# Performance analysis of multi-user DS-CDMA using wavelet based diversity schemes

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## Abstract

*This manuscript implements, a strategy for achieving maximum transmit diversity using an arbitrary number of transmit antennas for safe and secure communications and enhancing system efficiency by minimizing interference using antenna diversity. As, Wavelets have been thought as a powerful signal processing tool, it provide an intended results compared to conventional signal transforms. The research focuses on the efficiency of multi-user CDMA systems over Rayleigh and AWGN channels when the receiver knows the channel. The Wavelet-based Alamouti STBC scheme was used in the study as the diversity scheme. Because it works well in lower SNR values, Spread Spectrum communication through Discrete Wavelet Transform and thresholding becomes efficient. In addition, the Alamouti scheme is used to improve the performance further. Using simulation, it has been demonstrated that an STBC CDMA system based on wavelets has improved performance in cellular networks, and a performance comparison of this system with a traditional DS-CDMA system has revealed improved performance gains without the need for additional processing.. The output of a multi-user CDMA system in the AWGN (Additive White Gaussian Noise) channel and the Rayleigh fading channel is compared and evaluated.*

**Keywords:** *Space time block codes (STBC), Additive White Gaussian Noise, Rayleigh fading channel, Wavelets, Multi-user CDMA.*

## 1. Introduction

CDMA is based on the spread spectrum concept, in which each user has access to the entire available transmission capacity [1]. A pseudo-random (PN) code is used to scatter (i.e. multiply) a digital signal at the transmitter[2]. Wavelet transformations have been a more powerful method for correlation than the standard transform in recent years. The authors of [3] used a modern denoising technique in spread spectrum systems, in which wavelet coefficients replace noisy signal and code.

Wavelets for denoising are used in [4] and [5] in an effort to improve CDMA signal time delay estimation and code following. In [6] and [7] CDMA signal can be seperated from GSM utilizing wavelets and distinguishing proof of the CDMA signal is appeared. Denoising, which attempts to evacuate the small portion of the signal accepted as noise can be implemented by utilizing Discrete Wavelet transform [8]. The signal obtained from the physical environment contains the exasperating noise. And thus, Donoho [9] proposed wavelet denoising steps has connected numerous one or two dimensional signal after difficult or delicate thresholding strategies. More often, the noise can be imitated by using free zero-mean white Gaussian variables that are stationary. The most important thing to look at is BER reduction. Abd El-Fattahet al [10] receive the Weiner filter cascaded with the Wavelet filter; as a result, much better BER for lower SNR values can be obtained when compared to other denoising strategies.

The impact of using a wavelet-based technique on the execution of an MC-CDMA remote communication system [8] has been investigated. Donoho suggested the denoising procedure, which uses wavelet space thresholding, as a powerful technique [11]. Wavelets are used to detect the presence of a spread spectrum signal, which may enhance accuracy. The authors of [12] used a modern denoising technique in spread spectrum systems, in which wavelet coefficients replace noisy signal and code. The execution of the ICI mitigation for the higher-frequency offset is improved, and an effective search algorithm for generating the sub-optimal parameter for maximizing the carrier-to-interference proportion (CIR) is suggested [13]. Wireless technologies are as a rule connected in interactive media broadcasting, environment observing, portable communication, etc. In all applications, diminishing the BER is exceptionally critical. An approach for analyzing the achievability of DS-CDMA systems with imperfect SIC is proposed. Lower computational complexity than that of ESM and in this way benefits the speedy decisions of admission control and/or planning, which are basic for Quality of Service provisioning in DS-CDMA frameworks [14].

This research paper looks at how to improve the efficiency of a multi-user CDMA device in a fading channel environment by using Alamouti STBC encoding. As an antenna diversity system, Alamouti STBC is used. It's usually used to minimize the effects of multipath fading. The findings are compared to those of a radio combiner with no diversity and a radio combiner with the most diversity (MRC). The following is how the paper is organized: In section 2: Work related to this manuscript is discussed. This manusript deals with execution upgrade of Multi-user CDMA system utilizing Alamouti STBC encoding to work in a fading channel environment. Alamouti STBC is used as radio wire differences conspire. It is broadly utilized for relieving the impact of multipath blurring. The Alamouti STBC scheme, which is used in this study, is defined in Section 3. The counting of two transmit diversity schemes was discussed in Section 4: Device Model and Definition of DS-CDMA system over Rayleigh, Rician, and AWGN channels using STBC (Alamouti 2:1, Alamouti 2:2). In Segment 5: the wavelet denoising strategies utilized in spread spectrum is discussed about and threshold calculating parameters are inferred. The simulated results and discussions are presented in Section 6. In Segment 7, the paper comes to a close with a description of the scheme comparisons.

