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Performance Analysis for a Alamouti's STBC Encoded MRC Wireless Communication System over Rayleigh Fading Channel

Srabanty Ahmed Shaon[*], Sazzad Ferdous[**]

[*] Lecturer,ADUST
[**] B.Sc in E.E.E.,AUST

Abstract- This paper investigates the effect of antenna diversity for a double transmit and multiple receive antenna supported wireless communication system that employs single user Alamouti's space time block coding (STBC) and maximal ratio combining (MRC) scheme on secured text message transmission. The FEC encoded Alamouti-MRC transmission system under investigation implements RSA cryptographic algorithm and deploys various multi-level digital modulations (16- PSK, 16-DPSK and 16-QAM) techniques over an Additive White Gaussian Noise (AWGN) and Rayleigh Fading Channels. It has been observed from the study that in case of without receive antenna diversity the system shows comparatively worst performance in 16-DPSK scheme and satisfactory performance in 16-QAM. It is noticeable that the system performance is improved with increase in number of receive antenna. The performance analysis shows that with implemented Alamouti-MRC scheme (4 receive antenna) under 16-QAM digital modulation, the system provides excellent performance over a significant low signal to noise ratio(SNR) values.

Index Terms- Antenna Diversity, AWGN Channel, Bit Error Rate, MRC, Rayleigh Fading, STBC.

I. Introduction

Communication systems using multiple antennas at the transmitter and/or the receiver have recently received increased attention due to their ability to provide substantial capacity improvements while achieving low error rate and/or high data rate by flexibly exploiting the attainable diversity gain and/or the spatial multiplexing gain (Zhang et. al., 2011). Recently much attention has been paid on transmit diversity as an efficient technique to combat fading and simplify the implementation of mobile terminals (Zhu et. al., 2011). Several methods in transmit diversity are proposed in (Zhu et. al., 2011, Alamouti 1998, Wang and Wang 2004, Derryberry et. al.,2002). Among them, Alamouti space-time block coding (STBC) (Alamouti 1998) is very simple and attractive due to its advantages of not requiring feedback of channel state information and easy implementation. So far, studies on Alamouti space-time transmit diversity (STTD) have mainly assumed binary phase shift keying (BPSK) or quadrature phase shift keying (QPSK) modulation (Alamouti 1998, Wang and Wang 2004, Derryberry et. al., 2002, Gu and Leung2003). Although analytical studies have been presented for BPSK-modulated STTD systems with imperfect pilot symbol channel estimation (Gu and Leung2003). Since wireless communications is challenged by limited spectral resources, multi-user spatial multiplexing has recently received considerable attention. Multi-user MIMO systems can significantly improve system throughput via transceiver signal processing if the number of transmit antennas is much larger than the number of receive antennas (Choi et. al., 2004). Alamouti STTD has been analyzed analytically for multi-level quadrature amplitude modulation (M-QAM), which has become very attractive for wireless communications due to its high spectral efficiency, (Zhu et. al., 2011). An analytical expression for the BER of 16/64-QAM without STTD in Rayleigh fading with imperfect pilot symbol-assisted channel estimation was in (Tang et. al., 1999). However, the integration operation in the analytical formula requires heavy computation load, and thus it is impractical to extend to STTD systems. An effective approach to evaluate QAM performance analytically using the characteristic function was proposed in (Xia and Wang 2005).

We shall consider the case of the simple Alamouti's space-time block code as it is the only scheme which can provide full rate and full diversity for any signal constellations. Network security measures are provided using RSA algorithm to protect data during their transmission in the proposed scheme. Therefore, this paper focuses on the evaluation of the BER performance for the FEC encoded secured Alamouti-MRC transmission system for various multi-level digital modulations (16-PSK, 16-DPSK, 16-QAM) techniques over an Additive White Gaussian Noise (AWGN) and Rayleigh Fading Channel with the transmit diversity technique in conjunction with receive antenna diversity. The paper is organized as follows. Section 2 presents the system description, including the transmitter, channel, and coherent receiver models. Performance analysis is presented in Section 3. Finally, conclusions are drawn in Section 4.

