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An Efficient Algorithm for generation of High Performance Spreading Codes for MCCDMA Applications

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Abstract

Several coding techniques have been investigated for efficient transmission of data with MC-CDMA over wireless channels. Despite the efficiency of these coding techniques, they add much redundancy to the transmitted data, which increases the bandwidth and reduces the channel utilization. Chaotic spreaded transmission systems are highly secured synchronized systems that provides a more reliable communication. This work presents a novel algorithm to generate the chaotic spreading codes used in MCCDMA system. The correlation properties of spreading codes generated from various sources of chaotic signals are analysed. These are compared with the conventional spreading codes such as Hadamard and Pseudo random codes. The proposed algorithm generates the minimum correlated spreading codes.

Keywords: Multi Carrier Code Division Multiple Access (MCCDMA), Direct Sequence Spread Spectrum (DSSS), Spreading codes, Chaotic signals, Correlation.

1. Introduction

The high usage of wireless network services nowadays demand effective strategies to cope up with the increase in the number of users without human intervention, with increased requirement for bandwidth exhaustive services and quick change in the operator prototype, for evolving to LTE networks. The flexibility in the wireless communication can be obtained from these techniques.

Data transmission in real time requires high data rate or low BER performance against the channel impairments such as multipath fading and interferences. The limited availability of bandwidth also increases the demand for trustworthy communication. This system includes the real time data transmission such as image, video, audio etc.

The random sequences like PN sequences, Walsh-Hadamard sequences are mostly used spreading codes in direct sequence spread spectrum. These sequences have good correlation properties but it is insecure when reconstructed using linear regression.

The chaotic sequences which are acquired by various chaotic systems and maps hold infinite number of states in a deterministic manner and it never repeats itself. The length of the chaotic sequences is user defined, so multiple number of sequences can be easily generated. Choosing the best set of sequences can increase the privacy and also reduce the MAI(Multiple access Interference).

This paper describes a new method in retrieving the orthogonal sequences from various chaotic systems such as logistic maps, Chua's system and Rossler system. The correlation properties of these spreading codes and those of currently used PN sequence and Hadamard spreading code are also analysed.

2. Proposed System

In existing system, data is transmitted using MC CDMA in the application of 4G mobile telecommunication air interface, Hadamard code and Pseudo random sequences are used as the spreading codes.The existing spreading codes have poor autocorrelation and time sensitive orthogonality property causing data transmission inefficient.

A new algorithm is proposed to obtain the spreading code from chaotic signals. For multi user communication, several spreading codes can be easily generated. The advantages of using Chaotic sequence as a spreading code are the increased orthogonality between the users. In MC CDMA the wideband channels is subdivided into number of subchannels resulting in mitigation of interference. Spreading through chaotic sequence makes transmission more immune to noise and fading and also ensures the high degree of encryption. There is also an increase in Signal to Noise ratio and decrease in Bit Error rate.

3. DS CDMA

Direct Sequence Code Division Multiple Access (DS-CDMA) is a method of multiplexing users by distinct codes and in this method all users use the same bandwidth. In DS-CDMA, each user has a distinct spreading code. The selection of a good code is important, because auto-correlation properties and length of the code sets bound on the system capacity. The code sets can be divided into two classes: orthogonal codes and non-orthogonal codes. Walsh sequences fall in the 1st category, while the other sequences (PN, Gold and Kasami) are shift-register generated sequences. When the user codes are orthogonal, the output of the correlator in the receiver is zero except the desired sequence.

In synchronous DS-CDMA systems the code sequence in the receiver is exactly same with that in the transmitter, so there is no time shift between the users. When the user codes are orthogonal in the synchronized systems, there is no multiple access interference between the users after despreading. In practice, it is difficult to realize synchronized DS-CDMA systems and time shifts between users decrease the system's capacity. The most important measures that specify the codes performance are the orderly low values of cross-correlation between codes and the rate of correct of autocorrelation values from time shifts.

In DS-CDMA system, for despreading operation, the received data should be multiplied with the same code in the receiver. So the other user codes in the same frequency band must be uncorrelated with the desired user code. For this reason the DS-CDMA codes have to be designed so as to possess very low cross-correlation. Auto-correlation shows the measure of similarity between the code and its cyclic shifted copy. Because of this reason, the codes that have the best properties of auto-correlation have been frequently used in removing the asynchronization in communication systems.

