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Performance Evaluation of Alamouti Space-Time Block Coded Multi-User W-CDMA Wireless Communication System

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***ABSTRACT**--- In this paper, we made a comprehensive simulation study to evaluate the performance of a multi-user Wideband CDMA wireless communication system. The 2-by-1 spatially multiplexed ½-rated Convolutionally encoded system under investigation incorporates Alamouti space-time block coding scheme with utilization of Walsh Hadamard codes and various digital modulations (BPSK, DPSK, QAM, QPSK and 8PSK). In our study, MATLAB based computer programs have been developed to process the synthetically generated multi-user bit streams and text messages under Additive white Gaussian noise (AWGN) and Raleigh fading channels. The simulation results elucidate that a significant improvement of system performance is achieved with BPSK digital modulation scheme at a comparatively low signal to noise ratios. It has been anticipated from the simulation study that the implementation of Walsh Hadamard is highly effective to discriminate the data (Synthetically generated/text) of individual users.*

Keywords: Alamouti Space-time block coding (Alamouti STBC), Bit error rate (BER), Wideband CDMA, Walsh Hadamard.

I. INTRODUCTION

Wideband code division multiple access (W-CDMA), a third generation (3G) mobile wireless technology has been implemented with expectation to ensure much higher data speeds for mobile and portable wireless devices. This air interface technology was initially designed to support a maximum bit rate of 2 Mb/s with fulfillment of different Q_oS requirements. In order to satisfy the future service and application needs several technical enhancements are being studied and standardized for W-CDMA in 3GPP. With evolved W-CDMA technology, there is a need for another public wireless access solution to meet up the demand for data-intensive applications and enable smooth online access to corporate data services in hot spots. This need could be fulfilled by WLAN together with a high-data-rate cellular W-CDMA system. The WLAN offers an interesting possibility for cellular operators to offer additional capacity and higher bandwidths for end users without sacrificing the capacity of cellular users. The evolved W-CDMA air interface will provide better performance and higher bit rates than basic W-CDMA Judging from an application and services point of view, the data rate will be one of the distinguishing factors between 4G compatible and 3G like W-CDMA systems .The 4G systems are expected to support at least 100 Mb/s peak data rates in full-mobility wide area coverage and 1 Gb/s in low-mobility local area coverage. However, in W-CDMA systems, it has become a challenging task to eliminate both intersymbol interference (ISI) as a result of interchip interference (ICI) and multiple access interference (MAI) on transmitting information over multipath channels and for this purpose, various channel estimation schemes have been implemented [1], [2] .Our present study is based on the constraint that the channel state information (CSI) is known at the receiver.

II. Alamouti STBC Scheme

Alamouti presented a simple two-branch transmit diversity scheme in 1998. Using two transmit antennas and one receive antenna the scheme provides the same diversity order as maximal-ratio receiver combining (MRRC) with one transmit antenna and two receive antennas. The Alamouti Space-time Block Coding scheme is discussed below**.** Figure-1 shows the block diagram of base band representation of the Alamouti's two branch transmit diversity scheme. The scheme uses two transmit antennas and one receive antenna and is defined by the three functions such as encoding and transmission sequence of information symbols at the transmitter, combining scheme at the receiver and decision rule for maximum likelihood detection. In Encoding and Transmission Sequence, two signals are simultaneously transmitted from the two antennas at a given symbol period. The signal transmitted from antenna zero is denoted by s_o and from antenna one by s_1. During the next symbol period signal ($-s_1^*$) is transmitted from antenna zero and signal s_o is transmitted from antenna one where * is the complex conjugate operation. In Alamouti scheme, the encoding is done in space and time (space–time coding) and such encoding may also be done in space and frequency.

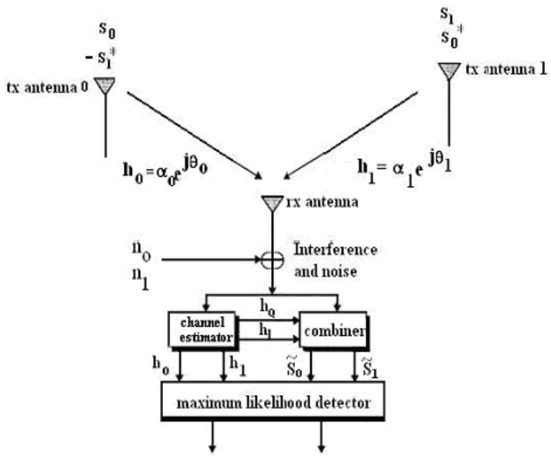

Figure 1. Conceptual block diagram of Alamouti Space-time Block Coding scheme[3].

