http://dx.doi.org/10.5370/JEET.2011.6.5.723

Rapid Acquisition of CM and CL Code for GPS L2C Software Receivers

Keum-Cheol Kwon* and Duk-Sun Shim†

Abstract – The GPS modernization program offered a new civil signal on the L2 band, and the first modernized GPS Block IIR satellite was launched in September 2005. Currently, eight GPS Block IIR-M satellites and two Block IIF satellites transmit L2C signal. The L2C signal contains two codes of CM and CL that are much longer than the L1 C/A code. Thus, the acquisition of the CM and CL codes takes more time compared with that of L1 C/A code. Under the assumption that the L2C signal is strong enough for detection, this paper suggests rapid acquisition methods for the GPS L2C signals for software receivers and compares its performance with that of other methods.

Keywords: GPS, Acquisition, L2C, Modernization, Software receiver

1. Introduction

After the launch of the first modernized GPS Block IIR satellite in September 2005, there are now 10 GPS satellites transmitting L2C signal including two Block IIF satellites. It contains two codes, namely, CM and CL of different lengths. The length of the L2 CM code is 20 msec, whereas that of the CL code is 1.5 sec, which makes the acquisition time of the L2 CM/CL code longer than that of the L1 C/A code case.

Various studies on the L2C signal have been performed since the early 2000s, whereas performance assessment of new signal design and the potential benefits of L2C receivers have been studied only in the early and mid 2000s ([1]–[4] and references therein). On the other hand, studies on L2C signal acquisition and tracking algorithms have also been conducted.

For the GPS L2C receiver design, rapid acquisition of L2C signal is necessary because the L2C CM/CL code is much longer than the L1 C/A code, and thus a number of studies have focused on acquisition [5]–[9]. Block processing Fast Fourier Transform (FFT) algorithms have been developed to perform signal acquisition for CM and CL codes [5] and FFT-based techniques for acquisition of L2C signals have been suggested for both CM and CL codes [6]. A rapid acquisition method of CL using the orthogonality of shifted versions of the CL code has also been suggested [7]. Acquisition and fine acquisition algorithms for weak L2C signal have been developed using the structures and properties of L2C to achieve high performance with reduced processing and memory requirements [8]. Software receivers have also drawn increasing attention due to their flexibility in demodulating a number of distinct RF transmissions and removing several analog components at the RF band [10].

In this paper, a rapid acquisition method for the L2C CM/CL codes for software receivers is suggested under the assumption that the L2C signal is strong enough to permit detection with 20 msec integration. The performance of the suggested method is compared with that of existing acquisition methods using live L2C and simulated data. Section 2 introduces the GPS L2C signal structure. Existing and proposed acquisition methods for GPS L2C CM and CL codes are given in Sections 3 and 4, respectively. Section 5 shows the acquisition results, and conclusions are given in Section 6.

2. GPS L2C signal structure

2.1 L2C Signal Structure

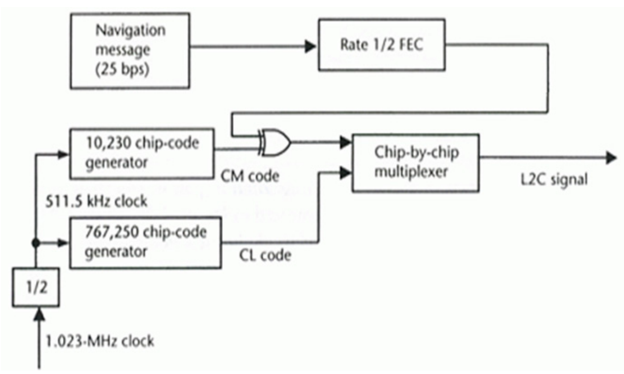


Fig. 1. L2C Signal Structure

The L2C signal structure is shown in Fig. 1. The L2C signal is composed of two ranging codes, namely, L2 CM

† Corresponding Author: School of Electrical and Electronics Engineering, Chung-Ang University, Korea. (dshim@cau.ac.kr)
* School of Electrical and Electronics Engineering, Chung-Ang University, Korea. (casey518@naver.com)
Received: April 1, 2011; Accepted: July 16, 2011

(moderate) and L2 CL (long). The L2 CM code is 20 msec long and contains 10230 chips, whereas the L2 CL code has a period of 1.5 sec and contains 767250 chips. The CM code is modulo-2 added to the data (i.e., it modulates the data) and the resultant sequence of chips is time-multiplexed with the CL code on a chip-by-chip basis, as shown in Fig. 2. The individual CM and CL codes are clocked at 511.5 kHz, whereas the composite L2C code has a frequency of 1.023 MHz. Code boundaries of CM and CL are aligned, and each CL period contains exactly 75 CM periods. This time multiplexed L2C sequence modulates the L2 (1227.6 MHz) carrier.

