Performance of LTE-A Full Rate and Full Diversity STBC under Real Scattered Environment

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Abstract

Objectives/Background: In Long Term Evaluation- Advance (LTE-A), there are different specialized elements accessible like odd time slots transmission, use of adaptive modulation etc. Notwithstanding, the BER performance analysis is required in genuine scattered environment like spatially correlated antennas at transmitter side and blemished channel state information accessible at the receiver (CSIR) for adaptive modulation. **Method/Statistical Analysis**:We are exhibiting Bit Error Rate (BER) performance of LTE-A full rate full diversity STBC under quasi-static fading channels with real practical assumption of spatially correlated antennas at transmitter side and blemished channel state information accessible at the receiver (CSIR). The spatial correlation between two antennas is supposed to be $0 < \eta < 1$, where η is spatial correlation among two transmit antennas and imperfectness of channel state information available at receiver are supposed to be $0 < \rho < 1$, where ρ the imperfection coefficient between actual channel and CSIR. **Findings**: It can be seen that at higher SNR channel state data accessible at receiver are more critical than transmit antenna correlation at transmitter.But at lower SNR up to 10dB, the impact of transmit antenna correlation at transmitter and channel state information at receiver is not assuming important part in the BER performance. **Applications**: This result analysis is useful for adaptive modulation in LTE-A full rate full diversity STBC where modulation orders have been change.

Keywords: Full Rate, imperfect channel state information available at the receiver (CSIR), Space Long term evaluationadvance (LTE-A), Spatially Correlated Antennas, Time Block Codes (STBC)

1. Introduction

Multiple Input Multiple Output (MIMO) systems turns out to be extremely famous in wireless standards such as Wireless Local Area Networks (WLAN), Long Term Evolution (LTE), Digital Video Broadcasting (DVB), Long Term Evolution- advance (LTE-A) and Worldwide Interoperability for Microwave Access (WiMAX). We can accomplish high diversity gain or multiplexing gain utilizing MIMO systems. Performance of MIMO systems have been investigated and well documented in literature.

The transmission scheme, space time coding (STC) is widely known in MIMO systems. The leading benefit

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of STC is less complexity, as the transmit diversity gain can be exploited without having CSI at the transmitter; for a case alamouti transmit diversity scheme¹⁻³ with two transmit antenna is orthogonal space time block code (OSTBC). It offers diversity gain of two and code rate of one. Though, schemes available for more than two transmit antenna can be composed which can give full diversity gain but not full code rate. It implies that the code rate is short of what one. In addition, alamouti STBC utilizes two or even time slots for transmission. In some wireless standards, for example LTE-Advanced, the choice is available in the frame structure to utilize three time slots for transmission of a STBC⁴.For this situation, generalized STBC can be utilized, which use three times slots yet code-rate is reduced⁴.

Recently, couple of novel STBC have been proposed in literature, which utilize more than two time slots without lessening code rate⁵⁻⁹. H (hybrid)-STBC has been proposed for even timeslot of three and two transmit antenna for transmission⁵. This scheme have full rate but not full diversity. For full diversity, QOSTBC code has been proposed in⁶. However, because of joint detection of two symbols, if there is an occurrence of higher order modulations, the Minimum Determinant Value (MDV) vigorously vanishes. This leads to poor performance. Thus, fast group decodable (GSTBC) scheme has been proposed in². This GSTBC provides full diversity and code rate. In⁸, GSTBC was proposed with arbitrary code measurements, including odd time slot. It filled in as an answer to the three-time-slot transmit diversity issue brought up in 3rd Generation Partnership Project (3GPP). Be that as it may, MDV vanishes in this GSTBC additionally for higher order modulation schemes. Recently in², new STBC has been proposed utilizing two antennas and three time slots with following facets i) Rate and diversity are full ii) Joint detection of three symbol using maximum likelihood (ML) iii) By expanding signal constellation MDV does not vanish iv) compatible with single antenna transmission mode. This STBC² has expected a quasi-static channel and perfect channel state information (CSI) accessible at the receiver (also called as CSIR). However, in a present situation of time varying channel ¹⁰⁻¹³, it is extremely hard to assume zero spatial correlation between two transmit antenna and present perfect CSIR because of limited on board resources accessible at the mobile terminal for reception. Thus, the real practical situation i.e. spatial correlation between two transmit antenna and imperfect CSIR at receive antenna have been assumed. For this situation, performance of LTE-Advance full rate and diversity STBC with spatial correlation at transmitter side and imperfect channel state information available at receiver is of importance.

