CSK based STBC-CDMA System: Design and Performance Evaluation

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Abstract:-

In this paper, the design of a communication system that combines a Multiple-Input Multiple Output (MIMO) scheme with a Code Division Multiple Access (CDMA) based on chaotic sequence have been discussed. Various design issues pertaining to this arrangement and the Bit Error Rate (BER) performance under Rayleigh fading channel have been investigated. Because of the non-periodic nature of chaotic signals, the signal after passing through the chaotic modulator is characterized by bit energy that can vary from one bit to another. As a result, the expression for the BER requires the computation of an intractable integral. To overcome this problem, the BER expression for a given chaotic map over all possible spreading sequences associated with a given spreading factor has been integrated. A system where the output of a Chaos Shift Keying (CSK) modulation scheme is combined with Space Time Block Code (STBC) for 2×1 and 2×2 Alamouti schemes has been considered. The BER computation has been approved by simulation results.

Keywords: Chaotic techniques, MIMO, CDMA, STBC.

1. Introduction

In this paper, a communication system that combines a MIMO scheme with chaotic sequence based on CDMA has been designed. The BER to match our proposed system and computed the BER performance for different chaotic maps with Space Time Block Code (STBC) under Rayleigh fading channel have been modified. For a practical application of CDMA, PN sequences are conventionally used for spreading scrambling and authentication. An alternative method to achieve security is by using orthogonal sequence for scrambling on physical layer. Some of these sequences include PN sequence, Gold sequence, etc.

The drawback of using these sequences is that they are periodic in nature and can be predicted on observation of large number of scrambled data. To contract this drawback, the use of nonperiodic chaotic sequences has been proposed. Although the chaotic sequences are more secure as compared to PN sequences, they are inferior in term of BER performance [1]. In order to overcome limitation of BER performance degradation, the use of a combination of chaotic modulation and STBC has been proposed. The performance of Chaos Shift Keying (CSK) with 2×1 and 2×2 Alamouti schemes for different chaotic maps over wireless channels have been investigated. The primary motivation for the design of a MIMO-CDMA based on CSK modulation scheme arises from the necessity to have secure communication links with good BER performance. The precise BER specification usually depends on the value dictated by the application. CDMA-MIMO system is based on combination of two technologies, CDMA and MIMO, which have been introduced to optimize the performance in the presence of two sources of degradation: multipath and multiuser interference [2, 3, and 4]. In DS-CDMA system, all users transmit on the same band at the same time. Individual users are distinguished only by means of spreading waveforms. The dominant impairment and the limiting factor in the detection process of synchronous DS-CDMA system is the loss of orthogonality betIen the spreading waveforms due to fading multipath propagation. It leads to multiple access interference (MAI) in DS-CDMA system. MAI can be mitigated through the use of MIMO schemes [4]. A classical set of spreading sequences used in DS-CDMA system are the binary sequences generated by linear feedback shift register (LFSR) schemes [5]. It has been reported that the chaotic sequences derived from chaotic time series exhibit orthogonality better than the conventional PN sequences. Further, there is a possibility of generating a large number of chaotic sequences, which could be used to support more number of users within allocated bandwidth for DS-CDMA systems [5]. Chaotic signals are non-periodic, broadband, and difficult to predict and to reconstruct [7]. Their properties match the requirements for signals used in communication systems, in particular for spread-spectrum communication and secure communication systems. To correctly demodulate the transmitted chaos shift keying (CSK) signal, the exact initial conditions must be known at the receiver side [8]. The possibility of generating an infinite number of uncorrelated chaotic sequences from a given map simplifies the application of these signals in multiuser case. Tent map, Logistic map, Chebyshev map and Tail shift map are typical examples of one-dimensional chaotic maps. To provide a secure communication channel, a chaos generator can be used to generate CSK sequences, where different sequences can be generated using the same generator but with different initial conditions [9]. In this paper, the system can correctly achieve the synchronization proposed in [10] to demodulate transmitted symbols. Many assumptions have been made in computing the BER performance of the chaos-based communications system in the single input single output (SISO) case [11, 12]. A widely used approach known as the simplified Gaussian approximation (SGA) considers the sum of dependent variables at the output of correlator as a Gaussian variable. This approach does not take into account the non-periodic nature of chaotic sequence, which leads to a low precision of BER approximations, especially when the spreading factor is low. Since the SGA is very crude in its Gaussian approximation, a better approach is to apply the Gaussian approximation conditionally on the chaotic spreading samples of the active user, and subsequently average over all chaotic spreading samples which the active user might employ [13]. The BER performance enhancement by using Alamouti MIMO techniques (2×1 and 2×2) is extensively discussed and comparison betIen various chaotic maps is made. The effect of the number of users in a cell on the BER performance is discussed for both CDMA-SISO and CDMA-MIMO based on CSK modulation scheme.

