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# Novel LTE-A High Rate and Full Diversity Space Time Block Code for Two Transmit Antenna and Three Time Slot

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***Abstract**—In long term evaluation- advanced (LTE-A), there is odd time slot available for data transmission in space time block code wireless communication system. But, higher code rate space time block code offer better data rate in long term evaluation- advanced (LTE-A) where odd number of time slot is available for transmission. In this paper, two new higher code rate space time block code have been proposed for two transmit antenna and one receive antenna using three time slot. Proposed space time block code BER performance outperform over alamouti space time block code. It also outperform in terms of code rate as well. Simulation results show that all proposed schemes give better performance in higher signal to noise ratio for given modulation order. This schemes offer higher code rate i.e.1.33 than alamouti full rate (code rate-1) scheme. At lower signal to noise ratio, the BER performance of proposed- 1 space time block code scheme offers better response than proposed- 2 space time block code scheme. At higher signal to noise ratio, proposed-1 and proposed-2 space time block code schemes have better alamouti BER performance.*

***Keywords—Long term evaluation- advanced (LTE-A) Space Time Block Coding (STBC), Code rate, High rate, Full diversity, Two transmit antenna, Three time slot.***

## I. INTRODUCTION

[1] is a pioneer who brings out basic concept of full code rate and full diversity space time block code. [2] has given fundamental theory of space time block code based on orthogonal design for any number of transmit and receive antennas which offered full diversity, easy maximum likelihood detection and partial code rate. Due to code rate issue in orthogonal transmission, there were many quasi orthogonal space time block codes have been proposed [3]-[10]. These offer full code rate, linear maximum likelihood detection and partial diversity.

In recent times, long term evaluation- advanced (LTE-A) have provision of odd time slot for data transmission in next generation wireless communication system [4].

3rd generation partnership project (3GPP) standard committee finalized cellular system standard across the globe [4]-[6]. Though, there is extremely complex to utilize orthogonal space time block code in the frame structure of long term evaluation- advanced (LTE-A) due to odd transmission time slots available for data transmission. Due to this constraint, researchers are emphases on two transmit antenna and three time slot in space time block code. In recent times, couples of novel space time block codes have been proposed in literature.

Hybrid space time block code has been presented in [6] for two transmit antenna and three time slot. The constraint in this scheme is diversity. It has full code rate however not full diversity. So, full diversity as well as full rate has been presented in [7]. When modulation order increases its minimum determinant value (MDV) evaporate. This will take towards poor performance. In [8], group decodable space time block code (GSTBC) was presented with random code measurements, with use of odd number of time slots. It fulfilled the requirement of three time slot transmit diversity matter which was initiated by 3rd Generation Partnership Project (3GPP). In recent times [9], novel STBC has been presented which make use of two antennas and three time slots with given aspects i) full diversity and code rate one ii) three symbol joint maximum likelihood (ML) detection iii) With expansion of signal constellation minimum determinant value (MDV) does not evaporate iv) single antenna transmission compatible mode. In [10], it improves all drawbacks of [9] including BER performance but still code rate remain one. This focus to increase code rate more than one.

## II. SYSTEM MODEL

we have considered Multiple Input Single Output (MISO) system equipped with $N_t$ ,where $N_t = 2$, transmit antennas with quasi static rayleigh fading channel, where channel will be constant for a block length of $T$ symbols, where $T = 3$. The received symbol $\mathbf{y}$ is $T \times 1$ matrix and presented by [9],

$$\mathbf{y} = \sqrt{q}\mathbf{X}\mathbf{h} + \mathbf{n} \qquad (1)$$

Here, the normalization factor $q$ , where $q = \gamma / N_t$ , guarantees that SNR ( $\gamma$ ) per symbol at the receiver is not determined by the number of transmit antennas $N_t$. In (1), $\mathbf{X}$ is the $T \times N_t$ STBC, consisting of M-QAM constellation with average power of a symbol as $E_s$ , which is given in design procedure. $\mathbf{n}$ denotes $T \times 1$ matrix, whose all entries are independent and identically distributed (i.i.d.) as $CN \sim (0, N_0)$. The signal to noise ratio per symbol $\gamma$ can be represented as $E_s / N_0$. In (8.1), $\mathbf{h}$ represented as $N_t \times 1$ channel matrix.

$$\mathbf{h} = \begin{bmatrix} h_{1,1} \\ h_{1,2} \end{bmatrix} \qquad (2)$$

The individual entry of $\mathbf{h}$ are $CN \sim (0,1)$. i.e. complex gaussian random variable with mean zero and variance one. Where $h_{i,j}$ represent channel coefficient between $i^{th}$ receive antenna and $j^{th}$ transmit antenna.

