THE INTERNATIONAL JOURNAL OF SCIENCE & TECHNOLEDGE

Performance Evaluation of an Alamouti Space-Time Block Encoded Multi-user DS-CDMA Wireless Communication System

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Abstract:
This paper evaluates the performance of a simulated Alamouti STBC encoded Multi-user DS-CDMA based wireless communication system. In this designed communication system, ½ rated convolutional encoding and interleaving schemes were utilized over an AWGN and Rayleigh fading channels. Two transmitting antennas and one receiving antenna was deployed in this scheme. The simulation study was made with the development of a computer program written in MATLAB source code and the BER results shows that the multi transmit antenna supported DS-CDMA system outperforms in retrieving various types of data of the individual user. The system is highly effective to combat inherent interferences under fading channel. System performance degrades while increasing level of digital modulations.

Keywords: *Alamouti code, STBC, DS-CDMA, AWGN and Rayleigh fading channel.*

1. Introduction

In multi-user communications, particularly in mobile telephony, many transmitting users as possible use a certain frequency band (channel). In the past, where analogue technology dominated circuitry, frequency division multiple access(FDMA) was used. Several users share a common channel while all users are frequency separated by sub-channels. Every user is communicating over an individual channel over the whole period of time of the call. This is not an efficient way of exploiting the frequency spectrum. Because the sub-channel is occupied even if no information is transmitted, and the system requires guard bands. Because it was found that mobile conversations have a duty factor of ½ (time used for conversation/time of call)**,** even more users can share a channel at the same time [1]. The availability of cheap digital circuitry made it possible to deploy digital mobile network systems, the 2nd generation mobile networks. Most networks exploit a technique known as time division multiple access(TDMA), such as the popular global system for mobile(GSM) [2, 3].In a TDMA system, several users share a common channel, but they are separated by time. Each user transmits and receives for a short period of time (time slot) within a frame.

There is another technology which is used for 2nd generation mobile networks. The idea is based on spread spectrum(SS) [4, 5] which has been in use for a long time in military and space applications and is called code division multiple access(CDMA) [6]**.** In CDMA networks all users share a common channel in time and frequency. The separation is done using a code. Each user transmits with a unique code, the spreading sequence, and since the receiver knows the user's code it can demodulate and extract the information.

CDMA offers many advantages over the other two techniques [1, 7]**.** The capacity is soft limited, which means that as more users are active the higher the background noise becomes and performance in terms of probability of errors degrades. It is less susceptible to the effects induced from a changing environment, which is important in mobile communications. Finally, it is generally believed that its capacity is much greater than that of the established (TDMA) systems [8, 9]. However, CDMA systems also have some additional constraints, which must be considered if it is to be used for cellular mobile communications, especially requirement for power control [10]. CDMA is also known as spread spectrum multiple access or SSMA because the use of spread spectrum waveforms is fundamental to CDMA. There are two main reasons why spread spectrum waveforms were traditionally used: low probability of intercept and resistance to jamming [11, 12]. There are two basic spread spectrum techniques: direct sequence spread spectrum (DS/SS) and frequency-hopped spread spectrum (FH/SS) [13]. Aurangzib *et. al* [14] recently studied some features of STBC MIMO-OFDM system and Hasna Hena *et. al* [15] tried to show some comparative study of DS-CDMA communication system. In this paper, we also tried to compare the performance of a DS-CDMA wireless communication system utilizing Alamouti STBC scheme under different modulation techniques. The performance evaluation is mainly based on the critical examination of the effects of synthetic generated signal transmission through its modulation and demodulation sections.

2. Concept of STBC and Alamouti Code

In this section, we study the design of space-time block codes (STBCs) to transmit information over a multiple antenna wireless communication system. We assume that fading is quasi-static and flat. We consider a wireless communication system where the transmitter contains N transmit antennas and the receiver contains M receive antennas. We follow our notations in equation (1)for the input–output relation of the MIMO channel. The goal of space-time coding is to achieve the maximum diversity of NM, the maximum coding gain and the highest possible throughput. In addition, the decoding complexity is very important. In a typical wireless communication system, the mobile transceiver has a limited available power through a battery and should be a small physical device. To improve the battery life, low complexity encoding and decoding is very crucial. On the other hand, the base station is not as restricted in terms of power and physical size. One can put multiple independent antennas in a base station. Therefore, in many practical situations, a very low complexity system with multiple transmit antennas is desirable. Space-time block coding is a scheme to provide these properties. Despite the name, a STBC can be considered as a modulation scheme for multiple transmit antennas that provide full diversity and very low complexity encoding and decoding.