2. CHAOTIC-CDMA COMMUNICATION SYSTEM

2.1 Chaotic Generators

Binary PN sequences are used in conventional DS-CDMA system. The most commonly used PN sequence is the *m*-sequence which is generated by linear feedback shift register. The *m*-sequence is a periodic sequence whose length depends upon the number flip flops in the shift register. The number of distinct m-sequences that can be generated with a given shift register is limited. By using code clock extraction techniques, an interceptor can wipe out the spreading sequences and extract the un-spread modulated user information. In this context, chaotic sequences, which have superior data masking characteristics compared with *m*-sequences, can be used to improve the covertness of the communications. Noise-like chaotic sequences can be used to effectively conceal the information bearing signals. Several chaotic maps, such as Tent map [14], Logistic map [15], Chebyshev map [7] and Tail shifted map [16] can be used to generate chaotic sequences.

2.2 CDMA TRANSMISSION SYSTEM BASED on CSK

Here, I give a brief description of CDMA system based on CSK modulation scheme which is modified in our proposed MIMO-CDMA system based on CSK modulation scheme discussed in section 3. The CSK system in Fig. 1 has L users. A stream of binary data symbols from active user l $(b_{l,i} = \pm 1, i = 1,2,\ldots)$ with bit period T_b is spread by a chaotic signal generated at the transmitter. The spreading factor (β) is the number of chaotic samples in a bit duration and these constitute a chaotic segment; T_c is the chip duration, so $T_b = \beta T_c$. The chaotic segment $\{x_l\}$ is assumed to have been started with a random initial sample value $x_{l,0}$ from the natural invariant distribution [17].

The output of chaotic signal generator

$$U_l(t) = \sum_{i=0}^{\beta-1} x_{l,i} \quad (1)$$

The transmitted signal of the lth user is thus

$$S_l(t) = \sum_{i=0}^{\beta-1} (b_l x_{l,i}) \quad (2)$$

The energy of a typical bit of lth user is given by

$$E_b^{(l)} = T_c \sum_{i=0}^{\beta-1} x_{l,i}^2 \quad (3)$$

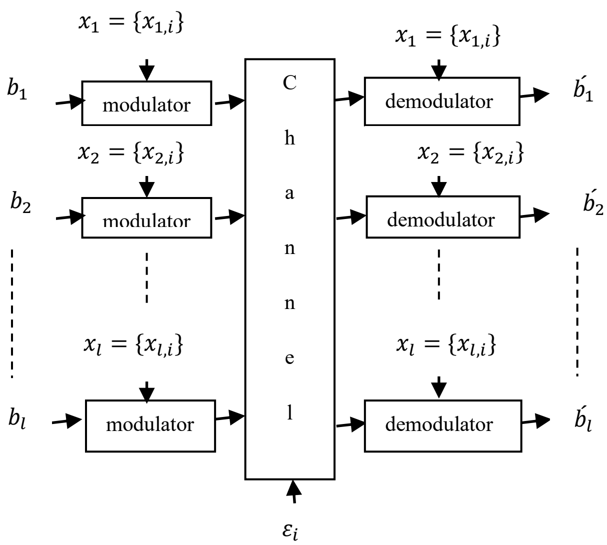


Fig 1. Block diagram of a multiuser coherent CSK communication system.

The bit energy depends on the sample values $x_{l,i}$ which are real numbers. Hence, the bit energy is not a constant in contrast to conventional system, such as binary phase shift keying (BPSK). I assume that the transmitted signal is communicated over a channel perturbed by Additive White Gaussian Noise (AWGN) channel. Let $n(t)$ be the Gaussian noise effecting reception by the lth user. I assume $n(t)$ has a two sided poIr spectral density given by

$$S_n(f) = N_0/2 \quad (4)$$

Let $\grave{n}(t)$ be the equivalent noise source of $n_t(t)$ specified as

$$\grave{n}(t) = \sum_{i=0}^{\infty} \varepsilon_{l,i} \quad (5)$$

Where $\{\varepsilon_{l,i}\}$ are independent Gaussian random variables with zero mean and variance

$$\sigma_n^2 = N_0/2T_c \quad (6)$$

Furthermore, all users are asynchronous and the received signal $r_l(t)$ of user l at time t includes the sum of $L-1$ interference signals from the other users and AWGN noise. Hence, $r_l(t)$ is given by:

$$r_l(t) = S_l(t) + \sum_{k=1,k\neq l} S_k(t) + \grave{n}(t) \quad (7)$$

By substituting (2) in (5) and (7) I obtain,

$$r_l(t) = \sum_{i=0}^{\beta-1} b_l x_{l,i} + \sum_{k=1,k\neq l} b_k x_{k,i} + \varepsilon_i = \sum_{i=0}^{\beta-1} Z_{l,i} \quad (8)$$

In coherent CSK communication systems, perfect synchronization is assumed [10]. The output of correlator is:

$$C_{r,u} = \int_0^{\beta T_c} r_l(t) U_l(t) dt \quad (9)$$

By placing (1) and (8) in (9) the correlator output can be expressed as,

$C(z_l, x_l) = T_c \sum_{i=0}^{\beta-1} z_{l,i} x_{l,i} = T_c C_s(z_l, x_l)$ (10)

