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# GPS Signal Acquisition Based on FFT

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*Abstract*— **The acquisition and tracking processes of Global Navigation Satellite System (GNSS) are heavy in the computation load of a GNSS receiver [1]. In order to track and decode the navigation information in the GPS signal, an acquisition algorithm must be used to detect the presence of the satellite signal. Once the signal is acquired, the necessary parameters such as code delay and Doppler shift must be obtained and then the parameters are passed to the tracking program in order to obtain the navigation information. This paper presents the serial search algorithm and the FFT acquisition algorithm based on real GPS IF data. Experiments are finished to compare the performance and computing speed of both the algorithms. As a result, it shows that FFT acquisition algorithm is efficient and further reduces the processing time in signal acquisition process.**

Keywords- GPS receiver; FFT; acquisition; serial search

## I. Introduction

The acquisition and tracking processes of Global Navigation Satellite System (GNSS) are heavy in the computation load of a GNSS receiver [1]. In order to track and decode the navigation information in the GPS signal, an acquisition algorithm must be used to detect the presence of the satellite signal. The procedure is a signal acquisition and the main purpose is to estimate code delay and Doppler shift parameters in order to keep track and demodulate the navigation data from the GPS receiver. There are often three GPS signal acquisition approaches including the serial search, circular correlation and the delay-multiply approach. The serial search algorithm searches sequentially through all possible combinations of code delay and Doppler shift in time domain. It is easy to implement in hardware and beneficial to GPS receiver, since only addition and multiplication operations are needed in the algorithm. However, the complete search will be a time consuming and heavy computation load process in GNSS receiver. Circulator correlation is based on Fast Fourier transform (FFT) in frequency domain which converts the GPS signal from time domain into frequency domain and is believed to be computationally efficient. But it is difficult to realize in hardware. The delay and multiply approach eliminates the frequency information in the input signal. And use the C/A code to find the initial point of the C/A code first and use FFT to find the frequency. From theoretically speaking, this is a very well algorithm, but it need advance research for real GPS satellite signals.

This paper presents the serial search algorithm and the circulator correlation based on FFT. In GPS signal processing, it proposes the FFT acquisition algorithm and compared it with the serial search algorithm. As a result, it shows that it is efficient and further reduces the processing time in signal acquisition process.

## II. Serial search acquisition

Serial search acquisition is a conventional algorithm for acquisition in code-division for GPS receiver. Figure 1 is a block diagram of the serial search acquisition algorithm.

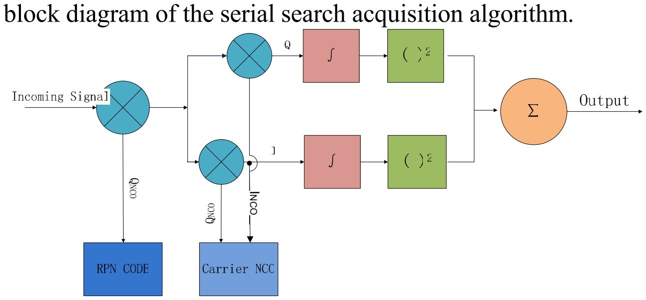


Figure 1. Block diagram of the serial search algorithm

Serial search acquisition is based on multiplication of locally generated PRN code sequences and locally generated carrier signals. Firstly, the incoming GPS IF signal is multiplied with a carrier replica which is generated by the PRN generator and corresponds to a specific satellite to wipe off the carrier wave from the signal. In the next step, the signal is multiplied with a code replica. Multiplication with the locally code replica generates the in-phase branch I, and multiplication with a 90° phase-shifted version of code replica generates the quadrature branch Q , which gives the navigation message.

The I branch and Q branch are integrated over 1 millisecond which corresponds to the length of one C/A code, squared and added. Compared all the adds with the given threshold, if it is exceeded, it can be regarded that the frequency and code phase parameters are obtained. Otherwise, the local code replica steps 1/2 chip until the entire code domain search is completed. If the signal still is not be acquired, the Doppler frequency step 500Hz. It performs two different sweeps, as can be seen from Fig.2: a frequency sweep over all possible carrier frequencies of IF ±10 kHz in steps of 500 Hz

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and a code phase sweep over all 1023 different code phases.