## III. DESIGN PROCEDURE

In (Bell, 2009), space time block code for two transmit antenna and three time slot have been studied,

$$X_{al} = \begin{pmatrix} s_1 & s_2 \\ -s_2^* & s_1^* \\ s_3 & s_3 \end{pmatrix} \qquad (3)$$

It have been observed that above method makes use of alamouti scheme specifically in first and second time slot, but in third slot exactly same symbol have transmitted. Several other codes for two transmit antenna have been proposed. [3]-[10].

Now, proposed schemes make use of two transmit antenna pattern. It uses alamouti code in different way. Several alamouti code rearrangements have been demonstrated. Alamouti code for $s_1$ and $s_2$ have been presented as,

$$B_{12}^1 = \begin{pmatrix} s_1 & s_2 \\ -s_2^* & s_1^* \end{pmatrix}$$

$$B_{12}^2 = \begin{pmatrix} s_1^* & s_2 \\ -s_2^* & s_1 \end{pmatrix}$$

$$B_{12}^3 = \begin{pmatrix} s_1 & s_2^* \\ -s_2 & s_1^* \end{pmatrix}$$

$$B_{12}^4 = \begin{pmatrix} s_1^* & s_2^* \\ -s_2 & s_1 \end{pmatrix}$$

Likewise, $B_{32}^{m}, m = 1,2,3,4$ stand for alamouti code for $s_3$ and $s_2$

$$B_{32}^{1} = \begin{pmatrix} s_3 & s_2 \\ -s_2^* & s_3^* \end{pmatrix}$$

$$B_{32}^{2} = \begin{pmatrix} s_3^* & s_2 \\ -s_2^* & s_3 \end{pmatrix}$$

$$B_{32}^{3} = \begin{pmatrix} s_3 & s_2^* \\ -s_2 & s_3^* \end{pmatrix}$$

$$B_{32}^{4} = \begin{pmatrix} s_3^* & s_2^* \\ -s_2 & s_3 \end{pmatrix}$$

Likewise, $B_{34}^{m}, m = 1,2,3,4$ stand for alamouti code for $s_3$ and $s_4$,

$$B_{34}^{1} = \begin{pmatrix} s_3 & s_4 \\ -s_4^* & s_3^* \end{pmatrix}$$

$$B_{34}^{2} = \begin{pmatrix} s_3^* & s_4 \\ -s_4^* & s_3 \end{pmatrix}$$

$$B_{34}^{3} = \begin{pmatrix} s_3 & s_4^* \\ -s_4 & s_3^* \end{pmatrix}$$

$$B_{34}^{4} = \begin{pmatrix} s_3^* & s_4^* \\ -s_4 & s_3 \end{pmatrix}.$$

Likewise, $B_{45}^{m}, m = 1,2,3,4$ stand for alamouti code for $s_4$ and $s_5$,

$$B_{45}^{1} = \begin{pmatrix} s_4 & s_5 \\ -s_5^* & s_4^* \end{pmatrix}$$

$$B_{45}^{2} = \begin{pmatrix} s_4^* & s_5 \\ -s_5^* & s_4 \end{pmatrix}$$

$$B_{45}^{3} = \begin{pmatrix} s_4 & s_5^* \\ -s_5 & s_4^* \end{pmatrix}$$

$$B_{45}^{4} = \begin{pmatrix} s_4^* & s_5^* \\ -s_5 & s_4 \end{pmatrix}.$$

Likewise, $B_{56}^{m}, m = 1,2,3,4$ stand for alamouti code for $s_5$ and $s_6$,

$$B_{56}^{1} = \begin{pmatrix} s_5 & s_6 \\ -s_6^* & s_5^* \end{pmatrix}$$

$$B_{56}^{2} = \begin{pmatrix} s_5^* & s_6 \\ -s_6^* & s_5 \end{pmatrix}$$

$$B_{56}^{3} = \begin{pmatrix} s_5 & s_6^* \\ -s_6 & s_5^* \end{pmatrix}$$

$$B_{56}^{4} = \begin{pmatrix} s_5^* & s_6^* \\ -s_6 & s_5 \end{pmatrix}.$$