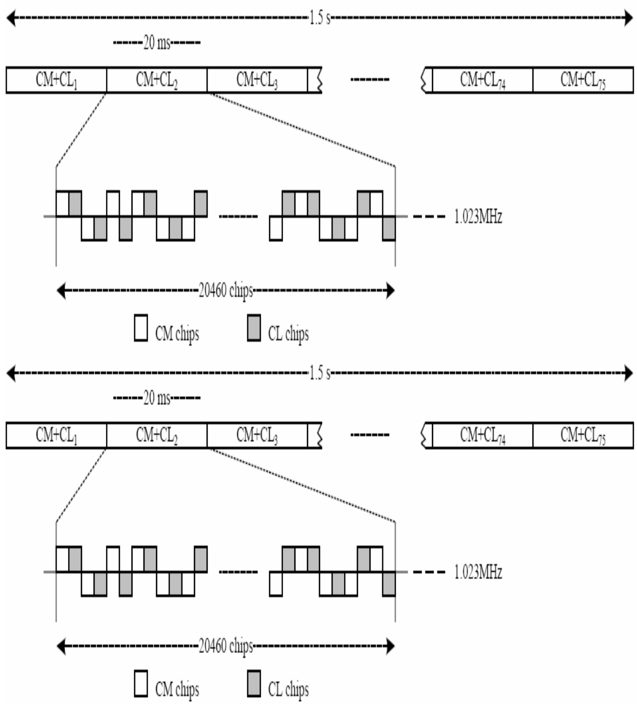


Fig. 2. L2C CM/CL Code Structure [4]

2.2 GPS L2C replica code

The GPS L2C signal has a TDM structure for CM and CL codes, for which acquisition should be performed sequentially. There are many combinations of local replica code for CM and CL, including Return to Zero CM (RZ CM), Return to Zero Extended CM (RZ ECM), and Non Return to Zero CM (NRZ CM). Among these combinations, RZ CM offers the best acquisition sensitivity and cross-correlation performance, making it a good choice for weak signal environments [4].

3. Acquisition of GPS L2C CM and CL Codes

We assumed that the L2C signal is strong enough to permit detection with 20 msec integration. The purpose of the acquisition is to identify all visible satellites to users. For the visible satellites, the outputs of the acquisition are Doppler frequencies and code phases.

3.1 L2C CM acquisition methods

The basic acquisition method for the L2C CM code is similar to that for the L1 C/A code. In this work, the length of the CM code is 20 msec, and thus, received data should be correlated with the generated L2C CM local replica code. Usually, the RZ CM code is used. To save time, FFT is used for time correlation.

3.1.1 Basic 20msec FFT

The basic CM acquisition method is shown in Fig. 3. For the generated code, the CL part can be ignored, and the CM-CM code or CM-zero code can be used in place of the CL code. Of the two, the CM-zero code shows the best cross-correlation performance.

The goal of acquisition is to perform a correlation with the incoming signal and a generated PRN code. Instead of multiplying the input signal with a PRN code similar to what is done in a serial search acquisition method, it is more convenient to perform a circular cross correlation between the input and the PRN code without the shifted code phase. A method of performing circular correlation through Fourier transforms has been reported [11].

The discrete Fourier transforms of the finite length sequences $x(n)$ and $y(n)$, both with length N, are computed as

$$X(k)=\sum_{n=0}^{N-1}x(n)e^{-j2\pi kn/N} \quad \text{and} \quad Y(k)=\sum_{n=0}^{N-1}y(n)e^{-j2\pi kn/N}.$$

The circular cross-correlation sequence between two finite length sequences $x(n)$ and $y(n)$ (both with length N and with periodic repetition) is computed as

$$z(n)=\frac{1}{N}\sum_{m=0}^{N-1}x(m)y(m+n)=\frac{1}{N}\sum_{m=0}^{N-1}x(-m)y(m-n)$$

In the following, the scaling factor $1/N$ is omitted. The discrete N-point Fourier Transform of $z(n)$ can be expressed as

$$Z(k)=\sum_{n=0}^{N-1}\sum_{m=0}^{N-1}x(-m)y(m-n)e^{-j2\pi kn/N}=X^{*}(k)Y(k),$$

where $X^{*}(k)$ is the complex conjugate of $X(k)$.