## 2. Related work

The lifting discrete wavelet transform approach (LDWT) is used to study the merging methods of an MC-CDMA. Is shown to maintain symmetry in the face of multipath Flat Fading Channels). The performance of MC-CDMA over a variety of channels, including the AWGN channel and FFC, is investigated, and BER versus SNR graphs are plotted and presented with care[15]. In the hexagonal shape cell, the average SER is computed for three NOMA methods for different users with different Signal to Noise Ratio values. When compared to PDMA and MUSA methods, the SCMA shows a 3% increase in average SER value[16]. Since existing techniques are capable of removing a relevant a part of the noise, the current method of denoising is to use a band pass or low pass filter with specific stop frequencies, because existing techniques are capable of removing a relevant a part of the noise; however, they are incapable if the noise is within the band of the signal to be analyzed. As a result, a variety of denoising techniques have been proposed to address this problem. It's difficult to model the signal because of the noise's origin and non-stationarity. However, if the noise is believed to be stationary, an empirically recorded signal distorted by additive noise can be interpreted as follows:

$$y(t) = x(t) + \sigma\varepsilon(t), \quad t = 0,1, \dots \dots \dots \dots n-1 \tag{1}$$

where y(t) denotes a noisy signal, x(t) denotes a noise-free real signal, ε(t) denotes separately normal random variables, and σ represents the noise level in y(t) (t). The goal of noise removal in this model is to reconstruct the first signal x(t) from a finite set of y(t)values without assuming a specific signal structure. The noise is modeled as a high frequency signal, which is then applied to an innovative signal, which is the same old approach to noise reduction. The regular Fourier transform can be used to bring out these high frequencies, which can then be removed with proper filtering. Since it relies solely on measuring the DFT, this noise reduction technique is both conceptually simple and efficient.

# 3. Alamouti STBC scheme

## 3.1. Space Time Multiuser CDMA System

STBC is an effective transmitting diversity technique for transmitting symbols from multiple antennas while maintaining orthogonal transmission from separate antennas [5] and [6]. STBC is a simple technique that provides mechanism for complete diversity, efficient encoding and decoding. The device produces a matrix whose rows and columns represent antennas and time, respectively, based on a data-stream block to be transmitted. Below is an interpretation of STBC

**Transmit antennas** →

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

$S_{ij}$ is the modulated symbol that will be transmitted from antenna j in time-slot i. The number of time slots is T, the number of transmitting antennas is nT, the number of receiving antennas is nR, and the length of this block is T. For our study, we find two diversity schemes:

1. Scheme I consists of two transmitting antennas and one receiving antenna.
2. Scheme II: two transmitting and two receiving antennas

## 3.2. Scheme-I: Two transmit antennas, one receive antenna

A diversity scheme, introduced by S. M. Alamouti, has been adopted for the scenario where two transmitters and one receiver are used. With two transmitting antennas and one receiving antenna, this simple and widely used scheme employs simple coding, which is the only STBC that can achieve full diversity gain without sacrificing data rate. The transmitter in Alamouti's scheme sends data in extremely small groups of two bits. The following three functions examine the scheme as well:

- Data symbols shall be encoded and transmitted at the transmitter;
- Receiver combination scheme
- The optimum probability detection decision law

### 3.2.1. The Encoding and Transmission Sequence:

At a given symbol time, two signals emitted from two antennas: antenna zero and antenna one, are denoted concurrently by $a_0$and $a_1$. During the next symbol moment,Signal $(-a_1^*)$ is transmitted from antenna zero, and signal $a_0^*$ is transmitted from antenna one, where $*$ stands for complex conjugate activity.The encoding process involves space and time coding. The assumption made forthis scheme is t hat over transmission of two consecutive symbols, the channel state remain fairly constant [10 ].The two consecutive symbols are based on the assumption that the fading is constant and that the c hannel at time t is set as

$$s_0(t) = s_0(t+T) = s_0 = \alpha_0 e^{j\theta_0} \tag{2}$$
$$s_1(t) = s_1(t+T) = s_1 = \alpha_1 e^{j\theta_1} \tag{3}$$

where T is the symbol's duration.
At time t, the obtained signals can be expressed as $y_0$ and $y_1$ at time T and t+T, on the other hand, can be written as

$$y_0 = y(t) = s_0a_0 + s_1a_1 + n_0 \tag{4}$$
$$y_1 = y(t+T) = -s_0a_1^* + s_1a_0^* + n_1 \tag{5}$$

where, $n_0$, $n_1$ are complex random variables that reflect receiver noise and interference, respectively.