II. COMMUNICATION SYSTEM MODEL

The MIMO wireless communication system under consideration is shown in Figure 1. In such a communication system, a single user is transmitting the secured text messages. For secret message transmission the most widely used public-key cryptosystem RSA is used here. After encryption of plaintext the ciphertext is converted into binary messages. The transmitted bits are channel encoded by a convolutional encoder of rate r = 1/2, interleaved for minimization of burst errors and then converted to M-ary signal. This M-ary signal is modulated using various types of multi level digital modulation techniques such as quadrature amplitude modulation (QAM), phase shift keying (PSK) and differentially phase shift keying (DPSK). The modulated digital signals are fed into the Alamouti Space Time Block Encoder, where the input stream is first segmented into two -symbol blocks. Each two-symbol block includes the first and second symbols *x1* and *x2*, respectively. During the first symbol period, the encoder will send $x1$ and $x2$ to the first and second transmit antennas, respectively. During the next symbol period x^*_1 and $-x^*_2$,where where * denotes complex conjugate, will be sent to the first and second transmit antennas respectively.

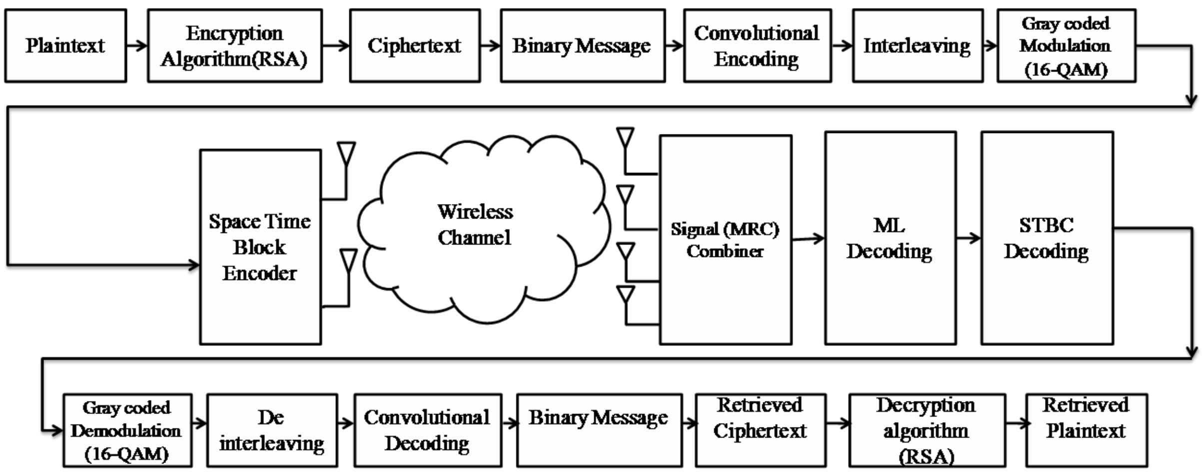

Fig1. Block diagram of FEC encoded Multi user MIMO STBC secured wireless communication system.

These two transmit antennas can either be collocated or distributed remotely if proper symbol timing synchronization scheme is adopted. Now the space-time encoded streams are sent to the wireless channels through the two transmit antennas. Assuming r^j_1 and r^j_2 are the received signals at the *jth* receive antenna at time *t* and *t + T*, respectively, then r^j_1 and r^j_2 are given by (Zhu et. al., 2011, Khan 2005, Mart´ınez et. al., 2011).

$$r^j_1 = h_{j1}x_1 + h_{j2}x_2 + n^j_1$$

$$r^j_1 = -h_{j1}x^*_2 + h_{j2}x^*_1 + n^j_2 \qquad (1)$$

where *hji*, i=1,2, j=1,2,……NR, is the fading coefficient for the path from transmit antenna *i* to receive antenna *j,j j* and *n1* and *n2* are the noise signals for receive antenna *j* at time *t* and *t + T*, respectively.

The receiver constructs two decision statistics based on the linear combination of the received signal. The decision statistics are given by

$$\tilde{x}_1 = \sum_{i=1}^{2}\sum_{j=1}^{NR} |h_{ji}|^2 x_1 + \sum_{j=1}^{NR} h_{ji}^{*} n_1^j + h_{j2}(n_2^j)^*$$
$$\tilde{x}_2 = \sum_{i=1}^{2}\sum_{j=1}^{NR} |h_{ji}|^2 x_2 + \sum_{j=1}^{NR} h_{j2}^{*} n_1^j - h_{j1}(n_2^j)^* \qquad (2)$$

