Signal Acquisition for Software GPS Receiver

Chitrakant Singh, Nitin Jain

Abstract: ***This paper presents the signal acquisition scheme. Compared to conventional GPS receivers, this design provides flexibility and low cost for algorithm redesign and different IF frequency selection capability. Complete Digital Down Conversion from IF to baseband I/Q and acquisition scheme are implemented using various software IPs of System Generator (SysGen) tool in a single Field Programmable Gate Array (FPGA) virtex-5. With simulation results, it is proved that this approach performs reliable digital down conversion and acquisition for software GPS receiver.***

Key words: GPS Receiver, DDC, FFT, Acquisition

I. INTRODUCTION

Global Positioning System (GPS) is a satellite-based navigation system. It is based on the computation of range from the receiver to multiple satellites by multiplying the time delay that a GPS signal needs to travel from the satellites to the receiver by velocity of light [1]. GPS has already been used widely both in civilian and military community for positioning, navigation, timing and other position related application.

In conventional hardware GPS receivers, acquisition is implemented by ASIC chips. The main advantage of using ASIC for signal processing is its high speed to provide real time service. But once the chip design is fixed, it cannot be modified for new GPS signal processing algorithm. The idea of software GPS receiver comes of the need to analyze and simulate new GPS algorithms. Compared to hardware GPS receiver, a software GPS receiver is based on software and performing all the signal processing and navigation calculation on high speed microprocessor. Therefore it offers much more flexibility especially when different algorithms should be tested. With the development of CPU, software GPS receivers can provide real time service now. As a result, a lot of research has been undertaken for software GPS receivers in recent years [2].

In this paper, GPS signal acquisition algorithms and implementation for software GPS receiver is presented with detailed analysis. We limit our discussion on civilian L1 band GPS signal since L2 band is for military purpose only. Simulation results prove that our software GPS receiver can perform reliable acquisition.

In software GPS receivers all the signal processing including acquisition, tracking, bit synchronization, sub frame, identifies and navigation solution are implemented using FPGA. So it is highly flexible and we can change the algorithms when necessary. On the contrary, Conventional hardware GPS receivers are realized by IC chips and the user doesn't have a free access to the algorithms inside the chip. This is the main difference between the software and conventional GPS receivers.

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II. SOFTWARE GPS RECEIVER MODEL

The architecture of software GPS receivers as shown in figure 1. It consists the antenna, RF front-end, intermediate frequency (IF) amplifier and A/D converter, which are the only hardware devices of the system. The RF front-end device is necessary to down convert the GPS signal to IF, and then the A/D converter digitizes the IF signal for software processing. In conventional GPS receiver, the software module in figure1 is implemented through an IC chip and hence the user does not have a free access to the algorithm built inside the chips. In software receiver, these blocks are fully implemented using high level programming languages and hence the user has complete control over the algorithms. This is the main difference between the software GPS receiver and a conventional hardware receiver [3].

The front-end involves a two step down-conversion of theL1 GPS signal to an IF of 21.25 MHz. The sampling frequency of A/D converter is 5 MHz. The center frequency of digitization IF signal is 1025 MHz according to the bandpass sampling theorem.

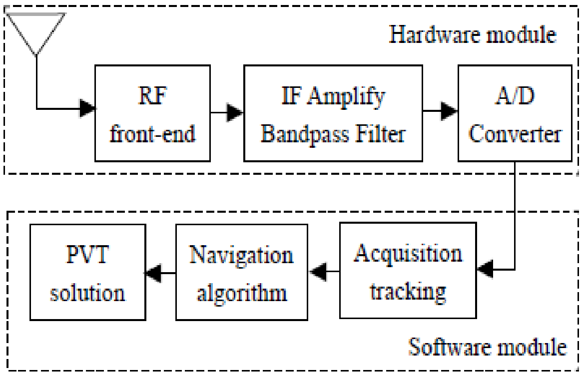

Fig.1Software GPS receiver architecture

III. SIGNAL ACQUISITION

This section describes the GPS signal acquisition process for software GPS receiver architecture. Acquisition is a coarse synchronization process giving estimates of the PRN code offset and the Doppler. This information is then used to initialize the tracking loops.

The GPS signal from the simulator is a combination of carrier wave, C/A code and navigation message.

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In order to extract the navigation data from the GPS signal, it is necessary to remove the carrier wave and the C/A code. The process of receiving GPS signals may be divided into three steps: acquisition, tracking, computing the position solution from recovered navigation data bits. Acquisition is used to detect the presence of signal from a particular satellite and calculate the initial code offset and Doppler shifted carrier frequency.

The two most important parameters to be determined by the acquisition program are the beginning of the C/A code and the carrier frequency of the input signal[4].

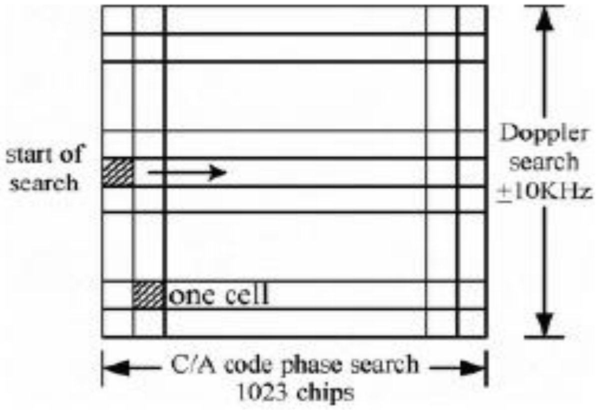

Fig.2 Signal acquisition process

IV. FFT BASED PARALLEL SEARCH ACQUISITION

In a software receiver, the acquisition is generally performed on a block of data using parallel search algorithm. After acquiring the desired signal, the relevant parameters are then passed on to the tracking program.

