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PERFORMANCE ANALYSIS OF DS-CDMA SYSTEM OVER AWGN AND FADING CHANNELS BASED ON DIVERSITY SCHEME

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ABSTRACT

This paper investigates, a technique which uses antenna diversity to achieve full transmit diversity using an arbitrary number of transmit antennas for secure communications and to improve the system performance by mitigating interference. The work is focused on the performance of DS-CDMA systems over Rayleigh, Rician and AWGN fading channel, in the case of the channel being known at the receiver .The diversity scheme used in the analysis is Alamouti STBC scheme. Using simulation and analytical approach, we show that STBC CDMA system has increased performance in cellular networks We also compare the performance of this system with the typical DS-CDMA system and show that STBC and multiple transmit antennas for DS- CDMA system provide performance gain without any need of extra processing . Evaluation and comparison of the performances of DS-CDMA system in the AWGN (Additive White Gaussian Noise) channel, Rician fading channel and the Rayleigh fading channel are provided.

Keywords: *Additive White Gaussian Noise, DS-CDMA, Rician distribution, Space time block codes (STBC)*

1. INTRODUCTION

CDMA works on the basis of spread spectrum techniques where in each user occupies the whole bandwidth accessible [1]. A digital signal is spread (i.e., multiplied by) at the transmitter with the aid of a pseudo-random noise (PN) code [2]. A receiver despreads the signal obtained, so as to recover the original information, by employing a locally generated PN code.

The next generation wireless systems are expected to meet the ever increasing demands, such as, high voice quality and bit rate, coverage, bandwidth and power efficiency, less effect of channel impairments, ability to be deployed in diverse environments, and so on. The remote units need to be small and lightweight to provide better service and work efficiently in any sort of environments [3]. In most scattering environments, antenna diversity is effective, practical and hence, a widely applied technique for reducing the effect of Rayleigh fading [3].

Fading is a common phenomenon which deteriorates the original signal while transmitted through wireless channel. This signal experiences both small-scale and large-scale fading. Small-scale fading is also known as Rayleigh Fading because if the multiple reflective paths are more in number and there is no line of sight signal component, the envelope of the received can statistically be described by a Rayleigh probability density function [4]. Space Time Block Code (STBC) is an effective transmit diversity technique used to transmit symbols from multiple antennas, which ensures that transmission from various antennas is orthogonal [5], [6]. A technique which uses chaotic communication system combined with adaptive beam forming is proposed, for secure communications and to improve the system performance by mitigating interference. For secure communications, chaotic sequences are used [7].

The effect of using wavelet based technique on the performance of a MC-CDMA wireless

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communication system has been investigated [8]. Wireless technologies have become familiar in recent years and usually applied in multimedia broadcasting, environment monitoring, mobile communication, etc. In all applications, reducing the BER is very important.

Our research paper deals with performance enhancement of DS-CDMA system using Alamouti STBC encoding to work in a fading channel environment. Alamouti STBC is used as antenna diversity scheme. It is widely used for mitigating the effect of multipath fading. This scheme will be described in detail later. The results are compared with no diversity technique and maximal ratio combiner (MRC).

The paper organizes as follows: section 2 describes the Alamouti STBC scheme which is used in this research. In Section 3 System Model and Description of DS-CDMA system over Rayleigh, Rician and AWGN channel using STBC has been discussed including two transmit diversity schemes (Alamouti 2:1, Alamouti 2:2) and corresponding capacities of the schemes have been evaluated mathematically. In Section 4 conducts the simulated results and discussions in Section 5, the paper is concluded by a summary of comparison of the schemes.

2. ALAMOUTI STBC SCHEME

2.1 Space Time Multiuser CDMA System

Space Time Block Code (STBC) is an effective transmit diversity technique used to transmit symbols from multiple antennas, which ensures that transmission from various antennas is orthogonal [5], [6]. Wireless transmission with high data rate, as well as diversity and coding gain, is quite achievable using STBC, which combats fading in wireless communications [5]. STBC is a highly efficient approximation to signaling within wireless communication that takes the advantage of the spatial domain by transmitting a number of data streams using multiple co-located antennas [9]. The main feature of STBC is the provision of full diversity with very simple, yet effective encoding and decoding mechanism.