We start our discussion about space-time block coding with a simple example. Let us assume a system with N = 2 (transmitting antennas) and one receiving antenna (M=1) employing Alamouti code is depicted in Figure1. To transmit b bits/cycle, we use a modulation scheme that maps every b bit to one symbol from a constellation with 2b symbols. The constellation can be any real or complex constellation, for example - PAM, PSK, QAM and so on.

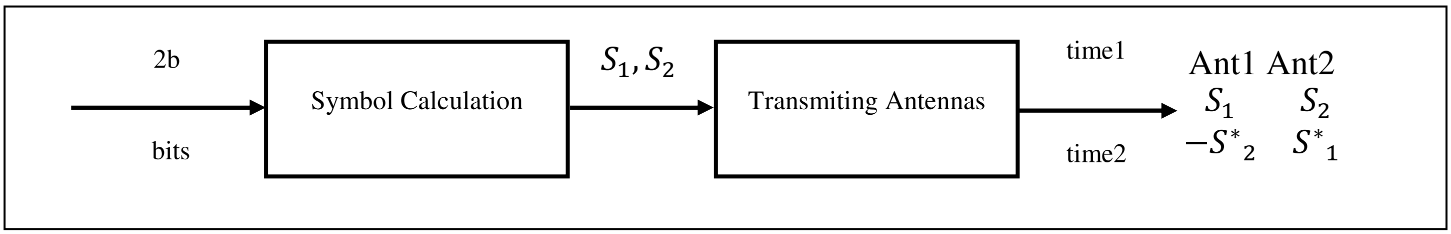

Figure 1: Transmitter block diagram for Alamouti code.

First, the transmitter picks two symbols from the constellation, using a block of 2b bits. If S_1 and S_2 are the selected symbols for a block of *2b* bits, the transmitter sends $S_1$from antenna 1 and S_2 from antenna 2 at time 1. Then at time 2, it transmits $-S^*_2$ and S^*_1 from antenna 1 and antenna 2, respectively. Therefore, the transmitted code word can be expressed by the following equation:

$$\boldsymbol{C} = \begin{pmatrix} \boldsymbol{S_1} & \boldsymbol{S_2} \\ -\boldsymbol{S}^*_2 & \boldsymbol{S}^*_1 \end{pmatrix} \qquad (1)$$

Figure 2 shows a block diagram of the decoder with M receiving antennas. Note that we use maximum ratio combining for the maximum-likelihood decoding with more than one receive antenna. In this case all of the above formulas are valid when every cost function is the sum of the corresponding cost functions for each receiving antenna.

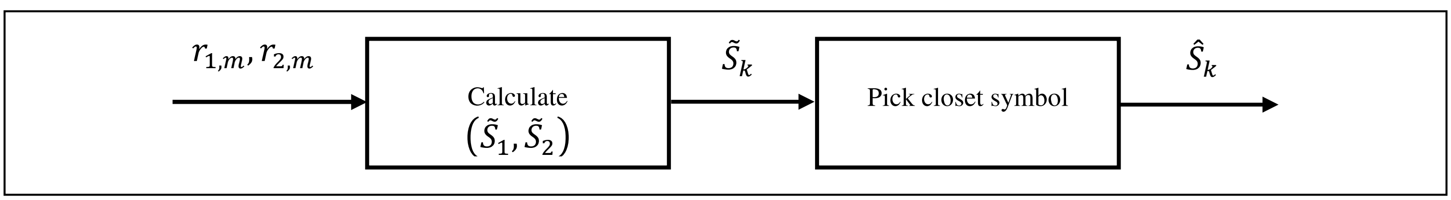

Figure 2: Receiver block diagram for Alamouti coded with MRC.

3. Proposed System Model and Description

In the presented simulated communication system model (Figure 3), the synthetically generated binary random data and text messages for multi-users have been considered. The individually generated random data and messages are then encoded with ½ and ⅔-rated convolution encoder. The encoder output is converted into a bipolar NRZ format and subsequently fed into BPSK, QPSK, 8PSK, 16PSK, 2QAM, 4QAM, 8QAM, and 16QAM digital modulator. The digitally modulated signal is then multiplied with generated pseudo random noise for each user.