This paper exploit LTE-A STBC framework², equipped with two transmit antennas and one receive antenna with quasi-static Rayleigh fading channel assuming spatially correlated antennas at transmitter side and imperfect channel state information available at the receiver (CSIR). The spatial correlations between two antennas are assumed to be $0 < \eta < 1$, where η is spatial

correlation between two transmit antennas and imperfection in CSIR are assumed to be $0 < \rho < 1$, where ρ the imperfection coefficient between actual channel and CSIR. Here $\rho = 1, 0$ and $\eta = 0, 1$ are corresponding to perfect CSIR, no CSIR and no correlation, full correlation respectively. The BER versus SNR performance is shown for different values of ρ, η for M-QAM constellation. It is observed that the error floor exists in the performance when $\rho \neq 1$. However, the error floor occurs at high SNR for less imperfectness in CSIR, i.e. high correlation ρ . The paper is composed as follows. Section II portrays the system model and in Section III, we present decoding with spatial correlation at transmitter end and imperfect CSI at receiver end. Sections IV and V deal with results and conclusion respectively.

2. System Model

In this article, 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 **y** is $T \times 1$ matrix and presented by²,

$$\mathbf{y} = \sqrt{q} \, \mathbf{X} \mathbf{h} + \mathbf{n} \tag{1}$$

Here, the normalization factor q, where $q = \gamma / N_t$, guarantees that SNR (γ) per symbol at the receiver is not determined by the number of transmit antennas N_t . In (1), **X** is the $T \times N_t$ STBC, consisting of M-QAM constellation with average power of a symbol as E_s , which is denoted as²

$$\mathbf{X} = \begin{pmatrix} x_1 & x_2 & x_3 \\ -x_2^* - x_3^* & x_1^* - x_3^* & x_1^* + x_2^* \end{pmatrix}^T$$
(2)

It shows that from first antenna, three symbols x_1 , x_2 and x_3 is transmitted at three different time instants, whereas from the second antenna, combinations of two symbols from the three symbols are transmitted as shown in (6). Due to transmission of two symbols at one instant, the power per symbol from the second antenna is half.

In (1), **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 γ can be represented as E_s / N_0 . In (1), **h** represented as $N_t \times 1$ channel matrix.

$$\mathbf{h} = \begin{bmatrix} h_{1,1} \\ h_{1,2} \end{bmatrix}$$
(3)

The individual entry of **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.

We assume that all the channel coefficients in **h** are spatially correlated, which are generated with known correlation using the following steps¹².

1, Stacking all the entries in one column, we can express

$$vector(\mathbf{h}) = \begin{bmatrix} h_{1,1} \\ h_{1,2} \end{bmatrix}$$
(4)

2. The transmit correlation matrix and receive correlation matrix can be denoted as $\boldsymbol{\vartheta}_{t}$ and $\boldsymbol{\vartheta}_{r}$ respectively,

$$\boldsymbol{\Theta}_{t} = \begin{bmatrix} E[h_{1,1}h_{1,1}^{*}] & E[h_{1,1}h_{1,2}^{*}] \\ E[h_{1,2}h_{1,1}^{*}] & E[h_{1,2}h_{1,2}^{*}] \end{bmatrix}$$
(5)

$$\boldsymbol{\vartheta}_{\mathbf{r}} = \left[\mathbf{E}[\mathbf{h}_{1,1} \mathbf{h}_{1,1}^{*}] \right].$$
 (6)

Here, d_t and represents spaces between two successive antennas at the transmitter and receiver respectively, while $J_0(x)$ is the zeroth order Bessel function of first kind. For higher values of d_t or d_r , spatial correlation will reduce and vice a versa.

