Analysis the effect of Diversity Technique on a Multi-User Wideband CDMA (W-CDMA) Communication System

Md. Ohidul Islam
Lecturer, Dept. of CSE
Atish Dipankar University of Science & Technology
Dhaka, Bangladesh

Md. Mahbubur Rahman
Lecturer, Dept of EEE
Jatya Kabi Kazi Nazrul Islam University,
Trishal, Bangladesh

Md. Arifur Rahman
Lecturer, Dept of EEE
First Capital University of Bangladesh
Chuadanga, Bangladesh

Farhana Enam
Associate Professor, Dept of ICE
Rajshahi University,
Rajshahi, Bangladesh

***Abstract*—W-CDMA (Wideband Code-Division Multiple Access), an ITU standard derived from Code-Division Multiple Access (CDMA), is a third-generation (3G) mobile wireless technology that promises much higher data speeds to mobile and portable wireless devices than commonly offered in today's market. This technology used in UMTS. This research work is incorporate on the performance evaluation of an Alamouti Space time block encoded multi-user W-CDMA communication system. The communication system under present study utilizing ½ rated convolutional encoding scheme BPSK modulation technique over an Additive White Gaussian Noise (AWGN) communication channel. With deployment of two transmit antennas and two receiving antenna in Alamouti scheme, the simulation study is made with the development of a computer program written in MATLAB source code and computer simulation results on BERs demonstrate that the multi transmit antenna supported W-CDMA system outperforms in retrieving synthetically generated bit stream of the individual user. It is anticipated from the simulation study that the diversity coded system is highly effective to combat inherent interferences as compared to direct transmission and its performance of the communication system degrades with the increasing of noise power and level of digital modulation.**

Keywords*— *W-CDMA; Alamouti STBC; Diversity Technique ;AWGN; Walsh Hadamard Code, BPSK.

I. INTRODUCTION

The main goal of the 3rd-generation cellular system is to offer seamless wideband services across a variety of environments, including 2 Mbps in indoor environment, 384 kbps in a pedestrian environment and 144 kbps in a mobile environment. The Japanese 3rd generation system employs wideband code division multiple access (WCDMA) technology. The International Telecommunications Union (ITU) is also considering W-CDMA technology for a global standard – IMT-2000. The ITU is an international standards body of the United Nations. The system approach is leading to a revolutionary solution instead of an evolutionary solution from the current IS-95 CDMA system [2]. The current IS-95 was designed based on the needs of voice communications and limited data capabilities, but 3rd-generation requirements include wideband services such as high-speed Internet access, high-quality image transmission and video conferencing. The current IS-95 CDMA standard specifies 1.25MHz channel bandwidth and 2288Mchips/s chip rate. The relatively narrow bandwidth and low chip rate makes it impossible for IS-95 to meet the data rate requirement of the 3rd-generation. While the cdma2000 system, which supports CDMA over wider bandwidths for capacity improvement and higher data rates, will maintain backward compatibility with existing IS-95 CDMA systems, the W-CDMA system [3] will use dual-mode terminals to retain the backward compatibility.

II. AN OVERVIEW OF WIDEBAND CDMA

In the previous chapter, the basic concepts of multi-user communications and the multiple access techniques used to allow multiple users to communicate have been reviewed. In this chapter, it is intended to focus on the major forms of Wideband code division multiple accesses (WCDMA) and the application of WCDMA. *Wideband Code Division* Multiple Access (W-CDMA) is a mobile wireless technology used in 3G of the mobile telephony networks. It is actually the true 3G version of GSM and also known as *Universal Mobile* Telecommunications System (UMTS) [11]. It uses 5MHz-wide radio channels as compared to 1.25MHz radio channels used by CDMA2000. W-CDMA evolved from the need to have higher data speed currently offered by GPRS and EDGE. So, W-CDMA provides high-speed broadband mobile service capable of delivering data transfer rate up to 2 Mbps for voice, images, data and video communications. W-CDMA emerged through the 3G Partnership Project (3GPP) that concentrated on the interoperability among the 3G networks and part of the IMT-2000 family of 3G standards [9]. Although CDMA2000 and W-CDMA where created by different projects, 3GPP2 and 3GPP, both share the same fundamental technology.

