

Design of Software GPS L2 Civil Signal Generator (ICCAS 2003)

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Abstract: This paper designs a software signal generator for the new GPS L2 civil signal. The CM/CL code and the message structure of L2CS described in GPS ICD PPIRN-200C-007 are used in designing the signal generator. The output of the GPS signal generator is designed as the sampled IF data with the sampling frequency 5.7MHz and stored in the binary data format. By analyzing both the spectrum characteristics of the output signal and the correlation properties of the CM/CL code, the validation of the designed GPS signal generator is shown. It should be mentioned that the modeling of the GPS satellite constellation and the error sources remains for implementing the software space segment of GPS.

Keywords: GPS, L2 Civil Signal, signal generator, IIR-M GPS satellites

1. Introduction

Most civil GPS users are relying on the L1 C/A-code signal which was originally intended only as an acquisition aid for the P(Y)-code. However, in the aspect of accuracy, it is difficult to eliminate the effect of the ionospheric delay if the receiver uses only L1 signal. Furthermore, in hostile reception environment, it is even difficult to acquire the GPS signal due to the poor cross-correlation properties of C/A-code.

To satisfy the increasing demands for improved GPS performance for civil users, the new L2 Civil Signal has been designed. This new signal will provide much improved cross-correlation protection relative to the C/A-code, improve the ionospheric delay correction capability and facilitate the ambiguity resolution. According to the GPS modernization plan, Block IIR-M GPS satellite will be launched from 2004, transmitting the civil code in L2 frequency as well as in L1 frequency with the updated signal structure. The positioning performance of the new GPS civil signal is expected about 3 meters (2dRMS) horizontally. The constellation of the next generation GPS satellites is scheduled to reach FOC (Full Operation Capability) in 2010. Therefore, it is necessary to design a signal transmitter, which can generate the new GPS civil signal, in order to design and test the GPS receiver tracking the new GPS civil signal.

This paper designs a software signal generator which will generate the new L2 civil signal. Section 2 summarizes the CM/CL code and the message structure of L2CS described in GPS ICD PPIRN-200C-007. In Section 3, a software-based L2civil signal generator is designed. The output of the GPS signal generator is the sampled IF data with the sampling frequency 18.53MHz and stored in the binary data format. In Section 4, the validity test of the designed GPS signal generator is performed by analyzing both the spectrum characteristics of the output signal and the correlation properties of the CM/CL code.

2. L2 Civil Signal Structure

The L2C signal contains two codes of different length, one of which provides a data message. The components of L2C signal can be summarized as follows:

- Code
 - CM : the moderate length code of 10,230 chip length, repeating every 29 millisecond and modulated with message data
 - CL : the long code of 767,250 chip length, repeating every 1.5 second without data modulation
- Data : the navigation message of 25bps data rate, FEC(Forward Error Correction) implemented, the same CNAV message structure as proposed for L5 signal
- Carrier frequency: 1227.6MHz
- Receiving Power : 2.3 dB lower than L1

The L2 signal generation scheme is shown in Fig.1. The signal options are controlled by four switches whose preferred positions are A1, B1, C1, D1. There are three options for the navigation message and the C/A code can be also transmitted optionally. The codes used in this satellite are CM and CL code each 10,230 and 767,250chips respectively. The CM code is modulated with the navigation message and chip-by-chip multiplexed with the CL code sequence resulting in the L2C code as shown in Fig. 2. Both the CM code and the CL code have a chip rate of 0.512Mchips/s. Hence, the chip rate of L2C code is 1.023Mchips/s which is same as that of the L1 C/A code.