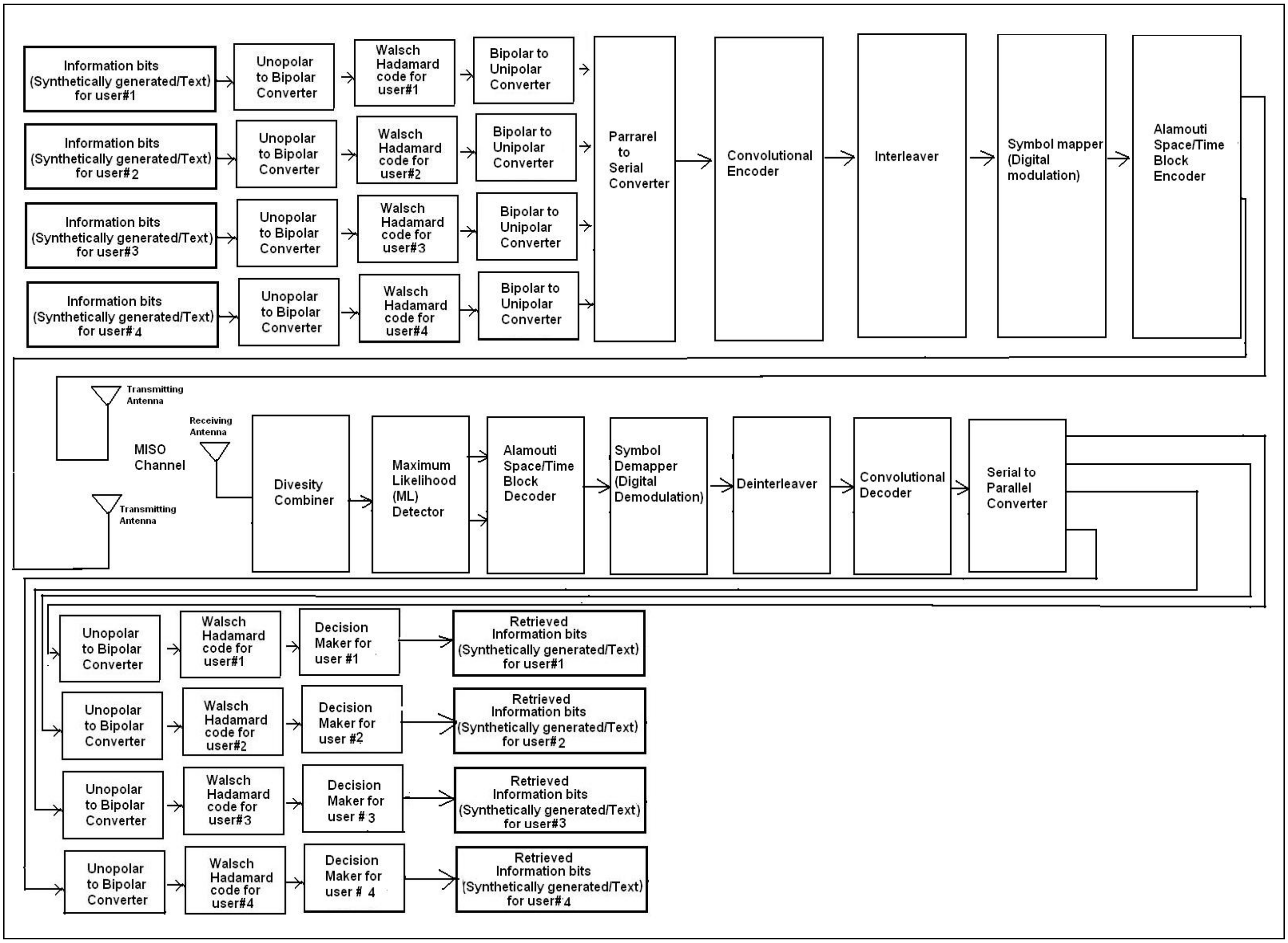

Figure 3: Block diagram of Alamouti encoded model for multi-user DS-CDMA system.