4. CHAOTIC SIGNALS

In general chaotic is nothing but the condition of randomness. Although there is no exact mathematical description for this random behavior, it has common properties by which it is being described.

1. It is sensitive to preliminary states.
2. It has topological integration.
3. Its continuous variations must be crowded.

A. Chua's circuit:

These circuits are based on the set of equations 4.1 and generates a chaotic signal which is random. This independent circuit consists of resistors and capacitors and is designed based on the constants chosen

1. One or more nonlinear elements
2. One or more locally active resistors
3. Three or more energy-storage elements.

Chua's circuit is shown in figure 4.1 wherein voltages X & Y are the chaotic signals. The chosen values are:

R= 2.5K, R1=220Ω, R2= 220 Ω, R3= 2.2k, R4= 22k, R5= 22k,
R6= 3.3k, R7= 100 Ω, R8= 1k, R9= 1k, R10=2.5k , C= 100nF,
C1= 10nF, C2=100nF.

The Chua System equations are given by:

$$\frac{dx}{dt} = \alpha[y - x - f(x)]$$
$$\frac{dy}{dt} = x - y + z$$
$$\frac{dz}{dt} = -\beta y \qquad \ldots. \qquad \text{Eq. 4.1}$$

The Chua’s circuit behaves chaotically based on some initial conditions and they are given as α=15.6, β=28, h=0.1. The set of equations in 4.1 are implemented in Matlab-simulink model as shown in fig. 4.2 and the Chaotic behaviour across xy, yz and zx are given in fig.4.3.

