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Implementation Of The Modernized GPS Signals L2C, L5 And Their Tracking Strategies

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ABSTRACT

Modern global positioning system (GPS) signals L2C and L5 have a new developmental prospect, although GPS was originally conceived for use by the military in their missions, it has become an important utility for a number of civil and commercial applications. The principal objective of modernizing GPS signal is to improve the overall performance of the system, in terms of improving the accuracy, providing better immunity to RF interference and multipath and better atmospheric corrections. These are done by providing additional coded civil signals on multiple carrier frequencies. New signals simulations provide effective design of simulation as well as various simulation algorithms. This article discusses the structure of modern GPS new L2C and L5 civilian signals, analyses principle and generation approach of the L2C ranging code and L5 two ranging codes in quadrature (I and Q channels), and their tracking strategies. The modern GPS signals simulation was constructed based on simulink. The result shows that the simulation platform is effective and reliable, and it is simple and intuitional which can provide a strong support for the engineering application.

KEY WORDS- **Global positioning system (GPS); L2C; L5; Tracking; Signal Generators**

United States announced a GPS modernization initiative in January 1999. The GPS modernization schedule is given briefly in Table 1: From Table 1, there were two carrier frequencies at 1575.42 and 1227.6 MHz called L1 and L2 in the Block IIR program. The first a coarse/acquisition (C/A) code that has a 1.023Mcps code along with 50 bps data is BPSK modulated onto the L1 carrier. The second precision code (P(Y)) at10.23Mcps along with the same data modulated both the L1 and L2 carriers. The C/A code is intended for civil applications, whereas the P(Y) code is designated only for U.S. authorized military users. In the Block IIR-M and Block IIF modernization program especially includes the adding of C/A replacement code on the L2 frequency, a third civil signal on the L5 frequency, and Military code (M-code) on the L1 and L2.

	Block IIR	**Block IIR-M**	**Block IIF**
First Launch IOC	1997 2001	2005 From 2009	2007 From 2010
L1 1575.42MHz	C/A P(Y)	C/A P(Y) M-code (C/A Plane)	C/A P(Y) M-code (P(Y) Plane)
L2 1227.60MHz	P(Y)	P(Y) L2C(+0.1dB) M-code (C/A Plane)	P(Y) L2C(+1.5dB) M-code (P(Y) Plane)
L5 1176.45MHz			L5I L5Q

INTRODUCTION

The satellite navigation/positioning systems develop well recently, especially for the Global Position System (GPS). GPS was designed to provide coordinated position and time synchronization information any where on the globe. TABLE 1. GPS MODENIZATION SCHEDULEThis article discusses the structure of modern GPS new L2C and L5 civilian signals, analyses the principle and generation approach of the L2C ranging code and L5 two ranging codes in quadrature (I and Q channels), and their tracking strategies. The modern GPS signals simulation was constructed based on Simulink.

1. L2 REPLACEMENT CODE:

The L2 civilian code is broadcast in quadrature to Y-code on the L2 carrier frequency (1227.6MHz). The L2C signal has completely new signal structure: Two new ranging codes which are multiplexed and data message organized as message types rather than one large message.

The L2C signal modulation is shown in Fig. 1.

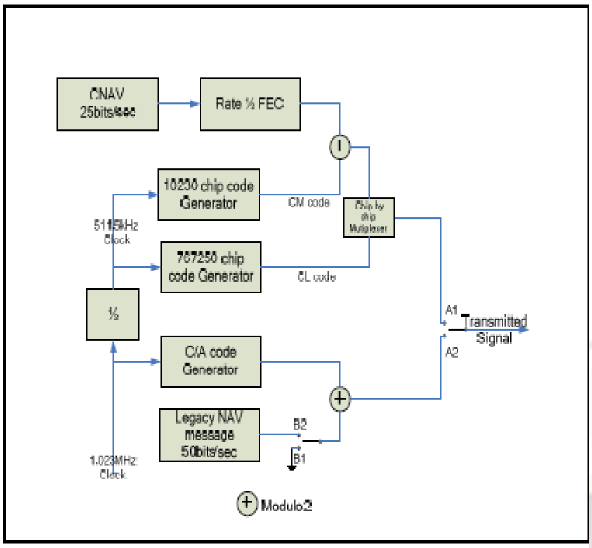

Figure 1. GPS L2C code signal modulation diagram

The L2C signal consists of two codes: CM code (medium length code) and CL code (long length code).