The pseudo randomly noise contaminated modulated signals for users are then added up and Alamouti STBC encoded and transmitted through two transmitters and passed through AWGN and Rayleigh fading channel. The channel output is then received by single antenna and multiplied with the generated pseudo random noise and demodulated. The demodulated signal for each user is processed. The processed output is sent up to the decision making device from where the transmitted information bits or messages for each user are extracted.

4. Results and Discussions

Simulation parameters for the proposed system model are summarized in Table- 1. The performance of the proposed system was evaluated in different channels.

Parameters	Types
No. of bits used for synthetic data	1000
Message Length	Variable
Modulation	BPSK, QPSK, 8PSK, 16PSK, 2QAM, 4QAM, 8QAM and 16QAM
SNR in dB	0-10
Channel	AWGN, Rayleigh
Channel coding	½- rated Convolution coding
No. of samples in each bit	10
Diversity scheme	Alamouti STBC (two transmitting and one receiving antenna)

Table 1: Summary of the simulated model parameters

The BER performance of convolution encoded DS-CDMA communication system under AWGN channel is shown in Figure 4. For a typical SNR value of 7dB, the BER for un-coded and convolution encoded DS-CDMA wireless communication system are 0.0650 and 0.0042, respectively. Here, the system performance is improved by 11.897 dB using error control coding scheme.

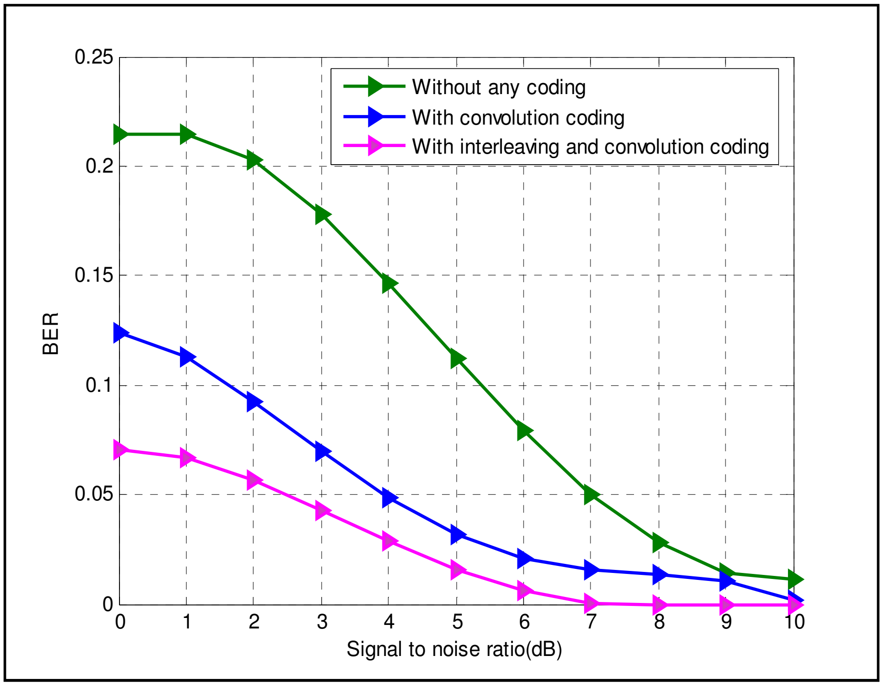

Figure 4: Performance of DS-CDMA wireless communication system over AWGN channel with and without implementation of errorcontrol coding scheme

The BER performance of convolution encoded DS-CDMA communication system under Rayleigh fading channel is shown in Figure 5. In this case, for a typical SNR value of 7dB, the BER for un-coded and convolution encoded DS-CDMA wireless communication system are 0.0930 and 0.0120, respectively which suggests that here also the performance of the proposed wireless communication system is improved by 8.893 dB using error control coding scheme.

