Correlator Design for L1/L2C GPS Signal

Jae-Won Chang*, Keun Taek Kim, and Sang Jeong Lee**

*Aircraft Division of General Aviation Department, Korea Aerospace Research Institute, 45 Eoeun-Dong, Yuseong-gu, Daejeon 305-764, Korea (Tel : 82-42-860-2946 ; Fax : 82-42-860-2009 ; E-mail : zdream@kari.re.kr)

** Department of Electronics Engineering, Chungnam National University, 220 Gung-dong, Yuseong-gu, Daejeon 305-764, Korea (Tel : 82-42-825-3991; Fax : 82-42-823-4494)

Abstract: GPS provides two services which include SPS(Standard Positioning Service) and PPS(Precise Positioning Service). While SPS users can navigate in more precise due to cancellation of SA(Selective Availability), SPS users has still less precision navigation than PPS users. L1/L2CS integrated receiver can provide more precise navigation to SPS users because the delay of Ionosphere will be cancelled by using two frequencies (L1 and L2). This paper designs an integrated L1/L2CS digital correlator to prepare the L2C signal that will be provided in 2003. Also L2CS transmitter is designed to confirm L2CS correlator.

Keywords: GPS, Navigation, Correlator, FPGA, L1 C/A, L2CS

1. INTRODUCTION

The Block IIR GPS satellites broadcast three navigation signals; C/A on L1, P or P/Y on L1, and P or P/Y on L2. Among these signals, only the C/A code on the L1 frequency is available for civil users. 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. The Block IIR-M satellites which will be scheduled for full operation capability (FOC) until 2010 will provide not only the C/A signal on the L1 frequency (L1 C/A) but also the civil signal on the L2 frequency (L2CS). When both L1 C/A and L2C signal is available, the ionospheric delay can be remove so that the positioning accuracy is expected within 3 meters horizontally. Furthermore, the L2CS has much improved cross correlation protection than L1 C/A, which can make it possible to fix the position in hostile environments like under foliage or indoor.

This paper designs the digital correlator for L1/L2CS GPS receivers. In section 2, the structure of the new L2 civil signal is summarized. The cross correlation protection property is checked and compared with that of L1 civil signal. Section 3 designs the digital correlator for treating both the L1 and L2C signal. In section 4, a test procedure for the designed correlator is suggested. Finally, some concluding remarks are given in section 5..

2. PROPERTIES OF L2 CIVIL SIGNAL

This section summarizes the signal structure of the L2CS and examines the cross-correlation protection property of the L2CS comparing with that of L1 civil signal through simulation.

2.1 The structure of the L2CS

It is well known that the GPS L1 C/A code is Gold code which is generated by two 10-bit shift registers, G1 and G2. There are three methods to generate L1 C/A code ; tap, delay, and state initialization. Figure 1 shows the state initialization method which easier to design hardware than the other methods.

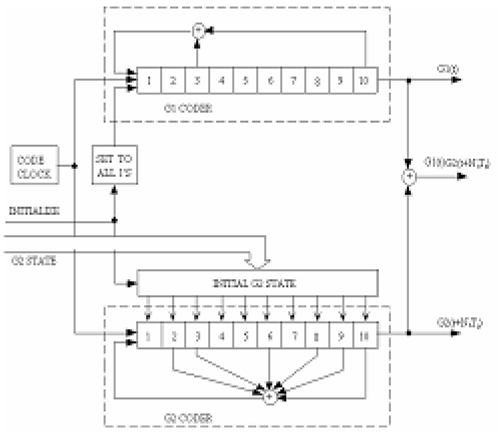

Fig 1. L1 C/A Code Generator

The L2CS code is the maximum length code generated by setting the start value and the end value of 27 bit shift register. Figure 2 shows the structure of the L2CS code generator.

