Performance Analysis of Spreading Sequences for Wireless DS-CDMA System

J.RAVINDRABABU[1], DASI SWATHI[1], J.V. RAVI TEJA[2], J. V. RAVI CHANDRA[3]
T. ESTHER RANI[1], V. USHASWINI[1], S. SATISH[1], N. PRANAVI SRI[1]
[1]E.C.E Department,
P. V. P. Siddhartha Institute of Technology,
Vijayawada,
INDIA

[2]Software Engineer-1,
FactSet Systems Pvt.Ltd,
Hyderabad,
INDIA

[3]C.S.E Department,
V. R. Siddhartha Engineering College,
Vijayawada,
Andhra Pradesh,
INDIA

Abstract: - Spreading sequences are essential to wireless communication systems. It is employed in direct sequence code division multiple access systems (DS-CDMA) to serve increased user count with different spreading sequences like orthogonal and non-orthogonal spreading sequences. Here our objective is to finda proposed generation of "New spreading sequence" by using this sequence, reducing the result of multiple access interference (MAI) by maintaining minimum correlation in DS-CDMA system and also the bit error rate (BER) performance of proposed sequence by using AWGN channel is evaluated. Additionally, the suggested sequence is contrasted with already-existing sequences like the Kasami even sequences, PN sequences, and gold sequences. The suggested sequence is the best option because it performs better than the current sequences.

Key-Words: - DS-CDMA, PN Sequence, Gold Sequence, Kasami Sequence, Multiuser Detection, MAI.

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1 Introduction

To effectively make use of the resources available bandwidth, Spread-Spectrum Communication Systems use spreading sequences where each user is identified by a unique spreading sequence possessing apt (or desirable) correlation properties as these play an important role. In addition, code sequence length limits the system capacity. Hence, the selection of spreading sequences is a significant step in spread-spectrum systems. Code sets can be classified as binary and non-binary code sequences. The eal numbers, ±1 are only the elements of the binary code sequence sets whereas the non-binary code sequence sets have elements more than two that are not real numbers like quadric-phase and poly phase-sequences. In the present era of binary logic circuits, spread spectrum systems utilize binary code sequences. Binary code sequences possess better auto-correlation and cross-correlation values when compared to those of non-binary code sequences. Spread-spectrum system performance depends on the correlation properties of the spreading sequence selected, [1]. To have a better BER performance the spreading sequences used should possess high auto-correlation values. At the same time, the reduction in MAI is possible if the spreading codes possess minimum cross-correlation values amid a pair of spreading sequences used, [2], [3], [4]. Taking the above salient aspects of spreading sequences into account, a critical review of existing ML sequences, Gold sequences, and Kasami sequences are explored.

2 Literature Review

A novel approach to spread spectrum modulation and the CDMA concept is presented in [5]. It offers various design considerations, one of which is how the spreading signal is formed. A novel approach to coding—which is sometimes essential and helpful for controlling interference in spread spectrum communication systems—has been presented in [6]. In [7], have been proposed a CDMA system whose performance is based upon characteristics of user-specific spreading sequences. This paper aims to evaluate the correlation properties of PN, Gold, and Kasami sequences and highlight the various factors that affect choosing one of these spreading sequences.