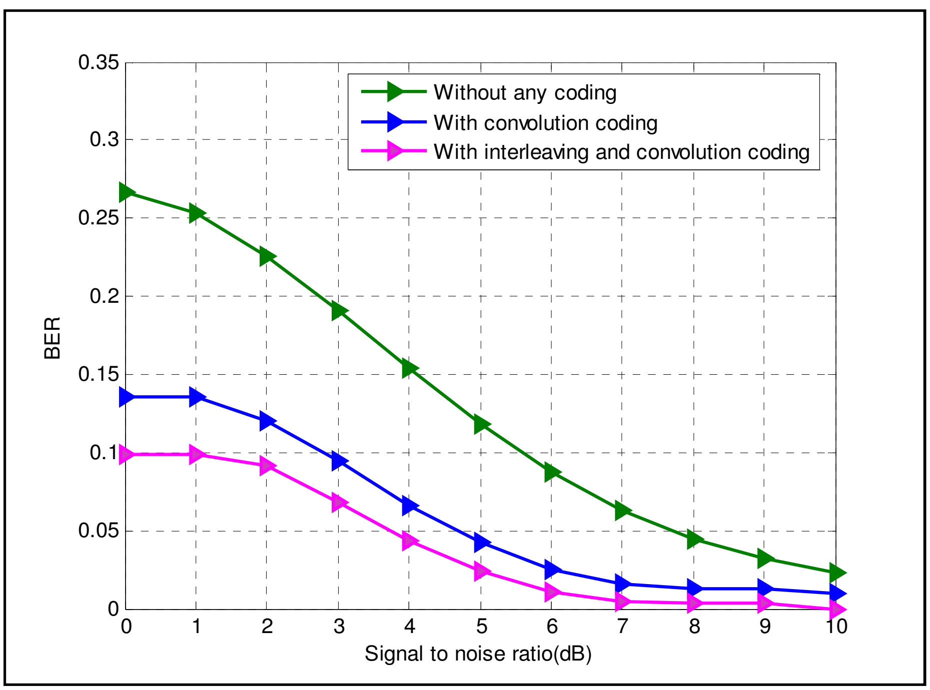

Figure 5: Performance of DS-CDMA over the Raleigh channel with and without error control coding scheme

Furthermore, the performance evaluation of Alamouti STBC encoded multi-user DS-CDMA wireless communication system has been studied. Different levels of PSK modulation have been considered here to explain the effect of an Alamouti STBC scheme in DS-CDMA wireless communication system which is revealed in Figure 6.

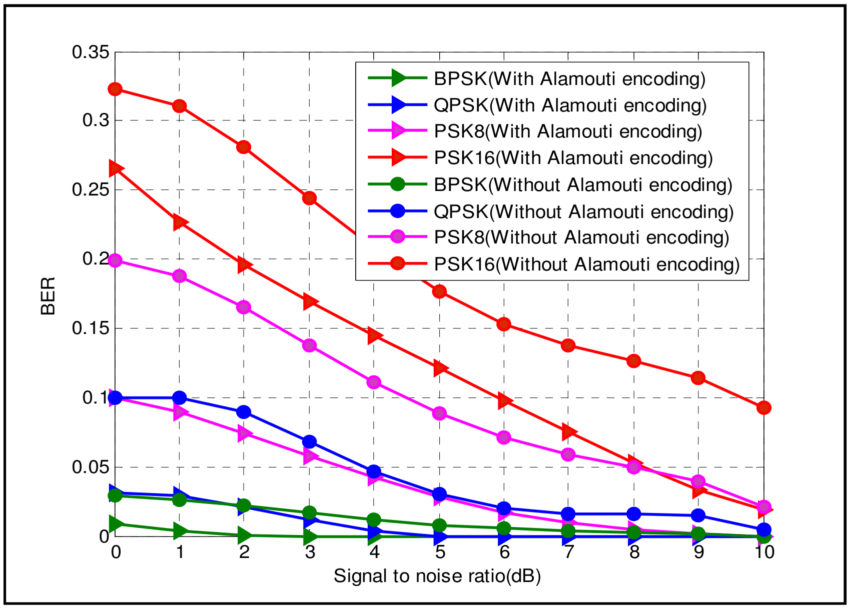

Figure 6: Performance of DS-CDMA at different levels of PSK modulation with and without implementation of Alamouti STBC scheme

From Figure 6, it is observed that at each modulation level of PSK, Alamouti STBC encoded DS-CDMA wireless communication system shows better performance. It is also seen that for a typical SNR value of 3dB, the BER for un-coded and Alamouti STBC encoded DS-CDMA scheme under BPSK digital modulation are 0.0252 and 0.0002 respectively which indicates that the system performance is raised by 21.004 dB as compared with that one for un-coded case. Similarly, for a typical SNR value of 5dB, the BER for un-coded and Alamouti STBC encoded DS-CDMA scheme under QPSK digital modulation are 0.0294 and 0.00022, respectively. In this case also the performance of the proposed wireless communication system is upgraded by 21.259 dB. For a typical SNR value of 9dB, the BER for un-coded and Alamouti STBC encoded DS-CDMA scheme under 8PSK digital modulation are 0.0542 and 0.00062, respectively, which indicates that the system outperforms by 19.416 dB. Similarly, for a typical SNR value of 9dB, the BER for un-coded and Alamouti encoded DS-CDMA scheme under 16PSK digital modulation are 0.1167 and 0.0183 respectively. It means that the system performance is improved by 8.04 dB. Comparing all those above results it can be concluded that the system performance is gradually improving by implementing Alamouti STBC with decreasing modulation levels.