The maximum likelihood decoding rules for the two independent signals x1 and x2 are then

$$\hat{x}_1 = \arg\min_{\hat{x}_1 \in S} [(\sum_{j=1}^{NR} (|h_{j1}|^2 + |h_{j2}|^2) - 1)^2 |\hat{x}_1|^2 + d^2(\tilde{x}_1, \tilde{x}_2)]$$
$$\hat{x}_2 = \arg\min_{\hat{x}_2 \in S} [(\sum_{j=1}^{NR} (|h_{j1}|^2 + |h_{j2}|^2) - 1)^2 |\hat{x}_2|^2 + d^2(\tilde{x}_1, \tilde{x}_2)] \qquad (3)$$

where $d2(x, y) = (x - y)(x^* - y^*) = |x - y|2$

The complex symbols are now digitally demodulated, de interleaved, convolutionally decoded and decrypted to recover the transmitted data.

III. PERFORMANCE ANALYSIS

The computer simulation has been conducted to evaluate the BER performance of the FEC encoded secured Multi-user STBC encoded MIMO wireless communication system based on the parameter given in Table 1. To illustrate the effect of various multi-level digital modulations (16-PSK, 16-DPSK, and 16-QAM) techniques over an Additive White Gaussian Noise (AWGN) and Rayleigh Fading Channel first the effect of 16-DPSK modulation technique is investigated with receive diversity.

Table 1:Simulated Model parameters

Parameter	***Description***
Type of input signal for the single user	Secured Text Message
No. of Transmitting and Receiving antennas	2X4
Channel coding	½ rated Convolutional Encoding
Digital Modulation Techniques	16-QAM, 16-PSK and 16- DPSK
Public key	{7,187}
Private key	{23,187}
Channel	AWGN and Rayleigh Fading channel
Signal to noise ratio, SNR	0 to 20 dBs

Figure 2 shows the BER performance evaluation of 16-DPSK modulation technique with the transmit diversity in conjunction with the receive diversity. At the BER values of 10-1 with the receiver diversity the SNR is reduced to about 4 dB and 7dB for 2X2 and 2X4 system, respectively. The BER performance evaluation of 16- PSK modulation technique with the transmit diversity in conjunction with the receive diversity is illustrated in figure 3. At the BER 10-2 with the transmit and receive diversity the required SNR are 10dB, 11.5dB and 13dB for 2X4, 2X3 and 2X2 system, respectively. Figure 4 depicts the BER performance evaluation of 16-QAM modulation. At the BER 10-2 the required SNR is reduced to 3dB when 2X2 antennas are applied compared to 2X1 antennas and for 2X4 the SNR is reduced to about 7 dB.

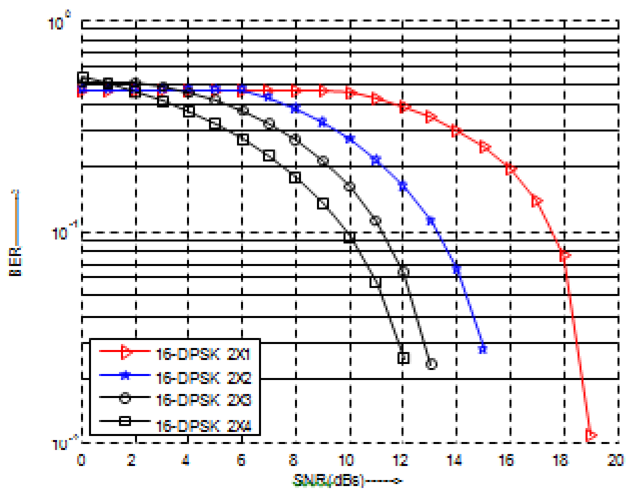

Fig 2. BER performance analysis for 16-DPSK system with transmitter and receiver diversity.

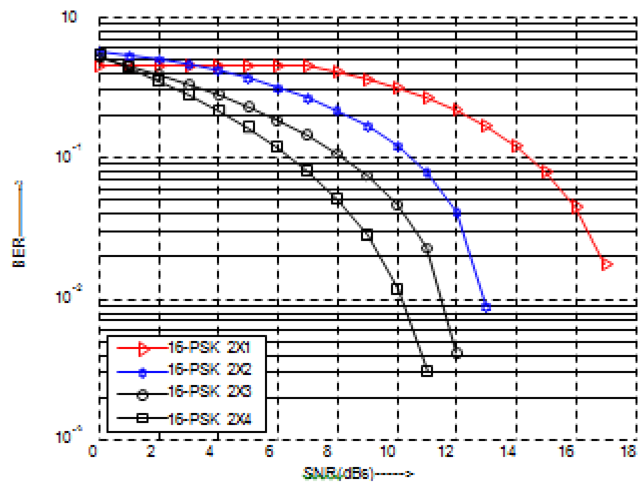

Fig 3. BER performance analysis for 16-PSK system with transmitter and receiver diversity.

