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Comparative Study on Signal Acquisition of GPS Positioning using Software Receiver

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***Abstract*— This paper provides comparison of GPS measured data on the best technique of signal acquisition for better accuracy. In the previous research work, it is proved that acquisition in time-domain employing parallel FFT method is the most suitable method for software-defined GPS receiver because of its fastest speed and the most accurate results.**

In this paper, two measured data are tested to prove the best method for signal acquisition of previous studies for better accuracy. For the test signals, the first one the is collected from the front-end device in University of Colorado, Boulder, CO, USA by Alban Rakipi, University of Tirana and the second one is measured with DVB-T TV tuner dongle based on RTL2832U, , on 24th October, 2016 in the campus in Kanazawa University, Japan. Simulation results show that receiver position is successfully estimated with the best algorithm of acquisition methods for better accuracy.

***Index Terms*— GPS; Software-defined; accuracy; receiver; acquisition .**

1) Introduction

Software receiver is an advanced technology that enables to replace hardware components in radio receivers with software. The receiver offers great operational flexibility for the implementation of radio communication system and can be used for development/examination of a new algorithm of GPS signal analysis, such as reduction of ranging errors.

Accuracy of position estimation is much related to performance of receivers. However, user accuracy depends on a combination of satellite geometry and local factors such as signal blockage, atmospheric conditions, and receiver design features/quality. In GPS receivers, signal is generally processed by ASIC (application specific integrated circuit) and it is not easy for researchers and engineers to examine their new algorithms/techniques inside the receiver [3]. There are many difficulties to get accurate acquisition results (Doppler frequency and code delay) and the less time consumption of processing. High accuracy of acquisition and tracking is very important for pseudorange calculation and positioning [11].

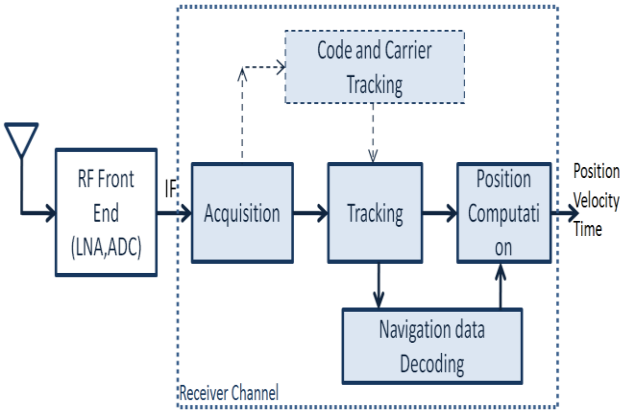

Figure 1. Functional Block Diagram of GPS Signal Processing

2) Signal processing

Signal Acquisition

The first step in GPS receiver operation is to know which satellite is visible currently. The purpose of signal acquisition is to identify visible satellites to the user. The tasks of the second step is the signal tracking, which contains two parts: code tracking and phase tracking, are refining the values of the code phase and Doppler shift of carrier frequency of replica signal generated in the receiver and keeping the track of these with respect to the time changed. During tracking of the incoming signal, bit series of navigation message are also obtained. After positioning computation from the decoded navigation message and pseudoranges the receiver location is obtained within the acceptable accuracy.

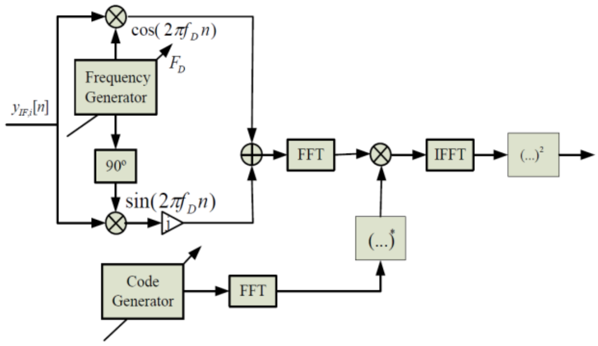

Figure 2. Block Diagram of Acquisition in Time Domain Employing Parallel FFT [3]

There are three different acquisition algorithms. They are the serial search in time domain, parallel search in time domain and parallel search using fast Fourier transform (FFT) in frequency domain. Though serial search is the slowest search method, it is usually implemented in hardware based receivers due to its simplicity. The parallel search (FFT method) in frequency domain usually implemented by software receiver since serial search method is computation intensive in the software approach [4]. In [9], the author is presented that a FFT-based fast algorithm which reduces the computation in order to achieve rapid long code acquisition[8].