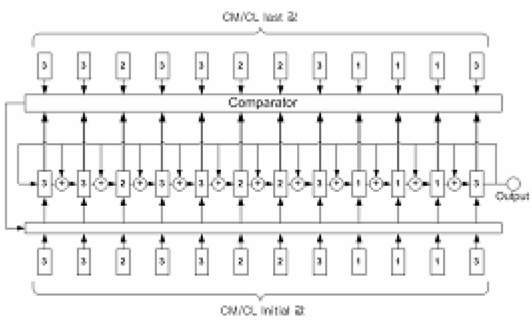

Fig 2. L2CS Code Generator.

The length of code which is generated from N-bit shift register is decided by

$$Number\ of\ Chips = 2^N - 1 \tag{1}$$

where N is the bit number of shift register. For instance, the bit number of L1 C/A code is 10 and the length is 1023 bits(chips). The chipping rate of the L1 C/A code is 1.023MHz, and the period of the pseudo random sequence is 1 millisecond. The bit number of L2CS code is 27 and the total length of L2CS code is 134,217,727. The chipping rate of the L2CS is 0.512MHz, and the period of pseudo random sequence is 262 sec. Figure 3 shows the generation method of the L1 C/A code, and Figure 4 shows the generation method of the L2CS code. Unlike the generation method of L1 C/A code, each L2CS code is chosen from the maximal length code by setting the start value and the end value. The L2CS code consists of two codes: the L2CS moderated length code (CM) and the L2CS long code (CL). The period of the CM code is 20msec and the period of the CL code is 1.5sec. The L2CS code is generated by chip by chip time-division-multiplexed (TDM) using these two codes. Even though the frequency of the CM code and the CL code is 0.512Mhz, the frequency of L2CS is 1.023MHz due to chip by chip TDM method.

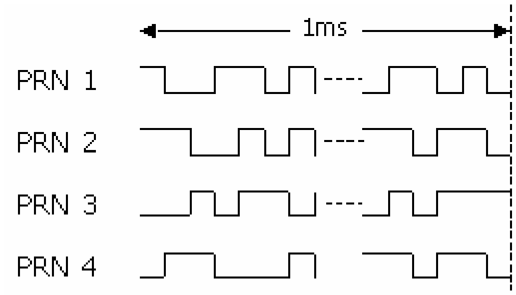

Fig 3. L1 C/A PRN Code.

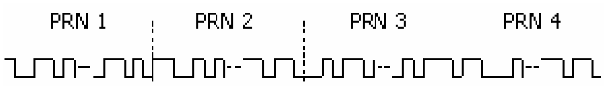

Fig 4. L2CS PRN Code.

Table 1 shows the characteristics of L1 C/A, L2 CM, and L2 CL code.

Table 1. Code characteristics.

	L1 C/A	L2 CM	L2 CL
Code Type	Gold Code	Maximal Length code	Maximal Length code
Chipping rate (Mchips/sec)	1.023	0.512	0.512
Code length (Chips)	1,023	10,230	767,250
Period (msec)	1	20	1500
Carrier Frequency (MHz)	1575.42	1227.60	1227.60
Data modulation (BPS)	50	25	No data

2.2 Cross correlation protection property

In this section, the autocorrelation and crosscorrelation characteristics of L2CS code are examined. Figure 5 shows the autocorrelation characteristics of the PRN 1 L1 C/A code. The maximum correlation value is 1,023. Figure 6 shows the cross correlation characteristics between the PRN 1 and the PRN 2 L1 C/A code. The maximum correlation value is 65. Figure 7 shows the autocorrelation characteristics of the PRN 1 L2CS code. The maximum correlation value is 1,534,500. Figure 8 shows the cross correlation characteristics between the PRN 1 and the PRN 2 L2CS code. The maximum correlation value is about 6000.