Among several organizations trying to merge their various WCDMA proposals are

- Japan's Association of Radio Industry and Business (ARIB)
- Alliance for Telecommunications Industry Solutions (ATIS)
- T1P1
- European Telecommunications Standards Institute (ETSI) through its Special Mobile Group (SMG)

All these schemes try to take advantage of the WCDMA radio techniques without ignoring the numerous advantages of the already existing GSM networks. The standard that has emerged is based on ETSI's Universal Mobile Telecommunication System (UMTS) and is commonly known as UMTS Terrestrial Radio Access (UTRA). The access scheme for UTRA is Direct Sequence Code Division Multiple Access (DS-CDMA). The information is spread over a band of approximately 5 MHz. This wide bandwidth has given rise to the name Wideband CDMA or WCDMA. There are two different modes namely

- Frequency Division Duplex (FDD)
- Time Division Duplex (TDD)

Since different regions have different frequency allocation schemes, the capability to operation either FDD or TDD mode allows for efficient utilization of the available spectrum [17]. A brief definition of FDD and TDD modes is given next.

FDD: The uplink and downlink transmissions employ two separated frequency bands for this duplex method. A pair of frequency bands with specified separation is assigned for a connection.

TDD: In this duplex method**,** uplink and downlink transmissions are carried over the same frequency band by using synchronized time intervals Thus time slots in a physical channel are divided into transmission and reception part.

A. MULTIUSER COMMUNICATION SYSTEM

In multi-user communications [12] 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. Figure-1 shows 3 transmitting users in the time t, frequency f and power P domain. After finishing a call, the sub-channel can be reused and allocated to another user [1].

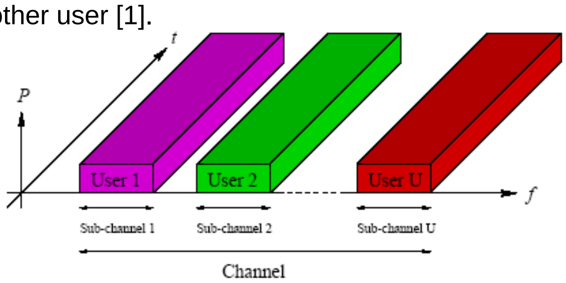

Figure-1: *Frequency division multiple access (FDMA)*

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. 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 accesses (TDMA) [1], such as the popular global system for mobile (GSM). Figure-2 shows how a TDMA system works. 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.

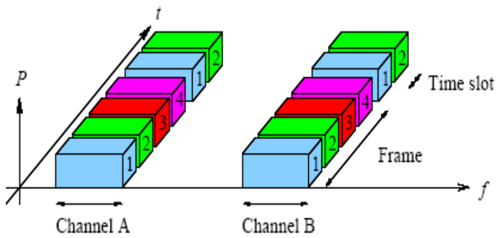

Figure-2: *Time division multiple access (TDMA)*

There is another technology which is used for 2nd generation mobile networks. The idea is based on spread spectrum (SS) which has been in use for a long time in military and space applications and is called code division multiple access (CDMA**)** **.** 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. Figure-3 shows how this technique works. Usually, within a network there are two channels, one for the uplink (mobile to base station) and one for the downlink (base station to mobile). All users share both channels at the same time. The number of users which can communicate simultaneously is dependent, among other factors, on the length of the spreading sequence (code, a series of binary data) [6].