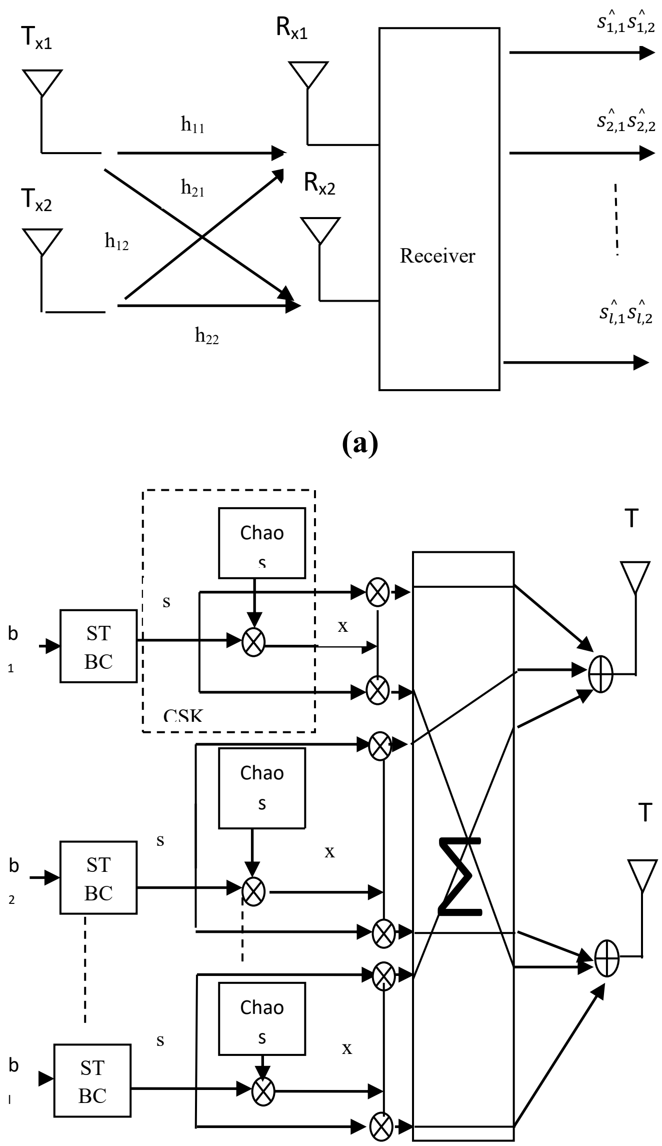
Where $C(z_l, x_l)$ is the decision variable and is the discrete covariance sum from (z_l, x_l). and $z_{l,i} = b_l x_{l,i} + \sum_{k=1,k\neq l}^{L} b_k x_{k,i} + \varepsilon_i, \;\; i = 0,1,\dots,\beta - 1.$

3. STBC-CDMA SYSTEM BASED on CSK

The block diagram of the proposed system STBC-CDMA based on chaotic technique is shown in Fig. 2.

Table 1. The design of the transmitted signa

Time	$s_1(t)$from T_{x1}	$s_2(t)$from T_{x2}
$[0, \beta T_c]$	$s_1 U_{l,i}(t)$	$s_2 U_{l,i}(t)$
$[\beta T_c, 2\beta T_c]$	$-s_2^* U_{l,i+\beta}(t)$	$s_1^* U_{l,i+\beta}(t)$



(a)

(b)

Fig 2. Block diagram of STBC-CDMA system based on CSK (a) Transmitter, (b) Receiver

Table 2. The received signal of the 2×1 Alamouti for lth user

Time	Received signal on R_{x1}
$[0, \beta T_c]$	$h_1 s_1 x_k + h_2 s_2 x_k + (\sum_{i=0}^{\beta-1} \sum_{k=1,k\neq l}^{L} N_1 + s_k^1(t))$
$[\beta T_c, 2\beta T_c]$	$-h_1 s_2^* x_{k+\beta} + h_2 s_1^* x_{k+\beta} + (\sum_{i=0}^{\beta-1} \sum_{k=1,k\neq l}^{L} N_2 + s_k^2(t))$

In coherent CSK modulator, the chaotic signal is first generated. Consider the lth symbol duration $[(l-1)T_b, lT_b]$, where T_b is the bit duration. If "+1" is transmitted, the chaotic signal will be sent. If a "-1" is transmitted, an inverted copy of the chaotic signal is used as transmitted signal.

In our case, I consider two cases. In the first case, the system is assumed to have two transmitter antennas and one receiver antenna. In the second case, it is assumed to have two transmitter antennas and two receiver antennas. The Almouti matrix for symbols s_1 and s_2 is:

$$\begin{pmatrix} s_1 & -s_2^* \\ s_2 & s_1^* \end{pmatrix}$$

The design of the CSK system with an STBC on the form of the code matrix. The data b_l for each user l are separated by chaotic sequences which generated by chaotic generator.

Where T_c is the chip interval.

Where N_1 and N_2 are zero mean Gaussian noise components.