3. Channel correlation matrix **R** can be expressed as

$$\mathbf{R} = \boldsymbol{\vartheta}_{t} \otimes \boldsymbol{\vartheta}_{r} \tag{7}$$

where \otimes denotes kronecker product.

4. Using Eigen Value Decomposition (EVD), we can write

$$\mathbf{R} = \mathbf{V}\mathbf{D}\mathbf{V}^* \tag{8}$$

where **V** is a unitary matrix and **D** is diagonal matrix for eigenvalues. The $()^*$ denotes transpose and conjugate.

- 5. Generate vector **r** of order 1×2, where each entry in **r** is independent and identically distributed as complex gaussian with mean zero and variance one.
- 6. Now vector (\mathbf{h}) can be expressed as

$$vector(\mathbf{h}) = \mathbf{V}\mathbf{D}^{1/2}\mathbf{r}$$
(9)

Now, from *vector* (\mathbf{h}) , we can get \mathbf{h} as defined in (4) and (5).

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.

3. Decoding

To represent the decoding of the LTE-A full rate full diversity STBC scheme with the maximum likelihood (ML) criteria.

At the receiver, we use maximum likelihood decoding (MLD) as 2

$$\left\|\mathbf{y} - \hat{\mathbf{h}} \mathbf{X}\right\|^2 \tag{3}$$

Where \mathbf{h} is the blemished CSI available at the receiver, which can be shown as

$$\mathbf{h} = \rho \, \hat{\mathbf{h}} + \sqrt{1 - \rho^2} \, \delta. \tag{4}$$

Here, δ is a matrix of $N_t \times 1$, wherein all the entries are complex normal with mean zero and variance one.

The parameter ρ characterizes the partial CSI since $\rho = 0$ corresponds to no CSI knowledge and $\rho = 1$ corresponds to perfect channel knowledge and values of $0 < \rho < 1$ account for partial CSI.

4. Results and Discussions

In this section, we present BER versus SNR performance with simulations for the considered system using 4-QAM, 8-QAM modulation for different values of ρ , η . The average SNR is to be denoted as E_s / N_0 in dB. Figure 1 to 7 shows BER versus SNR for various values of ρ , η such as for 1, 0.999, 0.998, 0.997, 0.996 and 0, 0.7, 0.9 respectively.



Figure 1. BER Vs. SNR for $\eta = 0$, $\eta = 0.7$, $\eta = 0.9$ with $\rho = 1$ and $\rho = 0.999$ under 4-QAM.

Figure 1 shows the performance of BER vs. SNR for various values of $\eta = 0$, $\eta = 0.7$, $\eta = 0.9$ with $\rho = 1$ and $\rho = 0.999$ under 4-QAM scheme. It can be observed that the performance of $\eta = 0.9$, $\rho = 1$ beats $\eta = 0.7$, $\rho = 0.999$ at SNR of 23dB onwards and $\eta = 0.7$, $\rho = 1$ beat $\eta = 0$, $\rho = 0.999$ at SNR of 23.5dB onwards.

Figure 2 shows the performance of BER vs. SNR for various values of $\eta = 0$, $\eta = 0.7$, $\eta = 0.9$ with $\rho = 1$ and $\rho = 0.998$ under 4-QAM scheme. It can be interpreted that the performance of $\eta = 0.7$, $\rho = 1$ beat $\eta = 0$, $\rho = 0.998$ at SNR of 21dB onwards and $\eta = 0.9$, $\rho = 1$ beat $\eta = 0.7$, $\rho = 0.998$ at SNR of 20.5dB onwards.