Within [8], Inter-symbol interference (ISI) is a phenomenon that consistently arises in multi-path communication channels. Many methods are used to reduce the effect of ISI. This paper examines the spreading codes' autocorrelation property, which minimizes the impact of the ISI. In this case, the spreading codes via the lowest autocorrelation property are obtained. Multiple access interference (MAI) has been proposed in [9], to occur in Code Division Multiple Access (CDMA) platforms when the spreading sequences are non-orthogonal and the communication channel maintains a higher number of users at once. This paper examines the spreading sequences' cross-correlation property, and as a result, we offer a technique for locating spreading sequences with the least amount of cross-correlation. By using these sequences, the CDMA system's resultant MAI is decreased, increasing system capacity. By contrasting the cross-correlation property of the suggested spreading sequence with those of existing spreading sequences, a significant advancement is revealed. To reduce the amount of autocorrelation and cross association among spreading codes other than zero-shift, bare minimum correlation spreading sequences are provided in [10]. The creation of orthogonal sets of sequences that can preserve the characteristics of whole complementary sequences is suggested in [11]. The suggested techniques apply to any sequence possessing an optimal two-level cross-correlation. The availability of many sequences is one of the CDMA code characteristics for next-generation wireless CDMA systems. For CDMA-based wireless systems, the qualities of Gold, Kasami, and pseudo-noise sequences were assessed. Spreading sequences are chosen to be orthogonal to minimise Multiple Access Interference (MAI) in synchronous systems such as the downlink mobile radio communication channel. In [12], the author tells Walsh codes are error-correcting orthogonal codes and PN sequences are generated sequences with random noises used in error-free communication. PN Sequence is a statistically random sequence with low correlation property. In [13], the cross correlation parameters and their properties of such sequences are as important as autocorrelation properties, and the system performance depends upon the aperiodic correlation in addition to the periodic correlation. The periodic and aperiodic cross-correlation functions for pairs in order of m-sequences and for groups of related (but not maximal-length) binary shift register sequences are surveyed in this paper along with several new results. These series are frequently employed in cryptography and communication.

In [14], a novel approach towards orthogonal spreading codes is considered. Here in this paper, we describe the performances of spreading codes when a large number of users access the communication system at a time. The performance analysis based upon the generation of a large number of spreading codes, minimum correlation properties of spreading codes, and bit error rate performances in comparison to other existing spreading codes.

3 Generation of Binary Sequences

Feedback shift registers are employed to generate binary code sequences and Galois field algebra is used in their analysis, [2], [3], [4]. A simplified feedback shift register is shown in Figure 1. Let the preliminary conditions of the s-stage shift-registers are (d_{s-1}, d_{s-2}, . . ., d_1, d_0) and the feed-back function g(a_0, a_1, . . . , a_{s-1}) is a binary function.

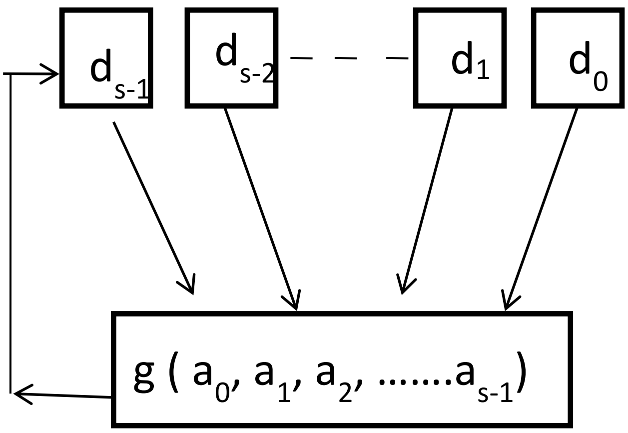

Fig. 1: simplified feedback shift register

At every clock pulse, the contents of every register are shifted to the adjacent register either on shift-right or on shift-left. An m-stage shift register used to generate binary sequences has a maximum period of 2^m-1. The sequences generated with a maximum period are known as Maximal Length (ML)-sequence or m-sequence.

3.1 ML-sequences

ML sequences are commonly used in spread spectrum systems, [15]. To generate Pseudo Random Noise sequences which are m-sequences, a Linear-Feedback Shift-Register (LFSR) is used and is shown in Figure 2.

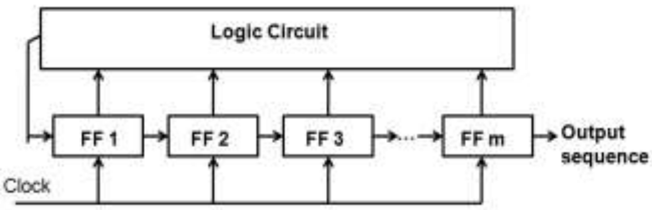

Fig. 2: Linear Feedback Shift Register

The binary Pseudo Random Noise sequence generated by the above LFSR is determined by three factors: i) the number of shift registers, m ii) the initial states of flip-flops, and iii) the feedback logic. Since the feedback logic uses only XOR gates, it precludes the zero initial states of the Flip-flips. Hence the maximum period of the sequences generated cannot be more than 2^m-1. When a binary sequence reaches this maximum period, then it is termed an ML sequence, [16], [17].