Let$((\sum_{i=0}^{\beta-1} \sum_{k=1,k\neq l}^{L} N_1 + s_k^1(t))= \acute{N}_1$ and $\left(\sum_{i=0}^{\beta-1} \sum_{k=1,k\neq l}^{L} N_2 + s_k^2(t)\right) = \acute{N}_2$.

As shown in Fig. 3, the received signal for lth user is first multiplied by a synchronized replica of chaotic sequence, and then summed over a time symbol βT_c, and finally decoded by a STBC decoder. In the first time block $[0, \beta T_c]$ of the receiver, the received signal y_1 for lth user after correlation with the local chaotic sequence is

$$y_{l,1} = T_c \sum_{i=0}^{\beta-1} [h_1 s_1 x_{l,i} + h_2 s_2 x_{l,i} + N_1][x_{l,i}] = (h_1 s_1 + h_2 s_2) \sum_{i=0}^{\beta-1} x_{l,i}^2 + \sum_{k=1,k\neq l}^{L} \sum_{i=0}^{\beta-1} N_1 x_{l,i} \quad (12)$$

The energy of a given bit b is as in equ.3. The equivalent baseband model on $[0, \beta T_c]$ of the received symbol is

$$Y_{l,1} = E_b(h_1 s_1 + h_2 s_2) + \acute{N}_{l,1} \quad (13)$$

Where $\acute{N}_1$ represent noise and interference of other users components. By analogy, the received symbol $Y_{l,2}$ for the second time $[\beta T_c, 2\beta T_c]$ for the lth user is given by

$$Y_{l,2} = E_b(-h_1 s_2^* + h_2 s_1^*) + \acute{N}_{l,2} \quad (14)$$

Where $\acute{N}_2$ represent noise and interference of other users components.

The block diagram of 2×2 Alamouti receiver for lth user is shown in Fig. 3.

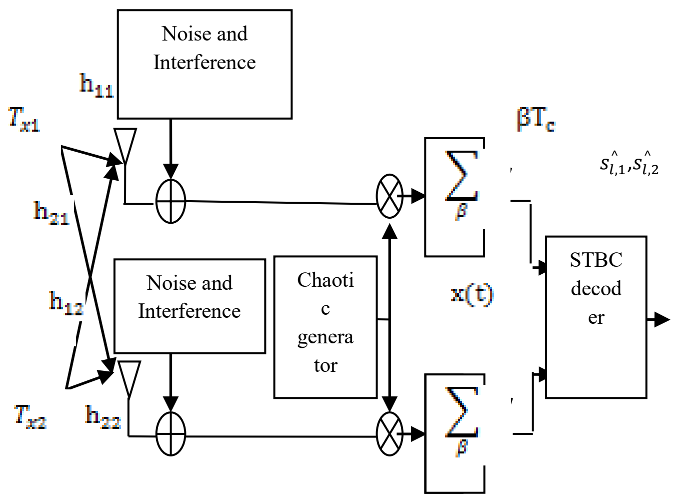


Fig 3. Block diagram of 2×2 receiver for lth user

Let $\sum_{i=0}^{\beta-1}\sum_{k=1,k\neq l}^{L} n_k^{1,2} + s_k^{1,2}(t) = \acute{n}_k^{1,2}$.

As shown in Fig. 3 the received signal for lth user is first multiplied by a synchronized replica of chaotic sequence, and then summed over a time symbol βT_c, and finally is decoded by a STBC decoder. In the first time block $[0, \beta T_c]$ of R_{x1}, the received signal y_{11} for the lth user after correlation with the local chaotic sequence is

Table 3. The received signal of the 2×2 Alamouti for lth user

Time	Received signal on R_{x1}
$[0, \beta T_c]$	$h_{11}s_1x_k + h_{21}s_2x_k + \sum_{i=0}^{\beta-1}\sum_{k=1,k\neq l}^{L} n_k^1 + s_k^1(t)$
$[\beta T_c, 2\beta T_c]$	$-h_{11}s_2^*x_{k+\beta} + h_{21}s_1^*x_{k+\beta} + \sum_{i=0}^{\beta-1}\sum_{k=1,k\neq l}^{L} n_k^2 + s_k^2(t)$

$$y_{l,11} = \sum_{i=0}^{\beta-1}[h_{11}s_1x_{l,i} + h_{21}s_2x_{l,i} + n_{k,\iota}^{\acute{1}}][x_{l,i}] = (h_{11}s_1+h_{21}s_2)\sum_{i=0}^{\beta-1} x_{l,i}^2 \sum_{k=1,k\neq l}^{L}\sum_{i=0}^{\beta-1} n_{k,i}^1 x_{k,i}$$

(15)

The equivalent baseband model on $[0, \beta T_c]$ of the received symbol on the first antenna is

$$Y_{l,11} = E_b(h_{11}s_1 + h_{21}s_2) + N_{l,11} \quad (16)$$

Where $N_{l,11}$ is a zero mean Gaussian noise component for lth user.

$$N_{l,11} = \sum_{i=0}^{\beta-1} n_l^{\acute{1}} x_{l,\iota} \quad (17)$$

By analogy, the received symbol $Y_{l,21}$ on the first antenna R_{x1} for the second time block $[\beta T_c, 2\beta T_c]$ for the lth user is given by

$$Y_{l,21} = E_b(-h_{11}s_2^* + h_{21}s_1^*) + N_{l,21}$$
(18)

Where the noise component is given by

$$N_{l,21} = \sum_{i=0}^{\beta-1} n_l^{\acute{2}} x_{l,\iota} \quad (19)$$

The received symbols $Y_{l,12}$ and $Y_{l,22}$ on the second antenna R_{x2} are computed in the same way.