### 3.2.2. The Combining Scheme

The combiner generates the following two combined signals which is sent to the detector of maximum probability

$$\widetilde{x_0} = y(t+T) = s_0^*y_0 + s_1y_1^* \tag{6}$$
$$\widetilde{x_1} = y(t+T) = s_1^*y_0 + s_0y_1^* \tag{7}$$

### 3.2.3. The Maximum Likelihood Decision Rule

Signals are assigned to one of two categories: $x_0$or $x_1$, depending on the decision rule used in the maximum detector of probability. As a result, the scheme reduces complexity and simplifies transmission greatly.

### 3.3.Scheme-II: Two transmit antennas, two Receive Antennas

Where a higher order of diversity is needed and multiple receiving antennas at the remote units are feasible, a diversity order of 2M can be used with two transmitting and M receiving antennas. In this section, a special case involving two transmitters and two receivers has been briefly illustrated in approximately the same way as in Section 3.2. The extension to M receive antennas is straightforward.

### 3.3.1. The Encoding and Transmission Sequence

This configuration's encoding and transmission sequence is similar to the case discussed in Section 3.2.1. Complex multiplicative distortions $s_0(t)$, $s_1(t)$, $s_2(t)$, $s_3(t)$ between first transmit antenna and first receive antenna, second transmit antenna and first receive antenna, first transmit antenna and second receive antenna , second transmit antenna and second receive antenna respectively.

The two consecutive symbols are modeled by assuming, fading is constant and the channel at time t is given as

$$s_0(t) = s_0(t+T) = s_0 = \alpha_0 e^{j\theta_0} \tag{8}$$

$$s_1(t) = s_1(t+T) = s_1 = \alpha_1 e^{j\theta_1} \tag{9}$$

$$s_2(t) = s_2(t+T) = s_2 = \alpha_2 e^{j\theta_2} \tag{10}$$

$$s_3(t) = s_3(t+T) = s_3 = \alpha_3 e^{j\theta_3} \tag{11}$$

where, T is the symbol duration.

After that, the received signals can be represented as

$$y_0 = s_0a_0 + s_1a_1 + n_0 \tag{12}$$

$$y_1 = -s_0 a_1^* + s_1 a_0^* + n_1 \tag{13}$$

$$y_2 = s_2 a_0 + s_3 a_1 + n_2 \tag{14}$$

$$y_3 = -s_2 a_1^* + s_3 a_0^* + n_2 \tag{15}$$

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

### 3.3.2. The Combining Scheme

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

$$\widetilde{x_0} = s_0^* y_0 + s_1 y_1^* + s_2^* y_2 + s_3 y_3^* \tag{16}$$

$$\widetilde{x_1} = s_1^* y_0 - s_0 y_1^* + s_3^* y_2 - s_2 y_3^* \tag{17}$$

### 3.3.3. The Maximum Likelihood Decision Rule

The maximum likelihood detector selects either $x_0$or $x_1$in compliance with the corresponding decision rule, as per the section 3.2.3.

## 4. System model and Description

The Proposed CDMA transmitter and receiver dependent block diagram of Wavelet implementing antenna diversity scheme is shown in figure. 1. At the transmitter, a random source of ones and zeros is used to produce a sequence of ones and zeros. The data input bits are translated to a symbol vector using modulation. The synthetically formed binary bit stream is modulated using BPSK digital modulation for n number of users, and these symbols are multiplied by the Walsh Hadamard code assigned to each user.

The Alamouti space time block encoder processes the coded symbols. Two sources of diversity are dynamically reflected in the production.

### 4.1. Signal Model of a DS-CDMA System

Consider a network with m transmitting antennas and n receiving antennas, each transmitting antenna transmitting a separate continuous pilot signal, and l users. Consider the complex baseband model for a downlink channel in a single cell DS-CDMA configuration. Let $s_l^{(i)}[k]$be the transmission of k$^{th}$ symbol from the transmission antenna *i* to the mobile station *l*. The $l^{th}$ user spread signal from transmit antenna *i* is:

$$p_l^{(i)}[kN + c] = A_l s_l^{(i)}[k] b_l^{(i)}[kN + c] \tag{18}$$

$k$= -∞,….,0,….,∞, $c$=0,1,…….N-1, i=1,2,……m

where, $A_l$denotes the amplitude of user *l*, $b_l^{(i)}[kN + c]$ denotes the $l^{th}$ user spreading sequence from transmit antenna *i*, *N* is the processing gain, *k* is the symbol index, and c is the chip index within a symbol span. Notice that the spreading sequences are orthogonal to each other throughout the symbol interval, and are normalized as $|b_l^{(i)}[kN + c]|$=1/$\sqrt{N}$.