1.a. CM (medium length code)

The CM code is modulated with data at 25 bps, convolutionally encoded with parameters K=7 and rate 1/2, to produce 50sps data. The CM code is short cycled to 10230 chips and repeats every 20msecs. The chip rate is 0.5115Mcps.

1.b. CL (long length code)

The CL code has no data modulation; the spreading is due to the spreading code. The CL code is short cycled to 767250 chips, so it repeats every 1.5secs and is synchronous with legacy. The chip rate is also 0.5115Mcps. Since there is no data on the CL code it can be carrier tracked by a phase locked loop (PLL), and a Costas or Squaring loop is not required. This is an important characteristic of the modern GPS signals.

Both codes are disjoint segments of a long-period maximal length code derived from a 27 stage linear shift register that is short cycled to get the appropriate period. One chip from each code broadcast alternately giving an effective rate of 1.023Mcps (same as C/A code).

In actuality there are three selectable options for the replacement for the C/A code: (1)The chip-by-chip ranging code with data message or without date message, (2) The C/A code without a data message, (3) The C/A code with the data message, see Figure 1 for the details.

C. L2C Navigation data (CNAV)

The L2C Navigation data stream includes the same data as normal GPS. The CNAV data rate is 25bps, and symbol rate is 50sps with 1/2 rate Forward Error Correction (FEC) encoding. The CNAV modulo 2 added to CM code only.

This article does not deal with the position calculation, so data message is binary system random code here, which does not have any practicality meanings.

2. THE NEW CIVILIAN SIGNAL-L5:

L5 is a new third civilian code that is broadcast in the ARNS band on a carrier frequency of 1176.45MHz. L5 is only available on Block IIF satellites. Independent operation from GPS L1/L2 means L5 is suited to Safety-of-Life applications. It has 24MHz signal bandwidth, and brands new signal structure. The L5 signal modulation is shown in Fig. 2.

As see in Fig. 2, L5 has two components, an in-phase component (I5) and a quadrature component (Q5). The inphase code (I) has data and a ranging code that are both modulated via BPSK onto the carrier. The data rate is 50 bps, but since it is coded with a rate 1/2, K=7 convolutional code the symbol rate is 100sps. The I5 code is multiplied by an Neumann-Hoffman (NH) code to extend the code period to 10ms from 1ms.

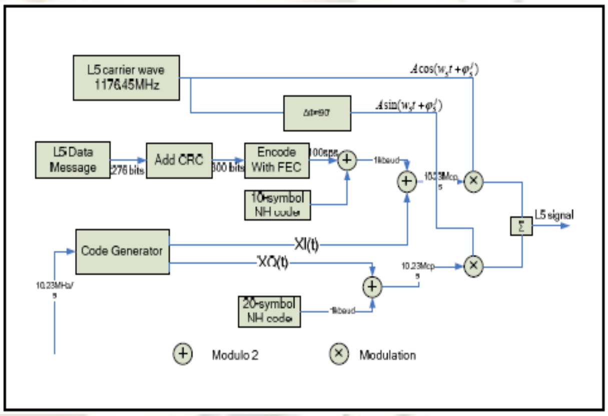

Figure 2. GPS L5 signal modulation diagram.

The quadrature code (Q) has no data message, but does have a ranging code which runs at 10.23Mcps with a period of 1ms. In a similar manner the Q5 code is multiplied by a 20 bit NH code to extend the period of that code to 20ms.

2.a. I5/Q5 code

The L5 I5 code and the L5 Q5 code are the modulo 2 sum of two extended codes clocked at 10.23Mcps (XA and XBIi or XBQi) which generated using 13-bit linear shift registers. Maximal length XA is short cycled by 1 and truncated at 10230 bits. At a 10.23MHz clock rate, the code period is 1 millisecond. The code polynomial for XA is as follows:

$$XA = 1 + x^9 + x^{10} + x^{12} + x^{13} \quad (1)$$

The registers are initialized with all 1's. The generator is reset to all 1's after every 8190 bits.

