

FFT BASED ACQUISITION TECHNIQUES OF GPS L2C SIGNALS

B.R. Iswariya¹ and H. Niros Kumar²

^{1,2}Department of Electronics and Communication Engineering, Kumaraguru College of Technology, India
 E-mail: ¹ishuraj23@gmail.com, ²niroskumar2020@gmail.com

Abstract

The modernization of the GPS lead to the launch of additional GPS signal, L2C second civilian GPS signal to become available in full constellation. L2C signals have longer ranging codes which leads to larger search space and increase in computational complexity. L2C signals makes use of two PRN sequences CM (Civil Moderate) and CL (Civil Long) of 20ms and 1.5sec long. In this paper a code generator is designed for generating the CM and CL sequences, and two local replica codes NRZ (Non Return Zero) and RZ (Return Zero) Codes are designed. The code phase and carrier Doppler are estimated based on the various FFT (Fast Fourier Transform) based acquisition techniques.

Keywords:

GPS, FFT, IFFT, L2C, Civil Moderate (CM), Civil Long (CL), Return Zero (RZ), Non Return Zero (NRZ)

1. INTRODUCTION

The current civil GPS signal consists of a single frequency transmission L1 (C/A). The Global Positioning System (GPS) modernization program deploys new Block IIR-M satellites, equipped to initiate the transmission of the new civilian signal L2 civil (L2C). One of the most commonly referenced limitations with GPS is the vulnerability of the L1 signal to Radio Frequency Interference (RFI) either intentional or unintentional. With its novel code structure and compact data format, the L2C signal can offer advantages like indoor positioning, ionospheric error elimination, and improved tracking performance [6].

The purpose of acquisition is to identify all satellites visible to the user. The two important parameters estimated are the Carrier Doppler and the Code Phase. Acquisition determines the frequency of the signal from a specific satellite, which can differ from its nominal value. In case of down conversion, the nominal frequency of the GPS signal corresponds to the IF. However, the signals are affected by the relative motion of the satellite, causing a Doppler effect. The Doppler frequency shift can in the case of maximum velocity of the satellite combined with a very high user velocity approach values as high as 10 kHz. For a stationary receiver on Earth, the Doppler frequency shift will never exceed 5 kHz [1].

The code phase denotes the point in the current data block where the L2C code begins. If a data block of 20ms is examined, the data includes an entire L2C code and thus one beginning of a L2C code.

Many different acquisition methods like FFT based circular correlation approach, Parallel code search acquisition; Parallel frequency search acquisition methods are used.

2. L2C SIGNAL STRUCTURE

The L2C signal (1227 MHz) is composed of two ranging codes, namely L2 CM (Civil Moderate) and L2 CL (Long). The L2 CM code is 20 ms long and contains 10230 chips, while the L2 CL code has a period of 1.5 s, containing 767250 chips. The CM code is modulo-2 added to data, and the resultant sequence of chips is time multiplexed with the CL code on a chip-by-chip basis. The individual CM and CL codes are clocked at 511.5 kHz, while 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 [2].

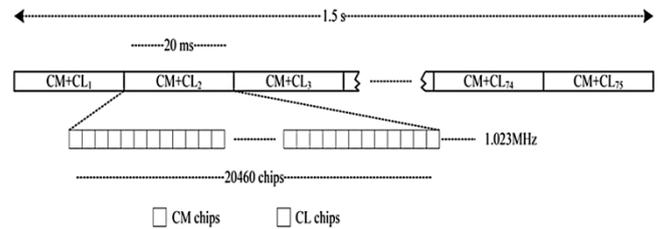


Fig.1. L2C signal structure

3. L2C CODE GENERATOR

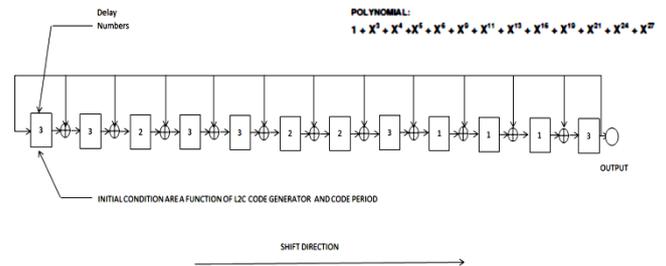


Fig.2. L2C code generator

Each L2 CM-code and L2 CL-code are generated using the same code generator polynomial each clocked at 511.5 Kbps. Same pattern is initiated and reset with a specified initial state. CM pattern is reset after 10230 chips resulting in a code period of 20 milliseconds, and CL pattern is reset after 767250 chips resulting in a code period of 1.5 seconds.

