International Journal For Technological Research In Engineering
Volume 2, Issue 7, March-2015 *ISSN (Online): 2347 - 4718*

REVIEW ON: GPS L1C CODE GENERATION ON FPGA

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Abstract: Pseudo random noise codes are a fundamental element of GPS and Galileo. The creation of the new L1C GPS signal presented the opportunity to choose both a family of spreading codes and an associated family of overlay codes. Various code concepts are used for the L1 civil signal of the Global positioning system. The L1C codes were created by using Weil-codes of prime length 10223. Selected Weil codes were padded with a fixed 7-bit pad to yield the L1C spreading code. L1C codes are enhancements of Weil codes that are based on Legendre sequence which consist of Legendre symbols. To calculate these Legendre symbols, the Euler criterion is used to evaluate quadratic residues. Due to the great length of L1C codes, this procedure causes Overflow problems. To overcome these problems, the quadratic reciprocity law, some related theorems and properties are introduced for the generation of L1C codes. The codes are perfectly balanced and exhibit good auto- and cross correlation. This makes the calculations comparatively easier. In addition, through simulations, the autocorrelation features of obtained Legendre sequences and L1C codes are compared.
Keywords: L1 civil signal, Legendre sequence, quadratic reciprocity law, Weil code.

I. INTRODUCTION

A satellite is an artificial object which has been intentionally placed into orbit. Such objects are also called as artificial satellites to distinguish them from natural satellites such as the moon. The world's first artificial satellite, the Sputnik I, was launched by the Soviet Union in 1957. A few hundred satellites are currently operational, whereas thousands of unused satellites and satellite fragments orbit the earth as space debris. Satellites are used for a large number of purposes. Common types include military and civilian earth observation satellites, communication satellites, navigation satellites, weather satellites, and research satellites. About 6,600 satellites have been launched. The latest estimates are that 3,600 remain in orbit. In those, only about 1,000 are operational. GPS signals include ranging signals, used to measure the distance to the satellite, and navigation messages. The navigation messages include ephemeris data, used to calculate the position of each satellite in orbit, and information about the time and status of the entire satellite constellation, called the almanac. The original GPS design contains two ranging codes: the Coarse/acquisition code, which is freely available to the public, and the restricted precision code, usually reserved for military applications. The C/A code is a 1,023 bit deterministic sequence called pseudo random noise which, when transmitted at 1.023mbps, repeats every millisecond. These sequences only match up, or strongly correlate, when they are exactly aligned. The P-code is also a PRN; however, each satellite's P-code is 6.187x1012 bits long and only repeats once a week. To prevent unauthorized users from using or potentially interfering with the military signal so it is passed through a process called spoofing. It was decided to encrypt the P-code; the encrypted signal is referred as the P(Y)-code. In section 2, some of the coding schemes introduced earlier are explained. Section 3 includes some future scope according to the necessity. Section 4 gives some concluding remarks on this paper.

II. CODING TECHNIQUES

The launch of the IIR-14 in 2005 began a new era with transmission of the L2 civil signal, along with the modernized military m-code signal. A third civil signal, called L5, will be transmitted from block IIF satellites. In the meantime, development of the next generation of satellites, called GPS III, and a modernized control segment continues, which will lead to greatly enhanced capabilities. An integral part of the GPS III capabilities begin developed is a new civil signal called L1C, which will be transmitted on the L1 carrier frequency in addition to current signals. The development of L1C represents a new stage in international GNSS, not only is the signal being designed for transmission from GPS satellites; its design also seeks to maximize interoperability with Galileo's open service signal. L1C has been designed to take advantages of many unique opportunities. There is a good reason to concentrate attention on L1. Today it carries C/A, the only civil GPS signal. In the future, even with new and modern L2 and L5 signals, L1 is expected to remain the most important civil frequency. This is primarily because it is less affected by ionosphere refraction error than L2 and L5. Pseudo random noise codes are a fundamental element of GPS and Galileo. Codes are indeed a keystone of any system that relies on code division multiple access to separate different transmission channels, and thus to distinguish one satellite from another.

A. GOLD CODES

Gold codes are a type of binary sequence used in telecommunication and satellite navigation. Gold codes are also known as gold sequences. Gold sequences were proposed by Robert Gold in 1967 and 1968. These are constructed by EXOR-ing two m-sequences of the same length with each other. Gold codes have bounded small cross correlations within a set, which is useful when multiple devices are broadcasting in the same frequency range. Gold code sequences consists of 2^n-1 sequences with a period of 2^n-1, which uses two LFSRs, each of length 2^n-1. If the LFSRs are chosen appropriately, gold sequences have better cross correlation properties than maximum length LFSR sequences. Gold codes can be generated from the following steps. Consider two maximum length sequences of the same length 2^n-1 such that their absolute cross correlation is less than or equal to $2^{(n+2)/2}$, where n is the size of the LFSR used to generate the maximum length sequence. The set of the 2^n-1 exclusive or of the two sequences in their various phases is a set of gold codes. The highest absolute cross correlation in this set of codes is $2^{(n+2)/2}+1$ for even n and $2^{(n+1)/2}+1$ for odd n.

