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Acquisition Algorithm for GPS L2C Signal on Dual-frequency Navigation Receiver

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Abstract. The newly broadcast GPS L2C signal will be extensively used due to its superiority. In order to acquire L2C signal fast in a dual-frequency GPS receiver, this paper firstly discusses two traditional acquisition algorithms, then proposes and implements a new algorithm based on the fixed phase relationships among C/A code, CM code and CL code and the fixed relationships of Doppler shift between the L1 channel and L2 channel. The experimental result demonstrates that the new acquisition algorithm can speed up the acquisition process substantially. It also suits other dual-frequency navigation receivers.

Introduction

The first BLOCK IIR-M satellite was launched on 26 SEP 2005(SVN 53, PRN 17), which transmits a second civil signal L2C on the L2 frequency and the military M signal on the L1 and L2 frequencies. There are 8 BLOCK IIR-M satellites currently，PRN01，PRN05，PRN07, PRN12, PRN15, PRN17, PRN29, and PRN31 [1]. The L2C signal consists of two codes: CM code (civil-moderate code) and CL code (civil-long code). The new modernized L2C signal has advantages, such as it is not encrypted, allowing civil receivers to receive the full SNR, the data-less pilot CL code signal has a lower tracking threshold, enhancing signal acquisition and tracking at low SNR [2]. With L2C in addition to the C/A code at L1, dual-frequency receivers can benefit from using the codes at both frequencies, exploit the data-less code channel at L2, and is more prone to eliminate the ionosphere irregularities and resolve phase ambiguity [3,4]. The L2C signal has great superiority for civil applications of GPS, capacitating receivers to measure in highly accurate.

The acquisition process is an important part of navigation receivers, for the purpose of finding rough estimates of carrier frequencies and code phases of satellite signals which initialize loops for signal tracking. Conventional acquisition schemes are mostly hardware-based approaches, which include both the time domain serial search and the frequency domain FFT methods. The time domain serial search algorithms are studied to be the simplest schemes for acquisition, but most of them are considerably time consuming. The FFT methods significantly speed up the acquisition process comparing with the time domain schemes [5]. However, the limitation on the number of FFT components within the receiver hardware makes it difficult to acquire further enhancement on the processing time. As a result of the special structure of L2C signal, a new design of acquisition algorithm is required to utilize the advantages. This paper studies on acquisition algorithms of L2C signal, and presents a new approach, which based on acquisition and tracking of C/A code at L1 channel of the dual-frequency receiver, the fixed phase relationships between C/A code, CM code and CL code are used to realize acquisition of CM code and CL code.

The remainder of this paper is organized as follows. Section II describes the structure of L2C signal. The new algorithm is emulated and verified in Section III, acquisition algorithms including the time domain serial search and the frequency domain FFT methods are also discussed. Section IV analyzes the performance of this acquisition algorithm by using statistical theory. Section V draws the conclusions.

Structure of L2C Signal

Modulated on the L2 carrier at 1227.6MHz, the L2C signal contains two different PRN codes:

The CM code is 20 milliseconds in length at a chipping rate of 511.5 Kbps. The sequence is a linear pattern which is short cycled every count of 10230 chips by resetting with a specified initial state. Assignment of initial states by GPS PRN signal number is given in [6].

The CL code is 1.5 seconds in length at a chipping rate of 511.5 Kbps. The sequence is a linear pattern which is generated using the same code generator polynomial as the one used for CM code. However, the CL code sequence is short cycled by resetting with a specified initial state every code count of 767250 chips. Assignment of initial states by GPS PRN signal number is given in [6].

For L2C signal, as shown in Fig.1, the navigation message is a 25 bps data stream which is coded by a rate 1/2 convolutional coder. When selected by ground command, the resulting 50 bps symbol stream is modulo-2 added to the L2 CM-code; the resultant bit-train is combined with L2 CL-code using chip by chip time-division multiplexing method (i.e. alternating between L2 CM$\oplus$data and L2 CL chips); the multiplexed bit-train is used to modulate the L2 carrier.