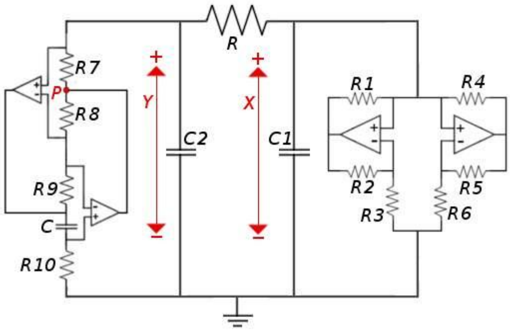


Fig 4.1 Chua’s circuit

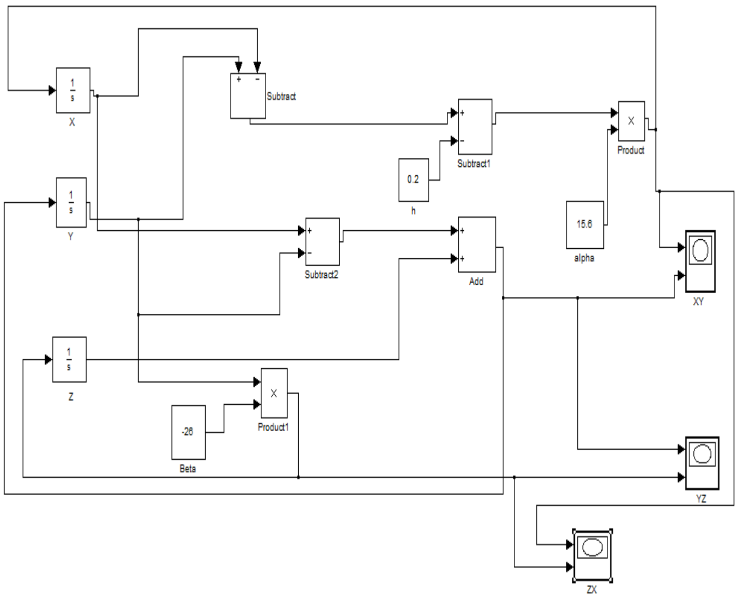


Fig 4.2 Simulink model of Chua System

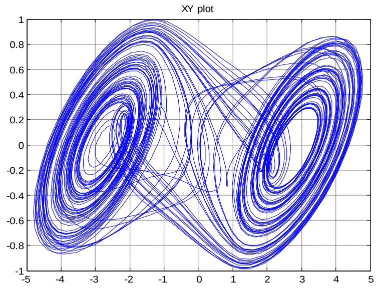
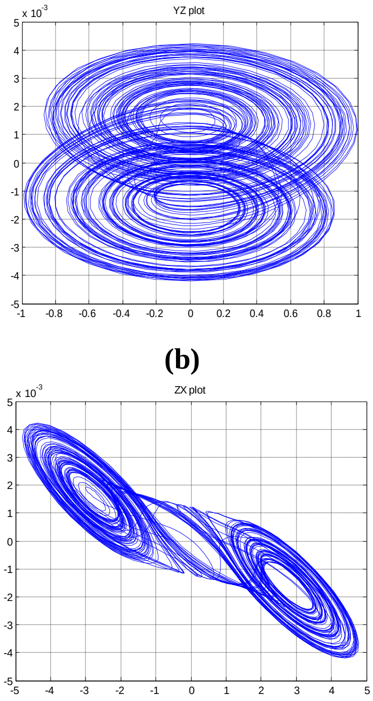


Fig. 4.3 (a) x-y chaotic behaviour



(b)

(c)

Fig 4.3 Chaotic Behaviour (a)x-y plot (b)y-z plot (c)z-x plot

B. Logistic map:

The logistic map is a polynomial mapping, a recurrence relation of degree 2, given by the equation 4.2. The signal x(n) behaves chaotically and has a very good autocorrelation property. This random behaviour can be used in spreading coded communication. By varying the initial condition [x(n)<1] for the logistic map and by choosing‘r’value between 3.57 to 4.0 we can get different forms of chaotic signals and the spreading sequences generated can be used for different users in the MCCDMA. For the logistic map given by

$$x(n) = r.x(n-1).(1-x(n-1));\ r = 3.999\ \&\ x(0) = 0.6 \qquad \text{Eq. 4.2}$$

The simulated chaotic signal is shown in fig.4.3

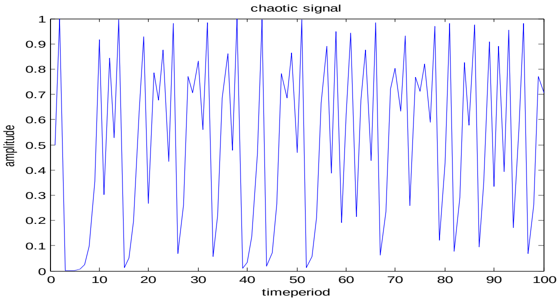


Fig 4.3 Chaotic Signal

C. Rossler System:

Rossler system is a continuous time dynamical system which is defined by the following set of differential equations :

$$\frac{dx}{dt} = -y - z$$
$$\frac{dy}{dt} = x + ay$$
$$\frac{dz}{dt} = b + z(x - c) \quad \ldots. \qquad \text{Eq. 4.3}$$

The Rossler circuit is shown in fig,4.3 and its hardware implementation in fig.4.4. Considering the initial condition values as a=b=0.2, c=5.7, the chaotic behaviour of the system is observed in the digital storage oscilloscope as shown in fig.4.5. The chaotic signals observed are given in figures 4.6 & 4.7.

