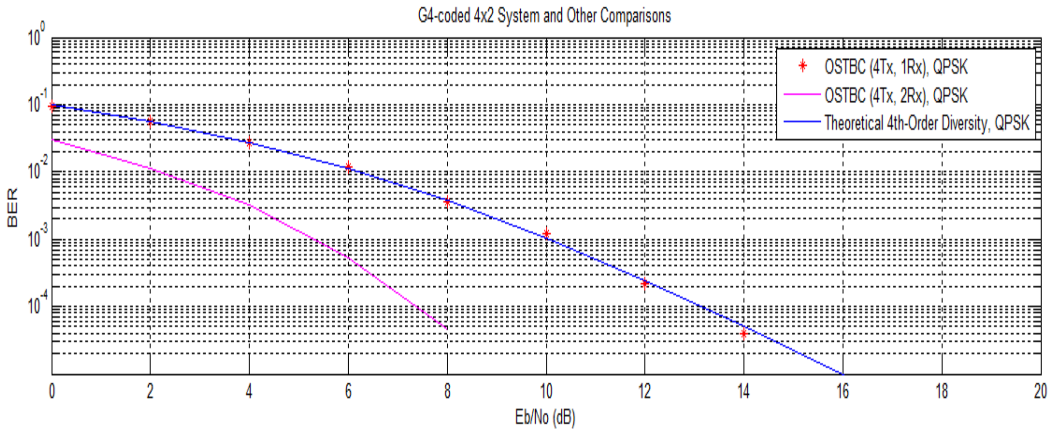

Figure-3. OSTBC for 4th order diversity.

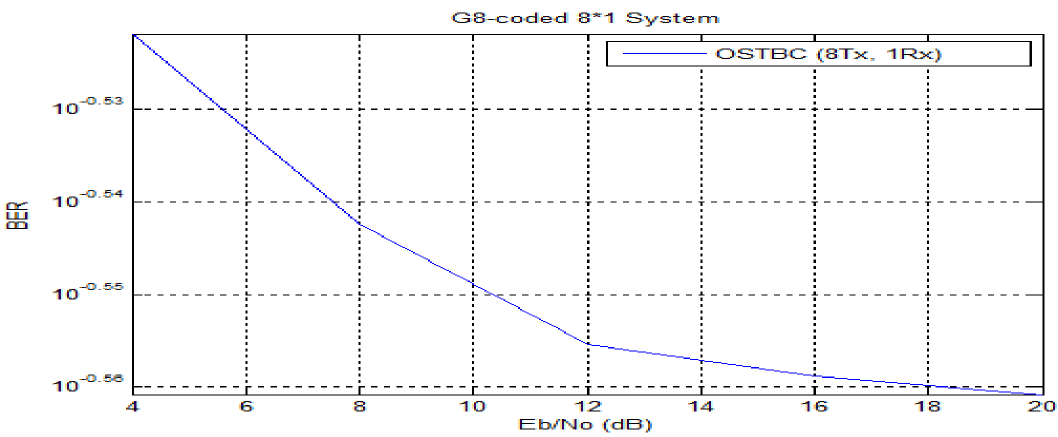

Figure-4. OSTBC for 8th order diversity.

Simulation results have been done using Mat lab for Rayleigh channel model. We described G2, G4, G8 for the case of N_r = 1, 2 and N_t = 2, 4, 8 using BPSK, QPSK mapping constellation. For each sample, blocks of 100 symbols are simulated; with this 10 bit errors are obtained. The simulation is automatically stopped when the Eb/No reached to 20dB. The Eb/No versus BER plotted for 1×2,2×1,2×2,4×1,4×2,8×1 MIMO configurations have been shown in figures 2,3,4. In this each transmitting antenna radiates half the energy in order to ensure the same total radiated power as with one transmitting. If each transmitting antenna was to radiate the same energy as the single transmitting antenna the performance should be identical. It is noted that when diversity order becoming double there is 3 db performance is achieved and this gain is independent of modulation. As the number of transmit antennas increases, the SNR and BER values are increased.

5. CONCLUSIONS

In this paper we have implemented the Alamouti's space–time block coding, a simple and elegant method for transmission using multiple transmit antennas in a wireless Rayleigh environment. We have also demonstrated the Orthogonal Space Time Block Coding for 4 and 8 transmit antennas, using simple maximum-likelihood decoding algorithm. The penalty of having more transmit antennas, which consequently reduces the energy per transmit antenna was observed. Simulation results have been shown clearly the performance of the MIMO using STBC. In the future we can develop MIMO system with OSTBC, for higher order transmit antennas using different modulation techniques and with Quasi orthogonal Space Time Block Codes (QOSTBC).

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