In an LFSR consisting of m number of FFs, the number of ML-sequences generated is given by:

$$N_p(m)= \frac{2^m-1}{m}\prod_{i=1}^{s}\frac{p_i-1}{p_i}$$

where,
$N_p(m)$ = No.of ML sequences
m= No.of shift registers in LFSR
p_i = prime-decomposition of 2^m-1

3.2 Properties of ML-sequences

The important properties of ML-sequences are [4]:

- Balance property: In each ML sequence, the number of 1's is greater than the number of zeros at least by one.
- Run property: A run is defined as the transition from one symbol (0 or 1) to the other in an m-sequence. The number of runs in a sequence is known as the run length
- Correlation property: Auto-correlation function $R(\tau)$ of ML sequences is periodic, and two valued and has a period of $T= NT_c$. where T_c is the chip duration. This property is known as the correlation property.

3.3 Decimation of ML-sequences

Spreading sequences or signature sequences with high peaked autocorrelation and minimal cross-correlation are of great utility in spread-spectrum systems, [1]. A variety of sequences can be generated by decimating a single sequence. For example, consider a sequence $\upsilon = \upsilon_0, \upsilon_1, \upsilon_2, \upsilon_3, \ldots$, then construct a sequence x by taking every v^{th} bit starting with $\upsilon_1$element of sequence υ and represent it by $\upsilon(v)$. Now, $\upsilon(v)$ is known as the decimation of υ by v. where v is a +ve integer, i.e., is: $x = \upsilon(v)$. Hence, $x = \upsilon_0, \upsilon_v, \upsilon_{2v}, \upsilon_{3v}, \ldots$If υ has a period N, then x has a period N_x given by
N_x= N / gcd (N,v)

where, gcd (N,v) represents the greatest-common-divisor of N and v. Example: the gcd (31, 5) = 1 since 31 and 5 are divisible by 1 only. The gcd (45, 81) = 9 since81= 3 x 3 x 9 = 9 x 9and 45 = 3 x 3 x 5 = 9 x 5. Therefore, 9 is the greatest common divisor.

3.4 Preferred Pairs of ML-sequences

The auto-correlation of any ML-sequence is a two-valued function whereas the cross-correlation between any two ML-sequences generated by primitive polynomials can be a many-valued function greater than two. It is possible to select a pair of ML-sequences with cross-correlation function having three values defined by [−1, −p(m), p(m)−2],

where

$$p(m)= 1+2^{(m+1)/2} \quad \text{for m is odd}$$

$$p(m)= 1+2^{(m+2)/2} \quad \text{for m is even}$$

A connected set is defined as the group of selected pairs of ML-sequences. The connected set size plays an important role in multiuser spread spectrum communication applications, [17].

3.5 Gold Sequences

The ML sequences have good auto-correlation properties. However their cross-correlation properties do not follow any specific guidelines and have excessive cross-correlation values in general. Further, for a given number of shift registers in a Linear Feedback Shift Register, the generation of a wide variety of m-sequences is restricted. The sequences proposed by Gold in 1967 - 1968 mitigate the above-said problems and are known as Gold sequences, [1], [2].

Gold sequences are derived by combining the two maximal -sequences from Linear Feedback Shift Registers, [1], [2]. These sequences offer more sets of sequences with suitable cross-correlation properties compared with those of the ML sequences. Let [υ, x] be any preferred pair of ML-sequences with period $N=2^m-1$, then the sequence obtained $\upsilon \oplus x$ is called a Gold sequence. If G[υ, x] denotes a set of Gold sequences given by:

$$\upsilon,\ x,\ \upsilon \oplus x,\ \upsilon \oplus Tx,\ \upsilon \oplus T^2x,\ \ldots.,\ \upsilon \oplus T^{N-1}x$$

whereT^Mx represents the sequence obtained by decimating the sequence x by M and concatenating it M times, where M = 0, 1, 2, 3, 4, . . , N−1. This set G[υ, x] contains N+2 sequences. The generation of Gold sequences is shown in Figure 3.