The maximal polynomial used for L2 CM- and L2 CL-codes is 1112225171 (octal) of degree 27. The L2 CM and L2 CL code generator is conceptually described in Fig.2 using modular-type shift register generator [2].

4. LOCAL L2C CODES

For efficient signal acquisition two local replica codes are been designed named Non Return Zero (NRZ CM) and Return

Zero (RZ CM). NRZ CM replica code is designed based on Chip Wise (CW) correlation strategy. Here the received L2C code samples are accumulated across each chip period, and the correlation is then performed at the L2C code chipping rate, reducing both the code search space and the computational complexity significantly. The detection performance of CW strategy is assessed as equivalent to that of the full-rate correlation, irrespective of the phase of the received L2C code. The NRZ CM codes allow a code search at larger steps without losing the acquisition sensitivity.

RZ CM replica code consists of L2C code with CM code alone and zeros in place of the CL code. Since, L2CL has a longer code length; it is normally not used for acquisition process. The RZ codes have a sharp triangular acquisition peak [3].

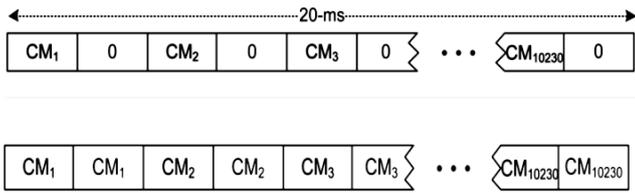


Fig.3. RZ and NRZ CM codes

5. ACQUISITION TECHNIQUES

Acquisition identifies all satellites visible to the user and determines two properties of the signal: code phase and carrier Doppler.

The received signal is a combination of signals from all visible satellites. When acquiring a satellite, the incoming signal is multiplied with the locally generated code corresponding to that satellite. The cross correlation between L2C codes for different satellites implies that signals from other satellites are nearly removed by this procedure. To avoid removing the desired signal component, the locally generated code must be properly aligned in time, to have the correct code phase.

Basically two types of acquisition are followed namely serial search and parallel search acquisition. The serial search acquisition method is a very time-consuming procedure to search sequentially through all possible values of the two parameters frequency and code phase. If any of the two parameters could be eliminated from the search procedure or if possible implemented in parallel, the performance of the procedure would increase significantly.

5.1 ACQUISITION BASED ON FFT (CIRCULAR CORRELATION)

The multiplication in frequency domain is equivalent to correlation operation in time domain. In the FFT based approach a search has been conducted to find out the correlation output of the two signals by circulation correlation. This is done by finding the correlation performance of one block of the input signal with the locally generated signal, which is split into a number of bins in Doppler and Code bin is determined using the circular correlation. The IFFT (Inverse FFT) process of the multiplication result of input signal (after FFT) and the conjugate of the local signal (after FFT) gives the correlation output of the sequence for the particular Doppler bin. The same

search has to be conducted for the entire Doppler bin of interest (here 50HZ).

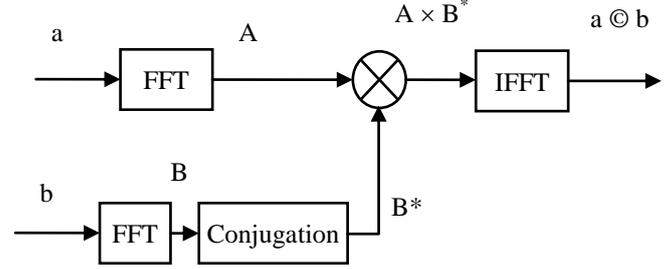


Fig.4. FFT based circular correlation

5.2 PARALLEL CODE SPACE SEARCH ACQUISITION

The acquisition is to perform a correlation with the incoming signal and a local L2C code. It makes a circular cross correlation between the input and the local code with shifted code phase. The incoming signal is multiplied by a locally generated carrier signal. Multiplication with the signal generates the In-phase signal, and multiplication with a 90° phase-shifted version of the signal generates the Quadrature signal. The signals are combined to form a complex input signal to the FFT function. The generated PRN (Pseudo Random Number) code is transformed into the frequency domain and the result is complex conjugated. The Fourier transform of the input is multiplied with the Fourier transform of the PRN code. The result of the multiplication is transformed into the time domain by an inverse Fourier transform. The absolute value of the output of the inverse Fourier transform represents the correlation between the input and the PRN code.

