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Spreading Code Generator in Direct Sequence Spread Spectrum Modulator

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Abstract— **This paper presents the FPGA implementation of spreading code generator in direct sequence spread spectrum modulator, in this Direct Sequence Spread Spectrum where by the original data signal is multiplied with a pseudo noise spreading code to be transmitted. This process can be done through the spreading code generator which can be implemented using VHDL in DSSS modulator on Spartan 6 FPGA family. spreading code has a Programmable chip rates up to 60 Mchip/s and spreading factor from 3 to 65335.Modulation is BPSK/QPSK and raised cosine square root filter with 20% rolloff where Filter can be bypassed.**

Keywords— **DSSS modulator, Pseudo code generator , Gold sequences, Maximal length sequences, barker codes, GPS C/A codes.**

1. INTRODUCTION

In some situations it is required that a communication signal be difficult to detect, and difficult to demodulate even when detected. Here the word 'detect' is used in the sense of 'to discover the presence of'. The signal is required to have a low probability of intercept – LPI. In other situations a signal is required that is difficult to interfere with, or 'jam'. The 'spread spectrum' signal has properties which help to achieve these ends. Spread spectrum[1] signals may be divided into two main groups – direct sequence spread spectrum (DSSS), and frequency hopping spread spectrum (FHSS).

Frequency hoping

- Signal broadcast over seemingly random series of frequencies

Direct Sequence

- Each bit is represented by multiple bits in transmitted signal
- Chipping code

In DSSS systems[2], the designer can reduce narrowband interference in the same channel by increasing the processing gain, but this technique cannot be used in FHSS schemes. However, FHSS schemes are less susceptible to jamming and the receiver is easier to implement.

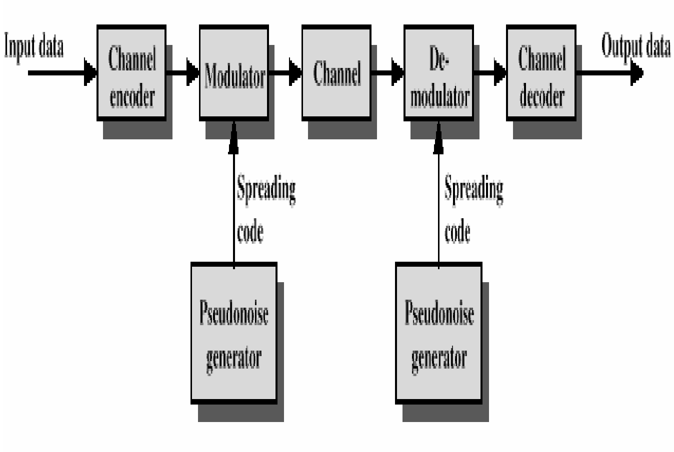

Figure 1: General spread spectrum model

2. DSSS MODULATOR

Direct sequence spread spectrum, also known as direct sequence code division multiple access (DS-CDMA), is one of two approaches to spread spectrum modulation[4] for digital signal transmission over the airwaves. In direct sequence spread spectrum, the stream of information is divided into small pieces, each of which is allocated across to a frequency channel across the spectrum. A data signal at the point of transmission is combined with a higher data-rate bit sequence that divides the data according to a spreading ratio. The redundant chipping code helps the signal resist interference and also enables the original data to be recovered if data bits are damaged during transmission[8].

The direct spread spectrum modulation[6] is done using a spreading code, which is independent of the data in the signal. Dispreading at the receiver is done by correlating the received signal with a synchronized copy of the spreading code. Direct spread sequence spectrum representation is given in below figure 2.

