ISSN 2229-5518

Performance of Chaos-Based MC-MC-CDMA in Frequency Selective Fading Channel

Maha George Zia

Abstract— This paper presents the effect of chaos sequences on the performance of multi-code multi-carrier code division multiple access (MC-MC-CDMA) communication system. Since a chaotic system dependence on its initial conditions, the multi-carrier scheme is established by using one chaotic sequence generator with different initial conditions for the code sequence set of M-ary modulation, and the multi-carrier scheme is established by using another chaotic generator with another different initial conditions. The simulation results demonstrated that the chaos – based MC-MC-CDMA system achieves significant performance improvement compared to Walsh-Hadamard codes in the conventional MC-MC-CDMA system.

Index Terms— chaos based spread spectrum, chaos generator, MC-MC-CDMA system, Walsh-Hadamard codes, fading channel, multicarrier system, spreading codes

1 INTRODUCTION

In order to spread the bandwidth of the transmitting signals, pseudo-noise (PN) sequences have been used extensively in spread-spectrum (SS) communication systems. The maximal-length linear code sequences (m-sequences) have very desirable autocorrelation functions. However, large spikes can be found in their cross-correlation functions, especially when partially correlated, as in the case of multi-path environments. It is proposed to use chaotic sequences as spreading sequences in SS systems. One major difference between chaotic sequences and the PN sequences is that chaotic sequences are not binary and the auto-correlation of these sequences is a delta-function while their cross-correlation is identically zero [1].

Based on Chaos theory, [2] provided a new method for detection of Direct Sequence Spread Spectrum (DSSS) signal. According to the analysis of intermittent chaos, chaotic oscillators array was used in the method. In addition, the system of Duffing Chaotic Oscillators Array was constructed for blind detection in very low signal-to-noise ratio (SNR). This detected method was effective when compared with wavelet decomposition at lower detection threshold which enhanced the performance system at very low signal-to-noise ratio (SNR).

A support vector machine receiver (SVM) for a multi-code Chaos-based CDMA (MC-CB-CDMA) system was proposed in [3], where the main aim for the assigning multiple spreading codes for each user was to provide unequal error protection on the transmitted data without using further error correction coding (ECC). The proposed SVM receiver was simplified by the recursive feature elimination algorithm so that it has a less complexity than the conventional correlator receiver and huge performance gain was achieved due to the multi-user detection capability from the SVM receiver [3].

A scheme of chaotic spreading sequence for multi- carrier code division multiple access system (MC-CDMA) was proposed in [4] to estimate the transmission channel. The proposed system used a chaotic sequence generated by a logistic map as a training signal and estimated channel parameters according to dynamics of the chaotic sequence. Encoding data by chaotic sequences was first built and then the orthogonal codes were used to spread the encrypted data for multiusers scheme. At the reception, first the channel parameters were identified using a training chaotic sequence in order to equalize the received data, and then the encrypted information was decoded for the desired user. The proposed system (chaos plus orthogonal codes) significantly outperforms the Walsh-Hadamard code spreading in MC-CDMA system. Moreover, chaotic code spreading approach for channel identification achieved significant improvement in the channel identification, comparing to using others training sequence or the least square method [4].

A chaos modulation scheme called initial condition modulation (ICM) which is based on chaotic signal separation was proposed in [5]. The proposed scheme transmitted two M-ary symbols in one period, its data rate is 2 $\log_2(M)$ times higher than other binary chaotic schemes under the assumption of the same bandwidth usage. In this system, the success of signal separation makes it possible to transmit multiple information streams through single channel. It also significantly improves data transmission rate and implies good information security [5].

This paper demonstrate the performance of MC-MC-CDMA system employing chaotic sequences and the simulation results show that this system can be better than the conventional MC-MC-CDMA system that uses Walsh-Hadamard codes in terms of symbol error rate (SER) probabilities.

The paper is organized as follows; section 2 describes the system model of MC-MC-CDMA based chaos sequences. The system analysis is presented in section 3. In section 4, the simulation results of SER performance of MC-MC-CDMA using chaos and Walsh-Hadamard codes are presented. Finally, conclusions are presented in section 5.