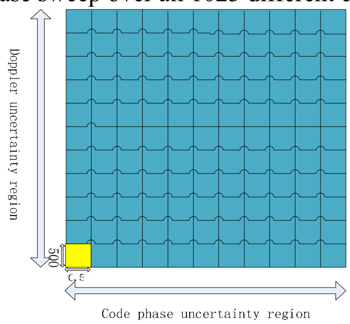


Figure 2. Signal Acquisition

Supposed that the received signal have 4092 points per millisecond by sampling 1 point every 4 points. One millisecond of data is searched and the process needs:

1023× (4092multiplctions, 4092addtions)

Since there are 21 Doppler bins, the combinations sums up to a total of:

21×1023× (4092multiplctions, 4092addtions)

Obviously, this consumes time. And the exhausting search routine tends to be the main weakness of the serial search acquisition.

## III. FFT Acquisition

The serial search acquisition algorithm searches sequentially through two dimensions combining frequency and code phase. It is an exhausting process to search the correct Doppler and code shifts. If one of the parameter 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. Figure 3 is a block diagram of FFT acquisition algorithm.

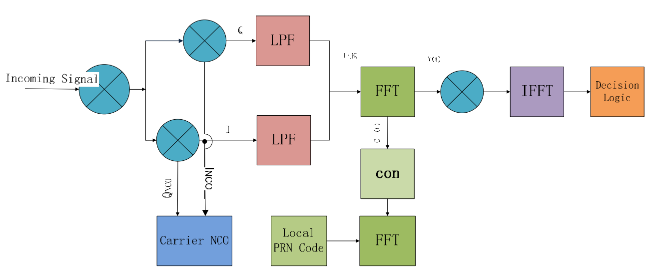


Figure 3. FFT Acquisition

As can be seen from Fig.3, the incoming digitized GPS IF signal can be expressed by Eq.(1) and the locally generated carrier signals can be depicted as Eq.(2).

$$y_{IF}(t_k) = A \cdot d(t_k - \tau) \cdot c(t_k - \tau)\cos[2\pi(f_{IF} - f_d)t_k - \phi(t_k)] + n_k \quad (1)$$

$$y_c(t_k) = c(t_k - \hat{\tau})e^{j2\pi(f_{IF} - \hat{f}_d)t_k} \quad (2)$$

where $y_{IF}$ is the incoming digitized GPS IF signal at sample time $t_k$ and $y_c(t_k)$ is the locally generated carrier signals. $A$ is the signal amplitude which indicates the power of the signal, $d$ is the navigation information with a rate of 50bit/s, $c$ stands for the C/A code of one GPS satellite, $\tau$ is the delay of the code chip. $f_d$ is the Doppler shift of carrier phase, $f_{IF}$ is the incoming digitized GPS IF signal frequency, $\phi(t_k)$ represents the initial phase of the GPS satellite, n is a white Gaussian noise.

The correlation function between the locally generated carrier signal $y_c$ and the incoming digitized GPS IF signal $y_{IF}$ can be defined as the following equation.

$$z(n) = \sum_{k=0}^{N-1} y_c(m) y_{IF}(n+m) \quad (3)$$

where m means the index of the sampling time sequence and N means the number of samples. The circular correlation is defined in FFT as:

$$\begin{aligned} FFT[z(n)] &= FFT[\sum_{k=0}^{N-1} y_c(m) y_{IF}(n+m)] \\ &= FFT[y_c(t_k)] \cdot FFT^*[y_{IF}(t_k)] \end{aligned} \quad (4)$$

where $FFT$ means Fast Fourier Transform and $FFT^*$ means complex conjugate of $FFT$. Eq. (4) in frequency domain can be rewritten as:

$$Z(k) = Y_c(k) \cdot Y_{IF}^*(k) \quad (5)$$

The correlation function in time domain can be written as

$$z(n) = IFFT[Z(k)] \quad (6)$$

The coarse Doppler shift and code delay can be directly detected at the highest correlation peak which is defined by the absolute value of correlation function. The above process is FFT-based circular correlation. Compared with serial search acquisition algorithm, the method minimizes the search time and allows direct acquisition of the signal using 1 millisecond data of the C/A code signal. However, the frequency search resolution depends on signal length: the longer the signal, the finer is the resolution.