If this code is long and pseudo-random then the interference induced from other users can be interpreted as an increased background noise level. CDMA offers many advantages over the other two techniques**.** 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 " (or bit error ratio (BER)) degrades. It is less susceptible to effects induced from a changing environment, which is important in mobile

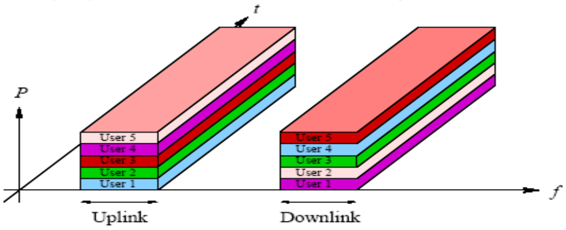

Figure-3: *Code division multiple access (CDMA)*

communications. Finally, it is generally believed that its capacity is much greater than that of the established (TDMA) systems**.** However, CDMA systems also have some additional constraints, which must be considered if it is to be used for cellular mobile communications, e.g. requirement for power control [4].

III. SIMULATION MODEL

The transmitter and receiver sections of the Alamouti space-time block coded multi-user W-CDMA wireless communication system is depicted in Figure-4. In this simulation work, ½-rated Convolutional encoder [10] is implemented as a channel coding scheme and BPSK is used as a digital modulation scheme. The synthetically generated binary bit streams are taken as a input data which are fed into ½-rated Convolutional encoder [14]. The channel encoded binary bit stream data are converted into complex

Table-1: Summary of the simulated model parameters

No. of bits used for synthetic data	5000
Bit rate	64 ,000 bits/sec
Channel Coding	½-rated Convolutional Encoder
Digital modulation(Symbol mapping)	BPSK
Diversity scheme	Alamouti Space time block coding
SNR, (Eb/No)	0 to10 dB

digital modulation symbols and these symbols are fed into Alamouti space time block encoder. Its output provides complex symbols in two diversity channels. In receiving section, the two transmitting message signals are processed with perfect knowledge of channel information in diversity combiner and its two outputs are fed into Maximum likelihood 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 digitally demodulated, channel decoded [18] and eventually processed to retrieve the transmitted bit stream. We do not explain each block in details. Here we only give the emphasis on Alamouti space time block encoder, BPSK Modulation Techniques and Spreading. The model parameters used in the present study are given in Table-1

A. ALAMOUTI SPACE TIME BLOCK CODE(A-STBC)

In 1998, Alamouti presented a simple two-branch transmit diversity scheme. 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 5 shows the block diagram of base band representation of the Altamonte'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 so 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 [13].

In order to get better understanding on the Alamouti STBC scheme, let us assume the Fading channel at time t is 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

$$h_o(t)=h_o(t+T)=h_o=\alpha_o e^{j\theta_o}$$

$$h_1(t)=h_1(t+T)=h_1=\alpha_1 e^{j\theta_1}$$

Where, T is the symbol duration.

The received signals can then be expressed as

$$r_o=r(t)=h_o s_o+h_1 s_1+n_o$$

$$r_1=r(t+T)=-h_o s_1^{*}+h_1 s_o^{*}+n_1$$

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 5 builds the following two combined signals that are sent to the maximum likelihood detector.

