AN ENHANCEMENT OF CODE AND ENERGY OPTIMIZATION IN PN SEQUENCE GENERATION

Rina Choudhary

School of Electronics Devi Ahilya Vishwavidyalaya University, Indore-452001

ABSTRACT

PN sequence is extensively used in CDMA communication system as spreading codes. Generally the PN sequence is generated by a dedicated software module. Present mechanism of generating PN sequence consumes lots of energy. In this paper we will see significant energy consumption reduction by the use of bit wise operators available in C language (middle level language).This approach optimizes the use of memory, providing lesser number of memories IO/memory fetches) resulting in better energy efficiency.

KEYWORDS: PN-Sequence (Pseudo Random Sequence code), short PN-sequence, Long PN- sequence, Generator Polynomial, Code division multiple access (CDMA), Energy optimization, Code optimization, C language, Bit wise operator

INTRODUCTION

Below shows a block Diagram (fig.1) for CDMA communication System [2] .CDMA (Code Division Multiple Access) is a technique where multiple users are allocated with different unique code sequence to share the same frequency, or the same channel [1]. So obviously there are multiple interferences due to multiple users. Such interference would be intolerable if the RF Bandwidth were limited to just the bandwidth that would be needed to support a single user. To overcome this problem CDMA system uses Spread spectrum techniques, where signal spread over a wide bandwidth. In this technique each user allocate code and the message signal coming from transmitter modulated with the sequence assigned to the user and locate the receiver exact code Sequence along with appeared noise, then original signal can be extracted. Pseudo Random sequence (PN) code is a deterministic sequence of pulses and acting as a noise when a code become exist it appears random but actually not random, the randomly definite sequence will repeat itself after its specific period.

We know PN-sequence (short and long) plays a vital role in CDMA communication system. PN sequences are generated by using LFSR (Linear feedback shift Register). A simple technique to generate randomly distributed errors with a desired error rate using a PN sequence also Simulated, statistically random errors are useful in the evaluation of error-correcting and source coders and other digital communication systems [7].

For generating short PN sequence 15 feedback registers are used and for Generating long PN-sequence 42 shift registers are used. The outputs of the feedback stages (registers) are taken and X-ORed to calculate the feedback value which becomes the input for the next cycle. The determinations of feedback registers are done using the generator polynomial. In our approach,

Feedback stages are determined using following generator polynomial:

Generator Polynomial used for 15 bit is

$X^{15}+X^{14}+1$ or [15, 14, 0]

Generator Polynomial used for 42 bit is

$X^{42}+X^{23}+X^{22}+X^{1}+1$ or [42, 23, 22, 1, 0]

Below Block diagram (fig.1) shows how extensively PN Sequence is used in CDMA Communication system.
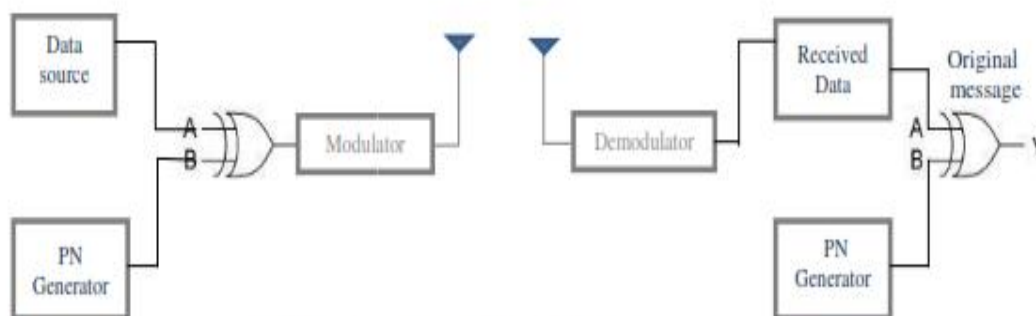