The parallel code phase search acquisition method has cut down the search space to the different carrier frequencies. The Fourier transform of the generated PRN code must only be performed once for each acquisition.

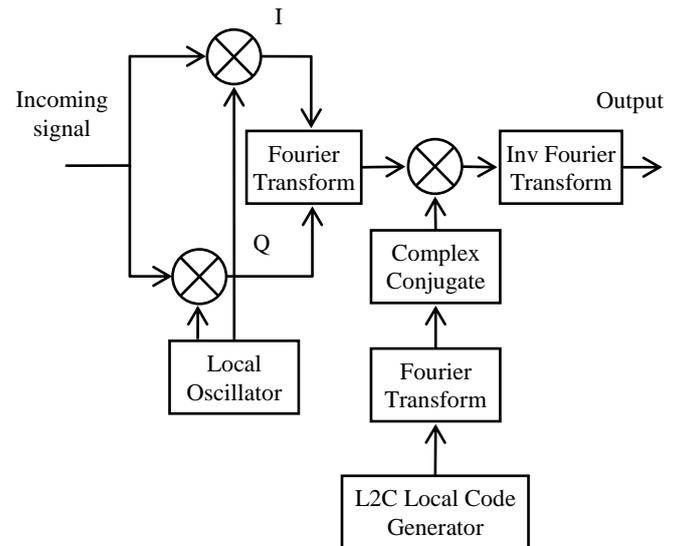


Fig.5. Parallel code space search acquisition

5.3 PARALLEL FREQUENCY SPACE SEARCH ACQUISITION

The acquisition is performed for the incoming signal and locally generated signals and the signal is multiplied with a locally generated carrier. Finally the Fourier transform is taken and correlated output is viewed. Here the incoming code and the locally generated code are generated in same code phase. Here the FFT computations involved are less since only once FFT operations are performed.

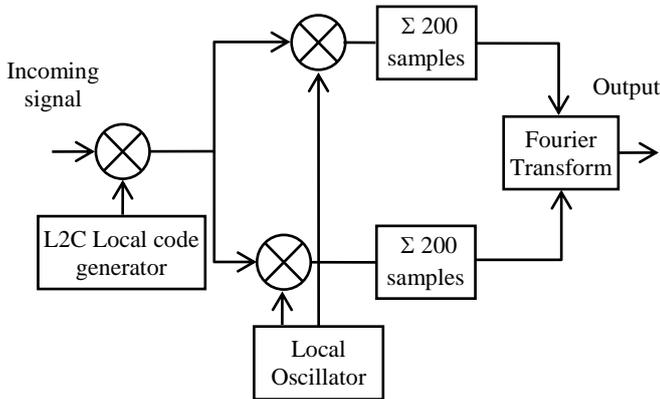


Fig.6. Parallel frequency space search acquisition

6. SIMULATION RESULTS

The acquisition methods are carried out in MATLAB 2012 simulation software. The chip rate is set as 1.023 MHz, the sampling frequency used is 20.46 MHz and the total number of samples considered in experiment is 20*20460 samples.

6.1 ACQUISITION BASED ON CIRCULAR CORRELATION FFT

The NRZ local code allows code search at longer steps without losing the acquisition sensitivity (1chip duration). The RZ code allows a sharper transition. The correlation peak for NRZ is 0.5069 and for RZ is 0.5.

