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Chaotic Code Division Multiple Access

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Abstract - Chaotic signals are gaining importance in the field of communication these days. The chaotic Pseudo Noise sequences give a uniform spread over the entire frequency bandwidth. The sequences produce good performance as Pseudo random patterns when used in Code Division Multiple Access (CDMA) systems. This paper introduces to the field of chaotic signals and demonstrates how it is used in CDMA systems

***Key Words*:** Chaotic signals, DS CDMA, Nonlinear systems, PN sequences.

1.INTRODUCTION

Since long time, the practice of electrical engineering has been dominated by a linear paradigm that has well served the needs for communications signal processing functions. These techniques are well established, mature, and solve a large lass of problems, being based on the classical superposition principle. Nonlinearity is always considered as an oddity and a nuisance than an inherent and possibly useful feature of nature. However nonlinear effects are to be harnessed in important and common signal functions such as frequency generation, frequency synthesis, and power amplification. We can see the development of nonlinear engineering techniques developing these days and many fields of engineering are getting greatly benefited with this technology. [1] Nonlinear effects prompted a flurry of research applying them to communications signal processing.

The first and perhaps most well-known sub discipline of nonlinear science is chaos, which is many times informally thought of as being synonymous with the nonlinear discipline. Discovery of chaotic synchronization around 1990, made many properties of chaos-a complex, noise like behaviour found in nonlinear dynamical systems-to be applied in a communications context. An essentially whole new era of nonlinear technique development followed in its wake, offering several potential benefits over classical approaches, including, for example, (1) unique privacy and frequency-reuse capabilities even for analog communications (still of military interest); (2) enhanced synchronization performance afforded naturally by the dynamics involved; and (3) several novel signal processing capabilities, several of which are impossible with linear methods. All these benefits contribute to the three fundamental considerations in communications design: efficiency, reliability, and security. [1]

One of the well-known and potentially useful nonlinear dynamical effects is the bounded, random-like behaviour of chaos, i.e., “deterministic noise” which can be used as Pseudo Noise sequence for Spread Spectrum applications. Code Division Multiple Access is an application of Spread Spectrum System where in different users are allotted different PN sequences and information to be transmitted is multiplied with the allotted PN sequences. The BER (Bit Error Rate) performances of DS-CDMA (Direct Sequence – Code Division Multiple Access) systems depend mainly on the correlation properties of the spreading sequences set [2], [3], [4]. The use of low cross correlation sets of sequences increases the BER performances and the system capacity as well.

Hence, it is imperative to design optimum spreading sequences sets that minimize the BER. Classical sets of spreading sequences used in actual standards of DS-CDMA mobile communication systems are binary sequences generated by LFSR (Linear-Feedback Shift Register) schemes. Even for minimum cross- correlation sequences, forming Gold and Kasami sets, the set dimension and the period of the sequences are limited by the LFSR polynomial degree. Another drawback of these sequences is induced by the generator linearity, which increases the interception probability.

The chaotic sequences present noise-like features that make them good for spreading in DS-CDMA systems [5], [6]. A single system, described by its discrete chaotic map, can generate a very large number of distinct chaotic sequences, each sequence being uniquely specified by its initial value. This dependency on the initial state and the non-linear character of the discrete map make the DSCDMA system using these sequences more secure.

In chaotic DS/SS communication systems, the detection of the data sequence is also based on correlation of the received signal with the chaotic sequence of the receiver. Before transmitting data information, the transmitter and the receiver must be synchronized. The transmitter-receiver synchronization may be attained in a number of ways, such as ranging from absolute time measurement and periodic transmission of pre-defined synchronizing sequence.

2. CHAOTIC MAPS

Discrete-time dynamical systems are a particular type of non-linear dynamical systems generally described as an iterative map $f : \Re^n \to \Re^n$ by the state equation

$$x_{k+1} = f(x_k),\ k = 0, 1, 2, \ldots\ldots \quad (1)$$

where n is the dimensionality of the state-space

$x_k \in \Re^n$ is the state of the system at time k. x_{k+1} denotes the next state. Therefore, k denotes the discrete time. Repeated iteration of f gives rise to a sequence of points $\left\{x_k\right\}_0^\infty$ known as an orbit. Clearly, equation (1) is a difference equation.

