Chaotic Spreading Sequence for Spread Spectrum Modulation in Stochastic Wireless Channels

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Abstract: ***In wireless communication system, spread spectrum techniques have been widely used because of the advantages like robustness against interference and noise, low probability of intercept, realization of Code Division Multiple Access (CDMA) and so on. One of the key aspects in such methods is the generation of the spreading sequence which continues to be challenging issue. This paper proposes a scheme for generating binary sequences from chaotic logistic map for use in Direct Sequence Spread Spectrum (DS SS) system in fading environment. The main advantages of such usage are increased security of the data transmission and ease of generation of a extended numbers of chaotic sequences. Generally to spread the bandwidth of the transmitting signals, pseudo-noise (PN) sequences, Gold sequences have been used extensively. We have generated a binary spreading sequences using logistic map. A comparison between Gold sequences and proposed sequences in faded environment have been derived. It is clearly seen that our sequences are comparable and even superior to Gold sequences in several key aspects such as bit error rate (BER), computational time and mutual information for three different spreading code lengths. Therefore, the proposed sequences can be effectively used as spreading sequences in high data rate modulation schemes.***

Keywords: Logistic map code, Gold code, BER**,** DS SS.

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1. Introduction

Spread spectrum is a system developed for military applications, to provide safe communications as it spreads the signal over a large frequency band. The idea behind spread spectrum is to use more bandwidth than the original message while maintaining the same signal power. A spread spectrum signal does not have a clearly distinguishable peak in the spectrum. This makes the signal more difficult to distinguish from noise and therefore more difficult to jam or intercept [1]. There are two predominant techniques to spread the spectrum, one is the frequency hopping (FH) technique, which makes the narrow band signal jump in random narrow bands within a larger bandwidth. Another one is the direct sequence (DS) technique which introduces rapid phase transition to the data to make it larger in bandwidth. Some of the spreading codes are pseudo noise (PN) code / Gold code etc. A PN code is one that has a spectrum similar to a random sequence of bits but is deterministically generated [2]. A Gold code, also known as gold sequence, is a type of binary sequence, used in telecommunication (CDMA) and satellite navigation (GPS). Gold codes have bounded small cross correlations within a set, which is useful when multiple devices are broadcasting in the same frequency range. A set of Gold code sequences consists of 2^n-1 sequences each one with a period of 2^n-1 [2]. But PN code and Gold code are limited to sequence length. Again flexibility is also poor because for same sequence length we cannot generate multiple numbers of sequences. Therefore, an efficient spreading sequence is generated using chaotic logistic map in faded environment and a comparison between generated sequence with Gold sequence is presented with the help of bit error rate, computational time and mutual information. This paper proposes a scheme for generating binary sequences from logistic map for use in Direct Sequence Spread Spectrum (DS SS) system in fading environment. The main advantages of such usage are increased security of the data transmission and ease of generation of a extended numbers of chaotic sequences. Generally to spread the bandwidth of the transmitting signals, pseudo-noise (PN) sequences, Gold sequences have been used extensively. We have generated a binary spreading sequences using logistic map. A comparison between Gold sequences and proposed sequences in faded environment have been derived. It is clearly seen that our sequences are comparable and even superior to Gold sequences in several key aspects such as bit error rate (BER), computational time and mutual information for three different spreading code lengths. Therefore, the proposed sequences can be effectively used as spreading sequences in high data rate modulation schemes.

The paper is organized as follows: Section 1 provides an introduction. Section 2 describes mathematical analysis of

Logistic map and related works (an overview of the existing binary sequences using logistic map). Section 3 states about the proposed method and simulation results. Finally, conclusion and discussions are summarized in section 4.

2. Mathematical Analysis of Logistic Map and Related Works

2.1 Mathematical Analysis of Logistic Map

The logistic map is nothing but a polynomial mapping of degree 2, it gives the idea of how complex, chaotic behaviour can arise from very simple non-linear dynamical equations. Chaos happens with small differences in the initial state of the system can lead to very big differences in its final state. A small error initially could then lead to a big one in the latter. Prediction becomes impossible, and the system appears to behave randomly [3]. Mathematically, the logistic map is written as

$$x_{n+1=} r * x_n(1 - x_n) \quad (1)$$

where x_n denoted a number between zero and one, population (at year 0). Also, *r* is a positive number, and represents a combined rate for reproduction and starvation, r has the range between zero to four and the logistic map behaviour is totally dependent on r.