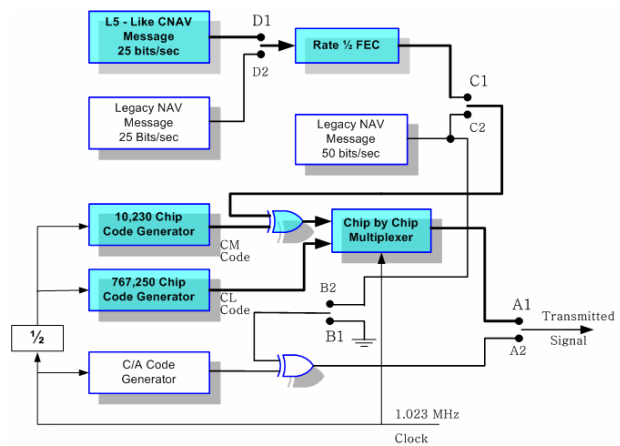


Fig. 1 L2C signal options in IIR-M satellite

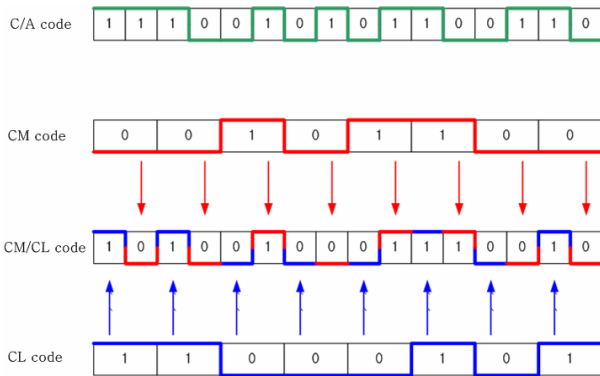


Fig.2 CM/CL code generation

The structure of the navigation message CNAV for L2C is basically same as that for the L5 signal. It is more compact and more flexible than that of the current NAV message. Instead of a fixed message format, CNAV allows the Control Segment to specify the sequence and timing of each message component consisting of 300 bit subframe. Since the data rate of the L2C signal is 25bps, each subframe requires 12 seconds to be transmitted. The message types are defined as follows:

- type 1 = Ephemeris message part 1
- type 2 = Ephemeris message part 2
- type 3 = Ionosphere, time biases, health bits, etc.
- type 4 = Almanac
- type 5 = Free form text message

3. Design of a Software L2C Signal Generator

The GPS L2C civil signal can be represented as

$$S_{L2}(t) = \sqrt{2P_c} D(t)C(t) \cos(\omega_{L2}t + \phi) \quad (1)$$

where P_c denotes the signal power, $D(t)$ denotes NAV data with binary format, $C(t)$ denotes the L2C code of 1,534,500 chip rate with the period of 1.5sec, ω_{L2} is the L2 carrier frequency (1227.6MHz) and ϕ denotes the phase error and oscillator drift error.

In generic GPS receivers, shown in Fig. 3, this signal is amplified, down-converted to IF signal, sampled and then processed to obtain the PVT information.

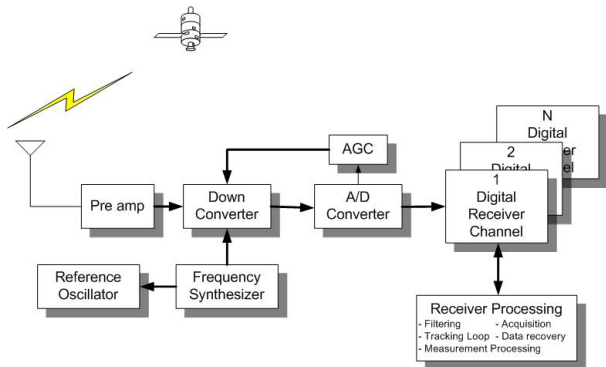


Fig. 3 The block diagram of generic GPS receivers

This paper designs a software-based L2C signal generator

whose output is the sampled IF data with the sampling frequency 5.7MHz and can be represented as

$$r_{if}(t_k) = s_{if}(t_k) + n_{if}(t_k) \quad (2)$$

$$s_{if}(t_k) = \sqrt{2P_{r_bp}} D_{bp}(t_k - \tau_r) C_{bp}(t_k - \tau_r) \cos(\omega_{if}t_k + \phi_r) \quad (3)$$

$$n_{if}(t_k) = x(t_k) \cos((\omega_{if} - \omega_{dopp})t_k) - y(t_k) \sin((\omega_{if} - \omega_{dopp})t_k) \quad (4)$$

$$\begin{aligned} \omega_{if} &= \omega_r - \omega_{LO} \\ &= \omega_{L2} + \omega_{dopp} - \omega_{LO} \end{aligned} \quad (5)$$