The channel at time t may be modeled by a complex multiplicative distortion $h_o(t)$ for transmit antenna zero and $h_1(t)$ for transmit antenna one. Assuming that fading is constant across two consecutive symbols, we can write

$$h_o(t) = h_o(t+T) = h_o = \alpha_o e^{j\theta_o}$$
$$h_1(t) = h_1(t+T) = h_1 = \alpha_1 e^{j\theta_1} \quad (1)$$

where, T is the symbol duration. The received signals can then be expressed as

$$r_o = r(t) = h_o s_o + h_1 s_1 + n_o$$
$$r_1 = r(t+T) = -h_o s_1^* + h_1 s_o^* + n_1 \quad (2)$$

where r_o and r_1 are the received signals at time t and t+ T and are n_o and n_1 complex random variables representing receiver noise and interference. The combiner shown in Figure 1 builds the following two combined signals that are sent to the maximum likelihood detector:

$$\tilde{s}_o = h_o^* r_o + h_1 r_1^*$$
$$\tilde{s}_1 = h_1^* r_o - h_o r_1^* \quad (3)$$

Substituting (1) and (2) into (3) , we get

$$\tilde{s}_o = (\alpha_o^2 + \alpha_1^2) s_o + h_o^* n_o + h_1 n_1^*$$
$$\tilde{s}_1 = (\alpha_o^2 + \alpha_1^2) s_1 - h_o n_1^* + h_1^* n_o \quad (4)$$

These combined signals are then sent to the maximum likelihood detector which, for each of the signals s_o and s_1 uses the decision rule expressed in (5) or (7) for PSK signals Choosing s_i iff

$$(\boldsymbol{\alpha}_o^2 + \boldsymbol{\alpha}_1^2 - \mathbf{1})|\mathbf{s}_i|^2 + \mathbf{d}^2(\tilde{\mathbf{s}}_o, \mathbf{s}_i)$$
$$\le (\boldsymbol{\alpha}_o^2 + \boldsymbol{\alpha}_1^2 - \mathbf{1})|\mathbf{s}_k|^2 + \mathbf{d}^2(\tilde{\mathbf{s}}_o, \mathbf{s}_k), \forall \mathbf{i} \ne \mathbf{k} \quad (5)$$

where, $d^2(\tilde{s}_o, s_k)$ is the squared Euclidean distance between signals $\tilde{\mathbf{s}}_o$ and $\mathbf{s}_k$ calculated by the following expression

$$\mathbf{d}^2(\tilde{\mathbf{s}}_o, \mathbf{s}_k) = (\tilde{\mathbf{s}}_o - \mathbf{s}_k)(\tilde{\mathbf{s}}_o^* - \mathbf{s}_k^*)$$
(6)

Choosing $\mathbf{s}_i$ iff

$$\mathbf{d}^2(\tilde{\mathbf{s}}_o, \mathbf{s}_i) \le \mathbf{d}^2(\tilde{\mathbf{s}}_o, \mathbf{s}_k), \forall \mathbf{i} \ne \mathbf{k} \quad (7)$$

The diversity order from the Alamouti two-branch transmit diversity scheme with one receiver is equal to that of two-branch MRRC [3],[4].

III. COMMUNICATION SYSTEM MODEL

It is assumed that a simulated multi-user MISO WCDMA wireless communication system depicted in Figure-2 utilizes a ½-rated Convolutional channel coding scheme

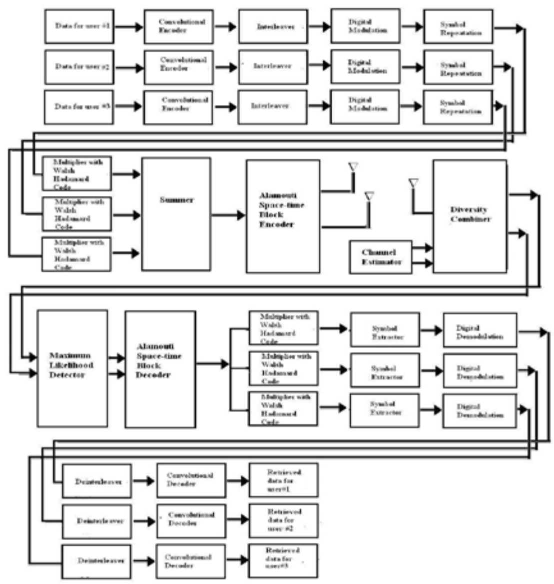

Figure 2. Alamouti space-time block coded multi-user WCDMA wireless communication system.