When the frequency domain representation of the cross correlation is found, the time-domain representation was also found through inverse Fourier Transform, as shown in Fig. 3.

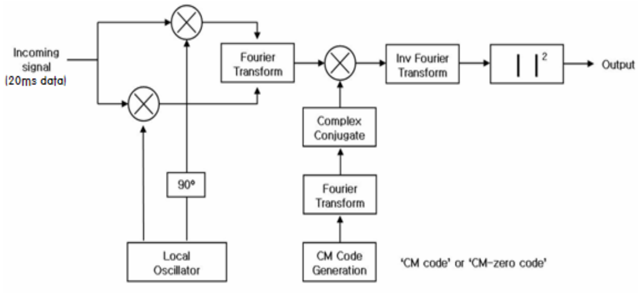


Fig. 3. Basic L2C CM acquisition

3.1.2 40 msec FFT [6]

The algorithm of the 40 msec FFT is the same as that of the 20 msec FFT. The only difference is that 40 msec data is used instead of 20 msec data. Moreover, the incoming signal used for FFT is that of 40 msec data instead of the 20 msec data shown in Fig. 3. The generated code for the 40 msec consisted of 20 msec of CM code and zeros of the same amount. For the correlation result, only the first 20 msec is used for peak detection.

3.1.3 20 msec Segmented FFT [6]

Taking the FFT on code sequences for 20 msec of CM code may seem like a formidable task. To reduce the computational burden and other possible issues, segmented FFT has been suggested in [6]. Due to possible data sign reversal, the incoming signal samples are held in a double length buffer, which is 40 msec long, and divided into 6 smaller segments denoted by S1 to S6 as reported in [6]. The local generated code replica is 20 msec long, which is segmented into parts with the same size denoted by R1, R2, and R3, respectively. In the present work, circular correlation is performed between the zero-padded S1 and joined R1 plus R2 using FFT. The segmented correlations between S1 through S6 and R1 through R3 were then added to form the final correlation values, and only the first half was used for peak detection.

3.2 L2C CL acquisition method

Once the CM code is acquired, the acquisition of CL code becomes simple. As the beginning point of CM code for the received data is known, only 75 segments of the generated CL replica code are tested with the received data of 20 msec.

3.2.1 Basic 20 msec FFT

Once the CM code acquisition is completed, the CM code phase is obtained. One CL code period contained 75 CM code sequences. Thus, the beginning point of CL code is obtained by comparing 75 segments of the generated CL replica code and the aligned received data of the 20 msec using the FFT method.

3.2.2 20 msec Hyper Code FFT [7]

In theory, different segments of CL code are mutually orthogonal; thus, a linear superposition of multiple segments of the CL code results in a shorter code containing all of the information in the total CL code. This is called a Hyper code [7]. Fig. 4 shows that 1.5 sec CL code is broken into M different segments (M=25 here), which are summed up to form a Hyper code. A total of 25 Hyper codes are correlated with a segment of received data, which is 20 msec long using FFT method. For the selected Hyper code, which is shown for maximum correlation, three original CL codes are retested for correlation with a segment of received data using the FFT method. With this method, the number of correlations is reduced from 75 to 28.

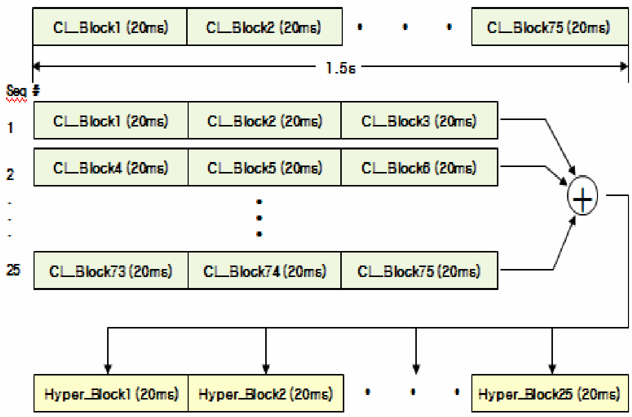


Fig. 4. L2C CL Hyper Code Method (M=25 case)

4. Rapid L2C Acquisition Method

We assumed that the L2C signal is strong enough to permit detection with 20 msec integration. The acquisition time for the L2C CM and CL codes is much longer than that of L1 C/A code. Hence, the objective of the rapid L2C acquisition is to reduce acquisition time. Therefore, rapid acquisition methods for both CM and CL codes are used in this work.