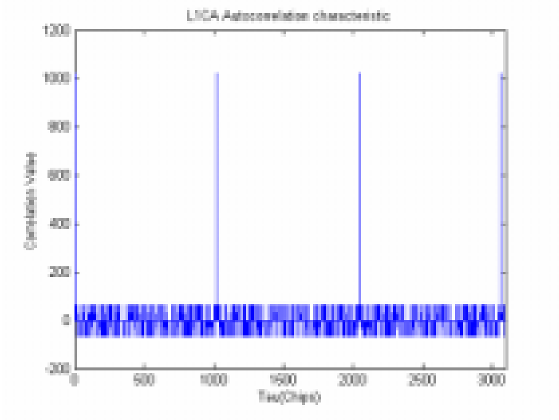

Fig 5. Autocorrelation characteristics of L1 C/A code

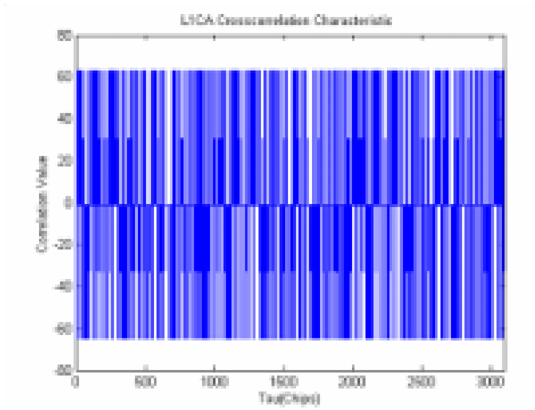

Fig 6. Cross correlation characteristics of L1 C/A code

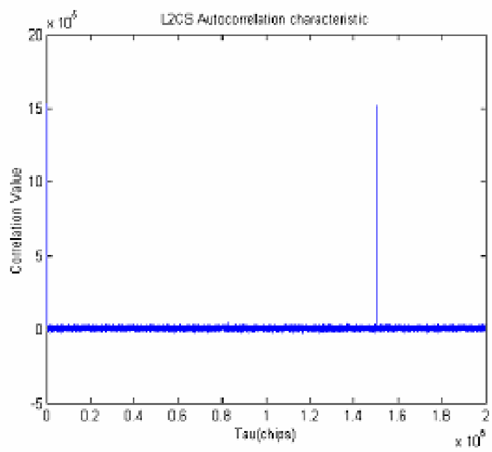

Fig 7. Autocorrelation characteristics of L2CS code

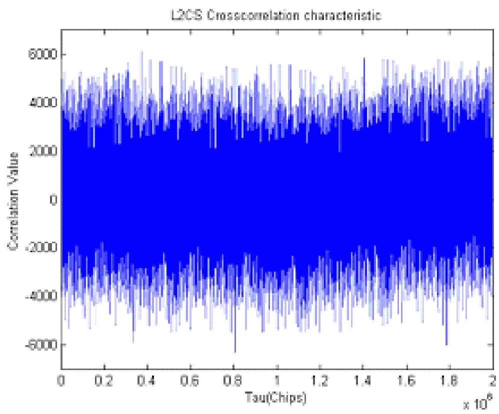

Fig 8. Cross correlation characteristics of L2CS code

Table 2 summarizes the correlation properties of L1 C/A and L2CS code. In the worst case considering the doppler effect, the correlation protection of L1 C/A and L2CS code is known to be 21dB and 45dB, respectively. Since the doppler effect is not considered in the simulation, the simulation result is higher than the worst case. It can be seen that the correlation protection of the L2CS code is 24dB better than that of the L1 C/A code.

Table 2. Comparison of the L1 C/A and the L2CS code

	Period	Auto-correlation	Cross-correlation	Correlation Protection	
				Simulation	Worst case
L1 C/A	1ms	1,023	65	24dB	21dB
L2 CS	1.5 s	1,534,500	6,000	48.2dB	45dB

3. DIGITAL CORRELATOR FOR L1/L2C GPS SIGNAL

This section designs the digital correlator for tracking L1/L2CS civil signal. It consists of the interface block, the tracking module block, and the control block. The digital correlator is designed using SYNOPSYS and inplemented on Altera FPGA.

