IMPLEMENTATION OF MAXIMAL LENGTH SEQUENCES FOR IMT MULTI-CARRIER

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ABSTRACT: This paper presents the implementation of Pseudorandom Binary Sequence (PRBS) i.e. Maximum Length Sequences (MLS) for International Mobile Telecommunications MULTI CARRIER (IMT-MC) i.e. CDMA2000 using MATLAB Simulink. The autocorrelation and cross correlation properties are studied and verified with simulation results and are found in close agreement. The MLS is mainly used as spreading code for 2G and 3G standard such as IS-95, CDMA2000 viz. EVDO, EVDV.

KEYWORDS: CDMA, EVDO, EVDV, IMT-MC, LFSR, MLS

I. INTRODUCTION

The CDMA system is a 3GPP2 standard born out of the International Telecommunication Union’s (ITU) International Mobile Telecommunications “IMT-2000” initiative, covering high speed, broadband, and Internet Protocol (IP) -based mobile systems. The concept of a "Partnership Project" was pioneered by the European Telecommunications Standards Institute (ETSI) early in 1998 with the proposal to create a Third Generation Partnership Project (3GPP) focusing on Global System for Mobile (GSM) technology whereas 3GPP2 is the standardization group for CDMA2000 , the set of 3G standards based on the earlier 2G CDMA technology. CDMA systems employ several types of codes, each with a specific characteristic, to allow multiple users to communicate simultaneously. The code uniquely identifies users so that they are able to transmit information while limiting interference to each other. CDMA systems use codes, such as maximal length sequences and Walsh codes, both in the forward and reverse links to have more users and to provide a higher Quality of Service (QoS). Maximum length Sequences (MLS) are used to multiplex and spread the data to be transmitted, depending on the different usage approach for each link direction i.e. forward and reverse. Mobile stations also use these sequences to identify Base Transceiver Stations (BTSs) within the network. [1]

They are known by Maximum length or N Sequence because they are the longest sequences that can be generated by a certain arrangement of shift registers or delay elements. MLS are also called pseudorandom binary sequence (PRBS) where the word ‘pseudo’ because
it is deterministic and after N elements it starts to repeat itself unlike real random sequences e.g. white noise and ‘random’ in a sense that the value of an element is independent of the values of any of the other elements of its set. The sequence is not truly random in that it is completely determined by a relatively small set of initial values, called the PRNG’s state, which includes a truly random seed. A random seed (or seed state, or just seed) is a number or a vector used to initialize a pseudorandom number generator. The choice of a good random seed is crucial for security and if the same random seed is deliberately shared, it becomes a secret key which can be used to synchronize remote systems, such as transmitters and receivers.

II. LFSR AND ITS VARIANTS

A linear feedback shift register (LFSR) is a shift register whose input bit is a linear function of its previous state. Thus, an LFSR is most often a shift register whose input bit is driven by the exclusive-or (XOR) a commonly used linear function of some bits of the overall shift register value. The initial value of the LFSR is called the seed (anything except all 0s, which would cause the LFSR to produce all 0 patterns) and because the operation of the register is deterministic, the stream of values produced by the register is completely determined by previous/current state. When the outputs of the flip-flops are loaded with a seed value and LFSR is clocked, it will generate a pseudorandom pattern of 1s and 0s. However, an LFSR with a well-chosen feedback function can produce a sequence of bits which appears random and which has a very long cycle. So LFSR are extremely good pseudorandom pattern generators.[2], [3]

![Fig.1: The Linear feedback shift register](image1)

![Fig.2: The variants of the LFSR](image2)

III. THE GALOIS LFSR REPRESENTATION

- An LFSR in Galois configuration as shown in Fig. 3, which is also known as modular, internal XORs as well as one-to-many LFSR, is an alternate structure that can generate the same output stream as a conventional LFSR but offset in time.

- Galois LFSRs do not concatenate every tap to produce the new input thus it is possible for each tap to be computed in parallel, increasing the speed of execution.

- In a software implementation of an LFSR, the Galois form is more efficient as the XOR operations can be implemented a word at a time only the output bit must be examined individually.
IV. **FIBONACCI LFSR REPRESENTATION**

- This LFSR configuration is also known as standard many-to-one or external XOR gates. As an alternative to the XOR based feedback in an LFSR, one can also use XNOR. As shown in Fig. 4.
- A state with all ones is illegal when using an XNOR feedback, in the same way as a state with all zeros is illegal when using XOR.
- The LFSR will only be maximum-length if the number of taps is even just 2 or 4 taps can suffice even for extremely long sequences.