STBC operates on a block of data-stream which is to be transmitted and produces a matrix whose rows and columns represent antennas and time, respectively. The usual and simplest representation of STBC is shown below

$$\text{Transmit antennas} \rightarrow$$

$$\textbf{Time - slots} \downarrow \begin{bmatrix} S_{11} & S_{12} & \cdots & S_{1_{nT}} \\ S_{21} & S_{22} & \cdots & S_{2_{nT}} \\ \vdots & \vdots & \ddots & \vdots \\ S_{T1} & S_{T2} & \cdots & S_{T_{nT}} \end{bmatrix}$$

Here, S_{ij} is the modulated symbol to be transmitted from antenna j in time-slot i. There should be T time-slots and nT transmit antennas as well as nR receive antennas. This block is usually considered to be of length T. We consider two diversity schemes for our analyses:

1. Scheme-I: two transmit antennas, one receive antenna
2. Scheme-II: two transmit antennas, two receive antenna

2.2 Scheme-I: Two transmit antennas, one receive antenna

For the scenario where the combination of two transmitters and one receiver is employed, a diversity scheme, proposed by S. M. Alamouti, has been adopted. This particularly simple and prevalent scheme, with two transmit antennas and one receive antenna, uses simple coding which is the only STBC that can achieve the full diversity gain without needs to sacrifice its data rate. As per Alamouti's scheme, the transmitter sends out data in groups of 2 (two) bits. The scheme may be analyzed by the following three functions [10]:

The encoding and transmission sequence of message symbols at the transmitter;
• The combining scheme at the receiver;
• The decision rule for maximum likelihood detection.

2.2.1. The Encoding and Transmission Sequence

At a given symbol period, two signals, transmitted from two antennas: antenna zero and antenna one, are denoted by a_0 and a_1 simultaneously. During the next symbol period, signal $(-a_1^*)$ is transmitted from antenna zero, and signal a_0^* is transmitted from antenna one, where $*$ stands for complex conjugate operation. The encoding is done in space and time (and hence space-time coding). The assumption made for this scheme is that the channel state remains fairly constant over the transmission of 2 (two) consecutive symbols [3], [11].

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Assuming that fading is constant across two consecutive symbols, the channel at time may be modeled as

$$s_0(t) = s_0(t+T) = s_0 \;= \alpha_0 e^{j\theta_0} \quad (1)$$
$$s_1(t) = s_1(t+T) = s_1 = \alpha_1 e^{j\theta_1} \quad (2)$$

where T is the symbol duration.
The received signals, y_0 and y_1 at time T and $t + T$ respectively can be expressed as

$$y_0 = y(t) = s_0 a_0 + s_1 a_1 + n_0 \quad (3)$$
$$y_1 = y(t+T) = -s_0 a_1^* + s_1 a_0^* + n_1 \quad (4)$$

where n_0, $n_1$are complex random variable representing receiver noise and interference.

2.2.2. The Combining Scheme

The combiner builds the following two combined signals that are sent to the maximum likelihood detector

$$\widetilde{x_0} = y(t+T) = s_0^* y_0 + s_1 y_1^* \quad (5)$$
$$\widetilde{x_1} = y(t+T) = s_1^* y_0 + s_0 y_1^* \quad (6)$$

2.2.3. The Maximum Likelihood Decision Rule

In the maximum likelihood detector, signals are chosen either x_0 or x_1 according to corresponding decision rule. Thus, the scheme reduces complexity and simplifies transmission greatly.

2.3 Scheme-II: Two transmit antennas, two Receive Antennas

When a higher order of diversity is needed and multiple receive antennas at the distant points are possible, it is feasible to afford a diversity order of 2*M with two transmit and M receive antennas [3]. In this section, a special case considering two transmitters and two receivers has been illustrated briefly in almost similar fashion as already done in Section 2.2. The generalization to M receive antennas is trivial.

2.3.1. The Encoding and Transmission Sequence

The encoding and transmission sequence for this configuration is identical to the case discussed in Section 2.2.1. The channel at time t can be modeled by complex multiplicative distortions $s_0(t)$, $s_1(t)$, $s_2(t)$, $s_3(t)$ between transmit antenna zero and receive antenna zero, transmit antenna one and receive antenna zero, transmit antenna zero and receive antenna one, transmit antenna one and receive antenna one, respectively.