The XBIi and XBQi are 8191 chip length codes that are not "short cycled". They are restarted at the end of their period and run over a period of 1ms and are synchronized with the XA code producing total of 10230 chips. The code polynomial for XBIi and XBQi is as follows

$$XB = 1 + x + x^3 + x^4 + x^6 + x^7 + x^8 + x^{12} + x^{13} \qquad (2)$$

The XB register is initialized with appropriate bits Corresponding to the PRN numbers. L5 code generation is shown in Fig. 3.

2.b. NH code

The NH codes are included to help reduce the cross correlation minor peaks, aid in resolving bit timing clock, and improve noise rejection. A 10-symbol Neumann-Hoffman (NH) code is used to further encode the symbols at 100sps. Symbol 1 is encoded as 1111001010, and symbol 0 is encoded as 0000110101. The 10 bits of NH code are modulo 2 added to the symbols at the PRN epoch rate of 1 kHz. The resulting symbol is used to modulate the L5 in-phase carrier at 1176.45MHz. The Q5 carrier has no data. But each of the 1ms Q5 code blocks are encoded with a 20-bit NH code. The 20 bits are modulo 2 added to the code chips at the PRN code rate of 1 kHz. The 20-bit NH code is given by 00000100110101001110.

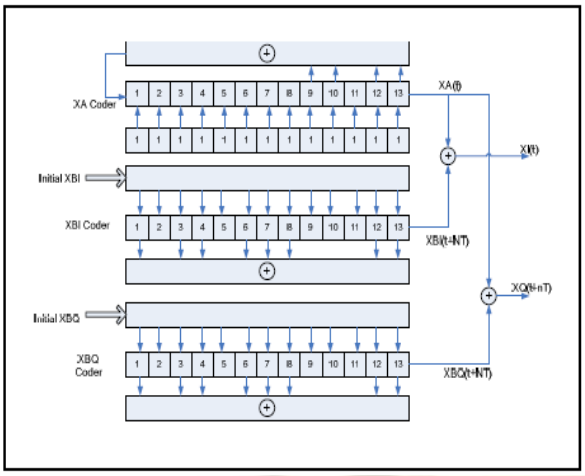

Figure 3. L5 Code Generation Block Diagram.

2.c. L5 navigation data (NAV)

The navigation data rate is 50bps. This article also used binary system random code as the navigation data.

3. THE SIMULINK SIMULATION OF GPS SIGNALS:

The modern GPS signals simulation was constructed based on Matlab/Simulink. The major used tool boxes and module libraries are Simulink sources, communication blockset and DSP blockset. Those module libraries offered the familiar communication modules, and it provides effective help to the FPGA design of signals simulation.

Based on GPS L2C code signal' structure, Fig. 4 shows the L2C signal Simulink modulation diagram.

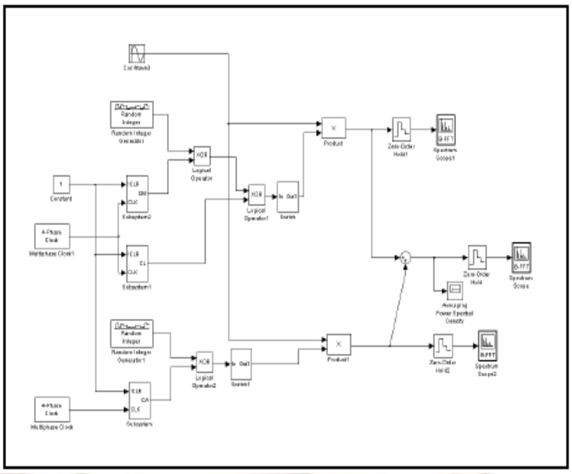

Figure 4. GPSL2C code signal Simulink modulation diagram.