2.2 Related Works

The study relating to logistic map sequence generating method is prepared after carefully going through other relevant works, a jist of which are presented serially according to the year of their publication.

In [4], a typical chaotic system, logistic map, under linear transformation is studied. A model, LT-Logistic-Map, is proposed, and its statistical property is derived. The result shows that the statistical properties of the model are identical with white noise. LT-Logistic-Map sequences are used to the spreading spectrum address codes. Using this model, large number of chaotic sequences can be generated and the privacy of transmission in spreading spectrum communication system can be enhanced. In [3], another work is related to an investigation on use of new type of sequences called chaotic sequences for DS-CDMA system. These sequences are generated by chaotic maps. The performance of chaotic sequences in DS-CDMA communication systems using various receiver techniques are investigate in this Thesis. In [5], Comparison between conventional spread spectrum techniques and spread spectrum using chaotic signals in terms of power spectral density, autocorrelation sequence are done. In [6], a pseudo random bit generator is proposed which is based on two chaotic logistic maps. Comparing the outputs of both the chaotic logistic maps the new pseudo random bit sequence is generated. A statistical testing on generated bit sequences is done by the most stringent tests of randomness: the NIST suite tests, to detect the specific characteristics expected of truly random sequences. In [7], the use of fractional order logistic equation to generate radar sequences is presented. A binary code is generated using fractional order logistic map equation. From the result it is shown that sequences with good merit factor can be generated by varying fractional order. In [8], chaotic spreading sequences is generated with arbitrary period, which optimizes the binary quantization thresholds with different fractal parameters and initial values. The result of this paper shows that the method can generate a huge amount of high performance chaotic spreading sequences with arbitrary period. The article supports the application of the chaotic sequences in spread spectrum communications. In [9], schemes for generating binary sequences from logistic maps are proposed. Using same length but different initial conditions of logistic map several binary sequences are generated. A comparison between maximum length sequences, Gold sequences and proposed sequences has been established, and demonstrate that the generated sequences are comparable and even better than maximum length sequences, Gold sequences. In [10], chaotic logistic map sequences and Tent map sequences are used to generate one new sequence. The output bits of two chaotic maps are EXORed to produce a random sequence of 1 000 000 bits. These designs are implemented on Field Programmable Gate Array, and the results are reported. After going through the existing works it can be noted that various methods are used to generate binary spreading sequences using logistic map and apply it as spreading sequences in various system using AWGN channel only but not in faded channel.

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3 Proposed Approach

First we consider the generation binary spreading sequences using logistic map and apply it to data transmission in faded environment. We also repeat the above with Gold sequences and compare it. The comparison factors are BER, computational time and mutual information. We describe the complete work in the following sections.

3.1 Binary Spreading Sequence Generation Using Logistic Map

Binary sequence is generated using logistic map in MATLAB simulink as shown in the Figure. 1

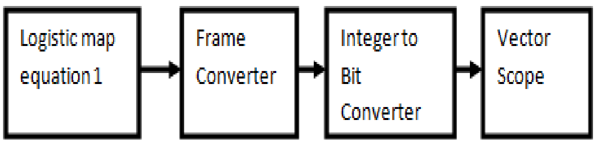

Figure 1. Block diagram of binary sequence generator

The Figures 2, 3 and 4 show that three different binary sequences for three different values of *r*.