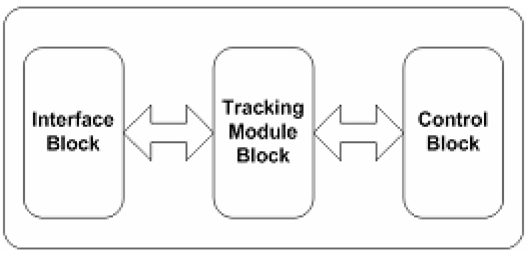

Fig 9. L1/L2CS integrated correlator.

The function of the interface block is to control the input and output signal between the correlator and RF front end/processor. The control block controls the tracking module block to acquire and track the satellite signal. Each channel in the tracking module block can be assigned to track the L1 C/A code or L2CS code. Figure 10 illustrates the code generator in the tracking module block. The CM code generator and the CL code generator have the same structure, but they can be distinguished by the start value and end value. The code generator is designed to generate the C/A code, the CM code, and the CL code. By setting proper value to the mode selector, the output of the code generator becomes the C/A code, the CM code, the CL code, or the CM/CL(TDM) code.

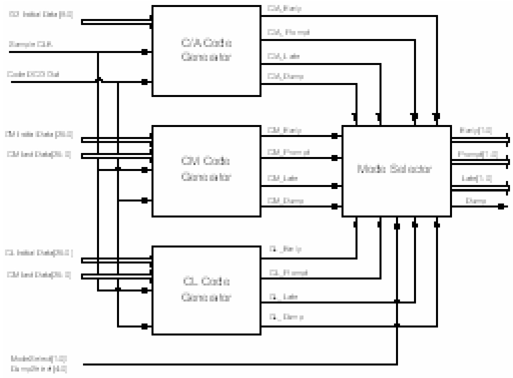

Fig 10. L1/L2CS Code Generator.

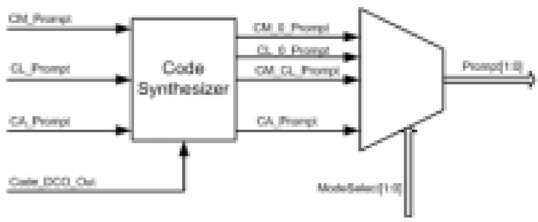

Fig 11. Mode Selector.

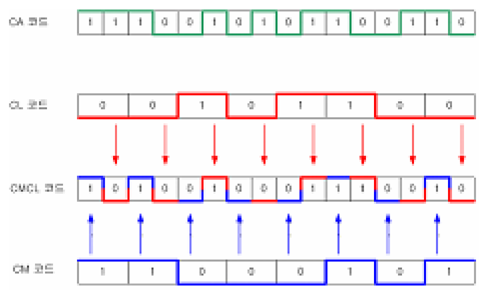

Fig 12. Mode Selector output codes.

4. EXPERIMENT

The performance of the designed correlator is examined in this section. First, the performance of the designed L1 correlator is tested using live GPS signals. Since the live L2CS signal is not available at present, two experiment methods are suggested to verify the performance of the L2CS correlator ; a simulation method using test signals, an experimental method using a L2CS transmitter.

Figure 13 shows the experimental result of static positioning using live GPS L1 signal. The circular error probable of the designed correlator for the GPS L1 C/A code is about 1.9m.

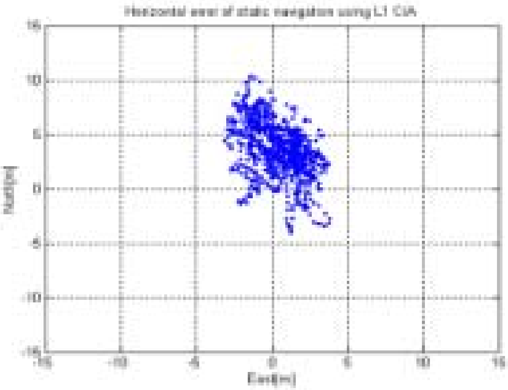

Fig 13. Horizontal error of static navigation (GPS L1 Signal).