The channel model for lth user is given by:

$$Y_l = E_b HS + N_l \quad (20)$$

The transmitted bits for lth user are estimated by multiplying the symbol Y_l by the conjugate transpose of the channel H, then

$$\begin{pmatrix} D_{s1,l} \\ D_{s2,l} \end{pmatrix} = H^* Y_l \quad (21)$$

Finally, the estimated bits are computed from the sign of the decision variable $s_{1,l} = sign(Ds_{1,l})$ and $s_{2,l} = sign(Ds_{2,l})$.

4. BER COMPUTATION for STBC-CDMA SYSTEM

The conditional BER of estimating a bit value 0 conditional that a 1 was transmitted is considered, and vice versa. The aim of this section is to calculate the bit-error probability exactly, rather than approximately from Gaussian approximations. Since the simplified Gaussian approximation (SGA) is very crude in its Gaussian assumption, a possibly better approach is to apply the Gaussian approximation conditionally on the chaotic spreading samples which the active user might employ. Thus $E(C_s)$ and $Var(C_s)$ are now considered conditionally on x_l and denoted by $E(C_s|x_l)$ and $Var(C_s|x_l)$. The overall BER requires the conditional error probabilities $p(b^\wedge = \pm 1|$ b=± 1).these are equal by symmetry and thus the overall BER does not depend on the properties of the transmitted $\pm$ values, and so,

$$BER = P\{C_S(Z_l, x_l) < 0 | b_l = 1\} \quad (22)$$

The Simplified Gaussian Approximation (SGA) technique can be used to accurately determine the BER when the value of the spreading factor β is large (> 50). It does not provide accurate estimates of the BER for small values of β. where $E(C_s)$ and $var(C_s)$ are the mean and variance of $C_S(z_l, x_l)$.

Because of the SGA presented above is very crude in its Gaussian assumption and a better approach is to apply the Gaussian approximation conditioned on the chaotic spreading samples which the active user might employ.

Thus $E(C_s)$ and $Var(C_s)$ are now considered conditionally on x_l and denoted by $E(C_s|x_l)$ and $Var(C_s|x_l)$.

The overall BER requires the conditional error probabilities $p(b^\wedge = \pm 1|$ b=± 1). These are equal by symmetry and thus the overall BER does not depend on the properties of the transmitted $\pm$ symbol values, the Conditional Gaussian Approximation (CGA) to the BER probability thus becomes [19]

The conditional Gaussian approximation (CGA) to the BER probability thus become [13,18,19].

$E_{xj} = Q[E(C_s|x_l)/\sqrt{Var(C_s|x_l)}]$ (23)

Where

$Q(x) = \int_x^{+\infty} \frac{1}{\sqrt{2\pi}} \exp(-u^2/2)$
(24)

Then

$E(C_s|x_l) = \sum_{n,p=1}^{2} h_{n,p}^2 \sum_{i=0}^{\beta-1} x_{l,i}^2$
(25)
$Var(C_s|x_l) = \left(\sum_{n,p=1}^{2} h_{n,p}^2\right)[(L-1)\sigma_X^2 + \sigma_n^2] \sum_{i=0}^{\beta-1} x_{l,i}^2 + 2\beta(L-1)\sigma_X^2$ (26)

Here σ_X^2 denote the variance of X. Hence using (26), CGA result for BER becomes

$BER = Q[E_{xl} \times \sum_{n,p=1}^{2} h_{n,p}^2 \sum_{i=0}^{\beta-1} x_{l,i}^2 / (\sum_{n,p=1}^{2} h_{n,p}^2 \sum_{i=0}^{\beta-1} \frac{x_{l,i}^2}{\beta\sigma_X^2})^{\frac{1}{2}} (\frac{1}{SNR} + \frac{1}{SOR} + \frac{2}{SOR} \sum_{k=1}^{\beta-1} x_{l,i}\, x_{l,i+k})^{\frac{1}{2}} \}]$ (27)

The notation $SNR = \beta\sigma_X^2/\sigma_n^2$, eqavinatly E_b/N_0 has been used to define the signal to noise ratio of the system and SOR defines the quantity $\beta/(L-1)$, which will be called the spreading –to-user-interference ratio.