• *Maha George Zia is currently an assistant professor in Software engineering department in College of Engineering - Salahaddin University, Iraq,. E-mail: mahageorge11@gmail.com*

2 SYSTEM MODEL

Consider MC-MC-CDMA system [6]. The proposed system uses 4-ary modulation called M-code sequence, where M= 4. As shown in Fig. 1, 4-ary symbol selects one of the 4 pre-mapped code sequences using one chaotic generator for transmission. The chaotic generator [7] and transmitted signal can be expressed as:

$$v_{n+1} = 4\,v_n^3 - 3\,v_n \qquad ,|v| < 1 \qquad (1)$$

$$\{v_1 \ if \ symbol "0" \ is \ transmitted\} \qquad (2a)$$

$$\{v_2 \ if \ symbol "1" \ is \ transmitted\} \qquad (2b)$$

$$\{v_3 \ if \ symbol "2" \ is \ transmitted\} \qquad (2c)$$

$$\{v_4 \ if \ symbol "3" \ is \ transmitted\} \qquad (2d)$$

Assuming that the chaotic sequences are generated independently of one another and the mean value of each of the chaotic sequences is zero in order to avoid transmitting any dc component which is a waste of power. In other words,

$$E\left[v_{i,k}(n)\right] = 0 \quad ,i = 1,2,..., M \ and \ k = 1,2,..., K \qquad (3)$$

Each chaotic sequence *v(n)* has a time domain spreading ratio of N. For k^{th} user, each symbol of the length N chaotic sequence is copied onto L subcarries branches and multiplied with the user specific scrambling code $c_{k,1}$, $c_{k,2}$, …. $c_{k,L}$ as shown in Fig.1 [6]. The user specific scrambling code is generated from another chaotic generator by changing its initial condition and is considered as spreading in frequency. The user specific scrambling code is generated using the chaotic generator [8]:

$$c_{n+1} = 4\,c_n\,(1 - c_n) \qquad (4)$$

In [6], subcarrier multiplications and summation are used in the transmitter and receiver. In this work, Inverse Fast Fourier Transform (IFFT) and Fast Fourier Transform (FFT) each of size L replaces the subcarrier multiplications and summation at the transmitter and receiver respectively. Also, because intersymbol interference (ISI) is minor in multicarrier CDMA, cyclic prefix is not employed.

At the receiver of Fig.1, a size L-FFT is applied to the input and the output of the FFT is then despread to generate each of the received chaotic sequence of length N. The received N chaotic sequence is correlated with each of the possible four chaotic sequences ($v_1(n)$, $v_2(n)$,.., $v_4(n)$) and the sequence that gives maximum correlation is then mapped back into an 4-ary symbol.

3 SYSTEM ANALYIS

Consider each user has the same code sequence set $v_m(n)\ \} 1 \le m \le M,\ 0 \le n \le N-1$ as shown in Fig.(1).

User k's i^{th} M-ary data symbol ($b_{k,i}$) is mapped to one of the code sequences in the code sequence set [6]. $v_{k,i}(n) = v_{k,i}\ , i = 1,2,...,M\ , 1 \le n \le N$ is the i^{th} chaotic transmit sequence of length N of user k and is generated from equation (1). Each symbol of the length N chaotic sequence $v_{k,i}$ is copied onto L subcarries branches and multiplied with the user specific scrambling code $C_{k,i}$ which is generated from (2) and can be written as:

$$C_{k,i} = [c_{k,1}, c_{k,2}, ..., c_{k,L}]^T \qquad (5)$$

$$S_{k,i} = v_{k,i}\,.\,C_{k,i} \qquad (6)$$

After that $S_{k,i}$ will go through IFFT of size L and the transmitted signal of user k can be written as:

$$s_k(n) = (1/L)\sum_{l=1}^{L} S_{k,i}(l)\, e^{j\,2\pi\, n\, l/L} \qquad (7)$$

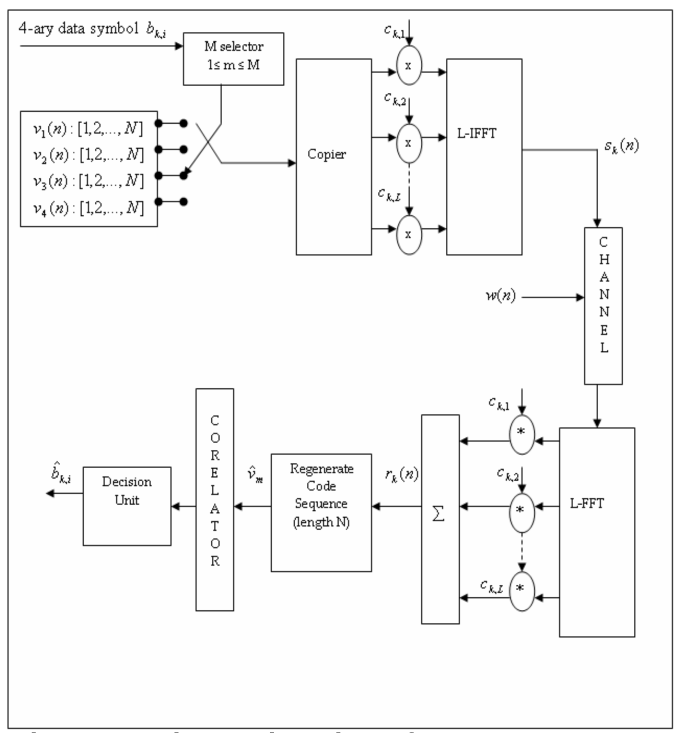

Fig.1 Transmitter and receiver of MC-MC-CDMA system

$s_k(n)$ passes through frequency selective Rayleigh fading channel which is modeled using Jake's model [9]. In the receiver of Fig.1, a size L FFT is applied to the input and the output is then despread to generate the received sequence code which can be written as:

$$r_k(n) = [R_1, R_2 ..., R_L]^T \left[\sum_{i=1}^{M} \sum_{k=1}^{K} \sum_{l=1}^{L} h_{k,l}\ v_{k,i}\ c_{k,l}\right] + [w_1, w_2, ..., w_L]^T \quad (8)$$

where $h_{k,l}$ is a Rayleigh distributed amplitude attenuation, and w_l is the additive white Gaussian noise with zero mean and unit variance. The N despread bits from a degenerated code sequence are correlated with each of M possible code sequences. The sequence that gives maximum correlation is then mapped back into an M-ary symbol.

4 PERFORMANCE COMPARISONS OF MC-MC-CDMA BASED CHAOS AND WALSH- HADAMARD CODES

The simulation results of SER performance of MC-MC-CDMA system based chaos and Walsh-Hadamard codes are presented using MATLAB. QPSK is used in the system, the channel is considered as frequency selective Rayleigh fading channel modeled as Jake's model [9].

Fig. 2 shows the SER performance of the MC-MC-CDMA system with different values of N and L=16. Both M-code sequence and the spreading code use the chaos generator represented by(1) and (4**)** respectively. It can be noticed that as N increases, the SER performance gets better.

In Fig. 3, the system uses different number of subcarriers for N=16 and SER performance gets improved as L is increased.

Walsh-Hadamerd codes and chaos codes are used in an alternative forms in Fig.4 for N=L=16. Four curves of SER performances are described. The first curve shows SER performance using chaos code for both M-code sequence and the spreading code. The second curve shows SER performances using chaos code for M-code sequence and Walsh-Hadamerd code for the spreading code. The third curve shows SER performances using Walsh-Hadamerd code for M-code sequence and chaos code for the spreading code. The fourth curve shows SER performance using Walsh-Hadamerd code for both M-code sequence and the spreading code. It can be notice that curve A outperforms curve D by 2.3 dB at SER = 10^{-4}**.**

Fig. 5, 1 and 4 users are applied to MC-MC-CDMA system based chaos for N = L = 16. It can be noticed that as the number of users is increased the SER becomes worse.

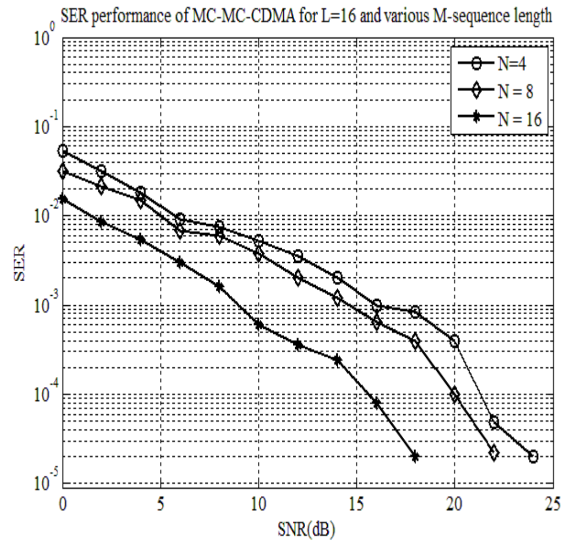

Fig.2 SER performance of the MC-MC-CDMA system with different values of N and L=16

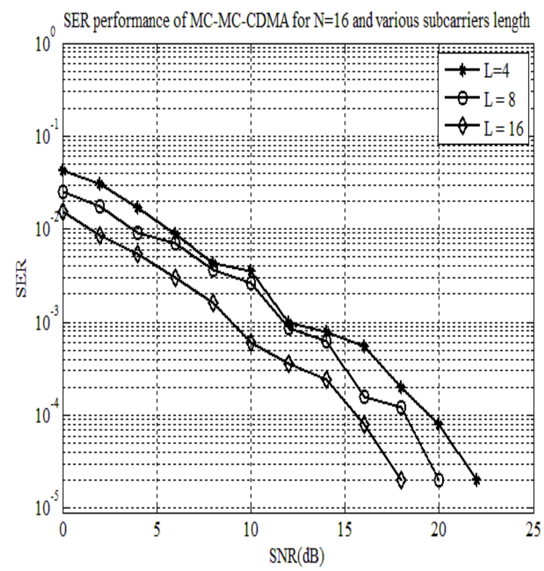

Fig.3 SER performance of the MC-MC-CDMA system with different values of L and N=16