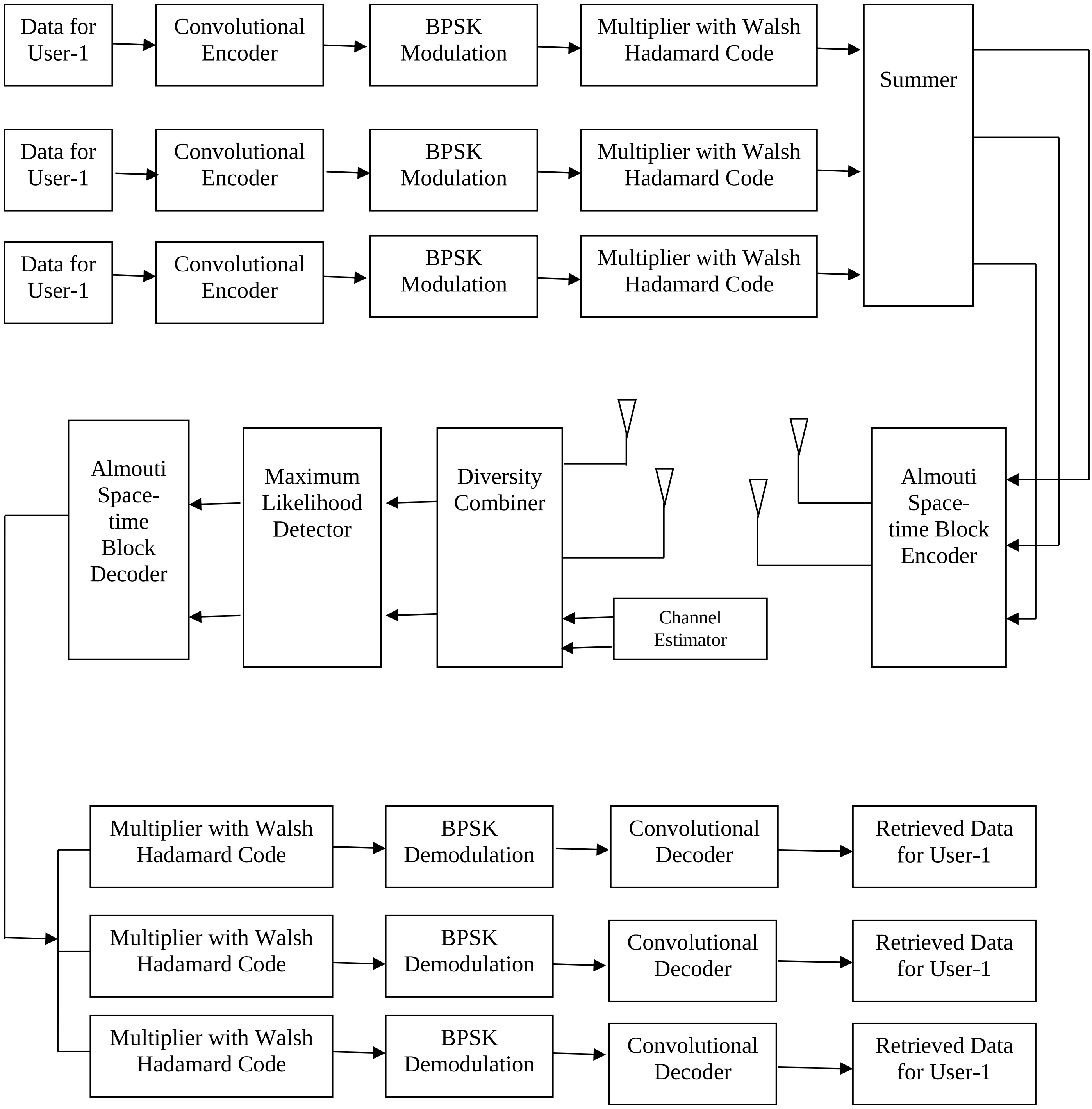

***Figure-4**: Alamouti Space-Time Block Encoded Multi-user W-CDMA Wireless Communication System*

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

Substituting all this equation, we get

$$\tilde{\mathbf{s}}_o = (\boldsymbol{\alpha}_o^2 + \boldsymbol{\alpha}_1^2)\mathbf{s}_o + \mathbf{h}_o^*\mathbf{n}_o + \mathbf{h}_1\mathbf{n}_1^*$$
$$\tilde{\mathbf{s}}_1 = (\boldsymbol{\alpha}_o^2 + \boldsymbol{\alpha}_1^2)\mathbf{s}_1 - \mathbf{h}_o\mathbf{n}_1^* + \mathbf{h}_1^*\mathbf{n}_o$$

These combined signals are then sent to the Maximum likelihood detector which, for each of the signals s_0 and s_1 uses the decision rule for PSK signals Choosing s_i iff

$$(\alpha_o^2+\alpha_1^2-1)|s_i|^2+d^2(\tilde{s}_o,s_i)\backslash$$
$$\le(\alpha_o^2+\alpha_1^2-1)|s_k|^2+d^2(\tilde{s}_o,s_k),\forall i\ne k$$

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

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

Choosing s_i iff

$$d^2(\tilde{s}_o,s_i)\le d^2(\tilde{s}_o,s_k),\forall i\ne k$$

The diversity order from the Alamouti two-branch transmit diversity scheme with one receiver is equal to that of two-branch MRRC [16].