$BER = Q[E_{xl} \times \sum_{n,p=1}^{2} h_{n,p}^2 \sum_{i=0}^{\beta-1} x_{l,i}^2 / (\sum_{n,p=1}^{2} h_{n,p}^2 \sum_{i=0}^{\beta-1} \frac{x_{l,i}^2}{\beta\sigma_X^2})^{\frac{1}{2}} (\frac{1}{SNR} + \frac{1}{SOR} + \frac{2}{SOR} \sum_{k=0}^{\beta-1} (1 - \frac{K}{\beta}))^{\frac{1}{2}} \}]$
(28)

Now, according to CGA result (28), the BER result for 2×1 Alamouti scheme can be written as the integral

$BER = Q[E_{xl} \times (h_1^2 + h_2^2) \sum_{i=0}^{\beta-1} x_{l,i}^2 / ((h_1^2 + h_2^2) \sum_{i=0}^{\beta-1} \frac{x_{l,i}^2}{\beta\sigma_X^2})^{\frac{1}{2}} (\frac{1}{SNR} + \frac{1}{SOR} + \frac{2}{SOR} \sum_{k=0}^{\beta-1} (1 - \frac{K}{\beta}))^{\frac{1}{2}} \}]$

$\sum_{l=0}^{\beta-1} x_{l,i}^2 = e_{bc}$ is the chaotic symbol energy, and $\frac{E_{xl}}{(\beta\sigma_X^2)^{1/2}} = \int_0^{\infty} \mathrm{p}\left(\mathrm{E_b^{(l)}}\right) \mathrm{dE_b^{(l)}}$ then

$$BER_{CSK} = \int_0^{+\infty} Q\{\sqrt{\frac{(h_1^2+h_2^2)e_{bc}}{\frac{1}{SNR}+\frac{1}{SOR}+\frac{2}{SOR}\sum_{k=0}^{\beta-1}(1-\frac{K}{\beta})}}\} * f(e_{bc})de_{bc} \quad (29)$$

And according to CGA result (29), the BER result for 2×2 Alamouti scheme can be written as the integral,

$BER = Q[E_{xl} \times h_{11}^2 + h_{21}^2 + h_{12}^2 + h_{22}^2 \sum_{i=0}^{\beta-1} x_{l,i}^2 / (h_{11}^2 + h_{21}^2 + h_{12}^2 + h_{22}^2 \sum_{i=0}^{\beta-1} \frac{x_{l,i}^2}{\beta\sigma_X^2})^{\frac{1}{2}} (\frac{1}{SNR} + \frac{1}{SOR} + \frac{2}{SOR} \sum_{k=0}^{\beta-1} (1 - \frac{K}{\beta}))^{\frac{1}{2}} \}]$

$$BER_{CSK} = \int_0^{+\infty} Q\left\{\sqrt{\frac{(h_{11}^2+h_{21}^2+h_{12}^2+h_{22}^2)e_{bc}}{\frac{1}{SNR}+\frac{1}{SOR}+\frac{2}{SOR}\sum_{k=0}^{\beta-1}(1-\frac{K}{\beta})}}\right\} * f(e_{bc})de_{bc} \quad (30)$$

Where e_{bc} is the standardized chaotic bit energy variable for the typical jth bit and $f(e_{bc})$ is its probability density function. HoIver, an analytical expression for $f(e_{bc})$ is difficult because the chaotic samples are not statistically independent, rather they are functionally dependent. Because the analytical expression of the probability density function (PDF) seems intractable, the only way to do so is to compute the histogram of the bit energy as shown in Fig. 4, folloId by numerical integration.

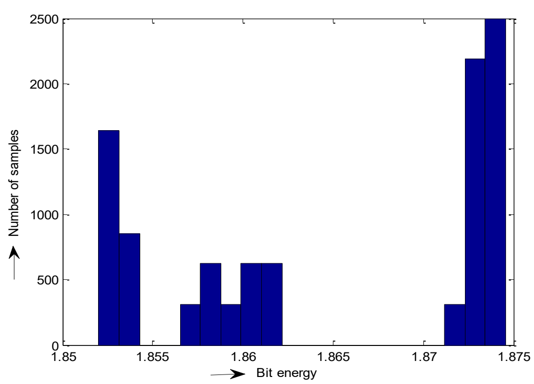


Fig 4. Histogram of the bit energy

Since an analytical expression appears to be hard to obtain, numerical integration remains a solution for performing the BER computation taking into account the bit-energy variation. The numerical integration expression 2×1 Alamouti scheme is given by

$$BER_{CSK} = \sum_{j=1}^{m} Q\left\{\sqrt{\frac{(h_1^2+h_2^2)e_{bc}}{\frac{1}{SNR}+\frac{1}{SOR}+\frac{2}{SOR}\sum_{k=0}^{\beta-1}\left(1-\frac{K}{\beta}\right)}}\right\} \mathrm{p}(e_{bc}^{(j)}) \quad (31)$$

And for 2×2 Alamouti scheme is given by

$$BER_{CSK} = \sum_{j=1}^{m} Q\left\{\sqrt{\frac{(h_{11}^2+h_{21}^2+h_{12}^2+h_{22}^2)e_{bc}}{\frac{1}{SNR}+\frac{1}{SOR}+\frac{2}{SOR}\sum_{k=0}^{\beta-1}\left(1-\frac{K}{\beta}\right)}}\right\} \mathrm{p}(e_{bc}^{(j)}) \quad (32)$$

Where m is the number of histogram classes created from the simulated spreading segment and $\mathrm{p}(E_{bc}^{(j)})$ is the probability of having the energy in integral centered on $E_b^{(j)}$.