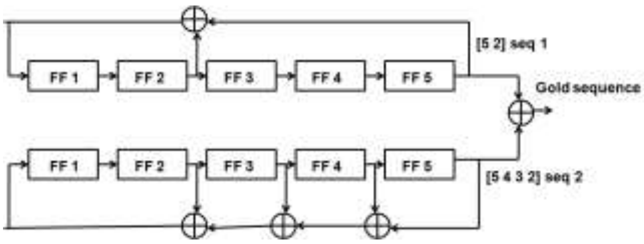

Fig. 3: Gold sequence generator

3.6 Kasami Sequences

These sequences are divided into two different sets called Kasami small-set sequences and Kasami large-set sequences are generated from ML sequences with even m values, [17].

3.6.1 Kasami small-set Sequences

These Sequences are generated using an ML-sequence, u of length N. Let $N = 2^m - 1$ where m indicates the even no.of shift registers in the LFSR. Now the ML-sequence, u is decimated by $(2^{m/2}+ 1)$ to get a sequence, W of length $\{ 2^m-1\}/\{2^{m/2}+ 1\} = 2^{m/2}- 1$. Next the sequence, W is concatenated by $(2^{m/2}+ 1)$ repetitions to form a sequence v of length N [17]. Then set of sequences is given by $\{u, v, u \oplus T^i\ \{v\}\ \}$, known as a small set Kasami sequences, where $T^i\{v\}$ indicates the left or right shift of the sequence v by i bits, *i* varying from 0 to $2^{m/2}- 1$.

For example m=4, the length of the PN sequence is 15, and taking every 5^{th} bit and repeating it to find the sequence v. Figure 4 shows the small set kasami sequence generator.

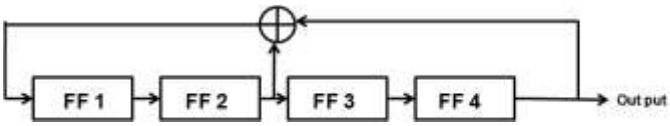

Fig. 4: Generation of small set kasami sequence

u =1 1 1 1 0 0 0 1 1 0 1 1 0 0 0
W =1 0 1
v =1 0 1 1 0 1 1 0 1 1 0 1 1 0 1
u xor v = 0 1 0 0 0 1 1 1 0 0 1
0 1 0 1

3.6.2 Large-Set Kasami Sequence

To generate large-set Kasami sequences the combination of small-set Kasami sequence and Gold-sequence is used. The generation of sequences can be found in the literature and not discussed here as it is not being used.

3.7 Kasami Odd Sequences

It is now employed to generate the small set Kasami sequence using LFSR containing m shift registers, where m is an odd number and is called a Kasami odd sequence. Kasami odd sequence sets possess very low cross-correlation values which are important for DS-CDMA systems. An *ML* sequence of length of $N = 2^{m,}$ with odd m is used to generate Kasami odd Sequences. Let thus generated Kasami odd Sequence, u is decimated by $2^{(m+1))2}$ to get a sequence, W of length$\{ 2^m\}/\{2^{(m+1)/2}\} = 2^{(m-1)/2}$. Next the sequence, W is concatenated by $2^{(m+1)/2}$ repetitions to form a sequence v of length N.

The period of v can be obtained by

$$\text{period} = \frac{N}{GCD[N, (2^{(m+1)/2})]}$$

$$= \frac{2^m}{GCD[2^m, (2^{(m+1)/2})]} \quad (\text{ since } N = 2^m)$$

$$= \frac{(2^{(m+1)/2})(2^{(m-1)/2})}{GCD[(2^{(m+1)/2})(2^{(m-1)/2}), (2^{(m+1)/2})]}$$

$$= \frac{(2^{(m+1)/2})(2^{(m-1)/2})}{(2^{(m+1)/2})]}$$

$$= (2^{(m-1)/2})$$

The small set Kasami odd sequence is given by $\{u, v, u \oplus T^i\ \{v\}\ \}$

where $T^i\{v\}$ indicates the left or right shift of the sequence v by i bits, *i* varying from 0 to $2^{(m-1)/2}$.