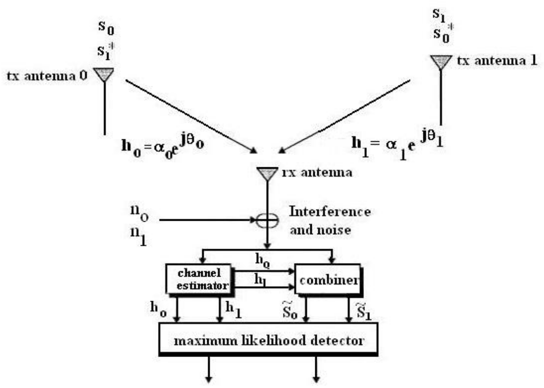

Figure 5: *Block diagram of Alamouti Space-time Block Coding scheme*

B. BINARY PHASE-SHIFT KEYING (BPSK)

BPSK (also sometimes called PRK, Phase Reversal Keying, or 2PSK) is the simplest form of phase shift keying (PSK). It uses two phases which are separated by 180° and so can also be termed 2-PSK. It does not particularly matter exactly where the constellation points are positioned, and in this figure they are shown on the real axis, at 0° and 180°. This modulation is the most robust of all the PSKs since it takes the highest level of noise or distortion to make the demodulator reach an incorrect decision. It is, however, only able to modulate at 1 bit/symbol and so is unsuitable for high data-rate applications when bandwidth is limited. In the presence of an arbitrary phase-shift introduced by the communications channel, the demodulator is unable to tell which constellation point is which. As a result, the data is often differentially encoded prior to modulation [15].

The general form for BPSK follows the equation:

$$s_b(t)=\sqrt{\frac{2E_b}{T_b}}\cos(2\pi f_c t+\pi(1-n)), n=0,1.$$

This yields two phases, 0 and π. In the specific form, binary data is often conveyed with the following signals:

$$s_0(t)=\sqrt{\frac{2E_b}{T_b}}\cos(2\pi f_c t+\pi)=-\sqrt{\frac{2E_b}{T_b}}\cos(2\pi f_c t)$$ for binary "0"

$$s_1(t)=\sqrt{\frac{2E_b}{T_b}}\cos(2\pi f_c t)$$ for binary "1"

where f_c is the frequency of the carrier-wave.

Hence, the signal-space can be represented by the single basis function

$$\phi(t)=\sqrt{\frac{2}{T_b}}\cos(2\pi f_c t)$$

where 1 is represented by $\sqrt{E_b}\phi(t)$ and 0 is represented by $-\sqrt{E_b}\phi(t)$. This assignment is, of course, arbitrary. This use of this basis function is shown at the end of the next section in a signal timing diagram. The topmost signal is a BPSK-modulated cosine wave that the BPSK modulator would produce. The bit-stream that causes this output is shown above the signal [19].

C. WALSH HADAMARD CODE

In UMTS and cdma2000, signaling and user data is spread twice in succession first with the channelization codes and later with the scrambling codes. The channelization codes are orthogonal Walsh codes, which are inherently more tolerant of interference caused by multiple users. . The scrambling codes, on the other hand, are not necessarily orthogonal and are built from the so-called PN codes [8].