## IV. Experiment and results analysis

The performance of the above processing algorithms is analyzed by the VC++ program using the real digitized GPS IF data with the sampling frequency of 16.368MHz.

Firstly, FFT acquisition algorithm is performed to acquire PRN 1 and PRN 2. The Doppler search range is ±14KHz with steps of 500Hz. Fig.4 and Fig.5 shows the correlation in 3D plot as a function of time and frequency. The search frequency index is from 1 to 29 and the number of C/A code bin is 16368.

As shown in Fig.4, the correlations are close to each other. The maximum correlation is so less than other false peaks. It will produce so-called false alarm probability in the acquisition. That is, there is no signal of PRN1 acquired in the receiver and it cannot be tracked. However in Fig.5, it can be seen that a good maximum correlation peak can be detected easily. The maximum correlation peak occurs at the 2368th C/A code bin and the 12th frequency bin (4.12893MHz), which indicates that the beginning of C/A code is located at this sample number. The coarse acquisition search is completed and can convert to fine frequency acquisition search and the tracking procedure.

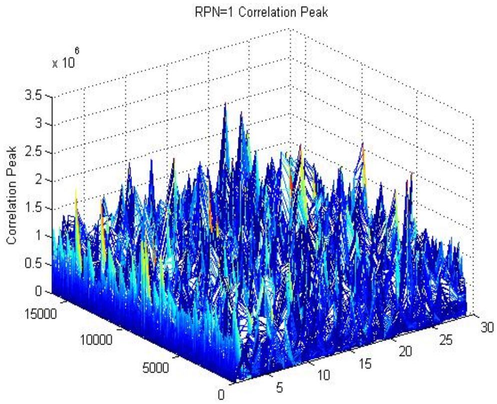


Figure 4. Correlation Peak of PRN1 using FFT

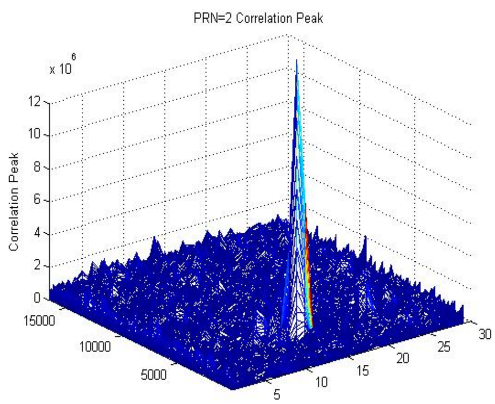


Figure 5. Correlation Peak of PRN2 using FFT

Secondly, the acquisition is performed using serial search acquisition with down sampling of 4 times. It reduces the data size from 16,368 points to 4092 points and thus reduces the computation time. That also means that the signal power will be decreased at the same time. The Doppler search range is ± 10KHz and the Doppler search steps is 500Hz. Fig.6 shows the correlation matrix for PRN1 whose signals cannot be detected in the receiver and Fig.7 illustrates the correlation peak of PRN 2 using the serial search acquisition algorithm.

From Fig.6, it can be seen that after the circular correlation, the beginning of the C/A code cannot be found because there is no signal for PRN1 to be detected. Compared with Fig.4, the resolution is decreased and the correlation peak is so less than other peaks. It can easily cause the false alarm probability. The largest correlation power at n = 3498, for 7 frequency components of PRN 2, centered at 4.13MHz, can be seen in Fig.7. The highest component at 4.12890MHz corresponds to real frequency of the incoming GPS IF signal.