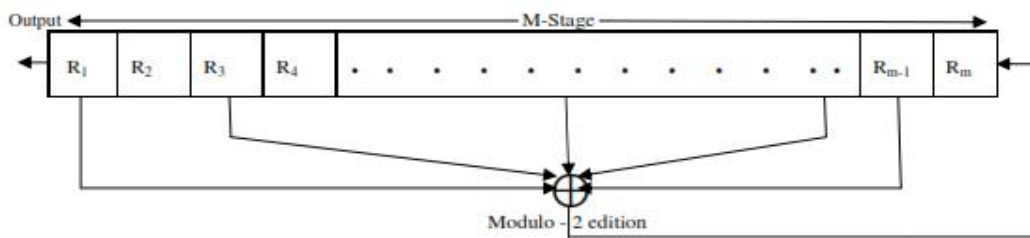Fig 1:Block diagram of CDMA communication system
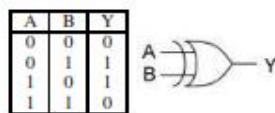
Fig:2 M-stage feedback shift-Register
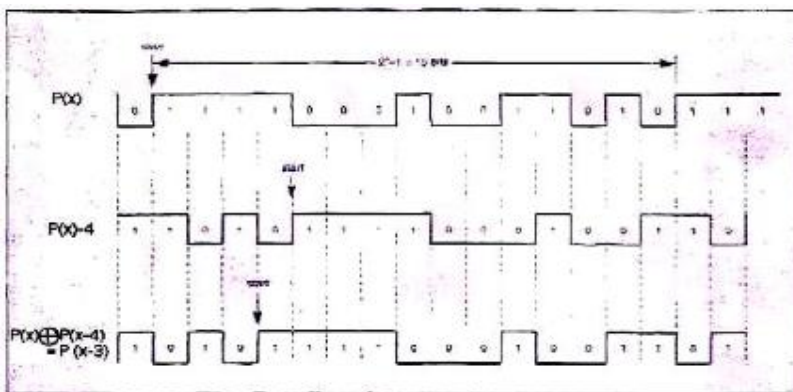

Fig. 3 Truth table and symbol of X-OR gate

Fig.4 Addition of PN sequences

GENERATOR POLYNOMIAL

The LFSR generated m sequence or maximal length sequence where m-sequence are generated by the given shift registers and length with feedback. This feedback function also called as characteristics polynomial and generated largest number of codes [5]. This polynomial depends on length and type of the sequence linear generator polynomial P(x) of degree n >0 is:-

$$P(x) = X^n + a_{n-1} X^{n-1} + \ldots \ldots \ldots + a_0$$

Fig 2 shows the m stage feedback shift-register also called maximal shift-register sequence produces length for short and long is $n = 2^m - 1$ bits generated by m-stage shift-register with linear feedback. The sequence is periodic with period n where each period contains $2^m - 1$ ones and $2^m - 1$ zeros. [6] The sequence length for short PN is determined by

$(2^{15} - 1) = 32767$

For long PN is

$(2^{42} - 1) = 4398046511104.$

This same sequence of bits outputted repeated after each interval of $(2^{15} - 1)$ and $(2^{42} - 1)$ for short and long PN sequences simultaneously.

When a PN sequence is shifted and the shifted sequence modulo-2 added to the non shifted sequence with an exclusive-OR gate, the result is the same PN sequence with some other shift. This is illustrated in Fig. 4, where a 15 bit PN sequence, P(x), is arbitrarily shifted by 4 bits to get, P(x - 4). The two sequences when modulo-2 added give a sequence which is a 3 bit shifted version, a P(x - 3), of the original sequence P(x). Only when the PN sequence is modulo-2 added to itself without shift is the result a sequence of zeros. A direct application of this property is in the generation of two identical sequences with a known, large delay between them.

CORRELATION

Correlation is a measure of similarity between two sequences. When the two sequences compared are different it is the 'cross correlation' and when they are the same it is the 'autocorrelation'. Mathematically, the correlation between two sequences x (k) and y (k) as a function of the time delay m is expressed as

$$R(m)_{ry} - \sum_{k=0}^{L-1} x(k) \, y(k + m)$$

For generating PN sequence two approaches may be taken.
1. Hardware based generation The entire set of feedback registers, feedback mechanism and generation

427

(calculation) mechanism may be implemented in a dedicated hardware. There are advantages as well as disadvantages of this approach.

Advantage
   (a) Energy consumption will be low.
   (b) Less time will be taken for execution.

Disadvantage
  (a) Hard to manage
  (b) Will require system connectivity or a separate mechanism to provide seed values and mask values.
  (c) Have challenges in testing the same.
  (d) Separate mechanism will be required to consume the generated PN-sequence.

2. Software based Generation Data structure array may be used for simulating the shift registers feedback and calculation mechanism can be implemented in software for generating the PN-Sequence [3]. There are also has advantage and disadvantage of this approach

Advantage
   (a) Easy to manage
   (b) Software will be running on system, no requirement of any additional mechanism for management or manipulating the seed values.
   (c) It can be tested with less effort.
   (d) The generated PN-sequence can be consumed by the other running software.

Disadvantage
   (a) Energy consumption will be high.
   (b) More time will be required for the execution.