The DSSS spectrum can be represented as

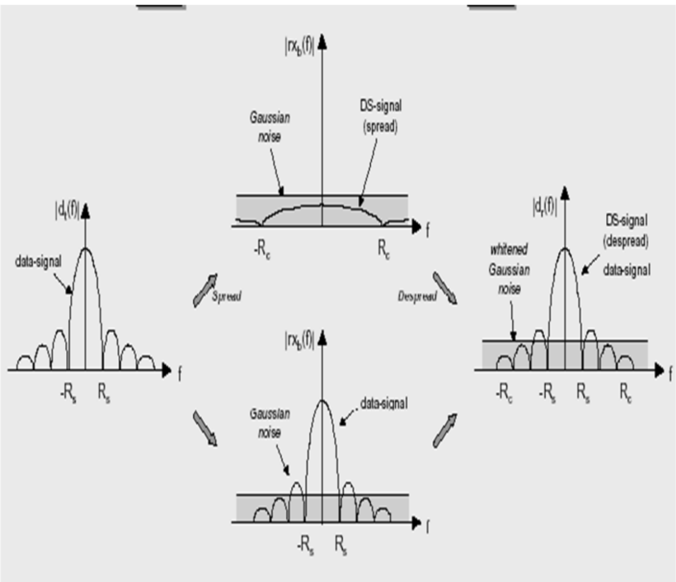

Figure 2: DSSS representation

Generally in Direct sequence spread spectrum communication systems, the input data signal is XOR'ed with spreading code which is generated by using spreading code generator. Spreading code is pseudo random sequence[6]. The direct sequence spread spectrum signal representation is given in below figure 3.

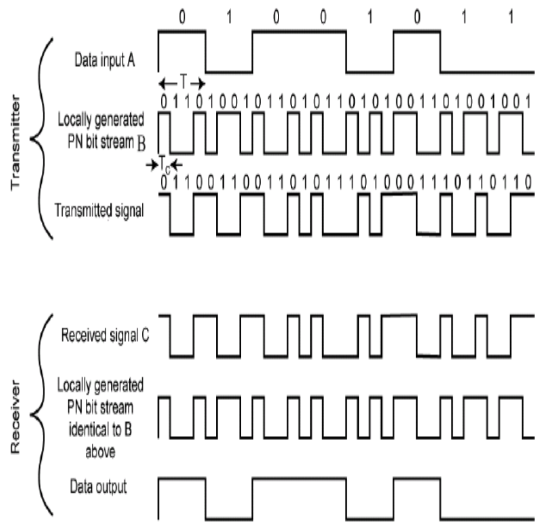

Figure 3: DSSS signal representation

The advantages of the direct sequence spread spectrum are Higher data rates , Zero inter symbol interference , Zero channel noise , Higher security , Effective utilization of bandwidth[3] and Multiple users can access the channel at a time.

The spreading code generator can be used both in modulator and demodulator. But in this we are using in modulator and the practical DSSS modulator given in below figure

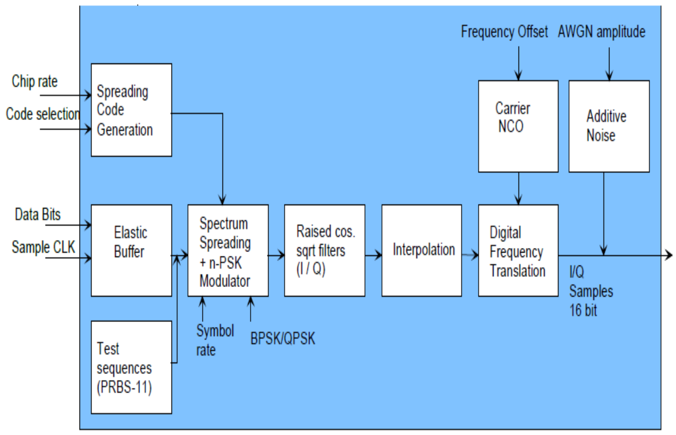

Figure 4: Block diagram of DSSS modulator

3. SPREADING CODES

In DSSS Modulator we used generate the spreading codes which are nothing but the PSEUDO-RANDOM sequences. These are of four types

1. Gold sequences
2. Maximal Length sequences
3. Barker codes
4. GPS C/A codes

For the code selection it requires a register and it is REG6 (3:0).

3.1 Gold sequences :

Gold sequences are generated using two linear feedback shift registers LFSR1 and LFSR2. The code period is 2^n-1, where n is the number of taps in the shift register. The LFSRs are initialized to all 1's at the start of each period. The LFRSs will generate all possible n-bit combinations, except the all zeros combination.

