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Audio Signal Transmission through Correlated Rayleigh Fading Channel with Alamouti-MRC System

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***Abstract*—Alamouti's space time block coding (STBC) and maximal ratio combining (MRC) scheme is considered on audio signal transmission to investigate the effect of antenna diversity on the system performance. The FEC encoded Alamouti-MRC transmission system under investigation deploys various multi-level digital modulations (16-PSK and 16-QAM) techniques over an Additive White Gaussian Noise (AWGN) and Correlated Rayleigh Fading Channels. Rayleigh channel correlation parameter ρ is varied from 0 to 0.9. Correlation in fading across multiple diversity channels results in a degradation of the system performance. It has been observed from the study that in case of without receive antenna diversity and the correlation parameter ρ=0.9 the system shows comparatively worst performance in 16-PSK scheme and satisfactory performance in 16-QAM. It is obvious that the system performance is improved with increase in number of receive antennas. The performance analysis shows that with implemented Alamouti-MRC scheme under 16-QAM digital modulation, the system provides excellent performance over a significant low signal to noise ratio (SNR) values.**

***Index Terms*—MRC, Correlated Rayleigh Fading, STBC.**

I. INTRODUCTION

MIMO (multiple-input multiple-output) technology has rapidly gained in popularity over the past decade due to its powerful performance-enhancing capabilities. Communication in wireless channels is impaired predominantly by multi-path fading. MIMO technology constitutes a breakthrough in wireless communication system design. The technology offers a number of benefits that help to meet the challenges posed by both the impairments in the wireless channel as well as resource constraints [1]. It is well known that correlation in fading across multiple diversity channels results in a degradation of the diversity gain obtained [2]. Ergodic capacity of maximal ratio combining (MRC) schemes over arbitrarily correlated Rician fading channels is obtained in [2] and find out the effects of channel correlation on the ergodic capacity. It shows that both the phase and the magnitude of correlation have an impact on the ergodic capacity of Rician fading channels. When channel knowledge is available at both the transmitter and receiver, MIMO transmit beamforming with maximum ratio combining (MRC) receivers [3], [4] is particularly robust against the severe effects of fading. Recently, MIMO-MRC has been investigated in uncorrelated and semi correlated channel scenarios [5]. In [5] it is proved that MIMO-MRC achieves the maximum available spatial diversity order, and demonstrated the effect of spatial correlation. The ergodic capacity of MRC with arbitrarily correlated Rician faded branches is computed and the effects of correlated branches on the performance of MRC diversity are determined in [6]. In [7]–[11], uncorrelated Rayleigh fading was considered, and the output SNR statistical properties were derived based on maximum eigenvalue statistics of complex central Wishart matrices.

Thus far, to the best of the author's knowledge, there is no such work available about the performance analysis presented here. 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. Therefore, this paper focuses on the evaluation of the BER performance for the FEC encoded Alamouti-MRC transmission system for various multi-level digital modulations techniques over an Additive White Gaussian Noise (AWGN) and correlated Rayleigh Fading Channel with the transmit diversity technique in conjunction with receive antenna diversity.

The paper is organized as follows. Section II presents the system description, including the transmitter, channel, and coherent receiver models. Performance analysis is presented in Section III. Section IV deals with the channel model. Finally, conclusions are drawn in Section V.

II. THE COMMUNICATION SYSTEM MODEL

The MIMO wireless communication system under consideration is shown in Fig. 1. In such a communication system, Matlab program is used to record 33075 samples of an audio signal, sampled at a rate of 11025Hz and 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

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digital modulation techniques such as quadrature amplitude modulation (QAM) and phase shift keying (PSK). 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 x_1 and x_2, respectively. During the first symbol period, the encoder will send x_1 and x_2 to the first and second transmit antennas, respectively. During the next symbol period, x^*_1 and $-x^*_2$, where * denotes complex conjugate, will be sent to the first and second transmit antennas, respectively.