In such a communication system, three users are simultaneously transmitting their synthetically generated information bits/text message. The transmitted information bits of each individual user are channel encoded and interleaved for minimization of burst errors. The interleaved bits are digitally modulated using various types of digital modulations such as Binary Phase Shift Keying (BPSK), Differential Phase Shift Keying (DPSK), Quadrature Phase Shift Keying (QPSK), Quadrature Amplitude modulation (QAM), Eight- Phase Shift Keying (8-PSK) and the number of digitally modulated symbols is increased (copied) eight times (as the processing gain/ sequence length of the orthogonal Walsh–Hadamard codes is eight) and subsequently multiplied with Walsh–Hadamard codes assigned for individual user. The Walsh–Hadamard and Convolutionally encoded interleaved digitally modulated symbols are summed up and fed into Space time block encoder for processing with implemented philosophy of Alamouti's G_2 Space time block coding scheme and eventually sent up from the two transmitting antennas [5]. In the receiving section, the transmitted message signals are processed with perfect knowledge of channel information in diversity combiner and its two outputs are fed into Maximum likelihood (ML) detector. In ML detector, the received two signals are compared with assumed signals based on acceptance of minimum Euclidian distance. The accepted two signals from ML detector are fed into Alamouti space time block decoder. The decoded signal is demapped (digitally demodulated), decopied, deinterleaved, channel decoded and eventually processed to retrieve the transmitted information bits.

IV. RESULTS AND DISCUSSION

The present simulation based study has been made for multi user MISO W-CDMA wireless communication system in consideration with various parameters presented in Table-1.

No. of bits used for individual synthetic data/text message	1024/1603,1568, 1680
Antenna Configuration	2 by 1
Channel Coding	½-rated Convolutional Encoder
Spreading Code	Walsh-Hadamard
Digital modulation(Symbol mapping)	BPSK,DPSK,QPSK, 8PSK and QAM
Diversity scheme	Alamouti Space time block coding
SNR, (Eb/No)	0 to10 dB

Table 1. Summary of the simulated model parameters.

In Figure-3, it is quite noticeable the impact of implementing Alamouti Space time block and channel coding schemes in performance enhancement of the system. For a typically assumed Eb/No value of 5 dB, the estimated values of cumulative bit error rates are 0.0060 and 0.0016 in case of implemented Alamouti STBC with Channel coding scheme and direct transmission (without implemented Alamouti STBC and Channel coding schemes) viz. an enhancement of system performance is achieved by 5.81dB.

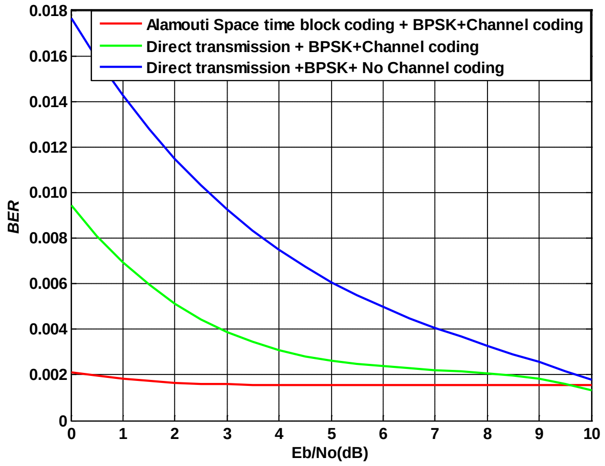

Figure 3. Effect of Alamouti Space time block coding and Channel coding schemes on BER performance for multi-users MISO wideband CDMA wireless communication system.

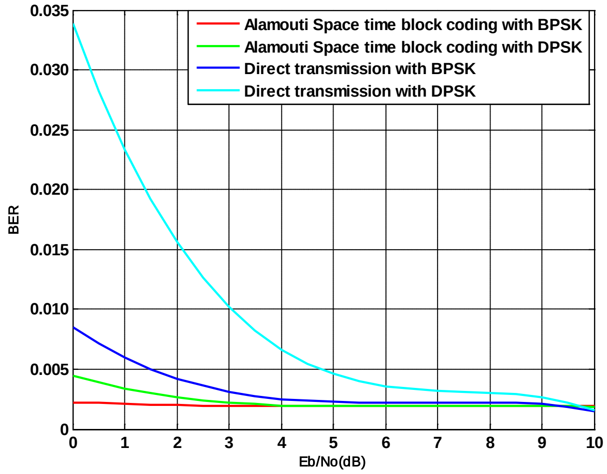

Figure 4. Comparison on BER performance for multi-users MISO wideband CDMA wireless communication system under implementation of BPSK and DPSK digital modulation scheme.