Gold codes are constructed by EX-ORing the two m-sequences of the same length with each other. If the LFSRs are chosen appropriately, gold sequences have better cross-correlation properties than maximum length LFSR sequences. To construct the Gold sequences it requires the polynomials G1 and G2.

Gold sequence polynomial G1 is

It is 24-bit. It Describes the taps in the linear feedback shift register 1.Bit 0 is the leftmost tap (2^0 in the polynomial). The largest non-zero bit is the polynomial order n. n determines the code period is 2^n –1.

Example:

$G1 = 1 + x + x^4 + x^5 + x^6$ is represented as 0x000039

This field is used only if Gold code or Maximal length sequences are selected.

In practical the below registers are used.

REG7 = LSB
REG8
REG9 = MSB

Gold sequence polynomial G2 is

It is 24-bit. It describes the taps in the linear feedback shift register 2
Same format as G1 above.
This field is used only if Gold codes are selected.
In practical the below registers are used.

REG10 = bits 7 – 0 (LSB)
REG11 = bits 15 – 8
REG12 = bits 23 – 16 (MSB)

Gold code G1/G2 phase offset

A Gold code is generated by adding two maximal length sequences (as defined by their generator polynomials G1 and G2).A set of orthogonal Gold codes can be created by changing the phase offset between the two maximal length sequences.
In practical the below registers are used.

REG35(LSB)
REG37 (MSB)

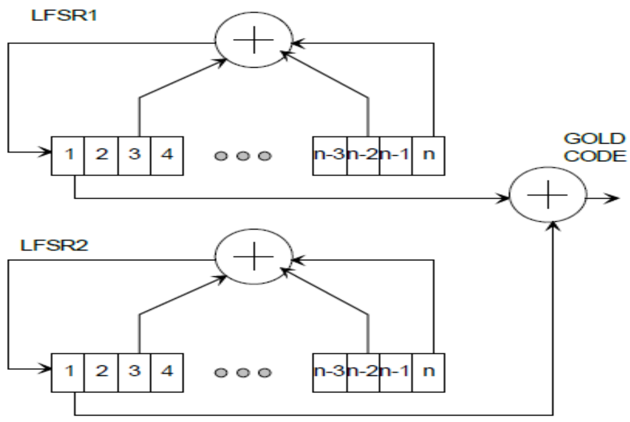

Figure 5: Representation of Gold sequence

3.2 Maximal Length Sequences :

Maximal length sequences are generated using one linear feedback shift register LFSR1. The code period is 2^n-1, where n is the number of taps in the shift register. The LFSRs are initialized to all 1's at the start of each period. The LFRSs will generate all possible n-bit combinations, except the all zeros combination. Each sequence is uniquely described by its generator polynomial. The highest order is n. The generator polynomial is user programmable.
Maximal length sequence polynomial G1 is

It is 24-bit. It describes the taps in the linear feedback shift register1.Bit 0 is the leftmost tap (2^0 in the polynomial). The largest non-zero bit is the polynomial order n. n determines the code period is 2^n –1.
This field is used only if Gold code or Maximal length sequences are selected.
In practical the below registers are used.

REG7 = LSB
REG8
REG9 = MSB

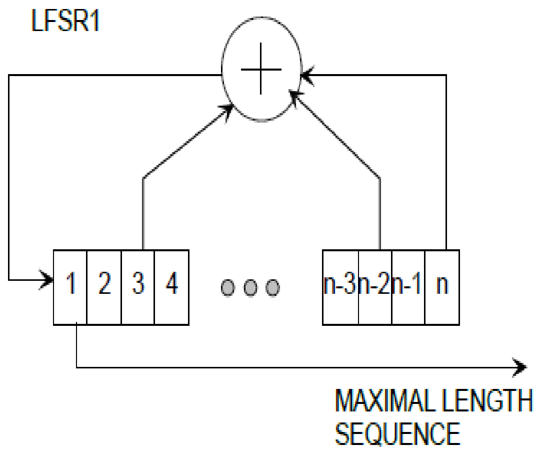

Figure 6: Representation of Maximal Length Sequence

3.3 Barker Codes :

A Barker code is a string of digits $a_i = \pm 1$ of length $l \geq 2$ such that

$$\left|\sum_{i=1}^{l-k} a_i a_{i+k}\right| \leq 1$$

For all $1 \leq k \leq l$. Barker codes are used for pulse compression of radar signals. There are Barker codes of lengths 2, 3, 4, 5, 7, 11, and 13, and it is conjectured that no longer Barker codes exist. They are short codes which have low-correlation side lobes. A correlation side lobe is the correlation of a codeword with a time-shifted version of itself.