In code division multiple access (CDMA) communication, the Hadamard code is referred to as Walsh Code, and is used to define individual communication channels. It is usual in the CDMA literature to refer to codewords as "codes". Each user will use a different codeword, or "code", to modulate their signal

Walsh codes are a set of perfectly orthogonal codes used to separate users on the downlink (DL) channel in CDMA systems. Code orthogonality between two codes W*i* and W*j* is defined as

$$\int_0^T W_i(t)W_j(t)dt=\delta_{ij}\cdot T$$

Walsh-Hadamard code consists of the row vectors of a Walsh code matrix arranged according to the order of Hadamard [7]. The elements of this Walse matrix are ±1, which can be rapidly generated from the following recursion relation:

$$H(i+1)=\begin{bmatrix}H(i) & H(i)\\ H(i) & -H(i)\end{bmatrix}$$

Where i=0, 1, 2, 3 … H(0)=+1

IV. SIMULATION RESULT

This section presents and discusses all of the results obtained by the computer simulation program written in Matlab2009b, following the analytical approach of a wireless communication system considering AWGN channel. The results are represented in terms of bit energy to noise power spectral density ratio (Eb/No) and bit error rate (BER) for practical values of system parameters. By varying SNR, the plot of Eb/No vs BER was drawn with the help of "semilogy" function. The Bit Error Rate (BER) plot obtained in the performance analysis showed that model works well on Signal to Noise Ratio (SNR) less than 10dB. Simulation results in figure-6, figure-7 and figure-8 shows the effect of Alamouti space time block coded multi-user W-CDMA communication system over AWGN channels using BPSK modulation schemes.

Figure-6 shows the effect of diversity technique for Alamouti space time block encoded wideband CDMA wireless communication system under AWGN for user-1. It is observed from the figure that the BER performance of the Alamouti space time block coded multiuser W-CDMA wireless communication system under BPSK modulation scheme for user 1 is quite satisfactory as compared to direct transmission. For a typical SNR value of 4 dB, the bit error rates are both 0 with Alamouti and No diversity scheme for user 1. But for SNR values of 3dB, the BER for Alamouti space time block coded W-CDMA system is lower than without any diversity technique. So, we can say that we can implement diversity technique for W-CDMA communication as compared to direct transmission.

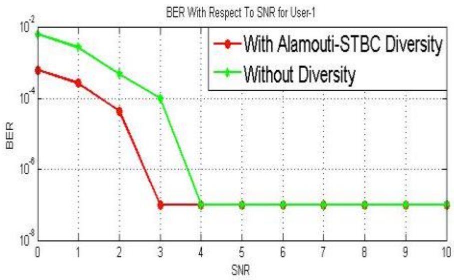

Figure-6: *BER Performance of Alamouti space time block encoded wideband CDMA wireless communication system under AWGN for user-1*

Similarly it is also observed from figure-7 and figure-8 that, with the implementation of diversity techniques, the multi-user W-CDMA communication system provide satisfactory performance with lower BER as compared to direct transmission.

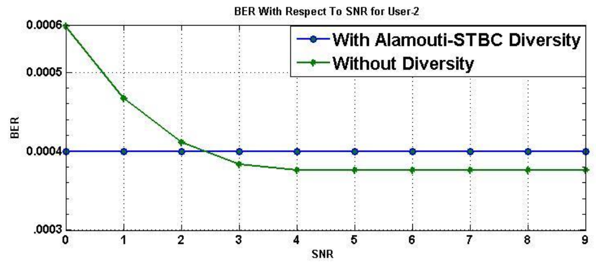

Figure-7: *BER Performance of Alamouti space time block encoded wideband CDMA wireless communication system under AWGN for user-2*

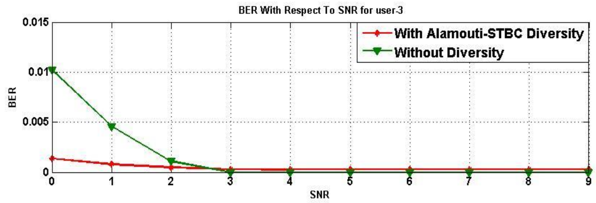

Figure-8: *BER Performance of Alamouti space time block encoded wideband CDMA wireless communication system under AWGN for user-3*

V. CONCLUSIONS

In this research work, the performance of a convolutionally channel coded multiuser W-CDMA wireless communication system with implementation of Alamouti space-time block coding scheme have been investigated. A range of system performance results highlights the impact of diversity and a low order of digital modulation under fading channel. In the context of system performance, it can be concluded that the implementation of BPSK digital modulation technique in Alamouti diversity encoded wireless communication system provides satisfactory performance.