Fig. 4 shows the block diagram of the software L2C signal generator. The L2C navigation message (CNAV) of 25bps becomes the symbol stream of 50sps by the rate 1/2 FEC convolution encoder. This 50 sps stream is synchronized and modulo-2 added to the 511.5Kchips/s CM code of 10,230chips (period of 20ms). The resulting sequence is chip-by-chip multiplexed with the 511.5 Kchips/s CL code of 767,250 chips (period of 1.5s) to generate a combined sequence at 1.023Mchips/s. The output of the carrier generator is a digitized signal of 4.62MHz which is modulo-2 added to the L2C code resulting in the digitized GPS L2C signal. The added noise is assumed to be white Gaussian with the power spectral density of $N_0/2$.

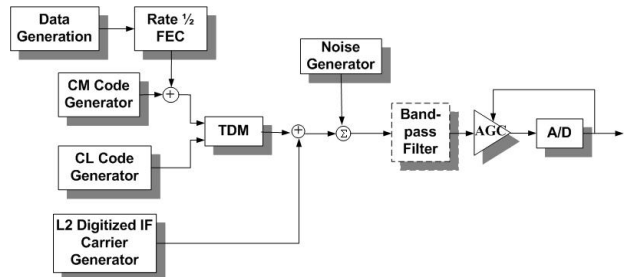


Fig. 4 Block diagram of GPS L2 signal generator

Fig. 5 shows the 27-stage shift register which is used to generate the L2C spreading code sequence. Depending on the initial state of the shift register, a particular CM or CL code sequence is selected. The shift register's end state is decoded to re-initialize the shift register with the initial state. The re-initialization mechanism is used to generate both the CM code with a period of 10,230 chips (20ms) and the CL code with a period of 767,250 chips (1.5s). The CM code is chip-by-chip multiplexed with the CL code, resulting in 75 repetitions of CM code for each CL code period. The initial state and the end state of the CM/CL code is prescribed in GPS ICD PPIRN-200C-007. The generated CM/CL code is perfectly balanced. The L2C navigation data will always be convolutionally encoded with a Forward Error Correction (FEC) of constraint length 7 as shown in Fig. 6. The digitized carrier signal for the L2C signal generator is generated using the carrier DCO shown in Fig. 7. The carrier DCO has an 18.53MHz sampling frequency and 4.62MHz output frequency as shown in Eq (6)