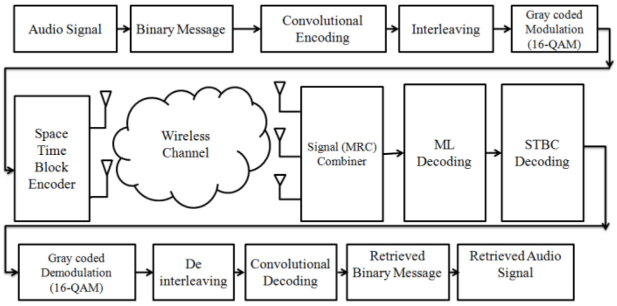


Figure 1. FEC encoded MIMO STBC-MRC wireless communication system

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 j^{th} receive antenna at time t and $t + T$, respectively, then r^j_1 and r^j_2 are given by [12][13-14].

$$\begin{aligned} r_1^j &= h_{j1}x_1 + h_{j2}x_2 + n_1^j \\ r_2^j &= -h_{j1}x_2^* + h_{j2}x_1^* + n_2^j \end{aligned} \tag{1}$$

where h_{ji}, i=1,2, j=1,2,……N_R, is the fading coefficient for the path from transmit antenna i to receive antenna j, and n_1^j and n_2^j 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

$$\begin{aligned} \tilde{x}_1 &= \sum_{i=1}^{2}\sum_{j=1}^{N_R}|h_{ji}|^2 x_1 + \sum_{j=1}^{N_R} h_{j1}{}^* n_1^j + h_{j2}(n_2^j)^* \\ \tilde{x}_2 &= \sum_{i=1}^{2}\sum_{j=1}^{N_R}|h_{ji}|^2 x_2 + \sum_{j=1}^{N_R} h_{j2}{}^* n_1^j - h_{j1}(n_2^j)^* \end{aligned} \tag{2}$$

The maximum likelihood decoding rules for the two independent signals x_1 and x_2 are then

$$\begin{aligned} \hat{x}_1 &= arg \min_{\hat{x}_1\in S}\left[\left(\sum_{j=1}^{N_R}\left(|h_{j1}|^2+|h_{j2}|^2\right)-1\right)^2 |\hat{x}_1|^2 + d^2(\tilde{x}_1,\tilde{x}_2)\right] \\ \hat{x}_2 &= arg \min_{\hat{x}_2\in S}\left[\left(\sum_{j=1}^{N_R}\left(|h_{j1}|^2+|h_{j2}|^2\right)-1\right)^2 |\hat{x}_2|^2 + d^2(\tilde{x}_1,\tilde{x}_2)\right] \end{aligned} \tag{3}$$

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

The complex symbols are now digitally demodulated, de interleaved, convolutionally decoded and rehabilitated again into audio signal.

III. THE CHANNEL MODEL

The correlated MIMO channel coefficients can now be generated by multiplying the uncorrelated MIMO fading channel vector by an MN × MN matrix C, which is referred to as the following correlation-shaping matrix or symmetric mapping matrix [15], that is,

$$\tilde{A}_l = \sqrt{P_l}\,C a_l \tag{4}$$

where P_l is the average power of the l th path, a_l is a vector-form representation of the uncorrelated MIMO channel gain matrix A_l. $\tilde{A}_l$ *is the correlated* MN×1 *MIMO channel vector.*

The correlation-shaping matrix C defines the spatial correlation coefficients. A spatial correlation matrix is given as

$$R=\begin{cases} R_{BS}\otimes R_{MS}: Downlink \\ R_{MS}\otimes R_{BS}: Uplink \end{cases} \tag{5}$$

where ⊗ denotes the Kronocker product. Using R in Equation (5) a root-power correlation matrix Γ is given as

$$\Gamma = \begin{cases} \sqrt{R}: \quad For\ Filed\ Type \\ R: \quad For\ Complex\ Type \end{cases} \tag{6}$$

where Γ is a non-singular matrix which can be decomposed into a symmetric mapping matrix (or correlation-shaping matrix) with the Cholesky or square-root decomposition as follows:

$$\Gamma = CC^T \tag{7}$$

C in Equation (7) can be obtained by Cholesky decomposition or square-root decomposition, depending on whether R_{BS} and R_{MS} are given as the complex matrices or real matrices, respectively.