4.1 10 msec CM-mix code method for CM acquisition

The acquisition time for the CM code is much longer than that for the CL code, because the Doppler frequency step should be decreased to 50 or 25 Hz due to the integration time of the 20 msec. The acquisition time for the CM code is reduced using the CM-mix code, which is obtained from the CM replica code being broken into two 10 msec segments and then added to binary addition, as shown in Fig. 5. The CM-mix code is correlated with 10 msec received data using FFT. When the code phase is

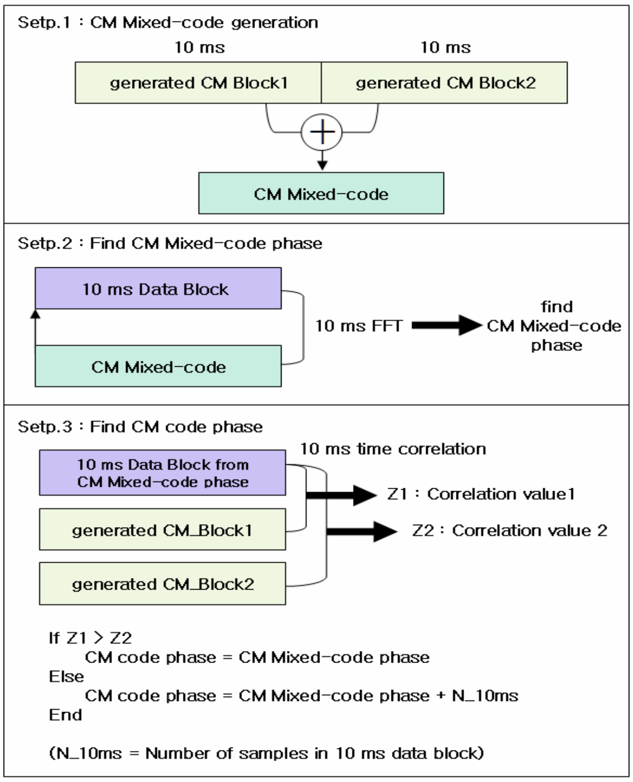


Fig. 5. L2C CM-mix code Method for CM Acquisition

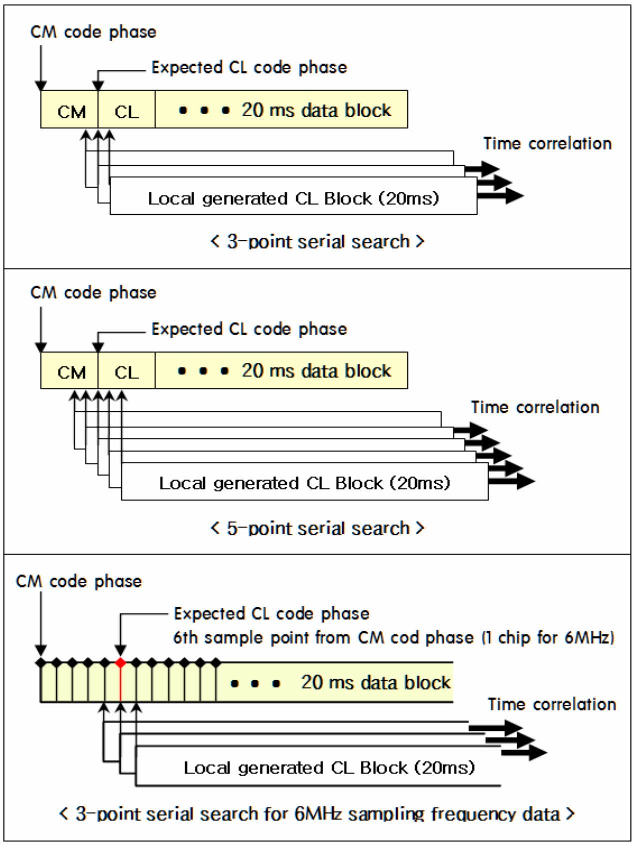


Fig. 6. N-point serial Search for CL Acquisition

obtained for the 10 msec data, which of the 10 msec segments belong to the CM code phase is determined following step 3 in Fig. 6. The 10 msec 1-point time correlation is used here instead of 10 msec FFT. The meaning of N-Point is explained in Fig. 6.

4.2 N -Point serial search for L2C CL acquisition

After the CM acquisition, 75 segments of the generated CL replica code are tested with the received data of 20 msec. As the CM code phase was known, time correlation is used instead of FFT, which was the N -point serial search.