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Signal Tracking

The tasks of the signal tracking, which contains two parts: code tracking and phase tracking, are refining the values of the C/A code phase and Doppler shift of carrier frequency of replica signal generated in the receiver and keeping the track of these with respect to the time changed. The code tracking is implemented as a delay lock loop (DLL) referred as early, prompt and late. The phase tracking is performed by tracking the phase or frequency of the signal by phase/frequency lock loop (PLL/FLL). Pseudorange is obtained from correlation between replica and received signals.[11]

Decoding and Positioning

During tracking of the incoming signal, bit series of navigation message are also obtained. The bit series are decoded into ephemeris data for each satellite according to the interface specifications of the signal [4]. For estimating user position coordinates a term, called pseudorange is frequently used. It is basically the distance measurement between satellite and receiver, including combined effect of all error sources [5]. By measuring the time of arrival (TOA) of the signal, the user's distance (range) from each of the satellite is calculated. By combining the range from a minimum of 3 satellites, the user position can be calculated in three dimensions. The basic pseudorange measurement equation can be given as [3]:

$$. \rho_r^k = \sqrt{(X^k - X_r)^2 + (Y^k - Y_r)^2 + (Z^k - Z_r)^2} \qquad (1)$$

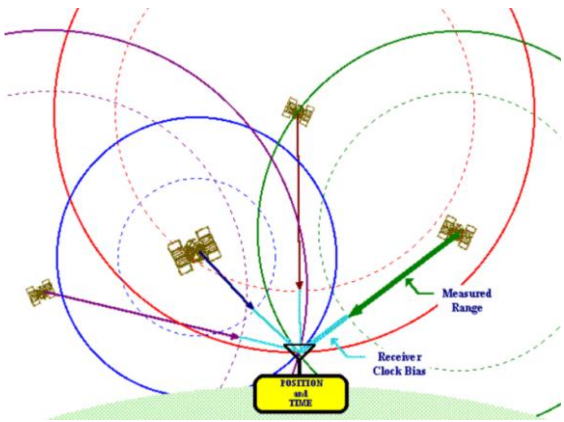


Figure 3. Estimation of positions at the intersection of each satellite [7]

The signals transmitted by the GPS satellites are used to measure the Time of Arrival (TOA) at the receiver. Since the propagation speed (the speed of light) is known, the distance (geometric range) can be calculated from the delay. The simplest method to implement the PVT stage of the GPS receiver is to consider the Least Squares (LS) solution [4].

3) GPS SIGNAL OBSERVATION AND POSITIONING USING SOFTWARE RECEIVER

The first GPS signal to make comparison was measured with a DVB-T TV tuner dongle based on RTL2832U, which can be used as a low-cost software receiver [8], on 24th October, 2016 in the campus in Kanazawa University, Japan. The receiver is a kind of direct conversion type and it can measure signals in a frequency range from 24MHz to 1766MHz, which includes L1 frequency band. The maximum sampling rate is 2.4 Msps with the bandwidth of 1 MHz. The output data is 8 bits real and imaginary components of baseband signal.

The first one the is obtained from the front-end device in University of Colorado, Boulder, CO, USA by the permission of Alban Rakipi, University of Tirana. The parameters necessary for processing these data are sampling frequency of 38.192 MHz and intermediate frequency of 9.55 MHz . The GPS signals were received, amplified, down-converted, and digitized into base band samples. The base band samples are then processed using software routines to acquire and track the direct GPS signal and to generate the receiver position information as explained in following sections[10].

RTK-SDR software was used to import the digitalized data into a personal computer, in which Corei7 processor is installed.GPS antenna was magnetic type attached with 5 m cable and draws about 10mA with additional gain of 28dB. It required the voltage from 3V to 5V. GPS Bias Tee was used to prevent DC power from entering from RF front end and to provide power to the GPS antenna. The RTL dongle was directly connected to the antenna which was mounted on the car, via Bias Tee[11].

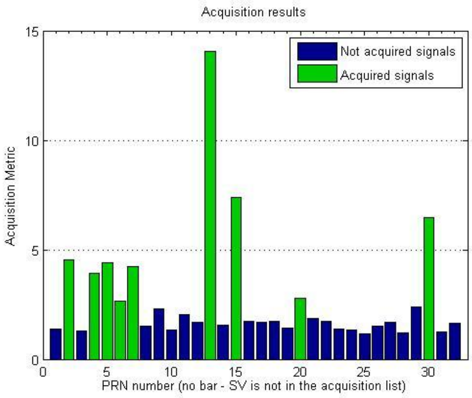
The L1 band signal was recorded for 60 seconds to ensure enough data to find position. The parameters of the recorded data for processing were 2.048 MHz of sampling frequency, code basic frequency of 1.023MHz and intermediate frequency was DC (0Hz) using 8 bit real and imaginary sample format. The recorded time to ensure navigation subframe was 37000ms and eight channels was used for signal processing. As it was introduced in the first section, the main focus of this paper is positioning using software receiver.