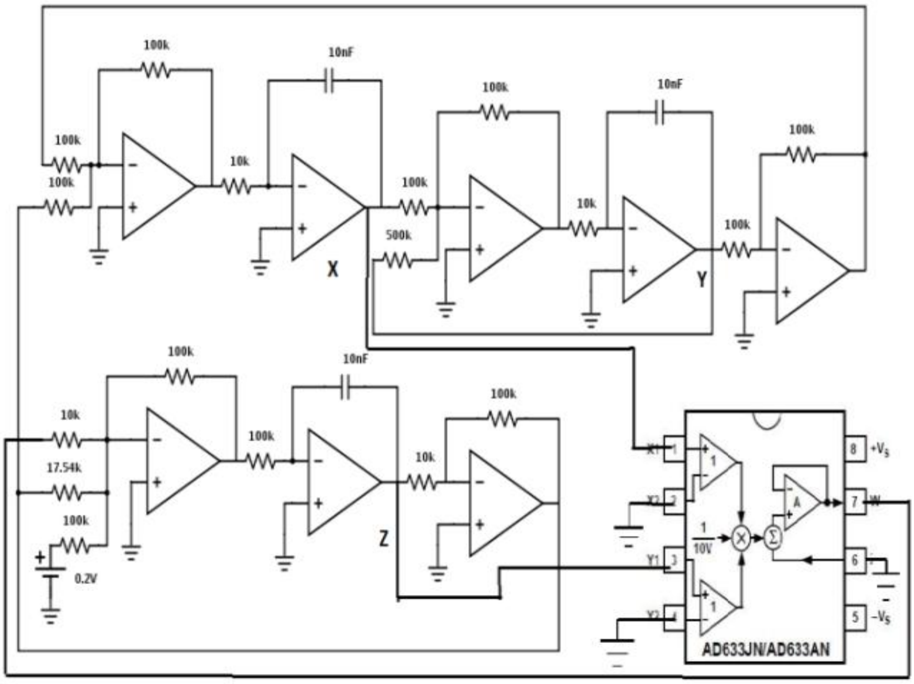


Fig 4.3 Rossler circuit

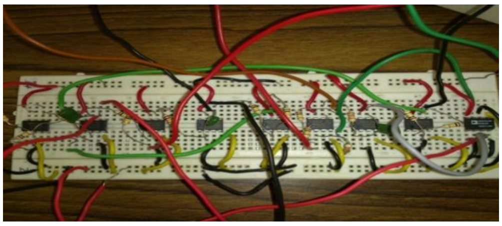


Fig 4.4 Hardware implementation of Rossler system

Fig 4.5 Chaotic Behaviour of Rossler system

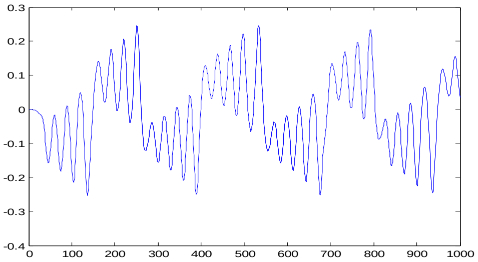


Fig 4.6 x-Chaotic signal from Rossler system

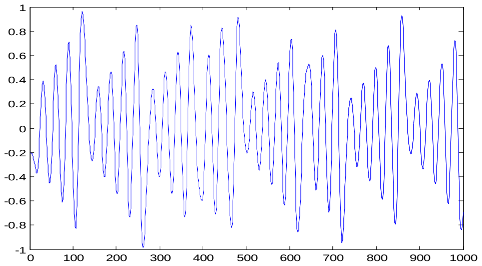


Fig 4.7 y-Chaotic signal from Rossler system

5. SPREADING CODES

A. Hadamard codes

Hadamard-Walsh codes are generated in a set of $N=2^n$ codes. The generating algorithm is as follows.

$$\mathbf{H_{2N}} = \begin{bmatrix} H_N & H_N \\ H_N & \overline{H_N} \end{bmatrix} \quad \ldots. \qquad \textbf{Eq. 5.1}$$

Where overscore denotes the binary complement of the bits in the matrix. The smallest set of N=0 is H_0= [1] with the length 1. The rows or columns of matrix H_N are the Hadamard-Walsh codes since H_N is symmetric.

As shown above, in each set, the first row of the matrix consist all 1's and rest of the rows contains N/2 0's and N/2 1's. Also row N/2 starts with N/2 1's and ends with N/2 0's. Orthogonality is the most important property of Hadamard-Walsh codes and therefore cross correlation between any two Hadamard-Walsh codes of the same set (matrix) is zero, when system is perfectly synchronized.

Walsh codes are not maximal length or random type codes. Although the members of the set are orthogonal, they do not give any spreading. They are used in forward channel of IS-95 CDMA type system. Walsh code spreading can be used if all users of the same channel are synchronized in time, because the cross-correlation between different shifts of Walsh codes is not zero.

B. PN sequence:

The Pseudorandom Noise sequence is generated from the logic shown in the figure 5.1. It is nothing but the linear feedback shift register triggered with a random initial sequence consisting of at least a 1 at each clock pulse. A random sequence is generated and it is shifted. The sequence from the Mth shift register is considered to be the output PN sequence. Length of the PN sequence generated is given by 2^n-1, where n is the number of shift registers.