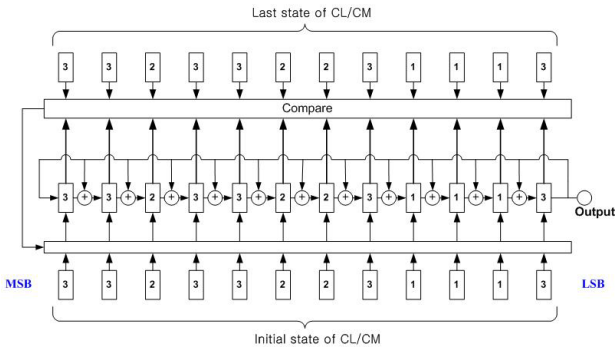


Fig. 5 CM/CL code generator

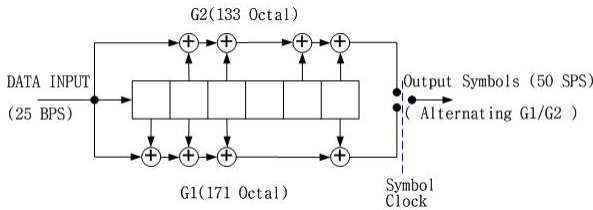


Fig. 6 Convolution encoder

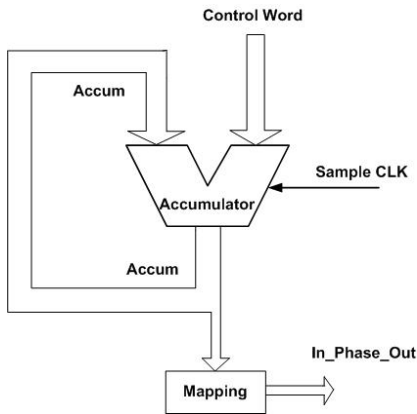


Fig. 7 Carrier DCO

$$f_o = \frac{w \times f_c}{2^N} \quad (6)$$

f_o : DCO output frequency = 4.62MHz
 where f_c : Sample clock frequency = 18.53MHz
 N : DCO length(bits) = 29
 w : DCO control word = 0x7FA794C

4. Simulation results

In this section, by analyzing both the spectrum characteristics of the output signal and the correlation properties of the CM/CL code, the validity test of the designed GPS signal generator will be performed. Fig. 8 and Fig. 9 show the auto-correlation and cross-correlation result of the generated CM code sequence. The maximum value of the auto-correlation and the cross-correlation is 10,230 and 300, respectively. As a result, the correlation protection value (the ratio of the auto-correlation and cross correlation value) is

obtained by

$$\text{Correlation Protection} = 20\log\left(\frac{10230}{30}\right) = 30.7 \text{ (dB)}$$

which is 10dB larger than that of the L1 C/A code as expected.

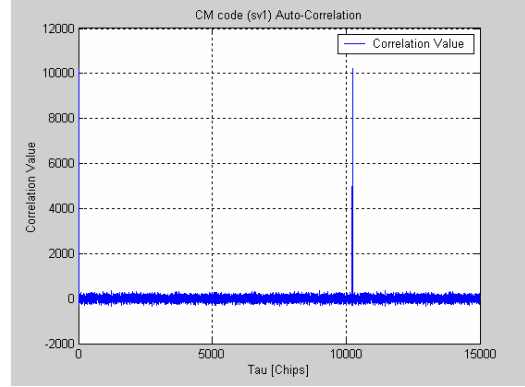


Fig. 8 Auto-correlation of the generated CM code

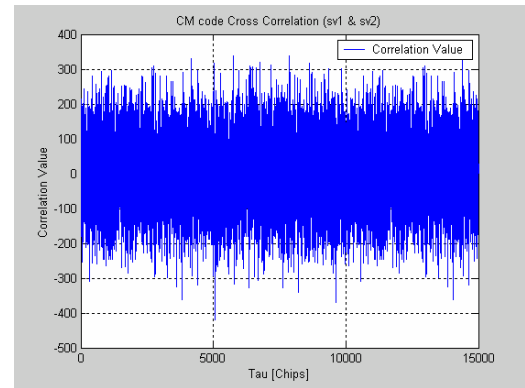


Fig. 9 Cross-correlation of the generated CM code

Fig. 10 and Fig. 11 show the auto-correlation and cross-correlation result of the generated CL code sequence. The maximum value of the auto-correlation and the cross-correlation is 767,250 and 4,000, respectively. As a result, the correlation protection value is obtained by

$$\text{Correlation Protection} = 20\log\left(\frac{767250}{4000}\right) = 45.6 \text{ (dB)}$$

which is 25dB larger than that of the L1 C/A code.