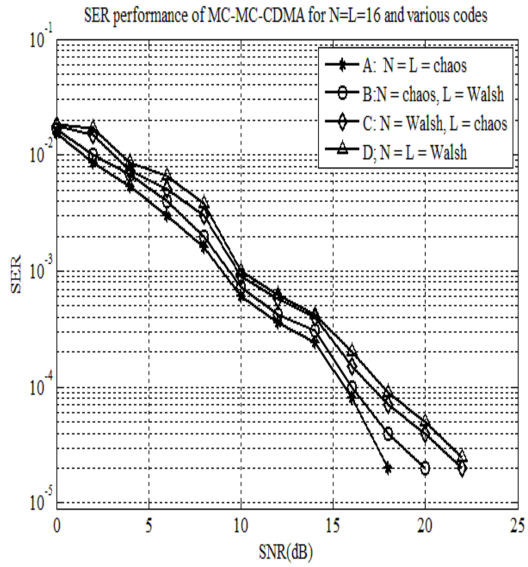

Fig.4 SER performance of the MC-MC-CDMA system with different codes and N = L=16

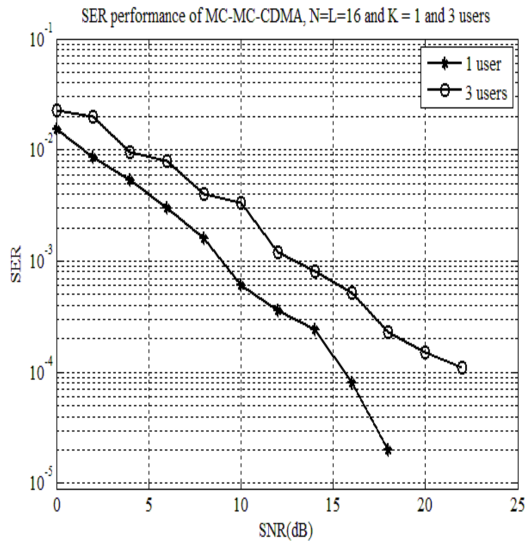

Fig.5 SER performance of the MC-MC-CDMA system with different users and N = L=16

5 CONCLSIONS

In this paper, MC-MC-CDMA system based chaos was presented and the SER performance was measured using MATLAB program for different values of M-sequence code length and spreading code length. Simulation results showed that MC-MC-CDMA system based chaos performs better than MC-MC-CDMA system based Walsh-Hadamard code in terms of SER performance.

REFERENCES

[1] Ghobad Heidari-Bateni, and Clare D. McGillem, "A Chaotic Direct-Sequence Spread-Spectrum Communication System", *IEEE Transactions on Communications*, vol.42, no. pp. 2/3/4, Feb./Mar./Apr. 1994.

[2] Xiong Gang, LÜ Ming, and Tang bin, "Direct Sequence Spread Spectrum Signal Detection Based on Chaos Theory", *ICCCAS 2007*, pp. 727-730.

[3] Johnny W. H. Kao, Stevan M. Berber, and Vojislav Kecman," Adaptive Multi-Code Chaos-Based CDMA with Unequal Error Protection using Reduced Support Vector Machine," *Globecom 2010 proceedings*, pp.1-5.

[4] Miloud Frikel, Said Safi, Boubekeur Targui, and Mohammed M'Saad, "Channel Identification Using Chaos for an Uplink/Downlink Multicarrier Code Division Multiple Access System," *Journal of Telecommunications and Information Technology*, vol.1, pp. 48-54, 2010.

[5] Mingdong Xu and Henry Leung," A Novel High Data Rate Modulation Scheme Based on Chaotic Signal Separation," *IEEE Transactions on Communications*, vol. 58, no. 10, pp. 2855-2860, OCT. 2010.

[6] Taeyoon Kim, Jaeweon Kim. Jeffrey G. Andrews, and Theodore S. Rappaport," Multi-code Multicarrier CDMA: Performance Analysis," *IEEE Communications* 2004, pp.

[7] Kohda T. and Tsuneda A., "Even- and odd-correlation functions of chaotic Chebyshev bit sequences for CDMA", in: *Proc. IEEE International Symposium on Spread Spectrum Technology and Applications*, Oulu, Finland, 1994, pp. 391–395.

[8] Heidari-Bateni G., and McGillem C.D., "Chaotic Sequences for Spread Spectrum: An Alternative to PN-Sequences", *IEEE ICWC '92*, pp. 437-440

[9] W. Wu, V. V. Srinivasan, C. Hsu, Y. Kim, and C. Lee, Optimal Channel Estimation for Capacity Maximization in OFDM Systems, Wireless Communication Project (EE-381K-11), Dept. of Electrical and Computer Eng., Univ. of Texas, Austin, pp.1-24, May 2003.