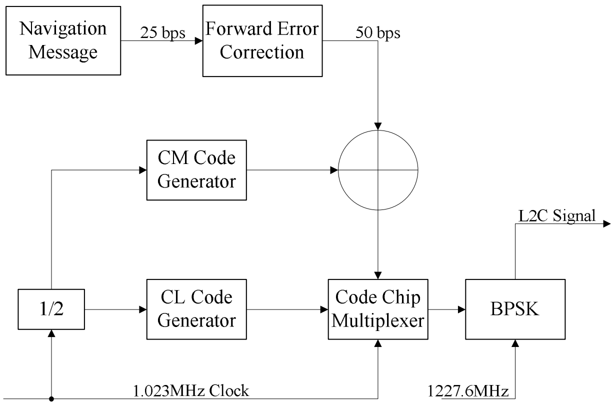

Fig.1 Block diagram of L2C signal structure.

The L2C code has the same level of noise and multipath as on C/A, because for noise and multipath performances, it behaves similarly to a BPSK modulation at 1.023MHz.

Acquisition Algorithm

Acquisition process detects the presence of the GPS signal in order to track and decode the information in the signal. Once the signal is detected, two important parameters must be measured. One is the beginning of the code phase and the other one is the carrier frequency of the input signal. The beginning of the code is used to despread the spectrum. Once the spectrum is despread, the output becomes a continuous wave (cw) signal and its carrier frequency can be found. The beginning of the code and the carrier frequency are the core parameters passed to the tracking loop.

Time domain serial search algorithm. Time domain serial search acquisition is a conventional algorithm for acquisition in code-division for navigation receiver. Fig.2 is a block diagram of the serial search acquisition algorithm.

The computational process of Fig.2 is given by

$$Output = \sum\left(\left(\int x[n]c[n]\cos[2\pi fn]\right)^2 + \left(\int x[n]c[n]\sin[2\pi fn]\right)^2\right) \tag{1}$$

where $x[n]$ is the incoming signal, $c[n]$ is the local code, f is the frequency of local carrier.

The serial search algorithm performs two different sweeps: a code phase sweep over all 10230 different code phases and a frequency sweep over all possible carrier frequencies of IF $\pm$10 kHz in steps of 500 Hz. After all, this sums up to a total of

$$10230\,(\,2\,\frac{10{,}000}{500}+1\,) = 419{,}430 \text{ combinations.} \tag{2}$$

Obviously, this is a very large number of combinations. This is also the main shortcoming of the serial search acquisition algorithm.

FFT acquisition algorithm. If one of the parameters could be eliminated from the search procedure or if possible implemented in parallel, it will expedite the process significantly. Parallel search schemes which based on FFT and Inverted FFT (IFFT) have been suggested. FFT acquisition algorithm converts the GPS signal from time domain into frequency domain and thus it eliminates one parameter to shorten the acquisition time. Fig.3 is a block diagram of FFT acquisition algorithm.

The computational process of Fig.3 is given by

$$Output = \left(IFFT\left(FFT(x[n]\cos(2\pi fn) + jx[n]\sin(2\pi fn)) \cdot FFT(c[n])^{*} \right) \right)^{2} \tag{3}$$

where $FFT(c[n])^{*}$ is the complex conjugate of $FFT(c[n])$.

The beginning of the code phase and the carrier frequency of the input signal can be directly detected at the highest correlation peak which is defined by the absolute value of correlation function. This method reduces the search time and allows direct acquisition of the signal using 1 millisecond data of the C/A code signal compared with serial search acquisition algorithm. However, the frequency search resolution also depends on signal length: the longer the signal, the finer is the resolution. The increased L2C code length and code period lead to a large search space in both the code phase and carrier frequency domain. That is the main weakness of the FFT acquisition algorithm. Therefore, a new approach is proposed to reduce computations in the following text.