Assuming that fading is constant across two consecutive symbols, it can be written

$$s_0(t) = s_0(t+T) = s_0 = \alpha_0 e^{j\theta_0} \quad (7)$$
$$s_1(t) = s_1(t+T) = s_1 = \alpha_1 e^{j\theta_1} \quad (8)$$
$$s_2(t) = s_2(t+T) = s_2 = \alpha_2 e^{j\theta_2} \quad (9)$$
$$s_3(t) = s_3(t+T) = s_3 = \alpha_3 e^{j\theta_3} \quad (10)$$

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

$$y_0 = s_0 a_0 + s_1 a_1 + n_0 \quad (11)$$
$$y_1 = -s_0 a_1^* + s_1 a_0^* + n_1 \quad (12)$$
$$y_2 = s_2 a_0 + s_3 a_1 + n_2 \quad (13)$$
$$y_3 = -s_2 a_1^* + s_3 a_0^* + n_2 \quad (14)$$

The complex random variables, n_0, n_1, n_2 and n_3 represent receiver thermal noise and interference.

2.3.2. The Combining Scheme

The combiner builds the following couple of combined signals that are sent to the maximum likelihood detector

$$\widetilde{x_0} = s_0^* y_0 + s_1 y_1^* + s_2^* y_2 + s_3 y_3^* \quad (15)$$
$$\widetilde{x_1} = s_1^* y_0 - s_0 y_1^* + s_3^* y_2 - s_2 y_3^* \quad (16)$$

2.3.3. The Maximum Likelihood Decision Rule

The maximum likelihood detector chooses either x_0 or x_1 according to corresponding decision rule, as was done in Section 2.2.3.

3. SYSTEM MODEL AND DESCRIPTION

Figure.2 presents the block diagram of the Alamouti STBC based DS-CDMA communication system with antenna diversity.

3.1 Transmitter Part

At transmitter, the data is generated from a random source, consists of series of ones and zeros. Modulation process is used to convert data input bits to symbol vector. BPSK and QPSK schemes are used to map the bits to symbols.

Modulation techniques are expected to have three positive properties:

a. Good Bit Error Rate Performance

Modulation schemes should be able to achieve low bit error rate in the presence of fading, Doppler spread, interference and thermal noise.

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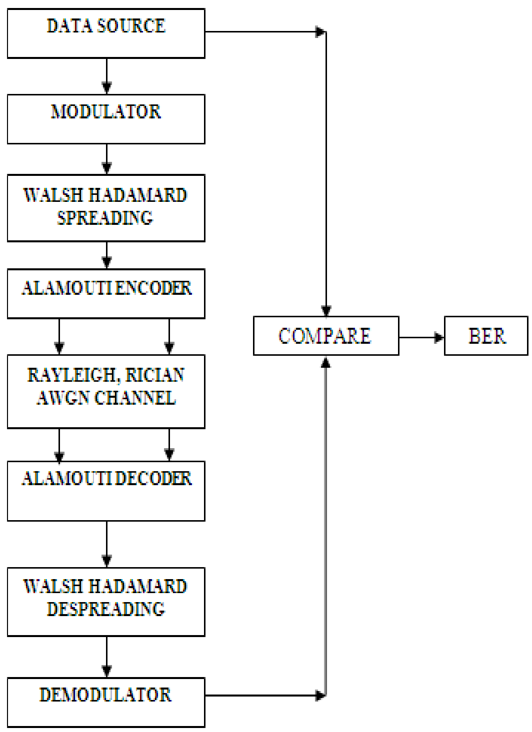

Figure 1:. Block Diagram for the simulated Alamouti STBC based CDMA system

b. Power Efficiency:

Power limitation is one of the crucial design challenges in portable and mobile applications. Power efficiency can be increased by using Non-linear amplifiers. However, non-linearity may degrade the BER performance of some modulation techniques. Constant envelope modulation techniques are used to prevent the re growth of spectral side lobes during nonlinear amplification

c. Spectral Efficiency:

The modulated signals power spectral density hould have a narrow main lobe and fast roll-off of side lobes. Spectral efficiency is measured in units of bit /sec/Hz. Walsh Hadamard codes are used for spreading and dispreading the modulated sequence.

3.2. Space Time Block Code (STBC)

Space-time coding refers to channel coding techniques for communication with multiple transmit and receive antennae. To create spatial diversity, Space-time block coding utilizes multiple transmit antennas. Data encoded by space-time block code, is divided into a stream of data and transmitted simultaneously using transmit antenna. The signal received by each receiver antenna will be linear superposition of the transmitted signals agitated by noise.