The quantized IF signal to GPS baseband processor can be expressed as

$$r(t) = AD(t-\tau^{D})\, C(t-\tau)\cos(2\pi(f_{IF}+f_d)t+\theta) + n(t) \qquad \text{----- (1)}$$

Where A is signal amplitude, D and τ^{D} are navigation data of 50 bits/second and its delay, C represents spreading C/A code with period of 1ms and rate of 1.023 MHz, τ is C/A code phase delay, f_{IF} is intermediate frequency, f_d is carrier Doppler shift, θ is carrier initial phase, $n(t)$ is noise.

There are two approached to perform acquisition, serial search in time domain and parallel search (FFT method) in frequency domain. Serial search in time domain is usually adopted in conventional hardware GPS receivers because of its simple implementation. But we must perform correlation over all the cells, so it is very time consuming. The idea of FFT acquisition is based on the theory of circular correlation. The correlation between two finite length sequence x(n) and h(n) both with length N is written as

$$y(n) = \sum_{m=0}^{N-1} x(m)\, h(n+m) \qquad \text{--------- (2)}$$

The DFT of y(n) is

$$y(k) = \sum_{n=0}^{N-1}\sum_{m=0}^{N-1} x(m)\, h(n+m)\, e^{j2\pi nk/N} \qquad \text{---------- (3)}$$

$$y(k) = X^{*}(K)H(k) \qquad \text{------------ (4)}$$

Where X*(k) is the complex conjugate of X(k). It means that the correlation value of x(n) and h(n) can be calculated as the multiplication of their corresponding DFT in frequency domain.

The block diagram of FFT based parallel search acquisition algorithm is shown in figure 3.

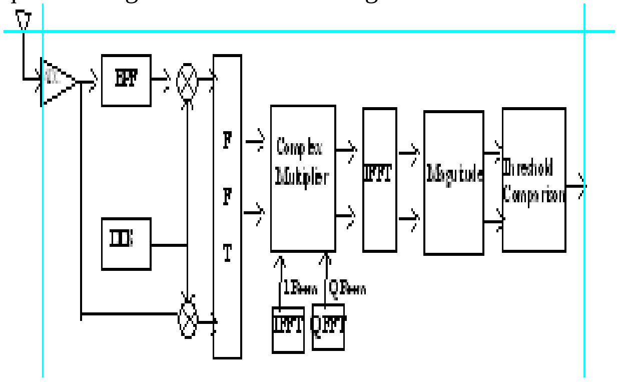

Fig.3The structure of parallel acquisition algorithm

This design uses Digital Down Conversion (DDC). In analog I/Q down conversion, there is more possibility of I/Q de-balancing. Also, receiver's performance degrades in case of non-availability of sharp analog filters. Hence DDC provides better accuracy and performance. DDC provides the I and Q channel, then FFT of I+jQ will multiply with complex conjugate of local C/A code FFT result. At last IFFT is performed for threshold comparison and the acquisition process is complete for software GPS receiver [3].

V. SIMULATION RESULT AND ANALYSIS

Figure shows the simulation result of signal acquisition for software GPS receiver which is based on FFT based parallel search algorithm.

In our design, IF frequency is 1.25 MHz, sampling frequency is 5 MHz, and GPS signal to noise ratio is 19 dB. In acquisition the non coherent integration period is 10 ms. At first FFT search is performed with Doppler step of maximum 6 Khz.

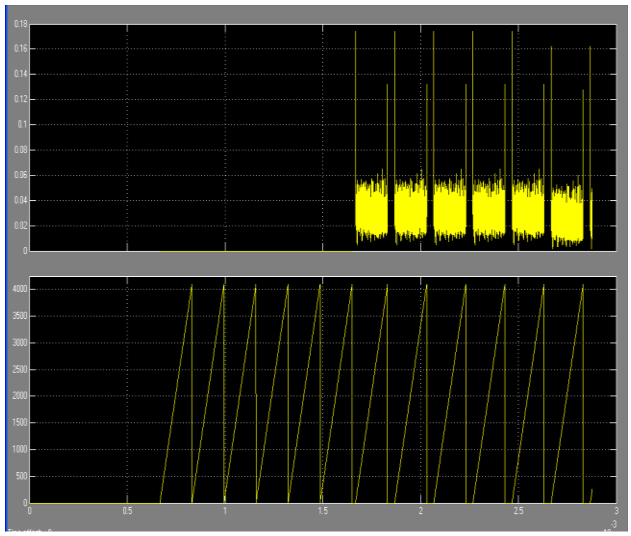

Fig.4 Signal acquisition result

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VI. CONCLUSION

In this paper we have investigated GPS signal Acquisition for software GPS receiver. The FFT based parallel search algorithm method has been studied. With simulation results, it is proved that this approach performs reliable digital down conversion and acquisition for software GPS receivers. The main strength of this approach is the possibility of redesigning the system at low cost with greater accuracy. In a GPS software receiver this flexibility is very useful when different algorithms should be tested, but also in cases where the GPS signal change. Additionally, this makes GPS software receiver more flexible when it comes to adapting the entire receiver to work on any other GNSS signals. To sum up, this approach leads to a compact, re-programmable, flexible, accurate and low cost realization of software GPS receivers with minimum analog components.

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