Our target is to create the pseudorandom numbers with uniform distribution in the interval of (0,1). The pseudorandom numbers generated by computer must possess the following property (1) Homogeneity of distribution, (2) Statistical Independence; (3) Sufficient long period.

Different nonlinear equations can be used to generate chaotic maps. There are more than 56 chaotic maps listed in literature. Some of the most common types of mapping used in practice are logistic map, tent map, Bernoulli map, Lorenz attractor, quadratic map, horseshoe map etc. In this work, logistic map is used to generate PN sequence.

2.1 THE LOGISTIC MAP:

Pseudorandom number generators that utilize Logistic chaotic systems are extremely sensitive to its initial value and parameters. The key is how to select the initial value and parameters to make sure that the chaotic sequence generated by it has good randomness.

Logistic map is an autonomous 1-D prototypical example from the discrete dynamical system class, which is described by the state equation

$$x_{k+1} = \lambda x_k (1 - x_k) \text{ , k = 0,1, 2,....... (2)}$$

where $x_k \in (0,1)$ and $\lambda \in (0,4)$. λ is known as the *control parameter*. Logistic map has regions of chaos when $\lambda \in$ (3.5 to 4).

A nonlinear process experiences a qualitative change in its dynamics when the nature of its fixed points changes. When a change in a parameter results in a qualitative change in the dynamics of a nonlinear process, the process is said to have gone through a bifurcation. All chaotic maps possess this very interesting period-doubling route between the ordered and chaotic behavior.

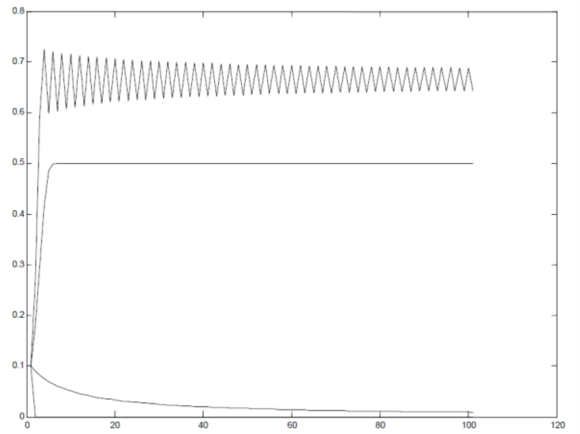

Fig (1) logistic map for λ =1,2,3 & 3.5.

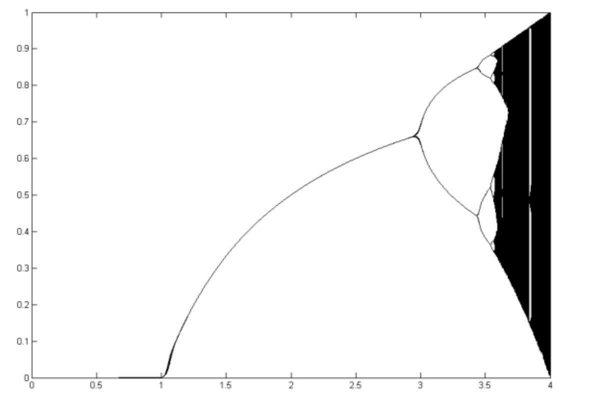

Fig (2) Bifurcation diagram for logistic map
Oscillation starts at λ =3.5

3. SYSTEM DESCRIPTION

PN sequences are widely used as spreading codes for direct sequences (DS) SS systems. Chaos-based design offers nonlinear PN sequences with approximate orthogonality that is especially valuable for asynchronous code-division multiple access (CDMA) systems. In this work PN sequence is generated using logistic map. To generate the PN sequence, the transformation used is given below.