To verify the performance of the designed L2CS correlator, a test signal can be generated. Figure 14 shows the test signal generator. The verification of the designed correlator can be simulated using this signal.

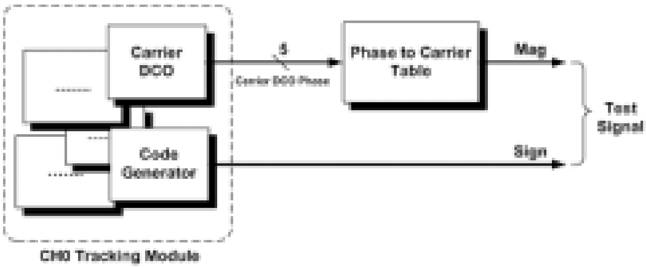

Fig 14. Test Signal Generator.

Another way to test the performance of the designed L2CS correlator is to design a L2CS code transmitter. Figure 15 shows the structure of the L2CS code transmitter designed in this paper. Figure 16 shows the output signal of the designed transmitter. It can be seen that the designed transmitter works well. It remains for further study to test the performance of the designed correlator using the transmitter.

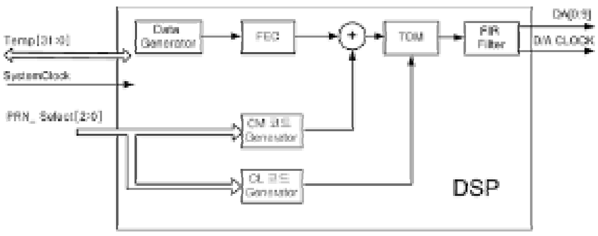

Fig 15. Structure of Designed L2CS Transmitter.

The figure 16 shows the output signals of designed transmitter and the results of simulation.

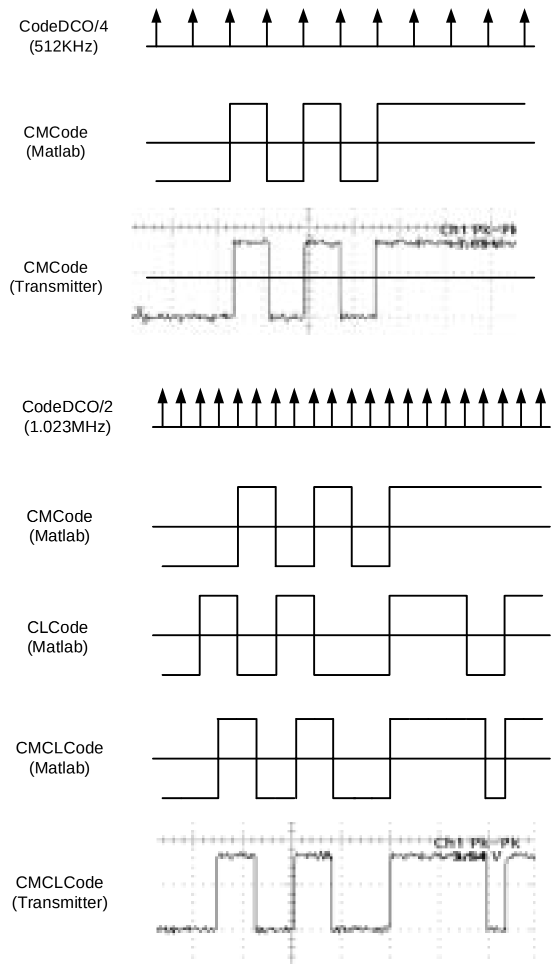

Fig 16. The output signals of Transmitter.

5. CONCLUSIONS

This paper designed the digital correlator for L1/L2CS GPS receivers. The structure of the new L2 civil signal was summarized, and the cross correlation protection property was examined and compared with that of L1 civil signal. The designed digital correlator consists of the interface block, the tracking module block, and the control block. It was designed using SYNOPSYS and inplemented on Altera FPGA. Also suggested was a test procedure for the designed correlator.

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