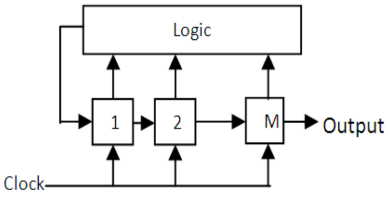


Fig 5.1 PN sequence generator

C. *Algorithm for generation of Spreading code :*

- Let the code length be **n** and number of samples is **n** and the length of chaotic signal be **N**.

  n=N/x

  where **x** is the segment length depending on code length and signal length.

- Code(i)= **(∑ Nj)**

  where i=0,1,2,...,n-1

  j= (i*x), (i*x) +1,……. (i*x)+x.

- Spreading code = 1, if Code (i)> [(max value) - abs (min value)]/2;

  0, otherwise

Eq. 5.2

From the reference [8] a spreading sequence from the maps can be used in wireless communication for encryption purpose as well as spreading codes in digital communication. The spreading codes generated has good autocorrelation and orthogonality property which increases the capability of retrieving the data from the signal detrained through fading channels.

D. Spreading code from Chua's circuit:

The chaotic signals X and Y generated from Chua system as discussed in section 4A are shown in figures 5.2 & 5.3. The samples of chaotic signal and average values obtained in each sampling interval are given in figure 5.4

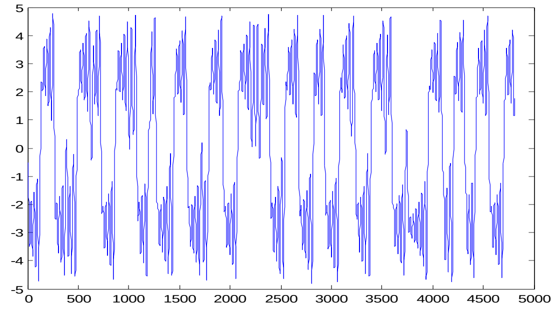


Fig 5.2 X-Chaotic signal from Chua's circuit

The above X-signal is sampled and sequence is generated. Variable spreading sequences can be generated by varying the size and the initial condition of the system, Similarly Y-signal shown in figure 4.3 can also be used to generate a sequence which has good orthogonality with the sequence generated from X-signal.

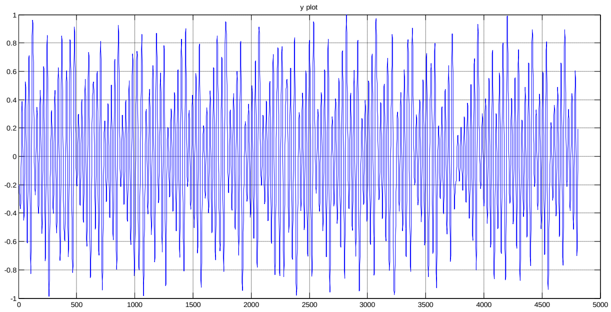


Fig 5.3 Y-Chaotic signal from Chua's circuit

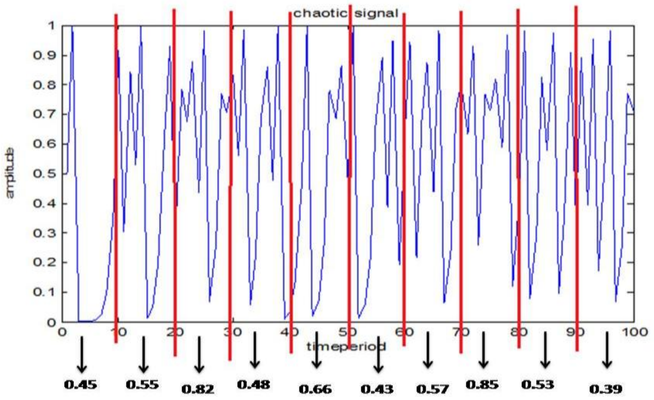


Fig 5.4 Sampled Chaotic signal and signal average

The average value is compared with the threshold value and by using eq.5.2 and spreading code is generated. In this example the threshold is computed as 0.5 and the code generated is then [**0 1 1 0 1 0 1 1 1 0].**

E. Spreading code from Rossler circuit:

From the hardware circuit implemented as shown in fig.4.3, the output is fed into the DSO (Digital Storage Oscilloscope) and stored in an external storage device as excel document, which is directly loaded in matlab programming.