B. Weil codes

Weil codes are basically new family of binary sequences with very good correlation properties. They exist for any length p, where p is a prime number. A Weil code is constructed as a shift-and-add of the well-known Legendre sequences based on quadratic residues. Therefore a family of (p-1)/2 Weil codes exists for length p. The even auto and cross correlation sidelobe magnitude for the whole family of Weil codes are bounded by $5+2\sqrt{p}$. Hence they are within 6dB of the Welch bound and within 3dB of Gold codes. Unlike gold codes, Weil codes often have reasonable odd correlation as well. Weil codes were also used for the generation of the L1C codes. The specific construction was first proposed in a spread spectrum context. Initially a Legendre sequence is generated with the help of a Legendre symbol and some theorems and rules. These Legendre sequences are then shifted by one bit and then added to form the Weil sequences. A weil code $w_i(a;w)$ is specified by the weil index w, ranging from 1 to n, which represents the shift of s(a), i is the PRN signal number and a is the integer variable to calculate Legendre symbols. A weil code $w_i(a;w)$ is defined as
$W_i(a;w)=s(a) \text{ xor } s((a+w)(\text{mod } m))$ where a<[0,m-1].
These Weil codes were used for the generation of the L1C codes for the newer generation of satellites. Here the Weil codes were generated from the well known Legendre sequences based on quadratic residues with the help of the Euler criterion. As the code length of the L1C is 10230, nearest prime number to the desired code length was 10223. So 10223 were chosen. Weil sequence of length 10223 was derived from the Legendre sequence using the Euler criterion and quadratic residues. The Euler criterion was used to calculate the quadratic residues of the Legendre symbol. Due to the great length of the Legendre sequence implemented, this method causes overflow problems.

III. FUTURE SCOPE

As we have seen the different coding schemes used for the GPS satellites in the earlier section. Each of the schemes possessed a drawback. The Gold codes were developed based on the LFSRs; if the LFSRs are not appropriately chosen then the cross correlation properties would be poor. Similarly for the Weil codes, if the modulus is large then the Euler criterion posses overflow problems. It is well suited for the smaller modulus or prime number. A new method has been proposed in the abstract. Instead of using the Euler criterion to calculate the quadratic residues we can use quadratic reciprocity law and some theorems related to it. The quadratic reciprocity law was introduced and proved by Gauss. This method reduces the complexity and increases the flexibility in generating the required code structure. When modulus L is large, the main scheme is to calculate a Legendre symbol by producing the Legendre symbols of the smaller modulus by decomposition and transformation according to the theorems and properties related to the law. This is one of the most important fundamental theorems in the elementary number theory.

IV. CONCLUSION

In this paper, two simple and traditional methods used for the generation of codes for the GPS satellites have been explained. These codes are generated by different methods but posses good correlation properties. Gold codes were generated from the LFSRs whereas the Weil codes were generated from the Legendre sequence with the help of Euler criterion. This paper is only a short introduction for the upcoming best improvements in the field of satellites and GPS.

TABLE I
TABLE OF GOOD SEQUENCE FAMILIES

Name	Length N	family size	Max sidelobe
Gold(odd)	2^n-1, n odd	N+2	$1+\sqrt{2}\sqrt{N+1}$
Gold(even)	2^n-1, n=4k+2	N+2	$1+2\sqrt{N+1}$
Kasami(small)	2^n-1, n even	$\sqrt{N+1}$	$1+\sqrt{N+1}$
Kasami(large)	2^n-1, n=4k+2	$(N+2)\sqrt{N+1}$	$1+2\sqrt{N+1}$
Bent	2^n-1,n=4k	$\sqrt{N+1}$	$1+\sqrt{N+1}$
No	2^n-1, n=2k	$\sqrt{N+1}$	$1+\sqrt{N+1}$
Gong	$(2^n-1)^2$	$\sqrt{N}$	$3+2\sqrt{N}$
Paterson, gong	P^2, p prime 3 mod 4	$\sqrt{N+1}$	$3+2\sqrt{N}$
Paterson	P^2, p prime 3 mod 4	N	$5+4\sqrt{N}$
Z_4 linear family I	$2(2^n-1)$, n odd	N/2+1	$2+\sqrt{N+2}$
Z_4 linear, family II	$2(2^n-1)$, n odd	$(N+2)^2/4$	$2+2\sqrt{N+2}$
Weil	P, prime	(N-1)/2	$5+2\sqrt{N}$

V. ACKNOWLEDGEMENTS

For the successful completion of this review paper received plenty of help from the staff members, friends and the internet web sources.

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