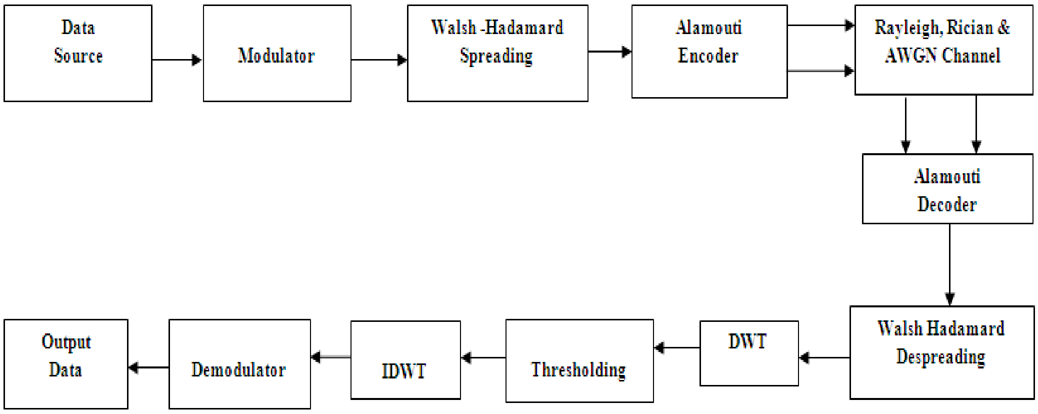


**Figure 1.Depiction of Wavelet Based Alamouti STBC CDMA system**

The $l^{th}$ user spread waveform from the transmit antenna $i$ can be given as:

$$X_l^{(i)}(t) = \sum_{n=-\infty}^{\infty} p_l^{(i)}[n]\emptyset(t - T_c n) \quad (19)$$

where the chip index is n=$kN + c$, the time index is $t$, and the uniform Nyquist chip waveform is $\emptyset(t)$. As a result, the equation above gives the transmitted signal from the base station's $i^{th}$ transmit antenna. The transmitted signal from each base station's transmitting antenna travels through time-varying multipath channels.

Let $h_{ij}(t)$ denote the continuous time-impulse response of the multipath channel from the transmit antenna j to the receiving antenna. The multipath signal's time-variant propagation through the mobile cellular radio channel can be modelled as follows:

$$h_{ij}(t) = \sum_{q=0}^{Q=1} \varphi_{ij,q}(t)e^{j\theta_{ij,q}(t)}\delta\left(t - \tau_{ij.q}(t)\right) \quad (20)$$

where, $Q$ is the number of multipath channel, δ(.) is the Dirac delta function, and $\varphi_{ij,q}(t)$, $\theta_{ij,q}(t)$ and $\tau_{ij.q}(t)$ are the time-variant attenuation, phase distortion, and propagation delay of the $p^{th}$ path from the antenna $j$ to the receiving antenna $i$. The $\tau_{ij.q}(t)$ propagation delay characterizes various multipaths and attenuates the time-variant and phase distortion characterizes the amount of the Doppler spread.
As a result, the signal received at the $i^{th}$ receive antenna can be written as:

$$R^{(i)}(t) = \sum_{j=1}^{m} \sum_{q=0}^{P-1} \varphi_{ij,q}(t)\, e^{j\theta_{ij,q}(t)} X_l^{(i)}(t) + N^{(i)}(t) i=1,2,\ldots\ldots\ldots\ldots I \quad (21)$$

where, $N^{(i)}$ is the $i^{th}$ AWGN receiving antenna with a mean zero and a single-sided spectral density $\sigma_n^2$, and the propagation delay is assumed to be $\tau_{ij.q}(t) = pT_c$ for simplicity.

The received signal $R^{(i)}(t)$ is sampled in the mobile station. At the chip limit, let $s^{(i)}(t)$ denote the nth sampled signal from the output of the $j^{th}$ receive antenna matched filter. The Rayleigh fading, Rician fading and AWGN are the channels under consideration. When the signal passes through those channels, the resulting noise and fading effects weaken it.Two transmitted message signals are processed in the receiver section in the diversity combiner, with full knowledge of the channel information. The Alamouti decoder decodes each of the M components that make up the receiver. Decoding is done with a Maximum Likelihood decoder. To obtain the data symbol, the chip sequence is multiplied by the desired user's complex conjugate code sequence. The operation is known as the despreading operation.