Barker (11) = 1 -1 1 1 -1 1 1 1 -1 -1 -1 => sum = +1 (balanced)
Barker (13) = 1 1 1 1 1 -1 -1 1 1 -1 1 -1 1 =>sum = +5 (unbalanced)
Or
11 bit Barker code: 101 1011 1000, or 0x5B8
13 bit Barker code: 1 1111 0011 0101, or 0x1F35
In this DSSS modulator we are going for 13-bit barker code.

3.4 GPS C/A Codes :

The C/A codes are 1,023 bits long gold codes transmitted at 1.023 Mb/s, implying a period of 1 ms. They combined with a navigation message using exclusive or and the resulting bit stream is used for modulation . These codes only match up, or strongly auto correlate when they are almost exactly aligned. Each satellite uses a unique PRN code, which does not correlate well with any other satellite's PRN code. In other words, the PRN codes are highly orthogonal to one another.

The C/A codes are generated by combining using exclusive or 2 bit streams generated by maximal period 10 stage linear feedback shift registers. Different codes are obtained by selectively delaying one of those bit streams. Thus:

$$C_i(t) = A(t) \oplus B(t+D_i)$$

GPS C/A codes are modified Gold codes of length 1023 with generator polynomials.

$$G1 = 1 + x^3 + x^{10}$$
$$G2 = 1 + x^2 + x^3 + x^6 + x^8 + x^9 + x^{10}$$

The G2 generator output is slightly modified so as to create a distinct code for each satellite. The G2 output is generated by summing two specific taps of the shift register.

GPS satellite ID:
GPS signals from different satellites are designated by a PRN signal number in the range 1 – 37. This field is used only if GPS C/A codes are selected.
REG18 (5:0)

4.RESULTS

In the design and implementation of spreading code generator in DSSS modulator, while doing simulation part for the code selection register we have to give 3 which is meant for barker codes and the output is 1F35 that can be shown below and in this for gold sequences, maximal length sequences and for GPS C/A codes the inputs are 1,2,4 respectively.

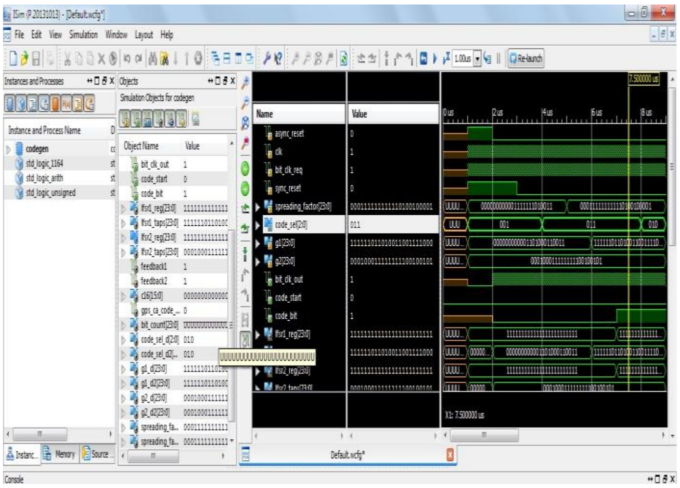

Figure 7 : results of spreading code generator

5. CONCLUSION

This paper presents design and implementation of the spreading code generator. In this whereby the original data signal is multiplied with a pseudo random noise spreading code. This spreading code has a higher chip rate (this the bit rate of the code), which results in a wideband time continuous scrambled signal). The benefits of using DSSS are resistance to jamming, sharing single channels among multiple users, less background noise and relative timing between transmitter and receivers. In this the spreading code generator can be used at both transmitter and receiver and here we are represented only at transmitter side.

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