The Doppler shift is time varying, thus, it is necessary to perform serial search for N times before and after the expected CL code phase, as shown in Fig. 6.

The number of N -point depends on the sampling frequency f_s. Lemma 1 provides the method for determining the number of N .

Lemma 1. Consider the N-Point serial search method for the L2C CL code acquisition. Suppose that the number of sampling points in each chip is an integer, and that L2C CM acquisition is completed with the carrier Doppler frequency step $\Delta f_{L2Ccarrier} = 25Hz$ or $50Hz$. Let f_s be the sampling frequency. Then we let $N = 3$ for $f_s < 16.39MHz$ when $\Delta f_{L2Ccarrier} = 25Hz$. Similarly, we also let $N = 3$ for $f_s < 8.20MHz$ when $\Delta f_{L2Ccarrier} = 50Hz$.

Proof: Suppose that $\Delta f_{L2Ccarrier} = 25Hz$, then the Doppler frequency shift on the CM/CL code is $\Delta f_{L2Ccode} = 25Hz/1200 = 0.0208Hz$. When the Doppler shift $\Delta f_{L2Ccode}$ for 1.5 sec is less than half the sampling period, only the three adjacent points need to be compared to detect the peak of the correlation, that is, $\frac{1.023\times10^6}{2f_s} > 0.0208\times1.5$, which gives $f_s < 16.39MHz$. Similarly, $f_s < 8.20MHz$ when $\Delta f_{L2Ccarrier} = 50Hz$.

4.3 N-point search with hyper code for CL acquisition

N-point serial search can be combined with the Hyper code method for CL acquisition. After a Hyper code for the identified maximum correlation was selected, three original CL codes are retested for correlation with a segment of received data using N-point search instead of the FFT method. With this method, the 20 msec FFT is performed 25 times, and the N-point serial search is performed with three original CL codes for the selected Hyper code.

5. Acquisition Results

5.1 Computing environment

The CPU is an Intel quad-core i7 (2.93 GHz) with 4GB

RAM, and MATLAB was used for computation. The GPS L2C data were obtained from two sources, namely, real and simulated data.

Live data were obtained at 21:00 on March 17, 2011 from the signal tap made by ACCORD Software & Systems Pvt. Ltd. The sampling frequency (f_s) of the live data was 6 MHz. Simulated data was obtained from Spirent Simulator using an RF module with intermediate frequency of 140 MHz and sampling frequencies of 6 and 22.4 MHz.

5.2 L2C CM acquisition results

Four acquisition methods of 20 msec FFT, 40 msec FFT, 20 msec segmented FFT, and 10 msec Mix-code were compared with live data with f_s =6 MHz and with simulated data with f_s =6 and 22.4 MHz. The performance index for acquisition referred to how long it took at less time. Matlab was used for calculations. Thus, absolute time taken for acquisition was less meaningful than relative time among the acquisition methods. Table 1 shows that the basic method of 20 msec FFT is better than the 40 msec FFT and 20 msec Segmented FFT methods. The 10 msec Mix-code method takes less time than 20 msec FFT, but some satellites are not acquired because noises for 10 msec Mix-code method are added and thus C/N ratio deteriorates.

Table 1. Results of L2C CM Acquisition

CM Acquisition			Live Data (2011, 6MHz)		Simulated Data (2008, 6MHz)		Simulated Data (2011, 22.4MHz)	
			Time (sec)	No. of Acquired	Time (sec)	No. of Acquired	Time (sec)	No. of Acquired
20ms FFT	Freq. Bin	25Hz	5.4	4	5.3	6	25.4	10
40ms FFT	Freq. Bin	25Hz	12.7	4	13.2	6	52.4	10
	Freq. Bin	50Hz	6.4	4	6.5	6	26.2	9
20ms Segmented FFT	Freq. Bin	25Hz	33.6	4	34.4	5	231	9
	Freq. Bin	50Hz	16.8	4	17.4	6	118	6
10ms Mix-code	Freq. Bin	25Hz	4.2	3	4.3	5	12.2	5
	Freq. Bin	50Hz	2.1	3	2.1	5	6.3	5

5.3 L2C CL acquisition results

Consider the results of four CL acquisition methods: 20 msec FFT, Hyper code FFT, Three-Point serial search, and Three-Point search with Hyper code. Table 2 indicates that the Hyper code FFT shows the worst result. Theoretically, the Hyper code FFT looks attractive because the number of 20 msec FFT operation in Hyper code FFT is much less than that of 20 msec FFT. However, it does not reduce the acquisition time compared with the Three-Point serial search method. Moreover, it does not track all the satellites. For the Three-Point serial search method, only 10 msec data can be used for correlation if the signal is strong enough. For the 22.4 MHz sampling rate, the Three-Point search with Hyper code can reduce CL acquisition time compared with Three-Point search method.