$$z(x) = \begin{cases} 1 & x \geq \tau \\ 0 & x \prec \tau \end{cases}$$

where z is the PN sequence and τ is the threshold value. ' τ ' is chosen as arithmetic mean of a large number of consecutive values of x to maintain balance. The binary data is multiplied with the PN sequence and then modulated using BPSK modulation. For each user a different initial value is taken to generate different PN sequences. Signal is transmitted through the channel, which is introducing Additive White Gaussian Noise. At the receiver, signal is first demodulated using BPSK demodulator and then multiplied with identical PN sequence used at transmitter to get back the signal

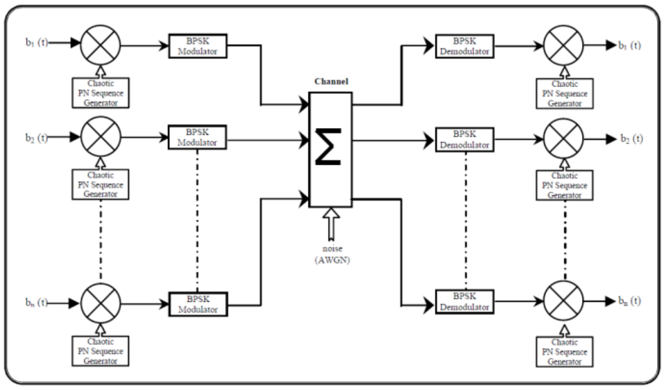

Fig (3) Block diagram of chaotic CDMA system

4. SIMULATION RESULTS

The graphs below show the data considered, logistic sequence, which is used to generate PN sequence, ACF of PN sequence. It is clear from ACF graph that ACF is almost zero except at one point. The signal is spreaded with PN sequence and PSK modulated. The transmitted signal is corrupted with AWGN. As PSD of the signal is very low effect of noise on the signal will be very less and we can get back the signal easily as shown in the graphs below.