For each user, the despreaded symbols are passed through the Discrete Wavelet Transformation, which consists of a filter and a down-sampler. With global soft thresholding, Daubhecies Wavelets are widely used in the denoising portion.

$$T = \sigma\sqrt{2logN} \quad (22)$$

where, $\sigma$ is the standard deviation of noise. The signal's length is denoted by the letter L. And the above equation sets a threshold for each branch. To retrieve the original signal, inverse operations are used. The original data symbol can be retrieved after demodulation.

## 5. Thresholding Techniques and Threshold Calculation

Denoising the spread spectrum usually employs two types of thresholding strategies:

### 5.1. Hard Thresholding

Hard Thresholding is a simple wavelet denoising technique (i.e., a ‘keep' or ‘destruct' strategy). If T is the threshold, the wavelet coefficient $w_t$ is subjected to a hard threshold operation

$$\delta^{H}{}_{T}(w_t) = w_t, \text{ if } |w_t| > T$$
$$= 0, \quad \text{otherwise} \quad (23)$$

This is not a continuous mapping; it only affects input coefficients that are less than or equal to the threshold.

### 5.2. Soft Thresholding

Soft thresholding [10] of the wavelet coefficient $\omega_t$ via is another standard denoising method.

$$\delta^{S}{}_{T}(w_t) = \text{sign}(w_t)(|w_t| - T)_{+}.$$

where, $\text{sign}(w_t) = +1$ if $w_t > 0$,
$= 0$ if $w_t = 0$,
$= -1$ if $w_t < 0$,
and $x_{+} = x$ if $x \geq 0$,
$= 0$ if $x < 0$. (24)

where $\text{sign}(w_t)$ is signum and sign(wt) is signum. Instead of forcing $w_t$ to zero or leaving it unchanged, soft thresholding pushes all of the coefficients towards zero. As a result, the smoothing effect of soft thresholding is greater than that of hard thresholding. Soft thresholding is favoured in this research work.

### 5.3. Threshold Calculation

If $m_s$ is the received signal and $\sigma_s$ be the standard deviation of the incoming signal, the signal $s(n)$ can be modeled as:

$$s(n) = m_s + \sigma_s w(n) \quad (25)$$

The impulse function of DD-DWF of three sub bands comprises a matrix of three columns correspondingly known as low pass filter, 1st high pass filter and 2nd high pass filter respectively. The obtained noisy signal s(n) is then filtered by the first matrix column and the threshold can be

determined using equation (26).
Wavelet filters operate well at low SNR values and then the incoming signals are combined and threshold estimates can be upgraded as:

$$\eta = \frac{(0.05128*\gamma*\sigma^2)}{(\sqrt{3.5}*\sigma_x)} \quad (26)$$

where, the scale parameter $\gamma$ is calculated using the equation below

$$\gamma = \sqrt{\log(L/4)} \quad (27)$$

where, L is the length of the filtered coefficient, and $\sigma^2$ is the noise variance, which is calculated using the formula from the subband HH1.

$$\sigma^2 = (\text{median}(|Y_{ij}|/0.6745)^2, Y_{ij} \epsilon \text{ subband HH1} \quad (28)$$

where, $\sigma_x$ is the standard deviation of the subband in question, as calculated by a standard matlab command.

# 6. Results and Discussion

The performance of the proposed scheme is addressed in the sections which follow. For simulation purposes a maximum of 4 users shall be considered. The simulation is carried out by assuming two transmitting antennas and one or two receiving antennas. The multi-user detection strategy reduces the effects of noise and fading and provides a diversity of two when the number of antennas receiving is two. By utilising the transmitter channel information, this scheme also completely cancels the interference. In addition, the BPSK modulation used in simulation sends data by changing the carrier phase. As a result of the use of two distinct potential stages, one bit per symbol can be encoded to reduce the rate of bit errors.

## 6.1. Performance of the Wavelet based Alamouti STBC (2 Tx - 1 Rx) DS-CDMA system over the Rayleigh fading channel

To investigate the device output under different channel conditions, simulations were performed. Figure 2 illustrates the output of BER vs SNR performance for the coded DS-CDMA method using the STBC technique of Wavelet based Alamouti's under the Rayleigh fading channel (number of transmitting antennas=2 & number of receiving antennas=1). Assume that the receiver is fully aware of the channel conditions.