Finally, different levels of QAM modulation have been now considered here to show the effect of the Alamouti STBC scheme in DS-CDMA wireless communication system in Figure 7. It is clear from the Figure 7, at each modulation level of QAM, Alamouti STBC encoded DS-CDMA wireless communication system shows improved performance.

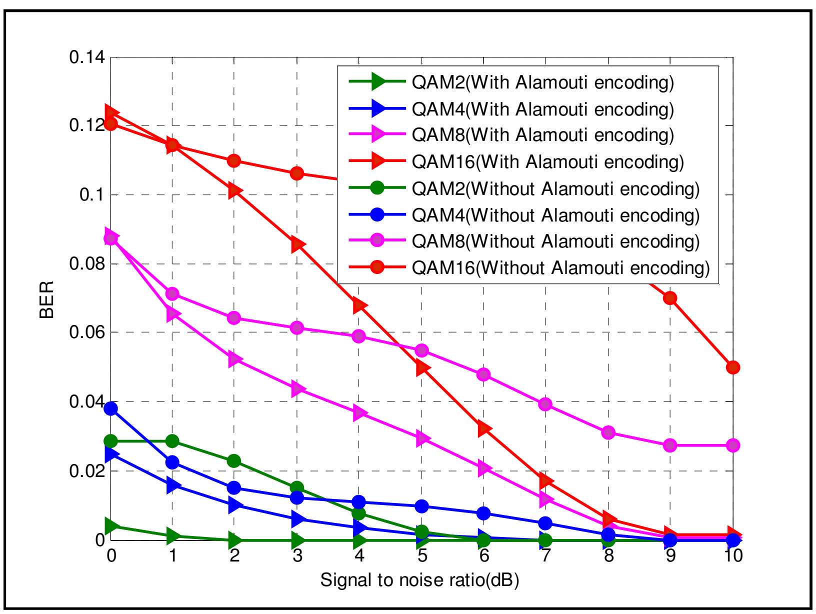

Figure 7: Performance of DS-CDMA at different levels of QAM modulation with and without implementation of Alamouti STBC scheme.

It is also seen that for a typical SNR value of 2dB, the BER for un-coded and Alamouti STBC encoded DS-CDMA scheme under 2QAM digital modulation are 0.0252 and 0.0002, respectively, which implies that the system performance is upgraded by 21.004 dB as compared with that result for without implementing Alamouti STBC encoded case. Similarly, for a typical SNR value of 4dB, the BER for un-coded and Alamouti STBC encoded DS-CDMA scheme under 4QAM digital modulation are 0.0126 and 0.0004, respectively. In this case also the system performance is improved by 14.98 dB. For a SNR value is 9dB, the BER for un-coded and Alamouti STBC encoded DS-CDMA scheme under 8QAM digital modulation are 0.0333 and 0.0042, respectively, which suggests that the system performance is enhanced by 8.99 dB. In case of typically assumed SNR value of 9dB, the BER for un-coded and Alamouti STBC encoded DS-CDMA scheme under 16PSK digital modulation are 0.0875 and 0.0184, respectively, which is an indication of improvement of the system performance by 6.772 dB. All these representative results also confirm that the system performance is gradually degraded while increasing modulation levels. The system performance is improving using error control coding scheme. Comparing all those above results it can be concluded that the system performance is gradually improving by implementing Alamouti STBC with decreasing modulation levels.

5. Conclusion

The BER results from our research suggest that Alamouti STBC multi-user DS-CDMA wireless communication system outperforms in retrieving various types of data of the individual user. The system is highly effective to combat inherent interferences under fading channel. BPSK and 2QAM shows almost the same performance followed by the same criteria. The system performance is degrading while increasing level of digital modulations.

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