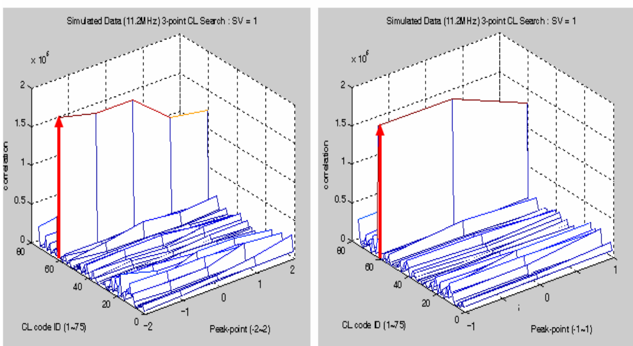
Table 2. Results of L2C CL acquisition

CL Acquisition		Live Data (2011, 6MHz)		Simulated Data (2008, 6MHz)		Simulated Data (2011, 22.4MHz)	
		Time (sec)	No. of Acquired	Time (sec)	No. of Acquired	Time (sec)	No. of Acquired
20ms FFT	20ms	0.9	4	0.9	6	4.3	10
Hyper-code FFT	20ms	0.5	3	0.5	6	2	7
3-point Serial Search	20ms	0.5	4	0.5	6	3.7	10
	10ms	0.3	4	0.3	6	1.8	10
3-point Search with Hyper-Code	20ms	0.5	4	0.4	6	2.4	10
	10ms	0.4	4	0.3	6	1.4	10

In Tables 1 and 2, the number of acquired satellites refers to the number for which tracking is successful. The CNAV data decoding is, therefore, successful.

5.4 Choice of N for N-point serial search for CL acquisition

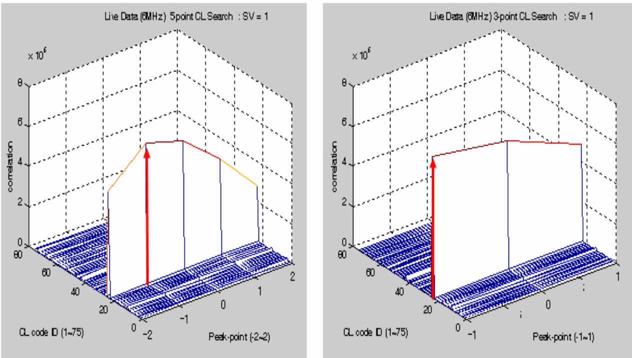
For the N-Point Serial Search method in Section 4.2, the number N has to be chosen. Lemma 1 shows that it depends on the sampling frequency f_s . Fig. 7 shows the correlation results of the N -Point serial search CL acquisition for simulated data with $\Delta f_{L2Ccarrier} = 50Hz$ and f_s =11.2Mz. When N =3, the correlation peak occurs at one point left of the nominal point, whereas when N =5, the correlation peak occurs at two points left from the nominal point. In this case, N =5 should be used to detect



(a) N =5 (b) N =3

Fig. 7. Correlation for the N -point serial search CL acquisition ($\Delta f_{L2Ccarrier} = 50Hz$, f_s =11.2Mz, simulated Data)

the peak point. Fig. 8 shows the correlation result for live data with $\Delta f_{L2Ccarrier} = 50Hz$ and f_s =6Mz. The correlation peak occurs at one point left from the nominal point for both N =3 and N =5. In this case, N =3 can be used to save time.



(a) N =5 (b) N =3

Fig. 8. Correlation for N-point serial search CL acquisition ($\Delta f_{L2Ccarrier} = 50Hz$, f_s =6Mz, live data)

Tables 3 to 5 show the correlation peak points from the nominal point for sampling frequencies 6, 11.2, and 22.4 MHz, respectively, where -1 refers to one point left from the nominal point, -2 means two points left from the nominal point, and so on. Table 3 shows that N =3 can be used for 6 MHz data, whereas Tables 4 and 5 show that N =5 should be used for 11.2 and 22.4 MHz data, respectively, to detect peak correlation. There is a discrepancy in Table 4 from the result of Lemma 1. For SV 1, 11, and 17 with $\Delta f_{L2Ccarrier} = 25Hz$ and $f_s = 11.2MHz$, Table 4 shows -2. This means that N=5 should be used, which seems to contradict the results of Lemma 1. For $f_s = 11.2MHz$, the number of sample points in each code chip is 10.9482, which is not an integer, so it may be 10 or 11, which is the cause for the discrepancy in the results of Lemma 1.