Rather than joint detection, the signals transmitted using different antennas are decoupled to achieve Maximum likelihood decoding. Using this technique, the orthogonal structure of the block code generates maximum likelihood decoding algorithm. This algorithm is based only on linear processing by the receiver antenna. This system will provide a better performance under a fading environment.

3.3. Fading and Multipath

Fading is coined as the distortion produced by the carrier-modulated telecommunication signal transmitted over propagation media. The term Multi-path propagation signifies the transmitted signal reach the receiver by two or more paths. In wireless communication, multi-path fading is induced by muti-path propagation. The common factors considered for multi-path fading are reflection from terrestrial objects, atmospheric ducting, ionospheric reflection and refraction. The phenomenon of diffraction, reflection and scattering will give rise to additional radio propagation paths apart from the direct optical LOS (Line of Sight) path between the radio transmitter and receiver and will result in constructive & destructive interference and phase shift in the signal.

3.3.1. Additive White Gaussian Noise Model

Additive-White Gaussian Noise (AWGN) environment is preferred in a wireless communication system or proximity detector or a local positioning system based on Time-of-flight. Additive white Gaussian noise (AWGN) is used to transmit signal while signals simulate background noise of channel on propagation.

$$y(t) = s(t) + n(t) \qquad (17)$$

that passed through the AWGN channel where s(t) is transmitted signal and n(t) is background noise.

3.3.2. Rayleigh Fading Channel

The term Multi-path propagation signifies the transmitted signal reach the receiver by two or more paths. The consequences of multi-path fading are reflection from terrestrial objects,

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atmospheric ducting, ionospheric reflection and refraction.

Mulitpath fading causes Raleigh fading as an effect of phase shifting of the signal and constructive & destructive interference. The standard statistical model of this is known as Rayleigh distribution. Rayleigh fading is coined when all signals reaching the receiver are reflected with no direct component. Channel Impulse Response is used to model multipath Rayleigh fading channels

$$c(t) = \sum_{i=0}^{l-1} \alpha_i \partial(t-\tau_i) \quad (18)$$

where, l is the number of channel paths, α_i and τ_i are the complex value and delay of path *i*, respectively. It is assumed that the CIR is constant during one DS-CDMA symbol though the channel is time variant as a result of motion of the mobile terminal. The propagation paths are considered to be statistically independent, with normalized average power.

3.3.3. Rician Fading Channel

A Rician model is obtained in a system with LOS propagation and scattering. The model is characterized by the Rician factor, denoted by K and defined as the ratio of the line of sight and the scatter power components. The pdf for a Rician random variable x is given by

$$g(x) = x(1+t)e^{-t(1+t)x^2} I_0(2x(\sqrt{(k(k+1)})))$$

where, $k = \frac{D^2}{2\sigma_r^2}$, x≥0 (19)

and D^2 and $2\sigma_r^2$ are the powers of the LoS and scattered components, respectively. The powers are normalized such that

$$D^2 + 2\sigma_r^2 = 1 \quad (20)$$

3.3.4. Bit Error Rate (BER)

The BER, or quality of the digital link, is calculated from the number of bits received in error divided by the number of bits transmitted.

BER= (Bits in Error) / (Total bits received).

In digital communication system, the number of bit errors is the number of received bits of a data stream over a communication channel that has been varied due to noise, interference, distortion or bit synchronization errors. The Bit Error Rate is the number of bit errors divided by the total number of transmitted bits during a particular interval of time and is a dimensionless performance measure, often expressed as a percentage.

4. RESULTS AND DISCUSSION

This section presents the computer simulations which investigate the BER performance of DS-CDMA system using two different diversity schemes.

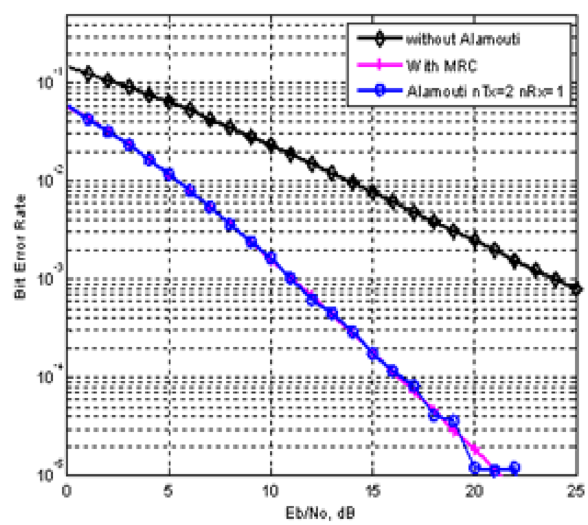

Figure 2: BER vs SNR in dB for Alamouti STBC (2 Tx & 1 Rx) based DS-CDMA system over AWGN and Rayleigh channel