A new acquisition algorithm. In dual-frequency navigation receiver, in case the C/A code modulated on the L1 carrier is tracked, the fixed phase relationships among C/A code, CM code and CL code are used to realize fast acquisition of CM code and CL code. Each CL cycle contains 75 CM cycles, each CM cycle contains 20 C/A cycles. Fig.4 shows the phase relationships.

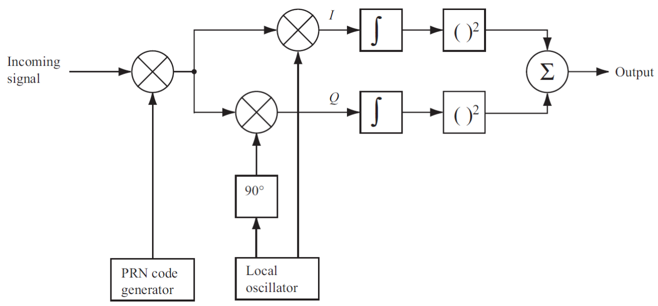

Fig.2 Block diagram of the serial search algorithm.

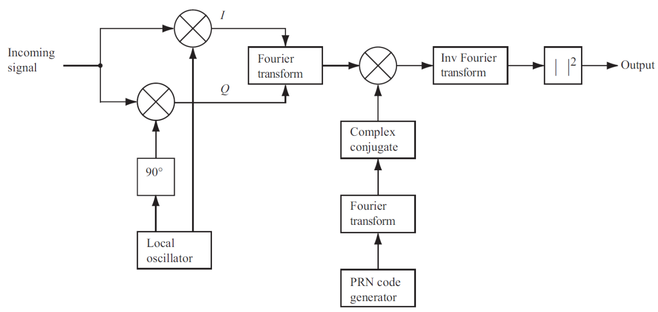

Fig.3 Block diagram of the FFT acquisition algorithm.

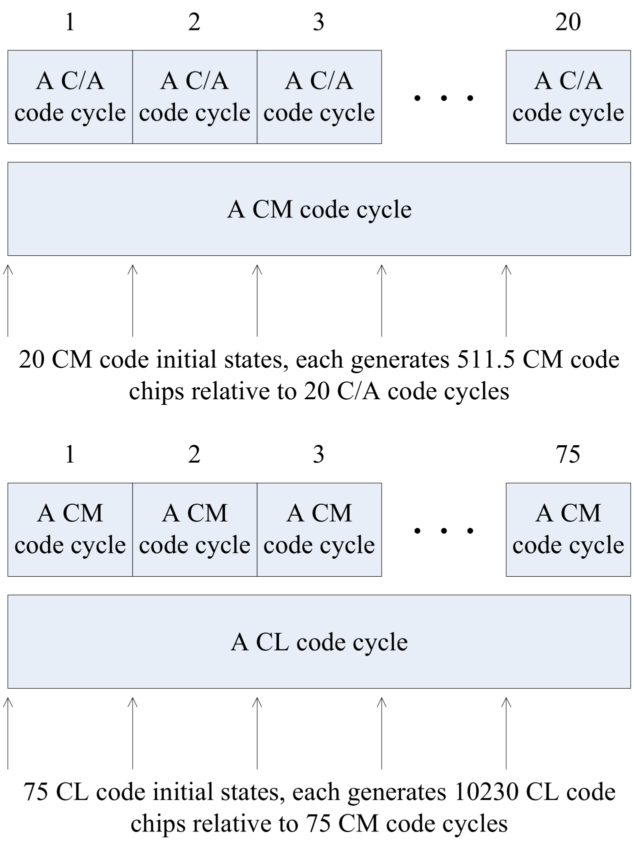

Fig.4 Phase relationships among C/A code, CM code and CL code.