Figure 2. BER Vs. SNR for $\eta = 0$, $\eta = 0.7$, $\eta = 0.9$ with $\rho = 1$ and = 0.998 under 4-QAM.

Figure 3 provides the performance of BER vs. SNR for different values of $\eta = 0$, $\eta = 0.7$, $\eta = 0.9$ with $\rho = 1$ and ρ =0.997 under 4-QAM scheme. It shows that the performance of $\eta = 0.7$, $\rho = 1$ beats $\eta = 0$, $\rho = 0.997$ at SNR of 18dB onwards and $\eta = 0.9$, $\rho = 1$ beats $\eta = 0$, $\rho = 0.997$ at SNR of 22dB onwards.



Figure 3. BER Vs. SNR for $\eta = 0$, $\eta = 0.7$, $\eta = 0.9$ with $\rho = 1$ and $\rho = 0.997$ under 4-QAM.



Figure 4. BER Vs. SNR for $\eta = 0$, $\eta = 0.7$, $\eta = 0.9$ with $\rho = 1$ and $\rho = 0.996$ under 4-QAM.

Figure 4 shows the performance of BER vs. SNR for various values of $\eta = 0$, $\eta = 0.7$, $\eta = 0.9$ with $\rho = 1$ and $\rho = 0.996$ under 4-QAM scheme. It can be observed that the performance of $\eta = 0.9$, $\rho = 1$ beats $\eta = 0$, $\rho = 0.996$ at SNR of 17dB onwards.

Figure 5 shows the performance of BER vs. SNR for varied values of $\eta = 0$, $\eta = 0.7$, $\eta = 0.9$ with $\rho = 1$ and $\rho = 0.999$ under 8-QAM scheme. It can be observed that the performance of $\eta = 0.9$, $\rho = 1$ beat $\eta = 0$, $\rho = 0.999$ at SNR of 23dB onwards.



Figure 5. BER Vs. SNR for $\eta = 0$, $\eta = 0.7$, $\eta = 0.9$ with $\rho = 1$ and $\rho = 0.999$ under 8-QAM.



Figure 6. BER Vs. SNR for $\eta = 0$, $\eta = 0.7$, $\eta = 0.9$ with $\rho = 1$ and $\rho = 0.998$ under 8-QAM.

Figure 6 presents the performance of BER vs. SNR for varied values of $\eta = 0$, $\eta = 0.7$, $\eta = 0.9$ with $\rho = 1$ and $\rho = 0.998$ under 8-QAM scheme. It can be interpreted from the figure that the performance of $\eta = 0.9$, $\rho = 1$ beat $\eta = 0$, $\rho = 0.998$ at SNR of 20dB onwards.



Figure 7. BER Vs. SNR for $\eta = 0$, $\eta = 0.7$, $\eta = 0.9$ with $\rho = 1$ and $\rho = 0.997$ under 8-QAM.

Figure 7 shows the performance of BER vs. SNR for varied values of η =0, η =0.7, η =0.9 with ρ = 1 and ρ =0.997 under 8-QAM scheme. It can be analyzed from the figure that the performance of η =0.9, ρ =1 beat =0, ρ =0.997 at SNR of 17dB onwards.

After analyzing all the results obtained above we can interpret that at higher SNR channel state information available at receiver are more important than transmit antenna correlation at transmitter. But, at lower SNR up to 10dB the effect of transmit antenna correlation at transmitter and channel state information at receiver have not played important role in the BER performance.

5. Conclusion

It can be perceived that at higher SNR, channel state information available at receiver is more important than transmit antenna correlation at transmitter. But at lower SNR up to 10dB, the effect of transmit antenna correlation at transmitter and channel state information at receiver is not playing important role in the BER performance. The applications of above result analysis are used for adaptive modulation in LTE-Advance full rate full diversity STBC.

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