An intermediate approach which is software based generation of PN sequence but acts/operates very closely to hardware. C is a language capable of accessing the system's memory in bitwise manner and it can perform bitwise operations as well. Bit wise operations available in C are listed below [4]

- Bitwise AND (&)
- Bitwise OR (|)
- Bitwise XOR (^)
- One's complement (~)
- Bitwise Left shift (<<)
- Bitwise Right shift (>>)

The approach under discussion uses right shift "X-OR" and "AND" operation for PN sequence generation. Comparison of this approach with any existing software based PN-sequence generation mechanism reveals the following:-

(1) Less memory usage: Mostly 2 bytes of memory for 15 bit sequence and 8 bytes of memory for 42 bit PN-sequence where as other software will use approximates 15x2 bytes and 42x2 bytes of memory as they will use array for implementation of LFSR.

(2) Less number of instructions execution per cycle: No logical overhead for X-OR operation as the instruction is readily available in C language

The above two comparisons shows nearly 70% reduction in memory fetches and instruction execution resulting

nearly 50% of less energy consumption for the generation of PN sequence.

When algorithms process for wideband wireless system, hardware dissipates power in two components. First component is the dynamic c power consumption ($P_{dynamic}$), it is due to switching capacitance second is the power dissipated (P_{access}) in address generation by the processor. P_{access} is dissipated when processor fetches instruction on input data or send the data to the memory. Using large number of unnecessary instruction gives more P_{access} dissipation.

Under this condition author gives the approach that the memory used for implementation of LFSR is just 2 bytes and 8 bytes for short and long PN sequence simultaneously. P_{acces} reduces due to the reduced number of external memory access, which reduces power dissipation arising from the address generation units.

Earlier work [9] on PN sequence generally polynomials are used for PN long (42 bit) sequence is

$$F(x)=1+x+x^2+x^3+x^5+x^6+x^7+x^{10}+x^{16}+x^{17}+x^{18}+x^{19}+x^{21}+x^{25}+x^{26}+x^{27}+x^{31}+x^{33}+x^{35}+x^{42}$$

For PN short (15) sequence is

$$F(x)=1+x^3+x^4+x^5+x^6+x^{10}+x^{11}+x^{12}+x^{15}$$

But here author uses the polynomial for PN long (42 bit) sequence is

$$F(x) = x^{42}+x^{23}+x^{22}+x^1+1$$

For PN short (15) sequence is

$$F(x) = x^{15}+x^{14}+1$$

By this polynomial generation having lesser number of feedback stages resulting better energy efficiency.

APPLICATIONS OF PN SEQUENCES
- PN sequences widely uses in CDMA communication system. It can acquire in the presence of channel error, false detection can be minimized without reducing the frame efficiency by using a long sequence multiplexed with the data.
- PN sequence uses in Spread spectrum modulation to spread the RF bandwidth of the signal, reducing the power spectral density.
- PN sequence also use for scrambling the data at the same rate to obtain spectral energy distribution within the signal band.

CONCLUSION
We can see in the above approach that the memory used for implementation of LFSR is just 2 bytes and 8 bytes for short and long PN sequence respectively. Lesser amount memory means lesser number of memory fetches and lesser number of instruction execution .The calculations shows nearly 70% of reduction in instruction on execution, which intern implies nearly 50% of less energy consumption for generating PN sequence. Also the generator

polynomial used for generation of PN sequence is having less number of feedback stages resulting better energy efficiency.

REFERENCES

[1] Raj Kamal, "Mobile Computing", Oxford University Press 2007.

[2] Clint smith, P.E., Daniel Collins "3G wireless Networks", second edition, Tata McGraw-Hill Communications, 2011.

[3] R. Leupers, "Code Optimization Techniques for Embedded Processors" Kluwer Academic Publishers, Boston, 2000.

[4] S.K. Shrivastava, Deepali Shrivastava, "C in Depth", second edition, BPB publication new Delhi, 2007.

[5] "On Pseudo-Random and Orthogonal Binary Spreading Sequences".Abhijit Mitra.Department of Electronics and Communication Engineering, Indian Institute of Technology, (IIT) Guwahati, India.

International Journal of Information and Communication Engineering 4:6 2008

[6] John G. Proakis, "Digital Communication Third Edition Department of Electrical and Computer Engineering, Northeastern University McGraw-Hill international editions, 1995.

[7] MUTAGI, R.N.: 'Circuit generates statistically random pulses' Electronic Engineering, UK, April 1995, pp.20

[8] Arthur Abnous. "Low-Power Domain-specific Processors for Digital signal Processing." Ph.D. dissertion, Department of Electrical Engineering, University of California, Bakerley, 2001.

[9] Low-power LFSR Kernel Architecture in Mobile Transmitter and Receiver Protocols and Software Defined Radios, C N Khairnar, Sanjiv Tokekar and Raj Kamal, International Journal of Recent Trends in Engineering (ISSN: 1797-9617), Vol. 2, No. 1, pp20-26, Nov 2009