- For r=3.61

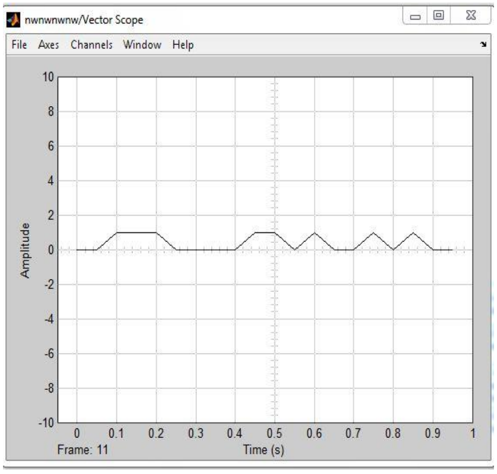

Figure 2. Sequences generated by logistic map for r=3.61

- For r=3.65

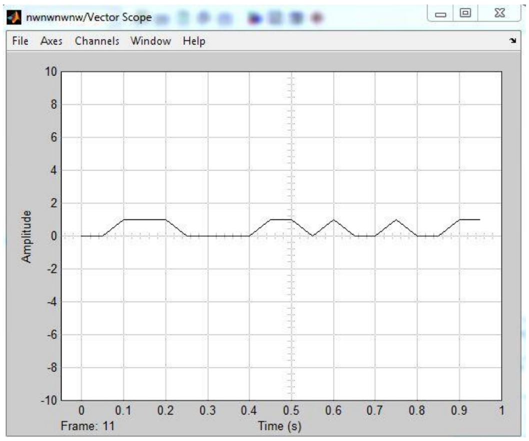

Figure 3. Sequences generated by logistic map for r=3.65

- For r=3.69

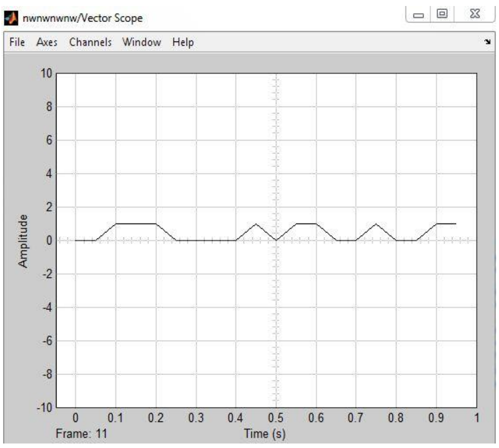

Figure 4. Sequences generated by logistic map for r=3.69

3.2 Overall System Model

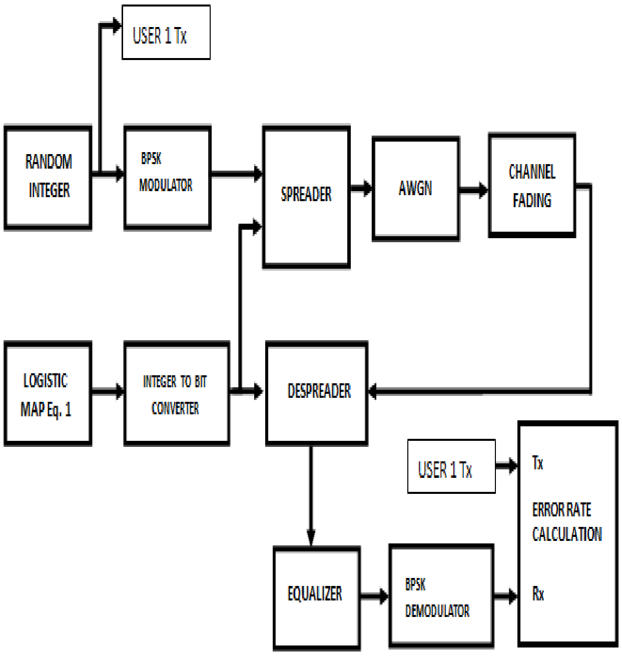

Figure 5. System Model

The overall system model is shown in the Figure 5. The entire system is implemented in MATLAB simulink. This is based a DS SS system using logistic map code as spreading sequence for three different spreading code lengths (N = 63, 127, 511). In this model, BPSK modulation and Rician fading channel is used. After implementing the system model in MATLAB simulink, BER is calculated for N = 63, 127, 511. Then BER is calculated for the same system using Gold code for N =63, 127, 511. Not only that but also the computational time of the system using both logistic map and Gold codes are calculated.