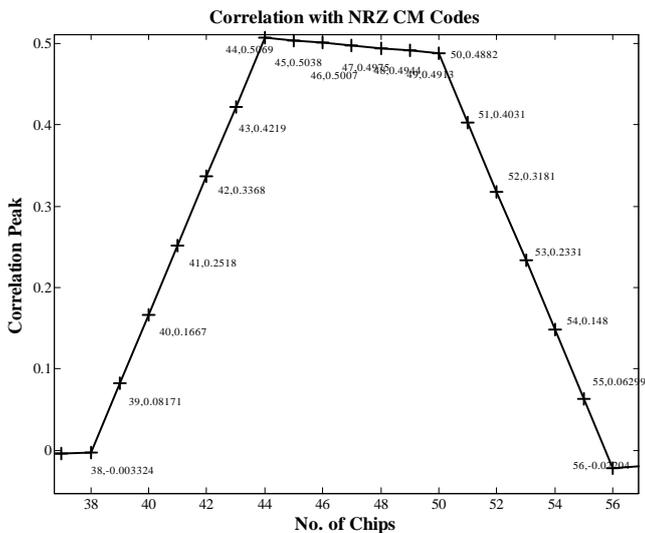


Fig.7. Correlation of received code with NRZ CM Codes

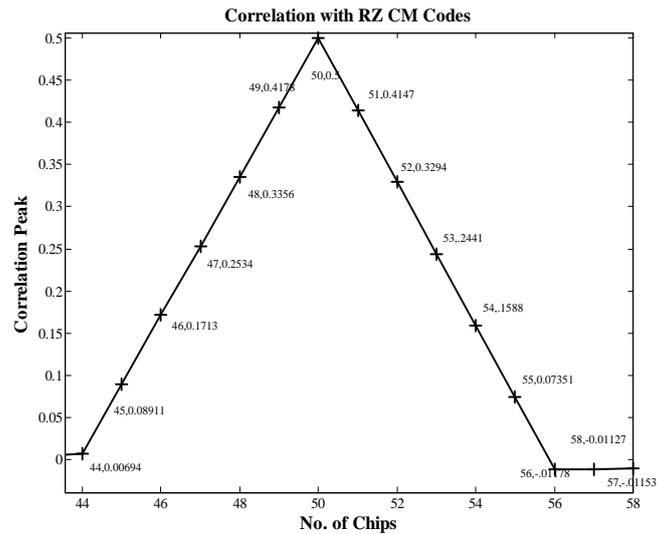


Fig.8. Correlation of received code with RZ CM codes

6.2 PARALLEL CODE SPACE SEARCH ACQUISITION

Here the code phase between the incoming and locally generated code is varied and the locally generated carrier frequencies are varied between 0 to 50 HZ doppler. Then each 20 samples are accumulated and added (pre-correlation filtering and down sampling) so incoming samples in 1 chip are averaged to one sample value. This leads to high computational efficiency and small correlation loss. Due to the locally generated carrier the correlation peak reduces to 0.2534 for NRZ and 0.2496 for RZ codes.

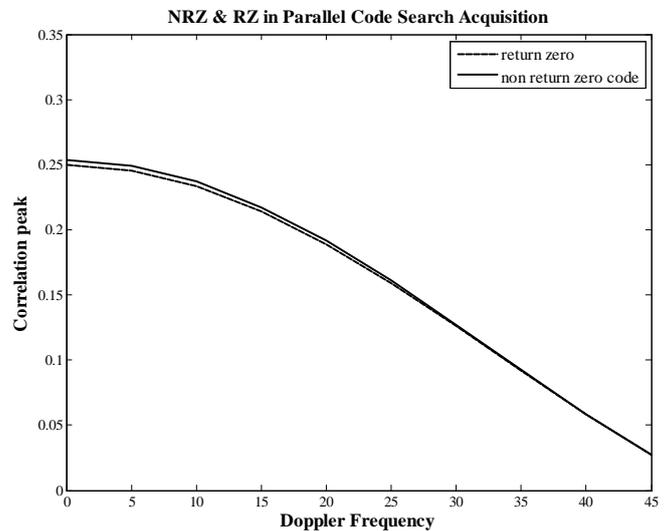


Fig.9. Comparison of correlation peak between NRZ and RZ local codes for various Doppler frequencies using parallel code search acquisition

6.3 PARALLEL FREQUENCY SPACE SEARCH ACQUISITION

In this method both the incoming and the locally generated code are assumed to be in same code phase. The IF carrier range is varied between 0 to 50 HZ and plotted for both local codes. The IF carrier and locally generated carrier are set at same

frequency to measure the best case Doppler effects, and by varying the code phase and measuring the worst case Doppler at 25HZ . The correlation peak is 0.2444 for NRZ codes and 0.2379 for RZ codes.