Figure 2 shows BER performance for coded DS-CDMA system using Alamouti's STBC technique (nTx=2 & nRx=1) in Rayleigh fading condition. It is assumed that the receiver has perfect knowledge of the channel condition. It is clear that Alamouti's STBC technique using two transmitting antennas and one receiving antenna for CDMA system inand the system which uses Maximum ratio Combiner using two transmitting antennas and one receiving antenna. And both the schemes are better than the typical DS-CDMA system

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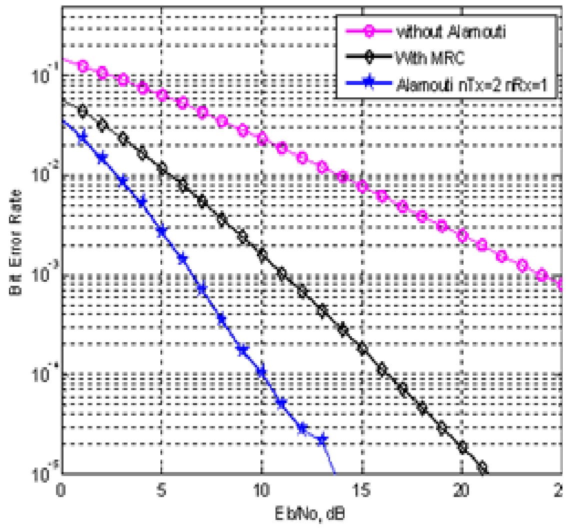

Figure 3. BER vs SNR in dB for Alamouti STBC (2 Tx & 1 Rx) based DS-CDMA system over AWGN and Rician channel

Figure 3 presents comparison of performance among typical DS- CDMA system, BPSK system using Maximal Ratio Combiner technique and CDMA system implementing Alamouti's STBC technique.

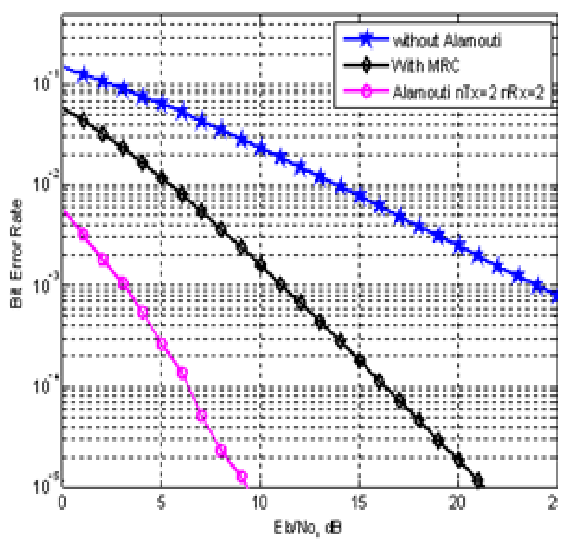

Figure 4. BER vs SNR in dB for Alamouti STBC (2 Tx & 2 Rx) based DS-CDMA system over AWGN and Rayleigh channel

When Alamouti's STBC technique is used for CDMA system, in Rician channel, the performance drastically improves by around 8dB. That means, it will require less power to transmit for same BER for CDMA system using Alamouti's STBC technique. It can be explained alternatively that for transmitting signal at a same power will give better BER for CDMA system with Alamouti's STBC technique than the typical CDMA system. It is evident that E_b/N_0 is decreased for CDMA system when Alamouti's scheme is used. Capacity of any system is inversely proportional to E_b/N_0, which indicates that the capacity increases for using Alamouti's scheme.

Figure 4 shows BER performance for coded DS-CDMA system using Alamouti's STBC technique (nTx=2 & nRx=2) in AWGN and Rayleigh fading condition. It is assumed that the receiver has perfect knowledge of the channel condition.