5. SIMULATION RESULTS and DISCUSSIONS

The idea behind this paper is to verify the performance of chaos in CDMA systems taking into consideration the dynamic properties of chaotic sequences specially the non-periodicity. A comparative study is made taking into consideration, different chaotic maps, SISO and different MIMO Alamouti modes (2×1 and 2×2).

Fig. 5 depicts the autocorrelation function and cross correlation function of the signal generated by a chaotic tent map. The signal isolation is achieved by the using spreading sequences that have low cross correlation and δ-like auto-correlation properties.

As expected, Fig. 6 shows that the BER generally decrease (improve) as the number of transmitting and receiving antennas increase. 2×2 Alamouti scheme gives 1.75 dB gains as compared to 2×1 and 4 dB as compared to SISO at BER of 10^{-5}.

Figs. 7 and 8 depict the BER performance of different chaotic maps implemented in SISO and MIMO systems. Tent map gives the best BER performance as compared to Chebyshev map, logistic map and tailed shift map. As compared to SISO--CDMA system, MIMO-CDMA system gives a gain of 2 dB.

The circle graph (black) represent BER curve for simulated CDMA-2×2 Alamouti based on CSK modulation scheme for chaotic tent map which is overlapped with a maximum deviation of 0.5 dB by the magenta curve represented theoretical BER computed in equs. 32.

In Figure 9 the BER of chaotic SISO system with β=10 goes above 10^{-5}, if the number of user are more than 5. By using chaotic MIMO system with β=10, the BER increases from 10^{-8} to 10^{-6} as the number of users increases from 1 to 20. If I increase the number of users beyond 20, the BER in chaotic MIMO system remain constant at 10^{-6}. Thus, I can extensively increase the number of users in cell without substantial degradation in BER.

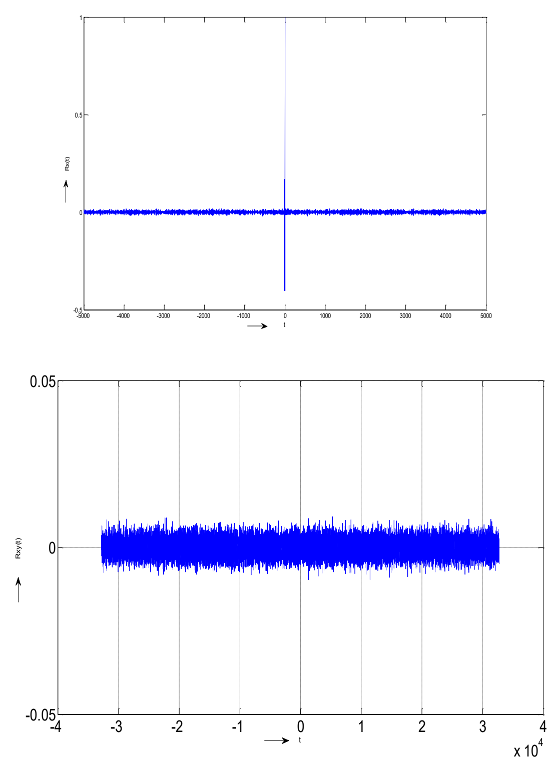


Fig 5. Measurement of auto- and cross-correlation of a chaotic tent map.

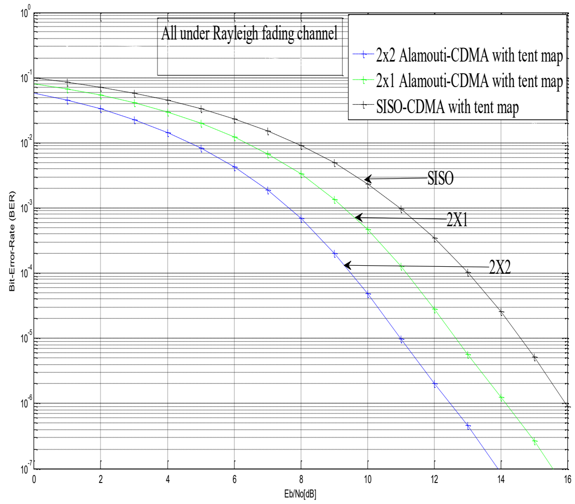


Fig 6. BER performance comparison betIen 2×2 , 2×1 and SISO communication systems for DS-CDMA under Rayleigh fading channels