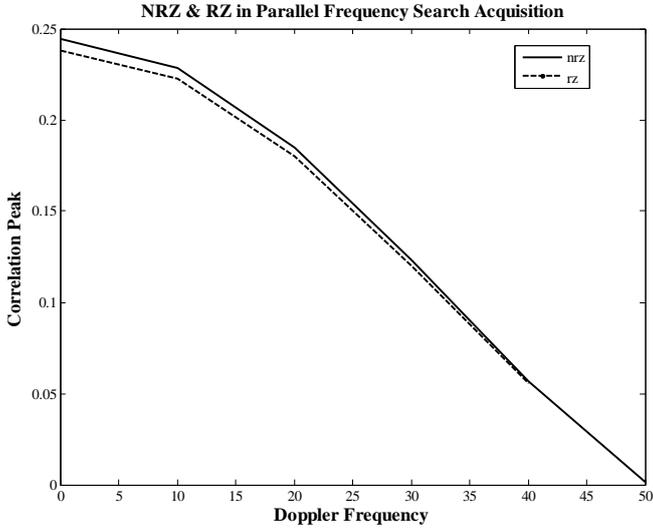


Fig.10. Comparison of Correlation peak between NRZ and RZ local codes for various Doppler frequencies (0 to 50 Hz) using parallel frequency search acquisition

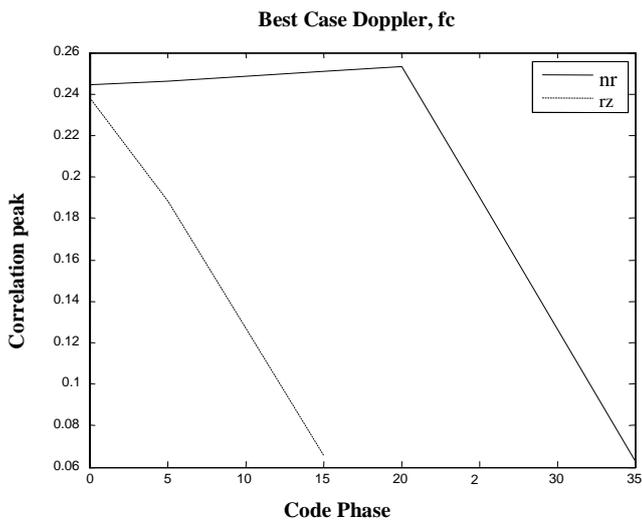


Fig.11. Best case Doppler, varying the code phase in steps of 5 [NRZ-0.2534, RZ-0.2379]

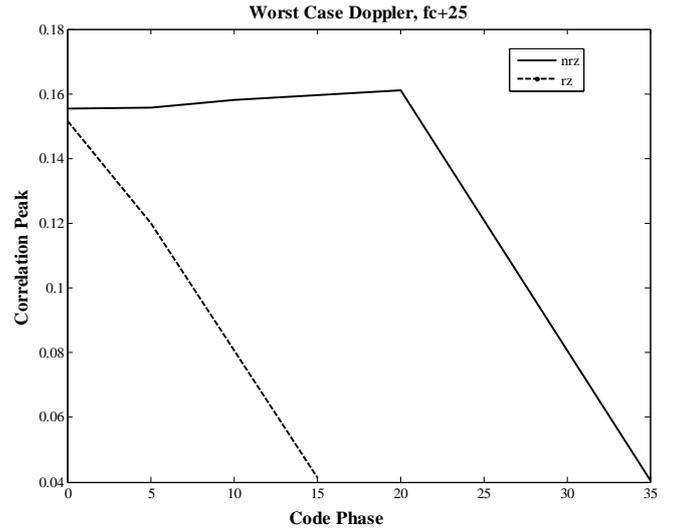


Fig.12. Worst case Doppler, varying the code phase in steps of 5 [NRZ-0.161, RZ-0.1576]

Table.1. Comparison of Various Acquisition Methods based on FFT computations

METHOD	FFT SIZE
Parallel code space search acquisition	409200 samples, $2^{19} = 524288$ point FFT
Parallel code space search acquisition – 20 samples – 1 unit	20460 samples, $2^{15} = 32768$ point FFT
Parallel frequency space search acquisition – 200 samples – 1 unit	2046 samples, $2^{11} = 2048$ point FFT

7. CONCLUSION

The L2C code is a Time Division Multiplexed code of the two separately generated codes (L2 CM and L2 CL). The results show the correlation peak, if the CL code is not used for acquisition based on the NRZ and RZ local codes. The acquisition based on circular correlation FFT, parallel frequency space search and parallel code space search acquisition are performed for various Doppler carrier and code phase to analyze the FFT computations. The results show that the parallel frequency space search acquisition provides less FFT computation and is the efficient method in terms of various Doppler effects and code phase. For future enhancement of the project, the parallel frequency space search acquisition could be implemented in FPGA and the results could be verified.

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