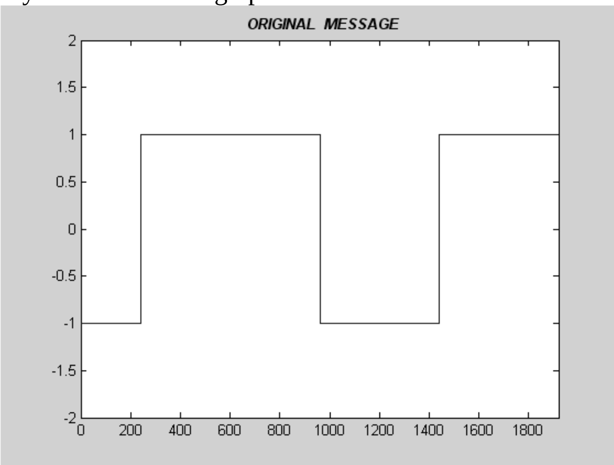

Fig (4) Original input message signal

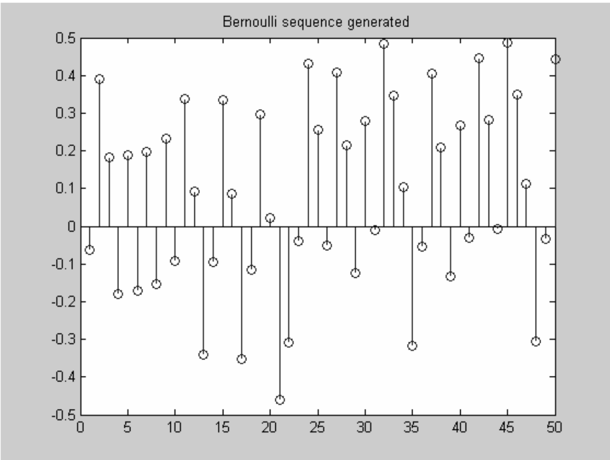

Fig (5) Chaotic PN sequence (Bernoulli's) signal

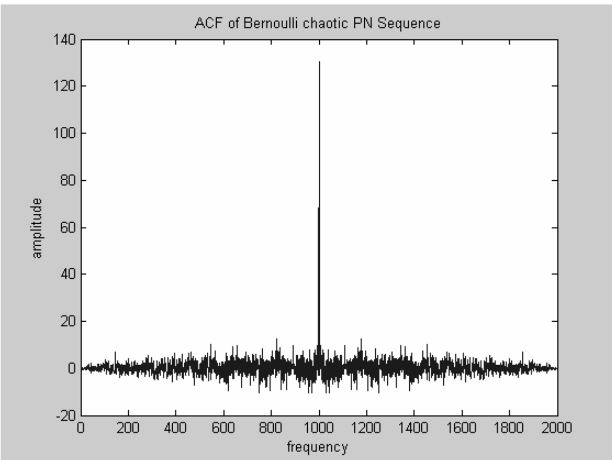

Fig (6) ACF of Bernoulli chaotic PN sequence

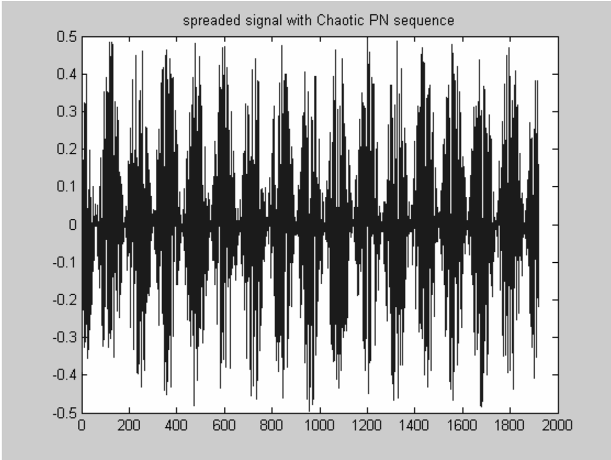

Fig (7) Generated Spread spectrum signal (Input signal multiplied with Chaotic PN sequence)

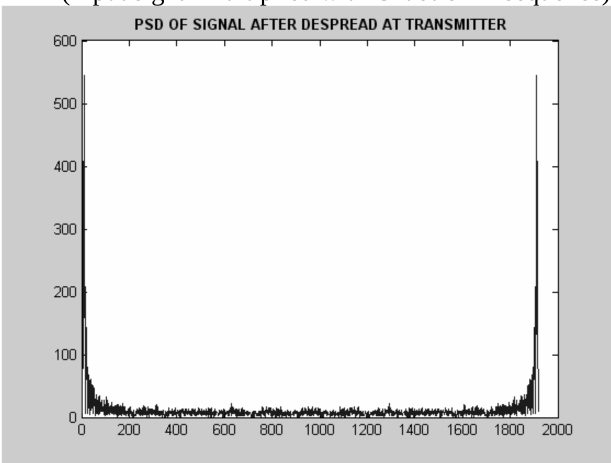

Fig (8) Power Spectral Density of signal at TX after de-spread

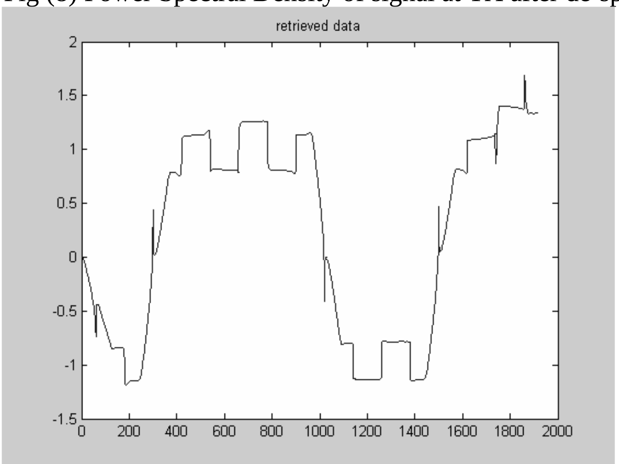

Fig (9) Signal received after demodulation and de-spread.

This signal is passed through the wave shaping networks like peak detector or zero crossing detector to retrieve the actual original signal

5. CONCLUSION

In this work, CDMA system with chaotic spreading is considered and simulation of the system is done in MATLAB. From the results it is clear that logistic map can be used to generate PN sequences and signal can be recovered reliably with this technique. Also randomness what we get with chaotic sequences are much better than linear shift register sequences.

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