According to Table 5, N =5 should be used, because the correlation peak may occur at +2 or -2 points. However,

Table 3. Correlation peak point from the nominal point for live data with $\Delta f_{L2Ccarrier} = 50Hz$ and $25Hz$, $f_s = 6MHz$

	Live Data 6MHz			Live Data 6MHz	
	5-Point			3-Point	
SV	50Hz	25Hz	SV	50Hz	25Hz
1	-1	-1	1	-1	-1
25	-1	-1	25	-1	-1
29	-1	-1	29	-1	-1
31	-1	-1	31	-1	-1

Table 4. Correlation peak point from the nominal point for simulated data with $\Delta f_{L2Ccarrier} = 50Hz$ and $25Hz$ and $f_s = 11.2MHz$

	Simulated Data 11.2MHz			Simulated Data 11.2MHz	
	5-Point			3-Point	
SV	50Hz	25Hz	SV	50Hz	25Hz
1	-2	-2	1	-1	-1
3	-1	-1	3	-1	-1
6	-1	-1	6	-1	-1
7	-1	-1	7	-1	-1
11	-2	-2	11	-1	-1
17	-2	-2	17	-1	-1
19	-1	-1	19	-1	-1
20	-1	-1	20	-1	-1
25	-1	-1	25	-1	-1
28	-1	-1	28	-1	-1

Table 5. Correlation peak point from the nominal point for simulated data with $\Delta f_{L2Ccarrier} = 50Hz$ and $25Hz$ and $f_s = 22.4MHz$

	Simulated Data 22.4MHz			Simulated Data 22.4MHz	
	5-Point			3-Point	
SV	50Hz	25Hz	SV	50Hz	25Hz
1	1	1	1	1	1
3	0	0	3	0	0
6	-1	-1	6	-1	-1
7	-2	-2	7	1	1
11	-1	-1	11	-1	-1
17	-2	-2	17	-1	-1
19	0	0	19	0	0
20	-2	-1	20	-1	-1
25	-1	-1	25	-1	-1
28	-1	-1	28	-1	-1

Table 2 shows that the three-point serial search provides successful results even for $f_s = 22.4MHz$. Even though CL acquisition provides the next point to the maximum correlation, the tracking algorithm can follow the input signal well. Fig. 9 shows that for $f_s = 22.4MHz$, the three-point serial search used for CL acquisition identifies all 10 satellites, indicating that the tracking is also successful. The three-point serial search method also shows successful result for $f_s = 28MHz$ and $f_s = 56MHz$ in terms of tracking and CNAV data decoding.

L2C-ACQUISITION

CM Acquisition : FFT search [25Hz]

CL Acquisition : Pre-gen 3-point [10ms]

Satellites to search : 1 3 6 7 11 17 19 20 25 28

Channel	PRN	Frequency	CM Code	CL Code	CL ID	Time	
1	1	5597750	392002	392023	11	25.7	1.8
2	3	5601950	358635	358656	11	25.8	1.7
3	6	5602100	9368	9389	10	25.7	1.7
4	7	5601850	200840	200861	11	25.9	1.7
5	11	5599450	93142	93163	11	25.7	1.8
6	17	5597975	427487	427508	11	25.7	1.8
7	19	5601450	189584	189605	11	25.9	1.7
8	20	5597525	437884	437905	11	25.8	1.8
9	25	5602525	286874	286895	11	25.7	1.7
10	28	5597700	289624	289645	11	25.8	1.7

CNAV Data Decode & Bit Synch from Tracking Result.

SV	Index	Point	PRN	Message type	CRC Check
1	1	25	1	35	Not enough bit
3	1	24	3	35	Not enough bit
6	1	25	6	35	Not enough bit
7	1	25	7	35	Not enough bit
11	1	25	11	35	Not enough bit
17	1	24	17	35	Not enough bit
19	1	66	19	35	Not enough bit
20	1	68	20	35	Not enough bit
25	1	25	25	35	Not enough bit
28	1	25	28	35	Not enough bit

Satellite PRN : 1 3 6 7 11 17 19 20 25 28

Fig. 9. Acquisition Result of basic CM and Three-Point serial search CL for simulated data ($f_s = 22.4MHz$)

6. Conclusion

For GPS L2C signal, rapid CM and CL acquisition methods are suggested and compared with existing methods. It is assumed that the signal is strong enough to permit detection with 20 msec integration. The objective of the rapid acquisition method is to reduce acquisition time. For CM acquisition, the CM-mix code can reduce CM acquisition time at the cost of C/N ratio reduction, thus resulting in misdetection for some satellites. For CL acquisition, N -Point serial search can reduce CL acquisition time. As it is a time-domain correlation method, only 10 msec data can be used to reduce the time further. This method shows the best performance for both live and simulated data. For the choice of the number N , the three-point serial search method provides successful results for tracking and CNAV data decoding up to a sampling frequency of $f_s = 56MHz$.