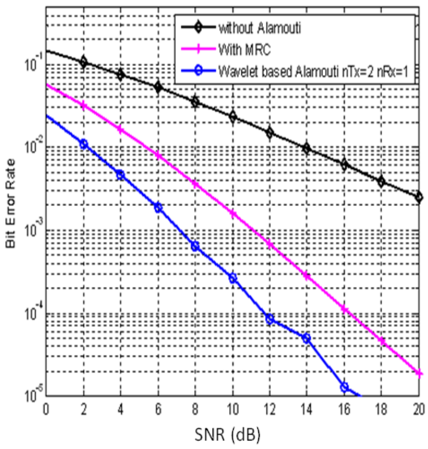


**Figure 2. Wavelet-based Alamouti STBC (2 Tx - 1 Rx) DS-CDMA system performance over Rayleigh fading channel**

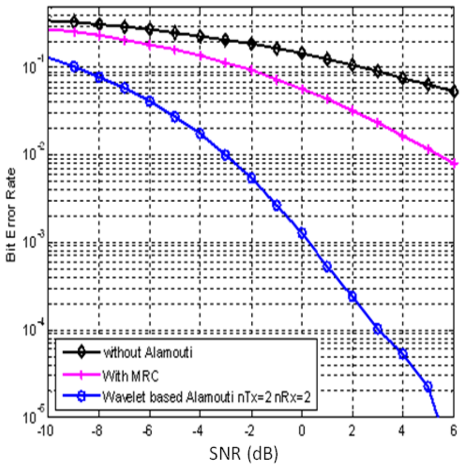


**Figure 3. Over the Rayleigh fading channel, BER vs SNR for the Wavelet-based Alamouti STBC (2 Tx - 2 Rx) DS-CDMA system**

The simulation clearly shows that the proposed technique outperforms both standard DS-CDMA and the method that employs the Maximum ratio Combiner.

In the presence of a Rayleigh fading channel, the obtained BER for a 6 dB SNR value is 0.0019, when using the Alamouti STBC scheme for two transmitting and one receiving antenna, but without the Alamouti encoding scheme, the BER is 0.0081 for the same 6 dB SNR value. As a result, it is clear that using Alamouti encoding results in a lower BER value. Also, when compared to a system without transmit diversity, a system with transmit diversity has a 4 dB improvement at a BER of $10^{-4}$. If the transmitted and received power are the same in both cases, the performance would be identical. The obtained BER is 0.001 for 6 dB SNR, which is also a 14 dB SNR improvement over that obtained without the Alamouti diversity.

Figure 3 shows that for BER=$10^{-4}$, the SNR required for the STBC-DS-CDMA based on DWT is about 2 dB for 2 Rx and 12 dB for 1 Rx; thus, a receiver diversity gain of 10 dB is achieved. And also, it was discovered that the DWT based STBC- DS-CDMA outperforms considerably than the system without diversity and the system employing MRC, for this channel model.

### 6.2. BER vs. Number of Users in the Rayleigh channel using two Tx-1 Rx antennas with varying dB values for wavelet-based STBC-DS-CDMA systems

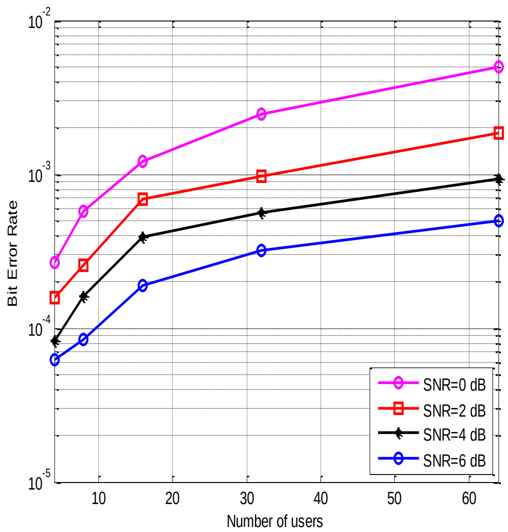


**Figure 4. With a spreading factor of 64, BER vs. Number of Users in the Rayleigh Channel**

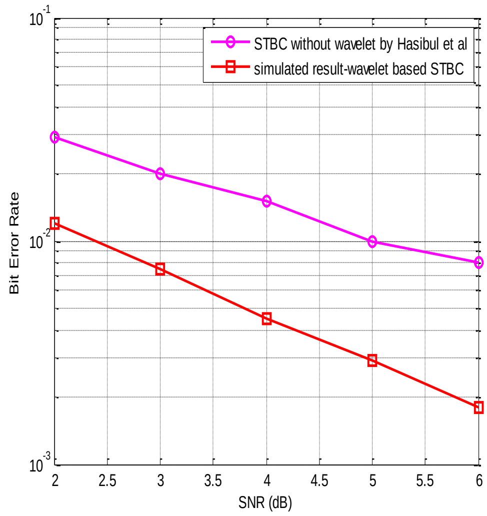


**Figure 5. In a Rayleigh fading channel with two Tx and two Rx antennas, the Alamouti STBC with and without Wavelet performed better in terms of BER vs. SNR.**