V. **THE MLS AND CDMA 2000**

A maximal-length LFSR produces the maximum number of PRPG patterns possible and has a pattern count equal to $2^n - 1$, where $n$ is the number of register elements in the LFSR. It produces patterns that have an approximately equal number of 1’s and 0’s and have an equal number of runs of 1’s and 0’s. As shown in Fig. 5 information bits from CDMA channels are spreaded using spreading code at rate 1.2288 Mcps. The polynomial used in CDMA2000 is 42 bits long as shown in equation 1. [1] The long code is a 439804651103chips long MLS (242-1 chips) generated by a 42-stage shift-register circuit described by the polynomial in equation 1. The transmission rate of this sequence is 1.2288 Mcps, resulting in one repetition of the sequence every 42 days, 10 hours, 12 minutes and 19.4 seconds approximately. The starting point of the sequence is the first ‘1’ after all 41 consecutive ‘0’s. All mobile stations and BTS channel elements have a long code generator. After the MS initialization state, the MS and its best server BTS have their long codes synchronized. A unique PNLC is used within the entire network however; masks of bits are applied to the sequence to reflect user-specific characteristics, as in Figs. 5, 6 illustrates the MLS generator and the offset mask application. The masks vary according to the function of the long code.[4][5]

$$p(x) = x^{42} + x^{35} + x^{33} + x^{31} + x^{27} + x^{26} + x^{25} + x^{24} + x^{19} + x^{18} + x^{17} + x^{16} + x^{10} + x^{7} + x^{5} + x^{3} + x^{2} + x^{1} + 1$$

(1)

Long code sequences can be used, for example, for privacy (message scrambling) on forward and reverse links and for identification of mobiles and access channels on the reverse link. There are two types of Long Code (LC) masks defined by CDMA standards,

- Public Long Code Offset Mask
- Private Long Code Offset Mask
VI. M-SEQUENCE PROPERTIES

- An m-bit register produces an m-sequence of period $2^m-1$.
- An m-sequence contains exactly $2^{(m-1)}$ ones and $2^{(m-1)-1}$ zeros. [4]
- The modulo-2 sum of an m-sequence and another phase (i.e. Time-delayed version) of the same sequence yields yet a third phase of the sequence.
- Define a run of length are to be a sequence of r consecutive identical numbers, bracketed by non-equal numbers. Then in any m-sequence there are,

  - 1 run of ones of length m.
  - 1 run of zeros of length m-1.
  - 1 run of ones and 1 run of zeros, each of length m-2.
  - 2 runs of ones and 2 run of zeros, each of length m-3.
  - 4 runs of ones and 4 run of zeros, each of length m-4.
  - $2^{m-3}$ runs of ones and $2^{m-3}$ run of zeros, each of length 1.
A sliding window of length m, passed along an m-sequence for $2^{m-1}$ position, will span every possible m-bit number, except all zeros, once and only once. That is, every state of an m-bit state register will be encountered, with the exception of all zeros.

Other interesting facts regarding m-sequences and feedback sets that produce them include the following:

- If the order of the feedback taps (as defined in Figs. 3 and 4) is reversed, the resulting sequence will be the time reversal of the original sequence, and will also be an m-sequence.
- The feedback set for any given m-sequence consists of an even number of taps, never odd.

VII. Correlation Characteristics And Results

The similarity between a function $F(t)$ and itself at a different time (phase offset) is known as auto-correlation and is quantified by the Auto-Correlation Function (ACF) as shown in equation 2. ACF for a PN sequence can be understood as the chip-by-chip comparison of a sequence (length L) with shifted versions of itself (offsets from 1 to L), as in equation 3.

$$ACF = \int_{-\infty}^{+\infty} F(t)F(\tau-t)dt$$ (2)

$$ACF = CC - NCC$$ (3)

Where: CC = number of Coinciding Chips between sequence. NCC = number of Non-Coinciding Chips between sequence.

<table>
<thead>
<tr>
<th>Phase offset (chips)</th>
<th>Sequence phase</th>
<th>Number of Coinciding Chips (CC)</th>
<th>Number of Non-Coinciding Chips (NCC)</th>
<th>Auto-Correlation Function (ACF)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>1011100</td>
<td>7</td>
<td>0</td>
<td>7</td>
</tr>
<tr>
<td>1</td>
<td>0111001</td>
<td>3</td>
<td>4</td>
<td>-1</td>
</tr>
<tr>
<td>2</td>
<td>1110001</td>
<td>3</td>
<td>4</td>
<td>-1</td>
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<tr>
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</tr>
<tr>
<td>4</td>
<td>1001011</td>
<td>3</td>
<td>4</td>
<td>-1</td>
</tr>
<tr>
<td>5</td>
<td>0010111</td>
<td>3</td>
<td>4</td>
<td>-1</td>
</tr>
<tr>
<td>6</td>
<td>0101110</td>
<td>3</td>
<td>4</td>
<td>-1</td>
</tr>
<tr>
<td>7</td>
<td>1011100</td>
<td>7</td>
<td>0</td>
<td>7</td>
</tr>
</tbody>
</table>

Table 1: Auto-correlation function for an MLS of length L = 7 and N = 3

Table -1 shows ACF results when comparing an MLS of length L = 7 and itself with different phase offsets. For non-zero offset, the number of non-coinciding chips always exceeds the number of coinciding chips by one, regardless of the offset. The maximum value (auto-correlation spikes) of the ACF is obtained only when both sequences being compared have the same phase.
VIII. Conclusion

In this paper, the Long code generator has been implemented using MATLAB SIMULINK with rate 1 for CDMA2000 3G services. The purpose of this paper was to study the properties viz. ACF and CCF for spreading code i.e. MLS. The MLS is mainly used as spreading code for 2G and 3G standard such as IS -95, CDMA2000 viz. EVDO, EVDV.
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REFERENCES


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