6. Autocorrelation and Cross correlation

These properties define that the signal is repetitive or not, if the autocorrelation or cross correlation value is very low then the repetitive of the same values is less i.e. a good correlation property. Autocorrelation of the binary sequence b(n) is being determined as follows:

$$R_{AC}(\tau)=\frac{1}{L}\sum_{n=0}^{L-1}b_i(n)b_i(n+\tau),\ 0\le\tau\le L-1 \quad \ldots. \quad \text{Eq. 6.1}$$

Consider two binary sequences $b_i(n)$ and $b_j(n)$ with the same length L, normalized cross-correlation function is given as follows:

$$R_{CC}(\tau)=\frac{1}{L}\sum_{n=0}^{L-1}b_i(n)b_j(n+\tau),\ 0\le\tau\le L-1 \quad \ldots. \quad \text{Eq. 6.2}$$

The autocorrelation and the cross correlation values are being listed below, for L=100. The correlation analysis of chaotic spreading codes from three different chaotic sources are compared with pseudo-random codes and Hadamard codes.

Spreading sequence	Auto correlation value	Cross correlation value
Logistic map	0.46	0.23
Chua’s system	0.37	0.18
Rossler system	0.34	0.11
PN sequence	0.503	0.49
Hadamard code	1	0.5

The analysis prove that the chaotic spreading code outperforms the existing codes. The simulation results are shown in figures 6.1- 6.4.

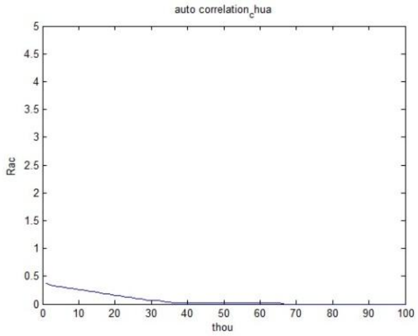


Fig.6.1 Auto-correlation of chua system generated chaotic spreading code

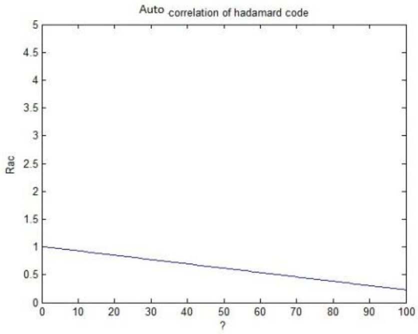


Fig.6.2 Auto-correlation of Hadamard spreading code

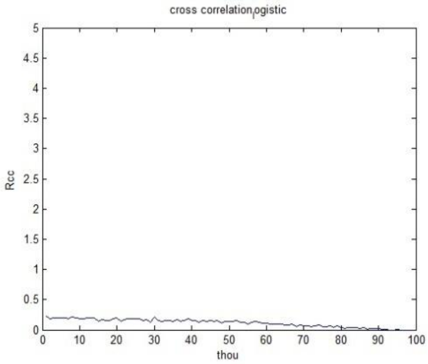


Fig.6.3 Cross-correlation of Logistic map generated chaotic spreading code

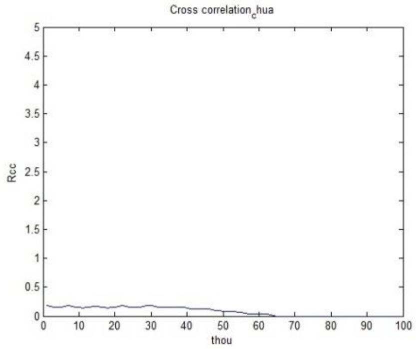


Fig.6.4 Cross-correlation of Chua system generated chaotic spreading code

7. Conclusion

The proposed algorithm generated high performance new spreading codes using chaotic signals. For multi-user communication system,this methodology is more versatile for any number of users. Chaotic systems such as Logistic map, Chua system and Rossler system are designed through simulation and hardware implementation. The correlation and orthogonality properties are analysed and compared with that of existing spreading codes.The generated codes can be further used in MCCDMA direct sequence spread spectrum communication. Further research can be carried out based on the reduction of PAPR using the Precoding technique the chaotic spreading codes.

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