For example, with m=5, the length of the sequence is $N= 2^5 = 32$. Taking 32 bit length ML-sequence u, decimating it by 8, and concatenate it four times the sequence W is obtained. The member (u xor v) of the small set Kasami odd sequence can be obtained by the binary addition of v with the ML-sequence u generated as shown in Figure 5.

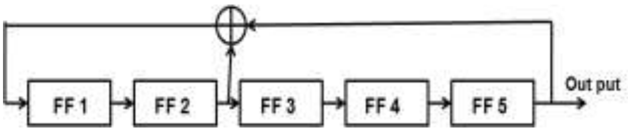

Fig. 5: Generation of Kasami odd Sequence

Therefore,
u = 1 1 1 1 1 0 0 1 1 0 1 0 0 1 0 0 0 0 1 0 1 0 1 1 0 1 1 0 0 0 1
W(8) = 1 1 0 1
v = 1 1 0 1 1 1 0 1 1 1 0 1 1 1 0 1 1 1 0 1 1 1 0 1 1 1 0 1 1 1 0 1
u xor v = 0 0 1 0 0 1 0 0 0 1 1 1 1 0 0 1 1 1 1 1 0 1 1 0 0 1 1 0 1 1 0 0

4 Simulation Results

Ultimately, since the suggested sequence has the lowest cross-correlation value out of all of them, it can manage the effects of MAI better than the other sequences. As seen in Figure 6, Figure 7 and Figure 8, the autocorrelation performance of the suggested Kasami odd sequence has been contrasted with other known spreading codes, such as the Gold sequence and small set Kasami even sequence. An impulsive peak, or maximum value, is seen at zero time shift in the average amount of autocorrelation vs. number of shifts, while side lobs show the lowest value relative to the others, or zero. Therefore, based on Figure 8, the suggested sequence's autocorrelation performs better than other spreading codes currently in use. For a sequence of length 31, the average cross-correlation magnitudes of the proposed sequence and other existing sequences are displayed in Figure 9, Figure 10 and Figure 11. It is observed that the sequences offer quite high magnitude of cross-correlation as compared to the proposed Kasami Sequences.