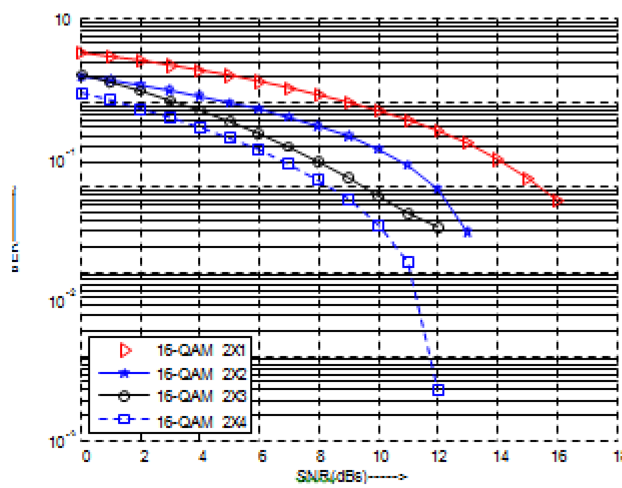

Fig4. BER performance analysis for 16-QAM system with transmitter and receiver diversity.

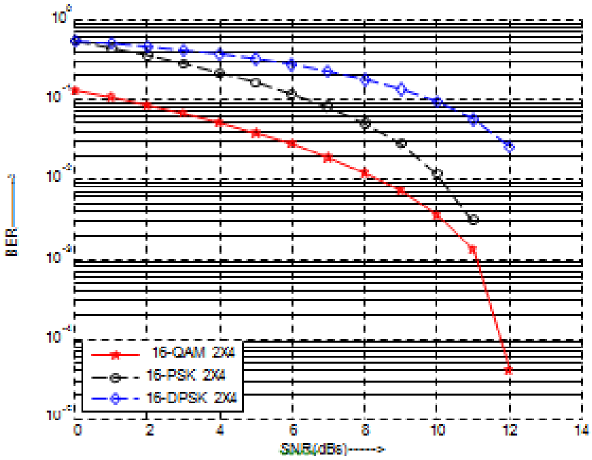

Figure 5. BER performance analysis for 16-QAM, 16-PSK and 16-DPSK system with 2X6 antennas.

Figure 5 shows the BER performance evaluation for all modulation techniques with 2x4 antennas configuration. At 9 dB SNR the BER values for 16-DPSK and 16-QAM are 0.1346 and 0.0071 respectively, viz. the BER performance is improved by 29.42dB.Under AWGN and Rayleigh fading channel environment, the transmitted and received secured text message is shown in Table 2 at 19dB SNR for the FEC encoded Alamouti- MRC transmission system for 16-DPSK modulation scheme with 2X1 antenna system. The erroneous characters in the retrieved text messages are shown in bold faces (Table 2). The error will be reduced with adaptation of 16-QAM system with more transmitter and receiver diversity.

Table 2: Message transmission in support of 16-DPSK modulation technique with 2X1 antenna system

	Transmitted secured text message and received text messages under Rayleigh fading channel
Transmitted Plaintext	If there were no noise, messages can be sent electronically to the outer limits of the universe by using small amount of power.
Retrieved Plaintext	If there we**Dq•LDnoise**,messages can be **se¢t elEc•D1.Dcally**•to the **outDD l}µ}t0•oV** the unive**D0 b• usDng shDllaamo-}P•OV** pow**(r**.

IV. CONCLUSION

In this work, we have presented simulation results concerning the adaptation of various signal detection schemes in a single user Alamouti's STBC-MRC wireless communication system. A range of system performance results highlights the impact of signal detection scheme and antenna diversity on secured message transmission system. The system performance improved with the receiver diversity. The system performance improved further with the adaptation of 16-QAM compared to 16-DPSK and 16-PSK.

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AUTHORS

First Author – Srabanty Ahmed Shaon, Lecturer,ADUST, srabanty_shaon@yahoo.com
Second Author – Sazzad Ferdous, B.Sc in E.E.E.,AUST, ferdous.sazzad@gmail.com

Third Author – Author name, qualifications, associated institute (if any) and email address.

Correspondence Author – Author name, email address, alternate email address (if any), contact number.