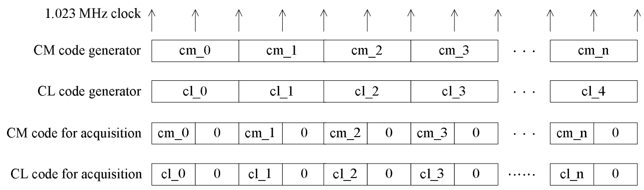

Fig.5 Local L2C code.

Utilizing 20 C/A code relative phase intervals in L1 channel, the receiver can acquire CM code in L2 channel by searching these positions. CM code is modulated by the navigation data, while CL code has no data modulation, so the receiver cannot use the chip-by-chip multiplexed code directly as local recurrence code. In the implement, as shown in Fig.5, PRN codes with a chip rate of 511.5 KHz are generated by CM and CL code generators, then chip-by-chip multiplexed with zero to generate local code with a chip rate of 1.023 MHz. CM and CL codes are replaced by zero in correlation calculation to obviate the influence of cross correlation between them [7].

The other important parameter, the carrier frequency of the input signal in L2 channel, can be calculated based on the fixed relationships of Doppler shift between the L1 channel and L2 channel for the same satellite. The Doppler shift can be calculated by the following equation:

$$\Delta f = \frac{fv}{c} \tag{4}$$

where f is the modulation frequency, v is the relative speed between the satellite and receiver, c is the speed of light. The Doppler shift in L2 channel for the same satellite can be calculated by the following equation:

$$\Delta f_2 = \frac{f_2}{f_1} \Delta f_1 \tag{5}$$

where f_1 and f_2 are L1 and L2 carrier frequency, Δf_1 is the Doppler shift of L1 carrier frequency.

Algorithm Implementation and Performance Analysis

The performance of the above processing algorithms is implemented by the TMS320C6416 digital signal processors of Texas Instruments using simulation signal which generated by FPGA. The sampling frequency of simulation signal is 20MHz, the center frequency of L1 channel is 5.58MHz, and the center frequency of L2 channel is 6.4MHz. The Doppler search range is ±6KHz with steps of 500Hz.

Time domain serial search acquisition algorithm is chosen as traditional algorithm because it consumes less hardware source and is easy to implement. Fig.6 shows the 3D plot of C/A code acquisition, max at (479,19) means the code phase difference and the Doppler frequency offset are 479 chips and 3KHz (500Hz×(19-13)) at the maximum correlation peak. Then 20 possible initial phases of CM code can be calculated as 479+i×1023, i=1:20. Fig.7 shows 20 correlations of CM code. The correlation peak is the 9th, so the initial phase of CM code is 9686 (479+9×1023).

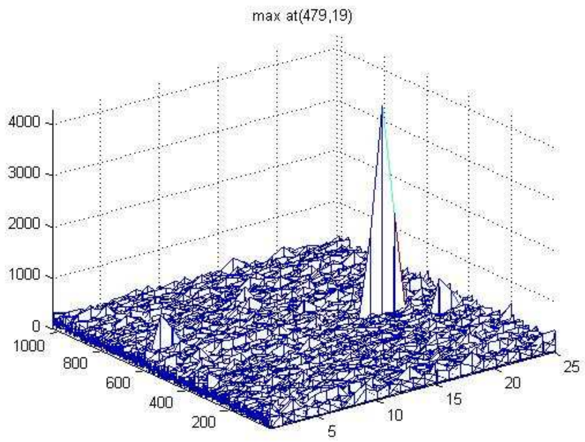

Fig.6 Correlations of C/A code.

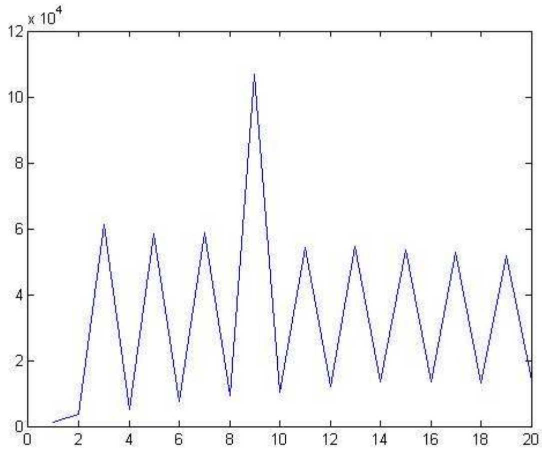

Fig.7 20 Correlations of CM code.