and $B_{61}^{m}, m = 1,2,3,4$ stand for alamouti code for $s_6$ and $s_1$,

$$B_{61}^{1} = \begin{pmatrix} s_6 & s_1 \\ -s_1^* & s_6^* \end{pmatrix}$$

$$B_{61}^{2} = \begin{pmatrix} s_6^* & s_1 \\ -s_1^* & s_6 \end{pmatrix}$$

$$B_{61}^{3} = \begin{pmatrix} s_6 & s_1^* \\ -s_1 & s_6^* \end{pmatrix}$$

$$B_{61}^{4} = \begin{pmatrix} s_6^* & s_1^* \\ -s_1 & s_6 \end{pmatrix}$$

A. Proposed design- I

Proposed design- I have been commencing from $B_{12}^{1}, B_{32}^{1}, B_{41}^{2}$ and $B_{34}^{3}$.

$$Q_1 = \begin{pmatrix} B_{12}^{1}(1,2) & B_{12}^{1}(2,1) + B_{32}^{1}(1,1) + B_{34}^{3}(1,2) \\ B_{12}^{1}(2,2) & B_{12}^{1}(2,2) + B_{34}^{3}(1,2) + B_{32}^{3}(2,2) \\ B_{32}^{1}(2,2) & B_{34}^{3}(1,2) + B_{41}^{2}(2,1) + B_{12}^{1}(2,1) \end{pmatrix} \quad (4)$$

$$Q_1 = \begin{pmatrix} s_1 & (-s_2^* + s_3 + s_4^*)/\sqrt{2} \\ s_2 & (s_1^* + s_4^* + s_3^*)/\sqrt{2} \\ s_3 & (s_4^* - s_1^* - s_2^*)/\sqrt{2} \end{pmatrix} \quad (5)$$

The above said matrices can be generalized as,

$$D_Q = \begin{pmatrix} \xi & 0 \\ 0 & \xi + \psi_n \end{pmatrix} \quad (6)$$

In which $\xi$ and $\psi_n, n = 1$ expressed as,

$$\xi = \sum_{x=1}^{K} |s_x|^2 \quad (7)$$

$$\psi_1 = 2\Re(-s_2 s_3^* s_4 - s_1^* s_4 s_3 + s_4^* s_1 s_2) \quad (8)$$

Where every $\psi_n, n = 1$ belongs to corresponding space time block code, $Q_i, i = 1$. Matrix is quasi orthogonal in which interference term $\psi_n, n = 1$ in code matrices $C_Q$.

Some additional space time block codes can be also obtained with diverse interference values.

B. *Proposed design- II*

Proposed design- II have been commencing from $B_{12}^{1}, B_{32}^{1}, B_{41}^{2}$ and $B_{34}^{3}$.

$$Q_2 = \begin{pmatrix} B_{12}^{1}(1,1) - B_{12}^{1}(1,2) - B_{32}^{1}(1,1) & B_{12}^{1}(2,2) - B_{32}^{1}(2,1) + B_{32}^{1}(2,2) \\ B_{12}^{1}(1,2) - B_{32}^{1}(1,1) - B_{41}^{2}(2,2) & -B_{32}^{1}(2,1) - B_{32}^{1}(2,2) - B_{34}^{3}(1,2) \\ B_{32}^{1}(1,1) + B_{41}^{2}(2,2) - B_{12}^{1}(1,1) & B_{32}^{1}(2,2) + B_{34}^{3}(1,2) + B_{12}^{1}(2,2) \end{pmatrix} \quad (9)$$

$$Q_2 = \begin{pmatrix} s_1 - s_2 - s_3 & s_1^* + s_2^* + s_3^* \\ s_2 + s_3 + s_4 & s_2^* - s_3^* - s_4^* \\ s_3 + s_4 - s_1 & s_3^* + s_4^* + s_1^* \end{pmatrix} \quad (10)$$

 

## IV. DETECTION PROCEDURE

We assume that channel matrix $\mathbf{h}$ is perfectly known at the receiver and is quasi-static at least for a period of one code symbol.

The decoding of the LTE-A full rate full diversity STBC scheme is to be done with the maximum likelihood (ML) criteria.