When the channel is assumed to be the Rayleigh fading channel, Figure 4 shows the average BER performance versus the number of users. A DS-CDMA system with k=4, 8, 16, 32, and 64 users was used in the simulations, and the signature waveforms were generated as random sequences with a spreading gain of 64.

The BER rate varies for different numbers of users when using the Rayleigh channel with a spreading factor of 64 and different $E_b/N_o$ values of 0 dB, 2 dB, 4 dB, and 6 dB. The simulation assumes a 64-bit spreading sequence with a Rician K-factor of 0. When the Rician K-factor is 0, it is observed that the receiver diversity estimates the average BER. This trait resembles Rayleigh fading when k=0.

It is clear that as the number of users increases, BER increases as well. When using the dB value of 4, for example, a BER of 0.000082 is obtained for four users, but a BER of 0.000935 is obtained for 64 users. However, when compared to the spreading factor of 4, this graph achieves a lower BER. It goes without saying that the higher the number of users, the worse the performance.

### 6.3. Comparison of the Alamouti STBC's BER vs $E_b/N_o$ performance with and without Wavelets

The performance of the Alamouti DS-CDMA system, which uses the Wavelet transform, is shown in Figure 5. And the simulated performance is compared to that of Jamil et al STBC's DS-CDMA system, which does not use Wavelets. Around a 3 dB gain improvement is obtained at a BER of $10^{-2}$. That is, using the Wavelet-based Alamouti's STBC technique, it will take less power to transmit the same BER for the CDMA system. When 2Tx-1Rx is used, it can be explained that sending signals at the same power would provide a better BER for the CDMA system using Wavelet Alamouti's STBC technique than the conventional DS-CDMA system using Alamouti STBC.

When 2Tx-2Rx antennas are used, the SNR required for the DWT based STBC- DS-CDMA was about 2 dB for a BER=$0.3*10^{-3}$, and 11 dB for the STBC- DS-CDMA reported by Hasibul et al; thus, a gain of 9 dB for the DWT against the conventional STBC- DS-CDMA is obtained.

### 6.4. Comparison of BER Performance of DS-CDMA for Alamouti STBC and Wavelet based Alamouti STBC in the Rayleigh Channel (2 – Tx and 1 – Rx)

Figure 6 shows the BER performance of an Alamouti-based DS-CDMA system versus a Wavelet-based Alamouti scheme for DS-CDMA systems. For simulation, a spreading factor of 64 is used for different SNR values.

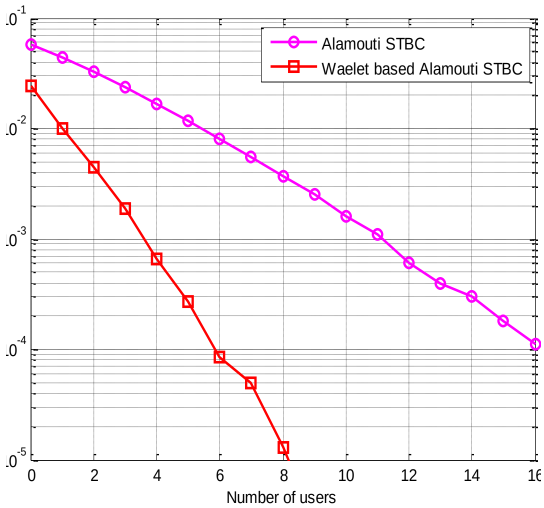


**Figure 6. BER vs. SNR for DS-CDMA with Alamouti STBC and Wavelet-based Alamouti STBC**

Because Wavelets are excellent decorrelators, separating signal from noise is simple. As a result, when the Wavelet filter is used in the Alamouti STBC system, the BER decreases while the SNR increases. For this simulation, 0 dB to 16 dB values are used. In the presence of a wavelet filter, SNR values of 1 dB, 3.5 dB, and 6 dB are obtained for BERs of $10^{-2}$, $10^{-3}$, and $10^{-4}$, respectively. When the Wavelet filter is used in the Alamouti scheme, SNR gain improves by nearly 4-8 dB when compared to when the Wavelet filter is not used.