3.3 Simulated Results and Discussions

3.3.1 BER: The Figure 6 shows that as the number of logistic map sequence increases the BER curves are closer to the theoretical one i.e. for spreading code length 511 the BER curve is more close than spreading code length 127 and 63. Again for Gold code not such difference is seen for different code lengths. The most noticeable aspect is that the BER curves of logistic map code are better than corresponding Gold code in considered case as shown in the Table I. Thus the logistic map code can be used as efficient binary spreading sequence.

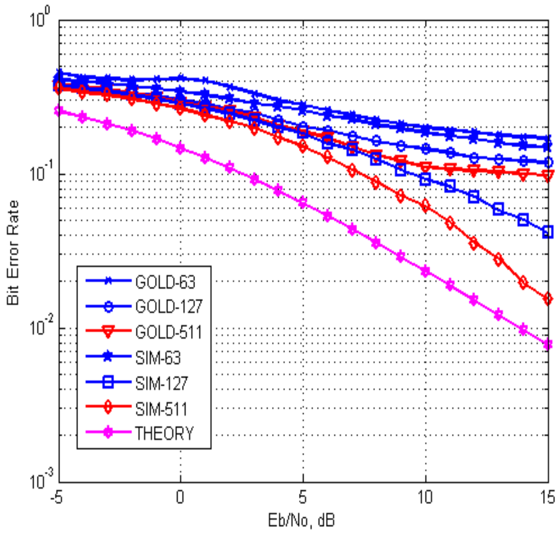

Figure 6. BER in fading channel for Gold and Logistic map code in DS SS systems for spreading code length 63, 127, 511.

I. TABLE I: PERCENTAGE IMPROVEMENT IN BER WITH LOGISTIC MAP CODE

Spreading code length	*Minimum*	*Maximum*
63	1.34%	12%
127	2.3%	65%
511	5%	84%

II. TABLE II: COMPUTATIONAL TIME (CT) OF THE SYSTEM MODEL USING LOGISTIC MAP CODE AND GOLD CODE IN SECONDS

Spreading code length	*CT using logistic map code*	*CT using Gold code*
63	1.20%	1.92%
127	1.66%	2.53%
511	2.00%	2.59%

3.3.2 Computational Time: Computational time of the system model using logistic map code and Gold code is calculated for three different spreading code lengths. Table II shows that the system model using logistic map requires less computational time than system using Gold code as spreading code. But for more spreading code length the system requires more computational time. Hence, the lower BER can be achieved at the cost of computational time.

3.3.3 Mutual Information: The Figure 7 shows that as the spreading code length increases the mutual information is also increases for both Gold code and logistic map code. But for same spreading code length the logistic map code gives better result in comparison to Gold code in case of mutual information, which is clearly visible from the Figure 7.

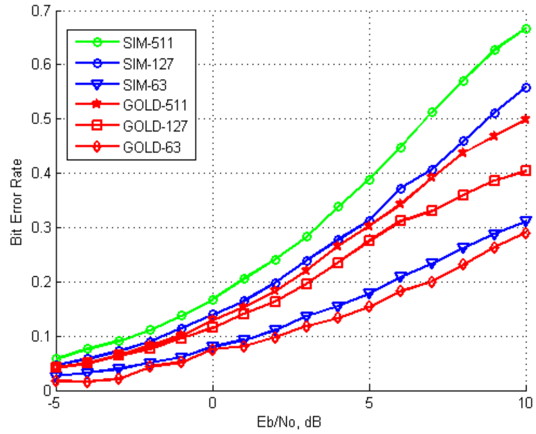

Figure 7. Mutual information for Gold and Logistic map code in DS SS systems for spreading code length 63, 127, 511.

4 Conclusion and Future Scope

It has been observed that logistic map sequences have several advantages over Gold code. First, flexibility is more because the period of logistic map sequence is no longer limited to 2^n-1 like Gold code and for same spreading code length we can generate extended number of spreading sequences, which is not possible in case of Gold code. Second, the BER performance is more close to the theoretical value than Gold code in faded environment. Third, computational time is lesser than Gold code as observed in implementations. Fourth, mutual information is also better than Gold code. Hence, logistic map sequence can be used as efficient spreading code where hardware implementation is challenging.

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