REFERENCES

[1] K Raith, and J. Uddenfeldt, "Capacity of Digital Cellular TDMA Systems", IEEE Transactions on Vehicular Technology, vol. 40, pp. 323–332, 1991.

[2] L Hanzo, and R. Steele, "The Pan-European Mobile Radio System", European Transactions on Communications, vol. 5, pp. 245–276, 1994.

[3] R.C. Dixon, "Spread Spectrum Systems with Commercial Applications", New York, USA, John Wiley and Sons, Inc., 3rd ed., 1994.

[4] R. L Pickholtz., D. L Schilling, and. L. B. Milstein, "Theory of Spread-Spectrum Communications -A Tutorial", IEEE Transactions on Communications, vol. 30, pp. 855–884, 1982.

[5] P. Jung, P. W Baier, and. A Steil, "Advantages of CDMA and Spread Spectrum Techniques over FDMA and TDMA in Cellular Mobile Radio Applications", IEEE Transactions on Vehicular Technology, vol. 42, pp. 357–364, 993.

[6] K. S.Gilhousen, I. M. Jacobs, R. Padovani, A. J. Viterbi, L. A Weaver,. and C. E., Wheatley, "On the Capacity of a Cellular CDMA System", IEEE Transactions on Vehicular Technology, vol. 40, pp. 303–312, 1991.

[7] M. A Mokhtar. and. S. C. Gupta, "Power Control Considerations for DS/CDMA Personal Communication Systems", IEEE Transactions on Vehicular Technology, vol. 41, pp. 479–487, 1992

[8] R. L. Peterson, R. E. Ziemer, and D. E. Borth, "Introduction to Spread Spectrum Communications", Englewood Cliffs, NJ: Prentice Hall, 1995.

[9] Ziemer, R.E., and Peterson, R.L., "Digital communications", Prentice Hall, Englewood Cliffs, NJ 1979

[10] Jorge Castineira Moreira, Patrick Guy Farrell, "Essential of error control coding", john wiley & Sons. Ltd.

[11] Pottie, G. J. "System design choices in personal communications". IEEE Personal Commun. Mag., 2: Oct. 1995, 50–67.

[12] Sundberg, C.-E. W. and Seshadri, N. "Digital cellular systems for North America.", IEEE Globecom, Dec. 1990, 533–7.

[13] Balaban, N. and Salz, J. Dual "Diversity combining and equalization in digital Cellular mobile radio". IEEE Trans. on Vehicular Technology, 40: May 1994, 342–54.

[14] Md. Polas Tai, Md. Ashraful Islam, Farhana Enam and Md. Arifur Rahman, "Secure Color Image Transmission Over WIMAX Communication System", Journal of Multidisciplinary Engineering Science and Technology (JMEST), Vol. 3 Issue 6, June – 2016, page 5040-5047, Berlin, Germany.

[15] Nuzhat Tasneem Aown, Md. Ashraful Islam, Md. Mizanur Rahman and A.Z.M. Touhidul Islam "Effect of AWGN & Fading (Rayleigh & Rician) channels on BER performance of a WiMAX communication System", International Journal of Computer Science and Information Security, IJCSIS, Vol. 10, No. 8, August 2012, USA

[16] Siavash M. Alamouti, "A Simple Transmit Diversity Technique For Wireless Communications", IEEE Journal on Select areas in Communications, vol.16(8), pp.1451-1458, 1998.

[17] Vijay K. Garg, "Wireless Communications and Networking", Morgan Kaufmann Publishers, San Francisco, California, 2007, USA

[18] Jorge Castiñeira Moreira and Patrick Guy Farrell, "Essentials of Error-Control Coding", John Wiley & Sons Ltd, 2006, United Kingdom.

[19] Theodore S Rappaport, " Wireless Communications Principles and Practice", Second Edition, 1996.