The block of CM/CL code generator in Fig. 4 is as follows:

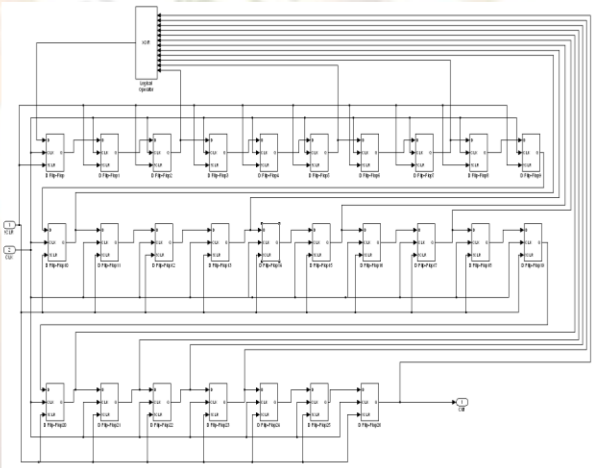

Figure 5. GPSL2C code generator in Simulink.

It is shown as Fig. 5 that the code generator consists of three major blocks, namely LFSR, Reset control, and Code clock. The CM/CL codes are generated from a linearity feedback shift register which is of size 27 bits. At every reset, the linearity feedback shift registers are loaded with initial values as per satellite. The codes for every satellite are independent. The reset control is used for generating the reset signals to CM LFSR every 10230 chips and CL LFSR every 767250 chips.
And Fig. 6 illustrates the product of the L2C code and the C/A code. The spectra of the BPSK (L2C) and BPSK (C/A) signals are plotted in Fig. 7.

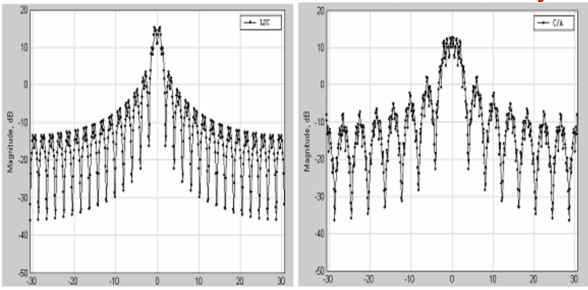

Figure 6. The Simulink emulation of the L2C code and C/A code.

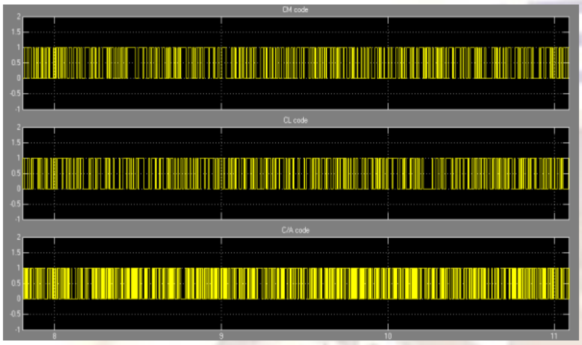

Figure 7. Power Spectral Density of BPSK (L2C) and BPSK (C/A).

The L2C signal consists of two codes: CM code and CL code. Both codes are chip by chip time-multiplexed at 1.023MHz to modulate the L2 carrier. From the Fig. 7, the simulation of the L2C code and C/A code matched the theory. As a time division multiplexed (TDM) signal, L2C has unique features that make it very different from C/A-code on L1 and I5/Q5 code on L5. Indeed, the CM code and CL code are significantly longer, thus having better correlation (as shown in Fig. 8) and spectral properties.

The L5 code generator is shown in Fig. 9(a). The L5 code generator used the module of the D Flip-Flop as the linear shift register, connected 13 D Flip-Flops as tapped feedback shift register based on the code polynomials. Fig. 9(b) shows the L5 code.