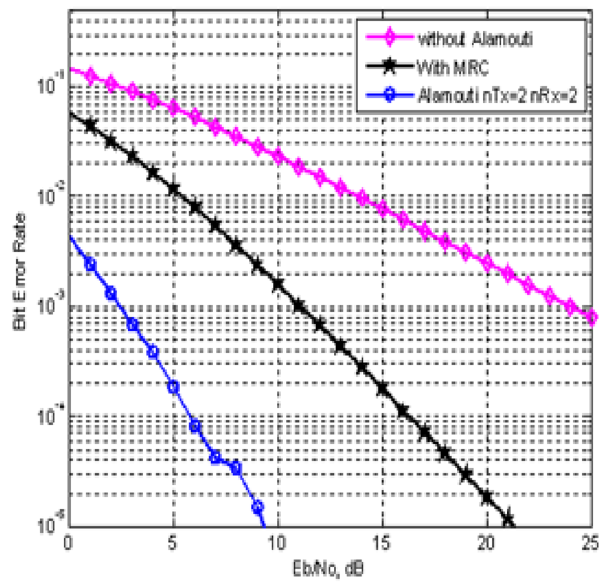

Figure 5. BER vs SNR in dB for Alamouti STBC (2 Tx & 2 Rx) based DS-CDMA system over AWGN and Rician channel

It is clear that Alamouti's STBC technique using two transmitting antennas and two receiving antenna for CDMA system in and the system which uses Maximum ratio Combiner using two transmitting antennas and two receiving antenna. And both the schemes are better than the typical DS-CDMA system.

Figure 5 shows BER performance for coded DS-CDMA system using Alamouti's STBC technique (nTx=2 & nRx=2) in AWGN and Rician fading condition. It is assumed that the receiver has perfect knowledge of the channel condition. It is clear that Alamouti's STBC

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technique using two transmitting antennas and two receiving antenna for CDMA system in and the system which uses Maximum ratio Combiner using two transmitting antennas and one receiving antenna. And both the schemes are better than the typical DS-CDMA system.

Table 1: Ber Values Of Stbc Ds-Cdma System For The Above Two Schemes Upto Snr Values Of 10 Db

	nTx=2 & nRx=1		nTx=2 & nRx=2	
dB	AWGN & Rayleigh channel	AWGN & Rician Channel	AWGN & Rayleigh channel	AWGN & Rician Channel
0	0.0581	0.0352	0.0055	0.0043
1	0.0440	0.0235	0.0033	0.0024
2	0.0328	0.0145	0.0018	0.0013
3	0.0239	0.0086	0.0010	0.0007
4	0.0169	0.0049	0.0005	0.0004
5	0.0118	0.0027	0.0003	0.0002
6	0.0081	0.0014	0.0001	0.0001
7	0.0055	0.0007	0.0001	0
8	0.0037	0.0004	0	0
9	0.0025	0.0002	0	0
10	0.0016	0.0001	0	0

Table 1 shows, in the presence of AWGN and Rayleigh channel, BER of 0.0003 is achieved for the SNR value of 5 dB using Alamouti STBC (nTx=2 & nRx=2) encoding , whereas for the same dB without using Alamouti encoding BER value is 0.0642. Thus lower BER is obtained when Alamouti encoding is used.

From Table 1, in the presence of Rician and AWGN channel, BER of 0.0001 is achieved for the SNR value of 6 dB using Alamouti's STBC technique, whereas for the same SNR without using Alamouti's STBC nTx=2 & nRx=2) technique BER value is .0632. In the presence of Rayleigh channel, BER of 0.0004 is achieved for the SNR value of 4 dB using Alamouti's STBC whereas for the same value of SNR without using the Alamouti encoding BER value is 0.0771.

5. CONCLUSION

In this paper, STBC DS-CDMA system has been implemented and analyzed. Using analytical and simulation approach, we have shown that using STBC in DS-CDMA system is advantageous over traditional CDMA system including better BER performance and lower complexity. We have analyzed both the schemes in AWGN channel, Rayleigh Fading channel and Rician Fading channel. It has been observed that BER performance of the system is improved with antenna diversity schemes. Alamouti scheme has been used as the antennal diversity.

The simulation results show that the BER performance is better using Alamouti scheme under AWGN and Rician channel where as it is worse under Rayleigh fading channel. In general BPSK scheme should have least priority compared to other mapping schemes, while considering in terms of spectral efficiency, bandwidth and bit rate support. Channels perform in the following order in terms of best (less SNR requirement) to worst (more SNR requirement) to maintain the required BER: AWGN, Rician, Rayleigh.

Future extension of this work has a lot of scope as noted. The proposed system is used with 2 antennas a maximum. It can further extend for more than two to improve the performance.

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