At the receiver, we use maximum likelihood decoding (MLD) as [9]

$$\left\|\mathbf{y}-\mathbf{hX}\right\|^2 \qquad (11)$$

## V. SIMULATION RESULTS AND DISCUSSION

In this section, we simulate bit error rate versus average signal to noise ratio performance using QPSK and BPSK modulation for three new proposed space time block code with two transmitter and one receiver using three time slots. The average SNR is to be denoted as in dB.

Figure 1 shows BER versus SNR for proposed- I space time block code with two transmit antenna and one receive antenna in three time slots under BPSK, QPSK modulation technique, quasi static rayleigh fading channel.

It can be observed that proposed-I scheme gives better performance in higher signal to noise ratio for given modulation order. This scheme offer higher code rate i.e.1.33 than alamouti full rate (code rate-1) scheme.

Table 1 shows minimum signal to noise ratio required for bit error rate in concern with audio and video application i.e. and BER. Table 1 shows 11dB SNR require for BPSK modulation and 14dB SNR require for QPSK modulation using proposed-1 space time block code scheme for audio application. It also shows 20dB SNR require for BPSK modulation and 23.5dB SNR require for QPSK modulation using proposed-I space time block code scheme for video application.

Figure 2 shows BER versus SNR for proposed- II space time block code with two transmit antenna and one receive antenna in three time slots under BPSK, QPSK modulation technique, quasi static rayleigh fading channel.
It can be observed that proposed-II scheme gives better performance in higher signal to noise ratio for given modulation order. This scheme offer higher code rate i.e.1.33 than alamouti full rate (code rate-1) scheme and similar compare proposed-I scheme

Table 2 shows minimum signal to noise ratio required for bit error rate in concern with audio and video application i.e. and BER. Table 2 shows 11dB SNR require for BPSK modulation and 13.3dB SNR require for QPSK modulation using proposed -I space time block code scheme for audio application. It also shows 20dB SNR require for BPSK modulation and 23.4dB SNR require for QPSK modulation using proposed -II space time block code scheme for video application.

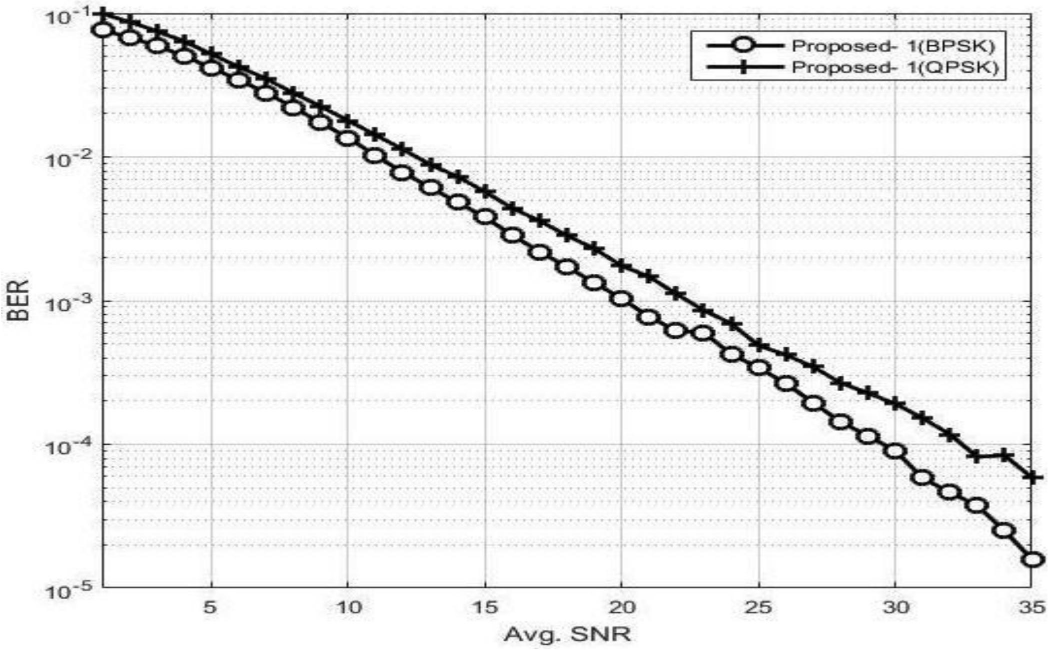


Fig. 1 BER Vs. SNR for proposed-I space time block code with two transmit antenna and one receive antenna in three time slots under BPSK and QPSK, Rayleigh fading channel