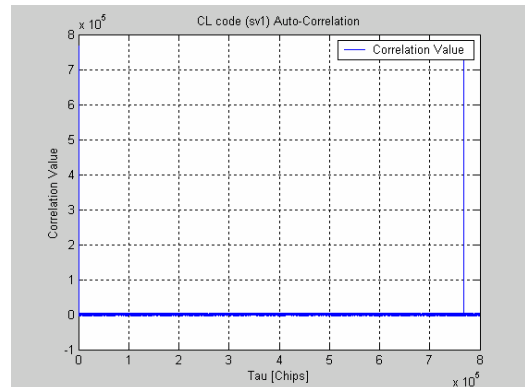


Fig. 10 Auto-correlation of the generated CL code

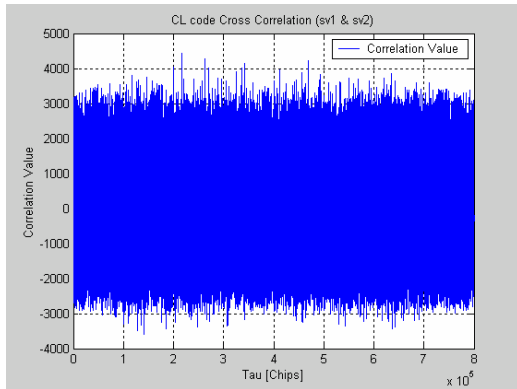


Fig. 11 Cross-correlation of the generated CL code

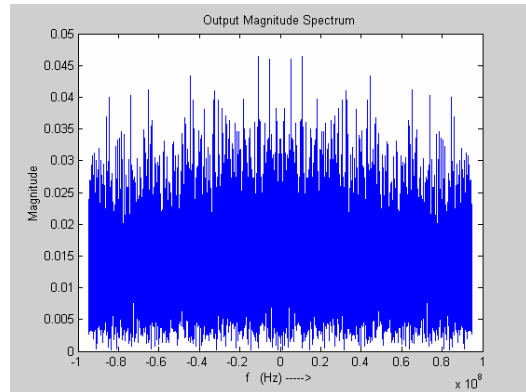


Fig. 14 Spectrum of the designed L2C signal

Fig. 12 shows the generated carrier with the frequency of 4.62MHz.

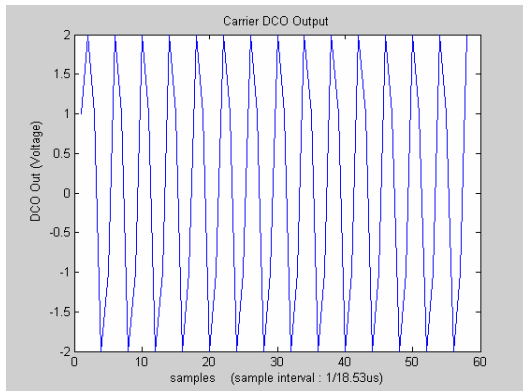


Fig. 12 The output of carrier generator

Fig. 13 shows the spectrum of the generated carrier, and Fig. 14 shows the spectrum of the generated carrier spreaded by the CM/CL code. From these, it can be seen that the designed signal generator works as expected.

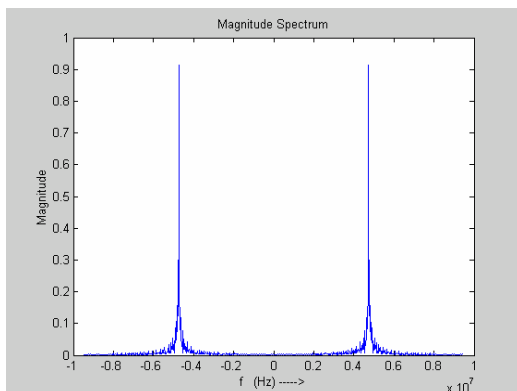


Fig. 13 Spectrum of the generated carrier

5. Conclusions

This paper designed a software signal generator for the new GPS L2 civil signal. The output of the GPS signal generator is the sampled IF data with the sampling frequency 5.7MHz and stored in the binary data format. By analyzing both the spectrum characteristics of the output signal and the correlation properties of the CM/CL code, the validation of the designed GPS signal generator was done. It should be mentioned that the modeling of the GPS satellite constellation and the error sources remains for implementing the software space segment of GPS.

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