IV. PERFORMANCE ANALYSIS AND RESULT

The computer simulation has been conducted to evaluate the BER performance of the FEC encoded MIMO Alamouti's STBC-MRC audio signal transmission system. Fig. 2 through 5 depicts the performance analysis for double transmit and multiple receive antenna diversity based on Alamuoti's STBC-MRC scheme for different M-ary modulation techniques. Performance analysis for 16-QAM and 16-PSK modulation techniques with the conjunction of double transmit and no receive diversity are shown in Fig 2 for the 0% to 90% correlated Rayleigh fading channels. There is an absolute difference in the performance analysis curve for the two modulation techniques unless the SNR reaches near to 18dB. For the highly correlated channel the system degrades in more quantity. At 14 dB SNR the BER performance improvement is recorded at 14.42dB for 0% correlated channel with 16-QAM modulation technique with respect to the 16-PSK modulation technique. In Fig. 3 an utter distinction in the performance analysis curve is observed also for the two modulation techniques but the performance is enhanced further compared to the case in Fig. 2. At the BER 10^{-2} the required SNR for the 0% and 90% correlated channels are approximately 12.5 dB and 13.9 dB respectively with the 16-QAM modulation techniques but the required SNR is more than 13 dB for the 16-PSK case. BER performance analysis for 16-PSK and 16-QAM system when transmitter and receiver diversity becomes 2×3 is shown in Fig. 4. At 10dB SNR the improvement in BER performance is 13.05dB for 0% correlated channel with 16-QAM than 16-PSK and the improvement is recorded 15.48dB for 90% correlated channel.

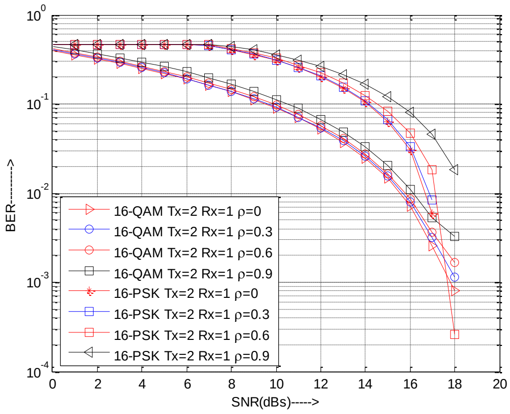


Figure 2. BER performance analysis for 16-PSK and 16-QAM system with transmitter and no receiver diversity.

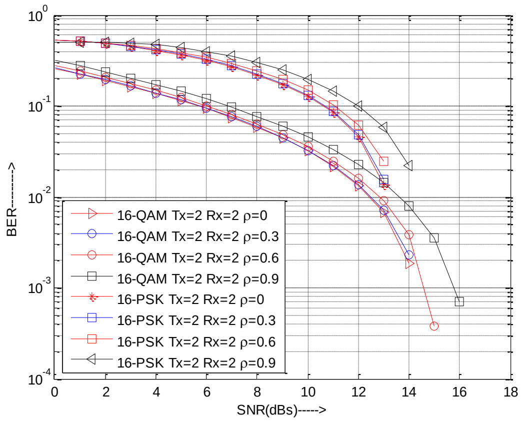


Figure 3. BER performance analysis for 16-PSK and 16-QAM system with transmitter and receiver diversity (2 ×2 antennas)