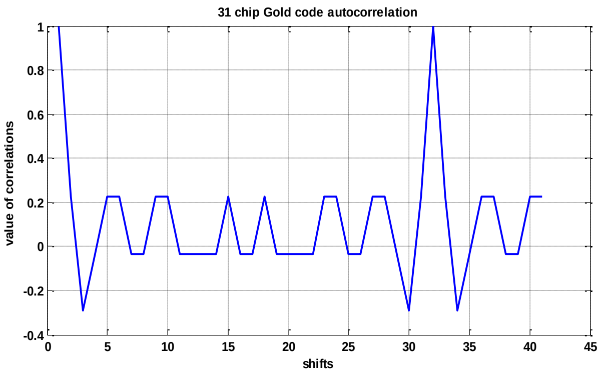

Fig. 6: Auto correlation of Gold Sequences m=5

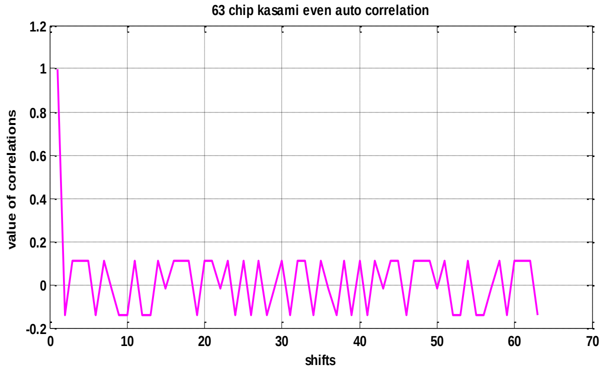

Fig. 7: Auto correlation of Kasami Sequences m=6

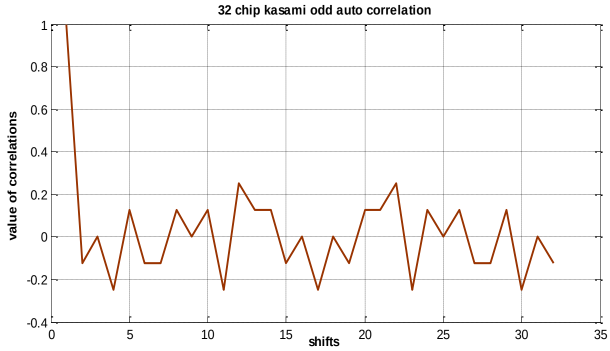

Fig. 8: Autocorrelation of proposed Kasami Sequences m=5

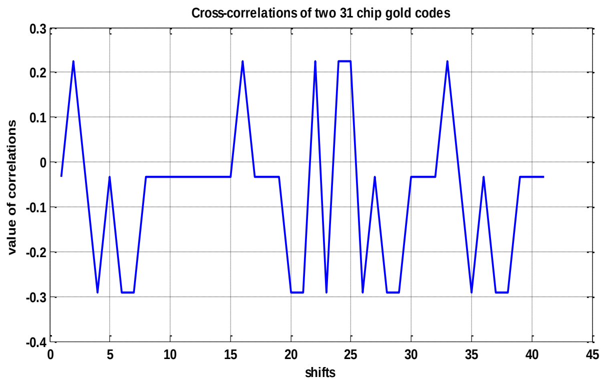

Fig. 9: Cross correlation of Gold Sequences m=5

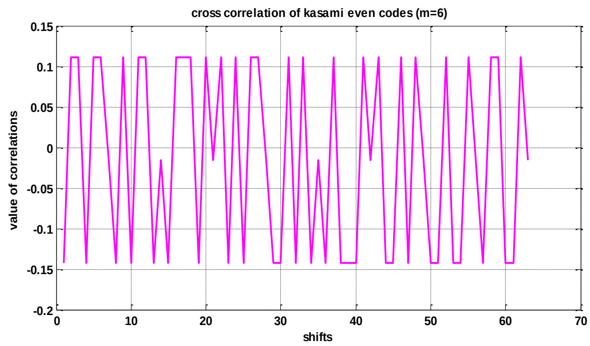

Fig. 10: Cross-correlation of Kasami Sequences m=6

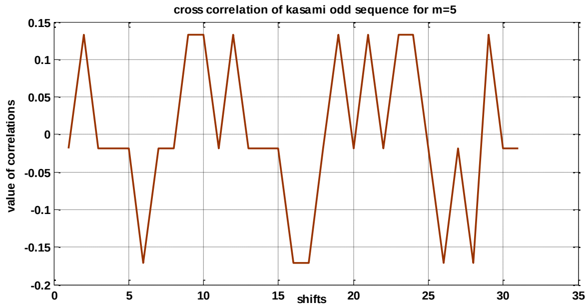

Fig. 11: Cross-correlation of proposed Kasami Sequences m=5

Ultimately, since the suggested sequence has the lowest cross-correlation value out of all of them, it can manage the effects of MAI better than the other sequences.

5 Conclusions

In a CDMA communication system availability of more codes, the minimum magnitude of cross correlation, and impulsive peak autocorrelation play a major role. To meet all these criteria, a Kasami-constructed set of sequences has been proposed in this paper. From the above discussion it is clear that the proposed Kasami even Constructed Set of Sequences gives low cross correlation value, impulsive autocorrelation without sacrificing the sequences. Hence it can be concluded that the proposed Kasami even Constructed Set of Sequences outperforms other existing sequences and provides an optimum solution for future CDMA communication systems. The present work is based on generating spreading sequences for CDMA systems satisfying the properties of autocorrelation and cross-correlation maintaining orthogonality between the sequences.

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Contribution of Individual Authors to the Creation of a Scientific Article (Ghostwriting Policy)

- J Ravindra Babu, D. Swathi Identified the problem statement and done the mathematical Analysis.
- J V Ravi Teja,J V Ravi Chandra have implemented the Algorithms in section 3.
- T. Esther rani, V.Ushaswini S.Satish, N.Pranavi carried out the simulation in section 4 using MATLAB

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Conflict of Interest

The authors have no conflicts of interest to declare.