In Figure-4, it is observable that the system outperforms in BPSK as compared to DPSK modulation. In BPSK, the cumulative BER value ranges from 0.0022 to 0.0019. The cumulative BER values for merely QPSK,8-PSK and QAM digital modulations have been presented graphically in Figure 5 as the estimated BER values in case of BPSK and DPSK are very low in comparison with higher order of modulation. The BER simulation graphs depicted in Figure-5 under implementation of Alamouti Space time block coding scheme confirms that the system shows better performance in QPSK and worst performance in QAM.

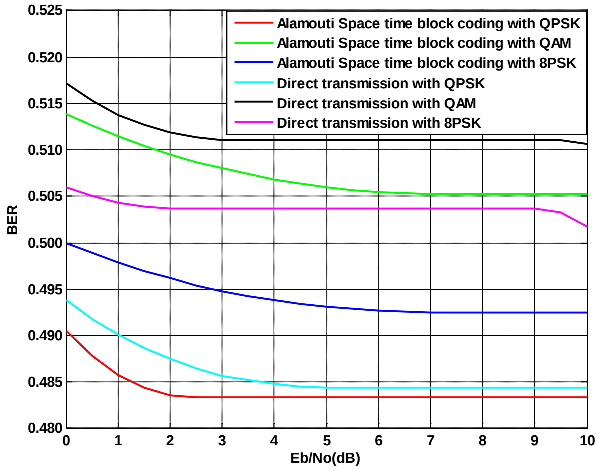

Figure 5. Comparison on BER Performance for multi-users MISO wideband CDMA wireless communication system under implementation of Alamouti Space time block coding scheme.

For a typically assumed Eb/No value of 5 dB, the estimated values of cumulative bit error rates are 0.4834 and 0.5060 in case of QPSK and QAM. In comparison with BPSK modulation (BER value: 0.0016), the system shows most satisfactory performance in BPSK and worst performance in QAM viz. the system performance is improved by 25.00 dB. The segments of transmitted and retrieved bits and full text messages for the three users at Eb/No value of 5 dB under BPSK modulation have been represented in Figure-6.

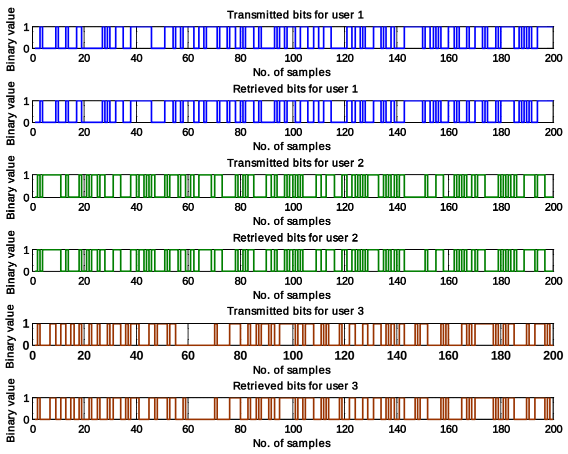

Figure 6**.** Transmitted and Retrieved bits in segmented form in a multi-users MISO wideband CDMA wireless communication system.

Work on a third-generation mobile communication started in ITU (International Telecommunication Union) in the 1980s, first under the label Future Public Land Mobile Telecommunications Systems (FPLMTS), later changed to IMT-2000.

(a)

MIMO-OFDM is a key technology for next-generation cellular communications (3GPP-LTE, Mobile WiMAX, IMT-Advanced) as well as wireless LAN (IEEE 802.11a, IEEE 802.11n), wireless PAN (MB-OFDM), and broadcasting (DAB, DVB, DMB).

(b)

This study assessed the potential for interference to consumer electronics from radio frequency (RF) fields radiated by general packet radio service (GPRS) 900/1800-MHz and wideband code division multiple access (WCDMA) 1900-MHz handsets.

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(f)

Figure 6. Transmitted and retrieved text message in the MISO wideband CDMA wireless communication system under BPSK ,AWGN and Rayleigh fading channels for (a) user#1 at 5 dB Eb/No, (b) user#2 at 5dB Eb/No, user#3 at 5dB Eb/No,(d) contaminated retrieved text message for user#1 at 0 dB Eb/No,(e) retrieved text message for user#2 at 0 dB Eb/No and (f) contaminated retrieved text message for user#3 at 0 dB Eb/No.

(Green marked letter is indicated of erroneous transmission).

V. CONCLUSION

In this present work, we have studied the performance of a convolutionally channel encoded multi-user MISO W-CDMA wireless communication system with implementation of Alamouti space-time block coding scheme. A range of system performance results highlights the impact of diversity and order of digital modulations under fading channels. In the context of system performance, it can be concluded that the implementation of BPSK digital modulation technique in Alamouti diversity encoded multi-user MISO W-CDMA wireless communication system provides satisfactory performance.

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