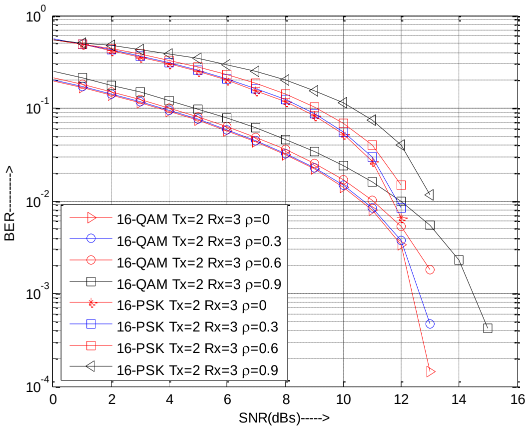


Figure 4. BER performance analysis for 16-PSK and 16-QAM system with transmitter and receiver diversity (2 ×3 antennas)

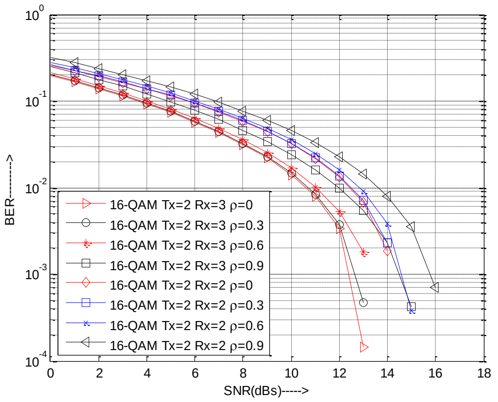
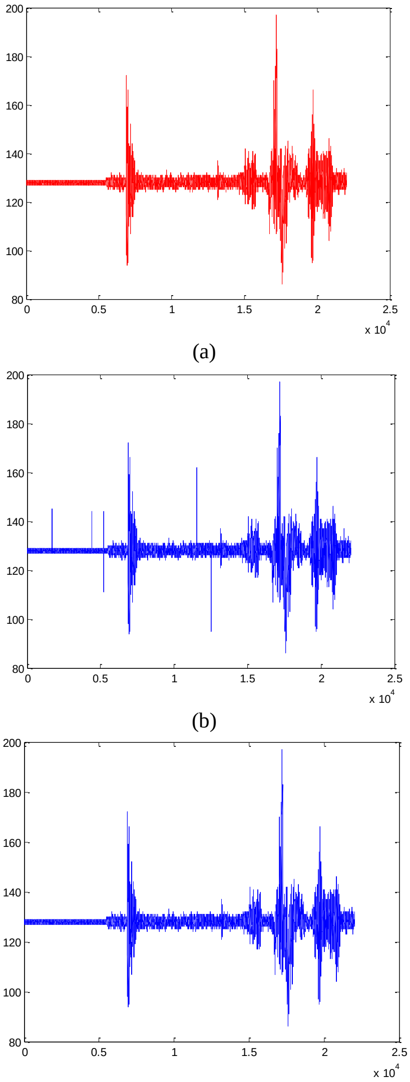


Figure 5. BER performance analysis for16-QAM system with transmitter and receiver diversity (2×2 and 2 ×3 antennas)



(a)

(b)

(c)

Figure 6. (a)Transmitted audio signal and Retrieved audio signal (b) at 16 dB SNR and (c) at 20 dB SNR with 2×3 antennas for 16 QAM scheme.

Finally Fig. 5 summarizes the performance analysis for 16 QAM scheme with 2×2 and 2×3 antenna configurations. With the increase in receive antenna diversity the system shows improved performance. 8.17dB BER performance enhancement is observed at

10dB SNR for 0% correlated channel when 2×3 antennas is employed compared to 2×2 antennas and for 90% correlated channel the BER improvement is 6.32dB. In addition the transmitted and retrieved audio signals are shown in Fig. 6.

V. CONCLUSION

In this work, we have presented simulation results concerning the adaptation of transmit and receive antenna diversity with digital multilevel modulation techniques for MIMO Alamouti's STBC MRC wireless communication system. The system performance get better with the more receiver diversity. In this context of system performance, it can be concluded that the implementation of 16-QAM digital modulation technique with 2×3 antenna arrangements provides acceptable result for such a correlated Rayleigh Faded Alamouti's STBC MRC wireless communication system.

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