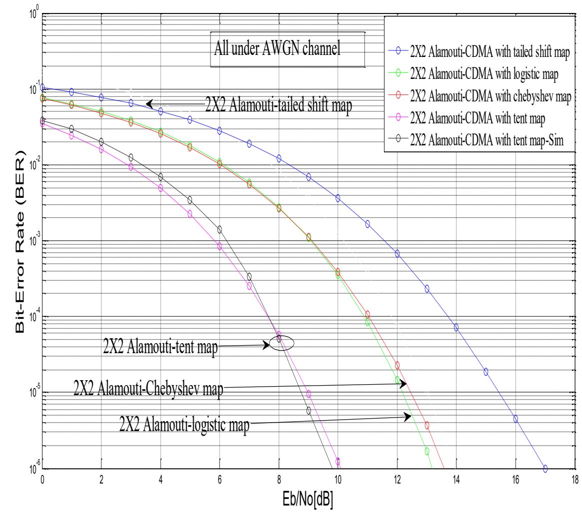


Fig 8. 2X2 Alamouti-DS-CDMA for different chaotic maps

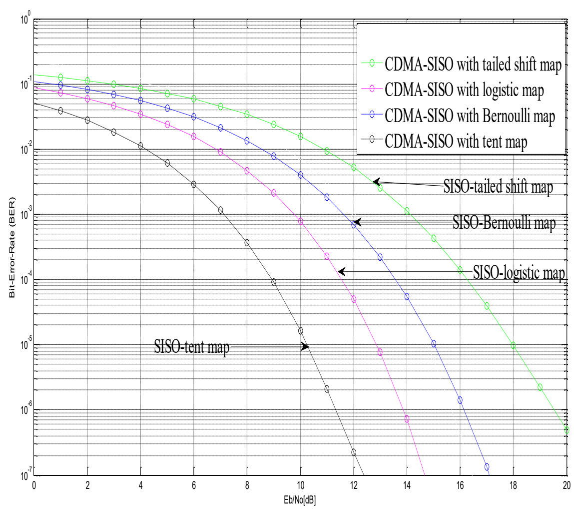


Fig 7. SISO-DS-CDMA for different chaotic maps

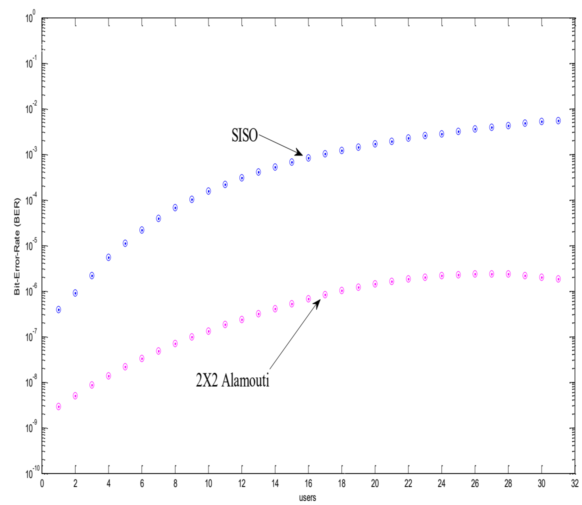


Fig 9. BER versus user number

6. CONCLUSIONS

In this paper, different chaotic maps with different spreading factors have been combined with MIMO communication channel in CDMA system. I have considered a system where the output of a Chaos Shift Keying (CSK) modulation scheme is combined with Space Time Block Code for two transmit antennas and one receive antenna, and two transmit antennas and two receive antennas under different fading channels. The Alamouti scheme with chaotic technique based CDMA system has many advantages over traditional CDMA systems including BER performance and increase the number of users. Simulation results show that 2×2 Alamouti scheme gives an additional 1.75 dB coding gain as compared to 2×1.

I conclude the paper by reiterating that the use of Chaotic CDMA-MIMO schemes have several advantages when compared with CDMA systems based on conventional PN sequences. MIMO systems also possess several advantages when compared to SISO systems using the same chaotic sequences for spreading.

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تصميم وتحليل اداء نظام التضمين الفوضوي بالاعتماد على نظام تصميم رمز الوصول المتعدد

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الخلاصة :

في هذا البحث تم تصميم نظام اتصالات يجمع بين تقنية الهوائيات المتعددة ورمز الوصول المتعدد باستخدام التقنية الفوضوية. بسبب الصفات الخاصة التي تتمتع بها الاشارة الفوضوية والتي منها امكانية توليد اشارة عشوائية لا يمكن تكرارها بعد فترة من الزمن وكذلك تتميز بعرض كبير للحزمة لذلك فان حساب نسة الخطأ للبت لا يكون بالطريقة الاعتيادية لكون طاقة البت تتغير من بت الى اخر. لقد تم حساب نسة الخطأ لهذا النظام بأستخدام طريقة خاصة تلائم هذه الصفات للإشارة الفوضوية التي تمر من خلال *Rayleigh channel* **وذلك بتضمين الاشارة بحامل من الاشارة الفوضوية** *(CSK)* **ودمجها** *2x1 or 2x2 Alamouti schemes*. **لقد تم حساب نسبة الخطأ للبت باستخدام المحاكاة.**