Acknowledgments

This research was part of the project entitled "Development of WADGPS Data Transmission System Using Pseudolite," which was funded by the Ministry of Land, Transport, and Maritime Affairs, Korea.

References

[1] Fontana R. D., W. Cheung and P. M. Novak, "The new L2 civil signal", in Proc. *ION GPS,* 2001, pp. 617-631.

[2] Liliána Sükeová, Marcelo C. Santos, Richard B. Langley, Rodrigo F. Leandro, Okwuchi Nnani, Felipe Nievinski, "GPS L2C Signal Quality Analysis", in Proc. ION 63th Annual Meeting, 2007, pp, 232-241.

[3] O. al-Fanek, S. Skone, G.Lachapelle, "Evaluation of L2C Observations and Limitations", in Proc. ION GNSS ITM of the Satellite Division, 2007, pp. 2510-2518.

[4] S.U. Qaisar, Receiver Strategies for GPS L2C Signal processing, Ph.D. Dissertation, The University of New South Wales, Australia, March, 2010.

[5] M. Psiaki, "FFT-based acquisition of GPS L2C civilian CM and CL signals," *in Proc. ION GNSS,* 2004, pp. 457-475.

[6] C. Yang, "Joint acquisition of CM and CL codes for GPS L2 civil (L2C) signals", *in Proc. ION AM,* 2005, pp 553-562.

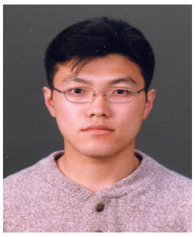
[7] A.R.A. Moghaddam, R. Watson, G. Lachapelle and J. Neilsen, "Exploiting the Orthogonality of L2C Code Delays for a Fast Acquisition", *in Proc. ION GNSS 19th ITM of the Satellite Division*, 2006, pp. 1233-1241.

[8] Ziedan N. I., "Acquisition and fine acquisition of weak GPS L2C and L5 signals under high dynamic conditions for limited-resource applications", *in Proc. ION GNSS 18th ITM of the Satellite Division*, 2005, pp. 1577-1588.

[9] Keum-Cheol Kwon and Duk-Sun Shim, "Fast Acquisition Method for GPS L2C Software Receiver", *in Proc.* 2011 KIEE Summer Conference, 2011, pp. 1754-1755.

[10] C-F Chang, R-M Yang, M-S Kao, J-C Juang, "A Novel Scheme and Modified Structure For Improved Software GPS Receiver", *in Proc. ION GNSS 20th ITM of the Satellite Division*, 2007, pp. 2813 - 2822.

[11] K. Borre, D.M. Akos, N. Bertelsen, P. Rinder, S.H. Jensen, A Software-Defined GPS and Galileo Receiver: A Single-Frequency Approach, Boston, Birkhauser, 2007, pp82-83.



Keum-Cheol Kwon He received his B.S. and M.S. degrees in Electrical and Electronics Engineering from Chung-Ang University, Korea in 2001 and 2003, respectively. He is currently a Ph.D. student at the same school. His research interests include computer architecture, embedded systems, and GPS.

Duk-Sun Shim He received his B.S. and M.S. degrees in Control and Instrumentation Engineering from Seoul National University, Korea, in 1984 and 1986, respectively. He received his Ph.D. in Aerospace Engineering from the University of Michigan, Ann Arbor in 1993. He served at the Department of Electrical Engineering and Computer Science in the University of Michigan as a post-doc from January 1994 to January 1995. Since 1995, he has been with the School of Electrical and Electronics Engineering in Chung-Ang University, Seoul, Korea where he is currently a Professor. He has served as an Editor for JEET (Journal of Electrical and Engineering & Technology) since 2009 and an Associate Editor in IJCAS (International Journal of Control, Automation, and Systems) since 2008. His research interests include robust control, filtering, GPS and inertial navigation systems, fault detection, and isolation.