TABLE I
LOWEST ESTIMATED SNR FOR PROPOSED-I TWO TRANSMIT ANTENNA AND ONE RECEIVE ANTENNA IN THREE TIME SLOTS-AUDIO AND VIDEO APPLICATION

| Modulation Technique | Audio application (Minimum required BER $10^{-2}$ ) | Video application(Minimum required BER $10^{-3}$ ) |
|---|---|---|
| BPSK | 11dB | 20dB |
| QPSK | 14dB | 23.5dB |

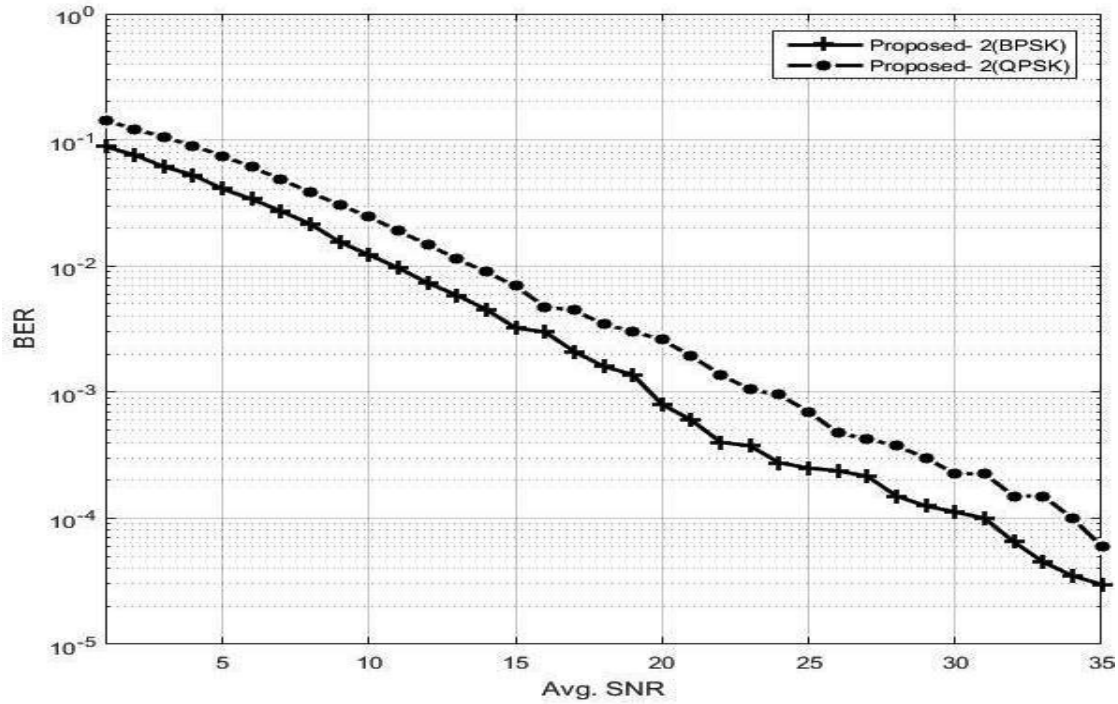


FIG. 2 BER VS. SNR FOR PROPOSED-II SPACE TIME BLOCK CODE WITH TWO TRANSMIT ANTENNA AND ONE RECEIVE ANTENNA IN THREE TIME SLOTS UNDER BPSK AND QPSK, RAYLEIGH FADING CHANNEL

TABLE III
LOWEST ESTIMATED SNR FOR PROPOSED-II TWO TRANSMIT ANTENNA AND ONE RECEIVE ANTENNA IN THREE TIME SLOTS-AUDIO AND VIDEO APPLICATION

| Modulation Technique | Audio application (Minimum required BER $10^{-2}$ ) | Video application(Minimum required BER $10^{-3}$ ) |
|---|---|---|
| BPSK | 11dB | 20dB |
| QPSK | 13.3dB | 23.4dB |

## VI. CONCLUSIONS

Higher code rate space time block code offer better data rate in long term evaluation- advanced (LTE-A) where odd number of time slot is available for transmission. So, proposed space time block code BER performance outperform over alamouti space time block code. It also outperform in terms of code rate as well. It can be observed that all proposed schemes give better performance in higher signal to noise ratio for given modulation order. This schemes offer higher code rate i.e.1.33 than alamouti full rate (code rate-1) scheme. At lower signal to noise ratio, the BER performance of proposed- I space time block code scheme offers better response than proposed- II space time block code schemes.

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