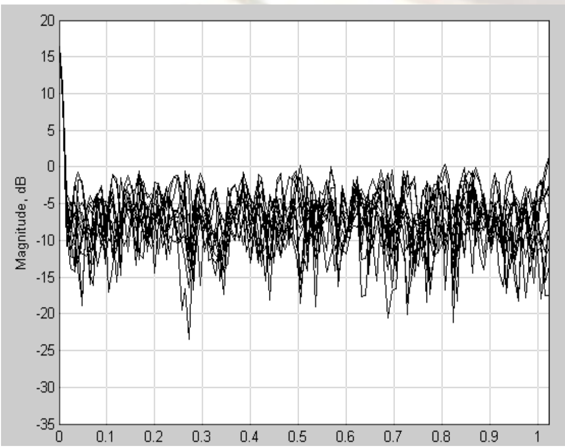

Figure 8. Autocorrelation diagram of CL.

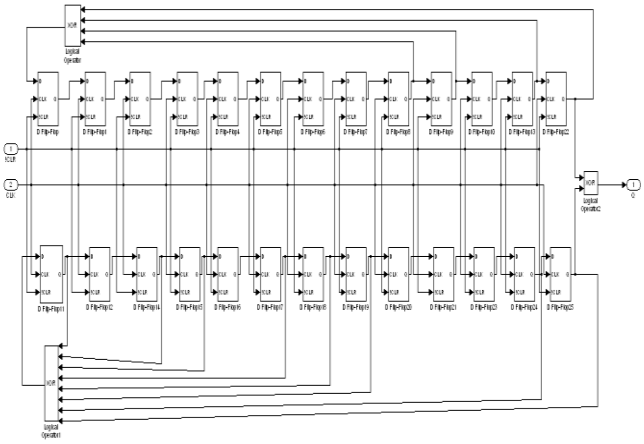

Figure 9(a) L5 code generator

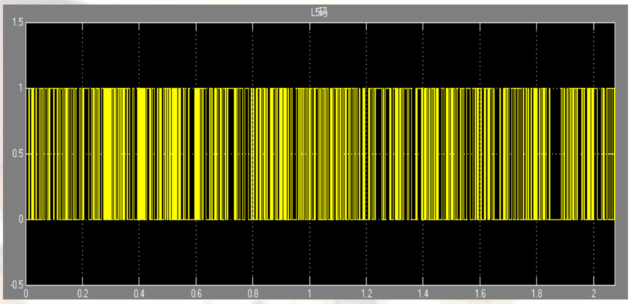

Figure 9(b). L5 code.

The spectra of the L5 signal is plotted in Fig. 10, the center frequency is 1176.45MHz.

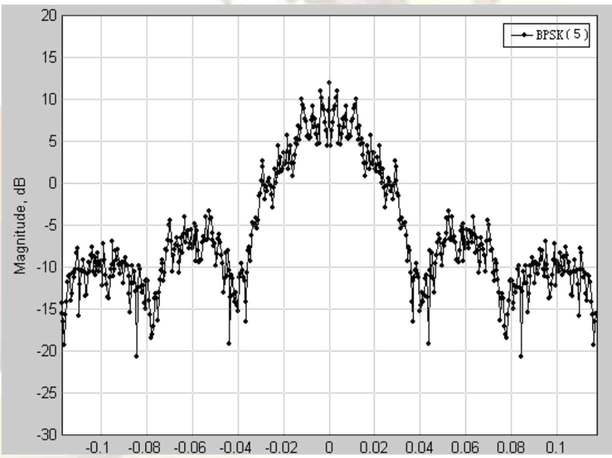

Figure 10. Power Spectral Density of L5 signal.

4.CONCLUSIONS:

This article discusses the structure of modern GPS new L2C and L5 civilian signals, analyses the principle and generation approach of the L2C ranging code and L5 two ranging codes in quadrature (I and Q channels), and then the modern GPS signals simulation was constructed based on Simulink. The modernized GPS signals, especially the L2C and L5 signals, will have wider civilian market. Although the new modernization of GPS has been declared, the most GPS receivers do not have ability of the receiving new signals. The research and implementation of the modernized GPS signals have an extensive applications prospect, which can provide a strong support for the engineering application.

As a result, Based on Simulink the modernized GPS L2C and L5 signals simulation can well reflect the building process of the modernized GPS. The structure of the GPS signals can be observed intuitionally from the Simulink simulation platform, which provides effective help to the design of simulation as well as various simulation algorithms. Besides, using Simulink to simulate GPS signals is simple and reliable.

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