Dynamic Logistic Map Based Spread Spectrum Modulation in Wireless Channels

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ABSTRACT

Generation of an efficient spreading code in Spread Spectrum Modulation (SSM) is always challenging due to considerations like optimum sequence length, physical layout of registers and power requirements. In this article, a design of a dynamic chaotic spreading sequence for application in a Direct Sequence Spread Spectrum (DS SS) based system with the considerations of wireless channels (Rayleigh and Rician) are presented. Generation of dynamic chaotic sequence for application in linear and nonlinear channels is done and a comparison with static chaotic sequence is presented. Evaluation of performance is done in terms of bit error rate (BER), computational time, mutual information and signal power for faded channel taking into considerations of different modulation schemes, which finally dictates the efficiency of the generated code. The performance of the generated dynamic logistic map-based sequence is compared to that obtained from Gold code under equivalent conditions.

KEYWORDS

DS SS, Dynamic Chaotic Sequence, Dynamic Logistic Map Code, Logistic Map Code, Spread Spectrum Modulation (SSM)

1. INTRODUCTION

An overall exponential growth can be seen in wireless communication systems over the last decades. Among many techniques developed for communication through the wireless medium, spread spectrum modulation (SSM) finds an important place. SSM is a system originally developed for military usages, to provide safe communications as it spreads the signal to a larger frequency band. It later became a primary component of code division multiple access (CDMA) system. The idea behind SSM is to use more bandwidth than the original message while maintaining the same signal power. Spread spectrum signals do not have clearly distinguishable peak in the spectrum. This results in making the signal more difficult to distinguish from noise and therefore it becomes hard to intercept or jam. There are two predominant techniques to spread the signal spectrum, one is frequency hopping (FH) technique, which makes the narrow-band signal jump within a larger bandwidth in random narrow bands. Another one is the direct sequence (DS) technique which gives rapid phase change to the data to make it larger in bandwidth (Rappaport, 1997). Gold code, pseudo noise (PN) sequence etc are the spreading codes which play a prominent role in SSM techniques. A PN code is one that has a spectrum similar to a random sequence of bits but is determinately generated (Tse & Viswanath 2005). A Gold code is a type of binary sequence, used in telecommunication primarily in CDMA and satellite navigation system like GPS (Tse & Viswanath 2005). Gold codes have bounded small cross-correlations, which is necessary when multiple devices are transmitting in the same frequency range. Generally, the set of Gold code sequences comprising of $2^n-1$ sequences each one with a period

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of $2^n$-1. But PN and Gold codes are limited to fixed sequence lengths with a system configuration. Also, flexibility is also poor because for same sequence length we cannot generate multiple numbers of sequences. Traditionally, to generate PN sequence, linear feedback shift register (LFSR) and certain sum-store blocks are used. Since Gold code is generated by doing exclusive-OR of two PN sequences, therefore, here also LFSR is required. Therefore, to generate PN or Gold code, a definite physical structure is required which consume significant power. The fixed length of LFSRs increases further constraints. The PN sequence length become confined within the LFSR size. In fading situations as observed in mobile conditions where there are variations in the propagation medium, a varying length PN sequence shall be more suitable than a fixed length one primarily to use the advantages of SSM to counter detrimental effects present in wireless channels. Continuous researches are going on to design devices that save power and demonstrate dynamic behaviour with respect to channel conditions required. Hence, in this paper an efficient dynamic spreading sequence generation method is presented using chaotic logistic map. The sequence thus generated is used as part of a SSM system designed for application method in nonlinear faded environment. Logistic map sequences have several advantages over other spreading sequence like Gold code, PN code etc. First, flexibility is more because the period of logistic map sequence is no longer limited to $2^n$-1 like Gold code. Also, for same spreading code length we can generate extended number of spreading sequences, which is not possible in case of Gold code and PN code. The generated dynamic and recursive logistic map sequences have moderate correlation property. It gives the better BER and mutual information performance than static logistic map sequence. Not only that optimization of the dynamic chaotic code can also be done using various optimization algorithms (Rajpurojit, Sharma, Abraham, & Vaishali, 2017; Sharma & Pant, 2017; Sharma, 2017; Sharma & Pant, 2017; Sharma & Milli, 2017). It is observed in implementation that for nonlinear approaches also it gives better results (BER and mutual information) than static chaotic sequence though signal power and computational time requirement are marginally more. The results are compared to that obtained using Gold code. The dynamic approach of chaotic sequence generation provides fall 40% at 10 dB in BER values compared to static approach. Similarly, the gain in mutual information is 30% at 10 dB with the dynamic method. But there is a marginal rise in computational time by maximum 38% and power also increases by 10%. Performance gains are obtain compared to Gold code which is clear from the simulation and shows better results. Therefore, the proposed sequences can be effectively used as spreading sequences in high data rate modulation schemes.

2. MATHEMATICAL ANALYSIS OF LOGISTIC MAP

A logistic map is a polynomial mapping having a degree of 2. It gives the idea that a complex chaotic behaviour can arise from simple non-linear dynamical equations. Chaos happens when a small difference initially in the system leads to very big difference in the final state of the system. A small error initially could then lead to a big one in the final state. Prediction thus becomes impossible, and then the system behaves randomly (Xueyi, Lu, Kejun, & Dianpu, 2000; Patidar, Sud, & Pareek, 2009).

Mathematically, the logistic map is written as,

$$x_{n+1} = r \cdot x_n \left(1 - x_n\right)$$

(1)

where, $x_n$ denotes a number between 0 and 1, population (at year 0). Also, $r$ is a positive number, and it represents a combined rate for reproduction and starvation. Also, $r$ has the range between zero to four and the logistic map behaviour is totally dependent on $r$, which is clearly seen in the Table 1.
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