4) RESULTS AND DISCUSSIONS

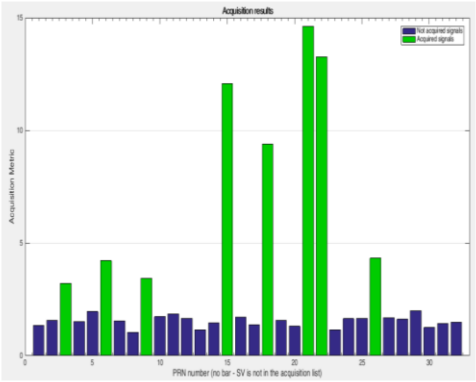
As it is proved that acquisition in time-domain employing parallel FFT is the most suitable method for software-defined GPS receiver because of its fastest speed and the most accurate results, the test signals were used the above method and results show the best accuracy of position estimation[8].

Figure 3 shows the results of the acquisition to determine which satellites are visible. Each bar shows correlation between observed signal and replica signal for each GPS satellite. Nine satellites are acquired for first testing signal and eight satellites are acquired for second testing signal.

Figure 4 shows tracking and navigation results for one of the visible satellite in two observed signal. The top two panels show the tracked signal; left one shows real and imaginary component plane and right one does time variation of the real component. Each cluster in left panel corresponds to the digital symbols 1 and -1. Navigation message is obtained by decoding the bit series. The other panels show parameters during the tracing process that is FLL, DLL and PLL.

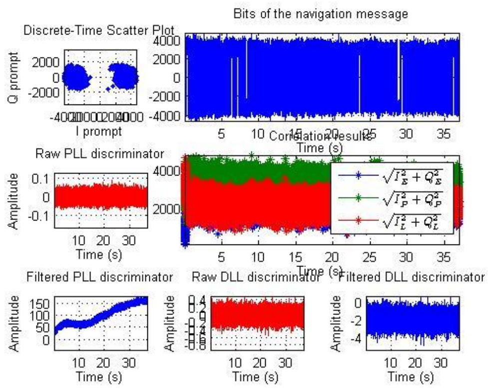


(a) First Signal

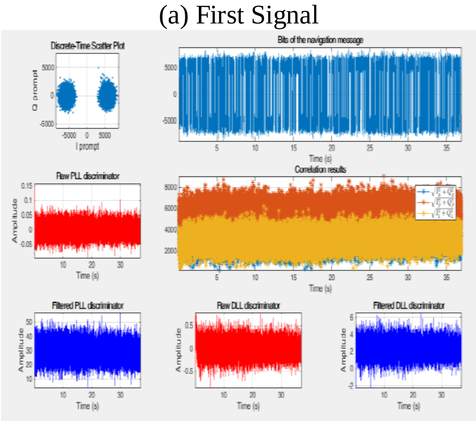


(b) Second Signal

Figure 3. Correlation between two observed signal and replica signal for each satellite



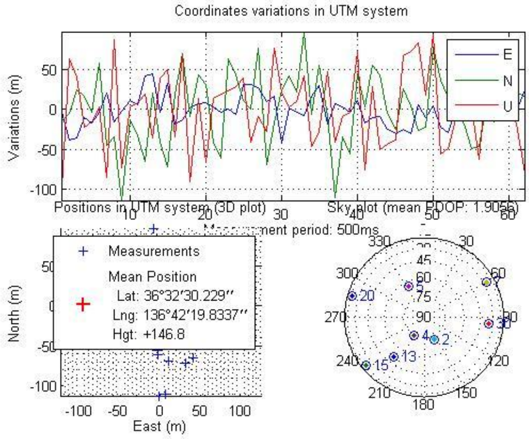
(a) First Signal



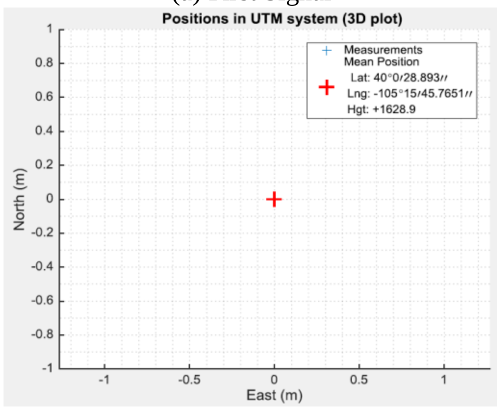
(b) Second Signal

Figure 4. Results of Signal Tracking and Navigation

After positioning computation from the decoded navigation message and pseudoranges, the receiver location is successfully obtained within accuracy of a few meters. The results shown in Fig 9 provided the location as a final output of complete software receiver.



(a) First Signal



(b) Second Signal

Figure 5. Results of Positioning

5) CONCLUSION

Acquisition in time-domain parallel FFT method is approved that one of the most reliable method at the previous publication. Two GPS signals were tested with the methods successfully. The processing results from the two signals with the method show seamlessly good time consume and better accuracy in GPS positioning. Further recommendation as future plan is to get better improvement at signal tracking and decoding by using software receiver.

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