# 7. Conclusion

The Wavelet-based STBC DS-CDMA system has been implemented and analysed in this paper. Using the simulation approach, it is demonstrated that using the STBC in a DS-CDMA system has several advantages over a conventional CDMA system, including improved BER performance and reduced complexity. In the AWGN and Rayleigh Fading channels, we investigated both schemes (nTx=2 & nRx=1 &nTx=2 & nRx=2). With Wavelet-based antenna diversity schemes, the system's BER performance has been observed to improve. The antennal diversity has been implemented using the Alamouti scheme. When comparing DS-CDMA with the Alamouti STBC alone, the BER drops dramatically due to the influence of Wavelets.

When it comes to spectral efficiency, bandwidth, and bit rate support, the BPSK scheme should have the lowest priority among the other mapping schemes. To retain the required BER, channels perform in the following order: AWGN and Rayleigh, from best (lower SNR requirement) to worst (higher SNR requirement). The maximum number of antennas used in the proposed system is two. It can be expanded to more than two in the future to increase performance.

## *References*

*[1] M. I. Youssef, A. E. Emam, and M. AbdElghany, "Direct Sequence Spread Spectrum Technique. With Residue Number System", Proceedings of World Academy of Science, Engineering and Technology, Volume 32,(2008).*

*[2] Raya Majid Alsharfa, "Design and Performance of MC-CDMA Transceiver based LDWT –OFDM in Flat Fading Channel", Communications Magazine, IOP Conf. Ser.: Mater,2019.*

*[3] AmirReza Momen, Hosein Ahmadi and Alireza Mirzaee, "A New Method in Spread Spectrum Signal Detection Based on wavelet transform" –CCECE/CCGEI, Saskatoon, IEEE,2005, May (600 – 602).*

*[4] L. Li et al, "High Resolution Time-Delay Estimation Based on Wavelet Denoising", ICCCAS, Vol.2 (2004), pp.876 - 879.*

*[5] S. Burley et al, "Enhanced PN Code Tracking and Detection Using Wavelet Packet Denoising", IEEESP Int. Sym.1998.*

*[6] K.C. Ho, et al, "On Improving the Accuracy of a Wavelet Based Identifier to Classify CDMA Signal and GSM Signal", ISCAS, (1999), pp. 564-567.*

*[7] H. Liu and K. C. Ho, "Identification of CDMA Signal and GSM Signal using the Wavelet Transform", Midwest Symposium.(1999).*

*[8] Jansen, M. "Noise reduction by wavelet thresholding", Springer USA, (2001).*

*[9] Donoho, D. L. "Denoising by soft-thresholding." IEEE Trans. Inform. Theory Vol.41, (1995).*

*[10] Abd El-Fattah, MA, Dessouky, MI, Diab, SM & Abd El-samie FE', Adaptive wiener filtering approach for speech enhancement', Ubiquitous Computing and Communication Journal, vol. 3, (2010), pp. 23-31.*

*[11] Arunarasi. J, Indumathi. P., Combined Wiener and Double Density Discrete Wavelet Filter Based Algorithm for Noise Reduction in CDMA Receiver, European Journal of Scientific Research, Vol. 53, No. 2, (2011), 269-279.*

*[12] Chen, G & Bui T, "Denoising of three dimensional data cube using bivariate wavelet shrinking", Image Analysis and Recognition, ICIAR, (2010), pp. 45-51.*

*[13] Nasri, M & Nezamabadi, H, "Image denoising in the wavelet domain using a new adaptive thresholding function', Neurocomputing , vol. 72, No. (4-6), (2009), pp. 1012-1025.*

*[14] Nader, A.K,Lalith,Arash. A, Seyed,V, "MC-DS-CDMA system based on DWT and STBC in ITU multipath fading channel models", Vol. 26, No. 4, (2018), pp. 280-292.*

*[15] Raya Majid Alsharfa, B, "Design and Performance of MC-CDMA Transceiver based LDWT –OFDM in Flat Fading Chann", Multiscale Modeling and Simulation, Materials Science and Engineering, IOP Conf. Ser.: Mater. Sci. Eng. 518 052018doi:10.1088/1757-899X/518/5/052018; (2019)*

*[16] Nagarjuna Telgam et al,"Multi user based performance analysis in upcoming 5G techniques", Journal of Critical Reviews. Vol 7, No. 12: 864-870, doi: 10.31838/jcr.07.12.152;( 2020)*