The acquisition time is given by

$$t = N \times (2 \times \frac{\Delta f}{500} + 1) \times T_i \tag{6}$$

where N is the number of chips of one cycle, Δf is the Doppler shift and T_i is integral time. If CM code is acquired directly and the Doppler shift at L1 frequency is assumed to 3 KHz, using (5) and (6), the acquisition time is

$$\begin{aligned} t &= 20460 \times (2 \times \lceil 2337.7 / 500 \rceil + 1) \times 0.02 \\ &= 4501.2s \end{aligned} \tag{7}$$

While the acquisition time of the new algorithm can be calculated as follows:
Using (5) and (6), the acquisition time of C/A code at L1 is

$$\begin{aligned} t_1 &= 1023 \times (2 \times 3000 / 500 + 1) \times 0.001 \\ &= 13.3s \end{aligned} \tag{8}$$

The acquisition time of CM code is

$$t_2 = 9 \times 0.02 = 0.18s \tag{9}$$

The total time is

$$t = t_1 + t_2 = 13.48s \tag{10}$$

The new algorithm reduces the acquisition time from 4501.2 seconds to 13.48 seconds, speeding up the acquisition process sharply.

Summary

Compared with the traditional C/A code, the L2C signal has many advantages and will be used extensively. This paper discussed the structure of L2C signal and two traditional acquisition algorithms. A new acquisition algorithm for L2C signal was proposed by analyzing the fixed phase relationships between C/A code, CM code and CL code. The new algorithm was implemented in a dual-frequency receiver, speeding up the acquisition process from 4501.2 seconds to 13.48 seconds. It also can be flexibly used in other dual-frequency navigation receivers

References

[1] The United States Naval Observatory.gpsb2.txt. http:// tycho.usno.navy.mil/ftp-gps,2008.12.

[2] Tom K. Meehan, David Robison, Tim N. Munson, Larry E. Young, “Orbiting GPS Receiver Modified to Track New L2C Signal,” Position, Location, And Navigation Symposium, 2006 IEEE/ION, pp. 1071-1073.

[3] J. Klobuchar, “Ionospheric Effects on GPS,” in Global Positioning System: Theory and Applications, Vol. I, Parkinson, B.W., and Spilker, J.J. Jr., eds., AIAA, 1996, pp. 485-516.

[4] Yanhong Kou, Xingyun Zhou, Yu Morton, Lei Zhang, “Processing GPS L2C Signals under Ionospheric Scintillations,” Position Location and Navigation Symposium (PLANS), 2010 IEEE/ION, pp. 771-782.

[5] James Bao-Yen Tsui, Fundamentals of Global Positioning System Receivers-A Software Approach, John Wiley & Sons, Inc., 2005.

[6] ARINC Engineering Services, Navstar GPS Space Segment/Navigation User Interfaces, IS-GPS-200, Revision D, 7 December 2004.

[7] Qaisar S , Dempster A, Receiving the L2C signal with "Namuru" GPS L1 receiver, International Global Navigation Satellite System Society IGNSS Symposium 2007, Sydney, Australia, Dec.2007, pp. 154-164.

[8] Li Cheng-jun, Lu Ming-quan, Feng Zhen-ming, Zhang Qi, "Study on GPS L2C Acquisition Algorithm and Performance Analysis," Journal of Electronics&Information Technology, Vol.32, No.2, Feb.2010, pp. 296-300.

[9] Kai Borre, Dennis M. Akos, Nicolaj Bertelsen, Peter Rinder, Søren Holdt Jensen, A Software-Defined GPS and Galileo Receiver - A Single-Frequency Approach, Birkhäuser Boston,2006.