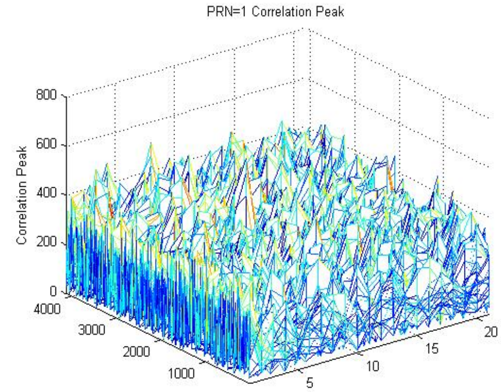


Figure 6. Correlation Peak of PRN1 using serial search

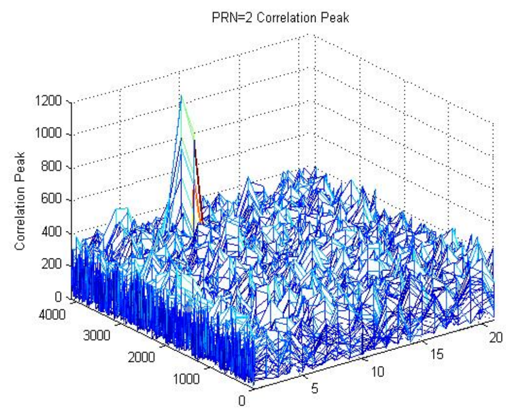


Figure 7. Correlation Peak of PRN2 using serial search

Finally, in this section we compare the consuming time of both algorithms. Fig.8 shows the processing time of serial search acquisition algorithm and FFT acquisition algorithm for acquiring 32 PRNs. Fig.9 shows the processing time of serial search acquisition algorithm and FFT acquisition method for acquiring 4 PRNs which can be detected in the space.

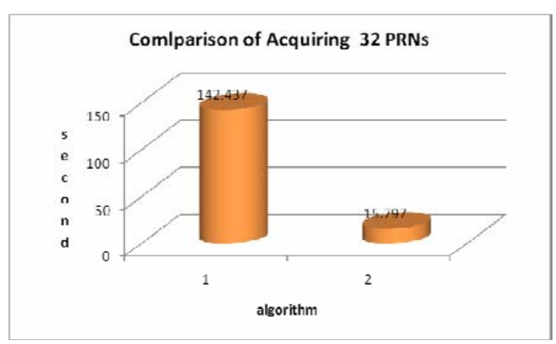


Figure 8. Comparison of consuming time in acquiring 32 PRNs

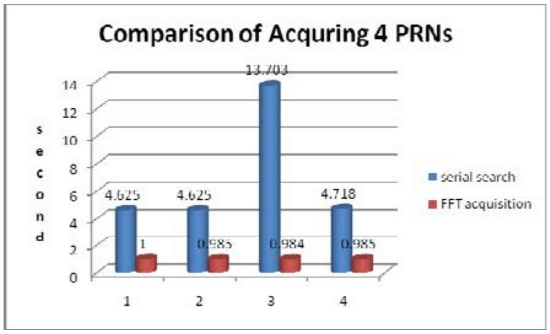


Figure 9. Comparison of consuming time in acquiring 4 PRNs

As shown in figures, some advantages of FFT acquisition algorithm can be concluded. From Fig. 8, the serial search acquisition algorithm consumes about 142.437 seconds to complete the acquisition process of 32 channels. On the other hand, the processing time using the FFT-based acquisition algorithm is 15.797seconds. The processing time of all-PRNs code acquisition based on FFT is reduced greatly than that of serial search acquisition algorithm as the number of PRNs in the summed code increases. Fig.9 illustrates FFT acquisition algorithm can reduce the time consuming of 75-80% respectively, especially for the 3$^{rd}$ PRN. The 3$^{rd}$ PRN consumes 13.703 seconds for serial search acquisition and 0.984 seconds for FFT acquisition to complete the process.

## V. CONCLUSION

In the GPS signal, the software receiver can detect and track the signal, then decode the navigation information for the positioning. In the paper, two signal processing algorithms based on real IF signal for GPS software receiver is presented. From the data analysis, the serial search acquisition algorithm is simple and can be easily realized in hardware. It will be beneficial to commercial GPS receivers and can also lower the cost of the GPS receivers. However, it is obvious that FFT acquisition algorithm is complex, but it is more efficient than that of serial search acquisition algorithm although serial acquisition algorithm is down sampled of 4 times. The computing speed is faster, even 13 times. The results of the experiments confirm valid operation of FFT acquisition algorithm.

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