Performance Evaluation of ssFFT based GPS Acquisition in the Harsh Environmental Conditions

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Abstract

In the design of a software GPS receiver, Acquisition is a preliminary stage of a software module and plays an important role in finding out the position. The computation time of Global Positioning System (GPS) acquisition has been greatly reduced by using sub-sampled fast Fourier transform (ssFFT) and thresholding. ssFFT exploits the recently developed sparse fast Fourier transform (or sparse Inverse fast Fourier transform) that computes in sublinear time. Compressed sensing based subsampling (CS-SS) has been done with different factors varying from 2 to 14 with the difference of 2. An important factor of the GPS receiver is that of receiver sensitivity because the signal gets faded depending on environmental factors. This paper presents a detailed performance evaluation of fast GPS acquisition in the presence of noise. Real-time data of satellite with Pseudo Random Noise (PRN) code 1 is used to verify the performance of the ssFFT based GPS Acquisition. The performances of the ssFFT based GPS acquisition are compared and evaluated using different Signal to noise ratios (SNR). The simulation results show that the considered system can operate continuously without fail even with very weak GPS signals. Same acquisition results have been obtained with SNR values of -10dB, -8dB, -6dB, -4dB, -1dB, -1dB and 1dB for subsampling factor of 0, 2, 4, 6, 8, 10 and 12 respectively.

Keywords: Global Positioning System, Sub-sampled fast Fourier transform, Acquisition, Interference, Signal-to-noise ratio.
1 Introduction

In order to complete navigation in GPS receiver, the acquisition is the initial and the most important process. The Acquisition involves a "2-D search operation" for available satellite signals, which includes "Frequency search" and "code-phase search" [1]. Acquisition needs a rough estimation of these two important parameters of GPS signal- Carrier frequency (fc) and code phase (ph) because, only after removing both the carrier signal and the PRN code from the modulated signal, tracking can be obtained [2].

Different environmental conditions such as ionospheric and tropospheric variability, signal obstructions, multipath, radio interference, etc contribute in the degradation of the GPS signal quality [3]. The fading can be so severe that the signal will drop completely below the receiver's threshold and required to be reacquired repeatedly. The scintillation effects due to ionosphere on GPS signal has been considered. The scintillation effect can last several hours in the evening period, broken with periods of no fading in between in the equatorial region. An important factor of GPS testing is that of receiver sensitivity [4]. Compressed sensing based subsampling (CS-SS) has been done with different factors varying from 2 to 14 with the difference of 2. The simulation results show that the considered system can operate continuously without reacquiring the signal.

The paper is organized as follows. Section 2 briefly discuss about literature survey. Section 3 describes the receiver architecture and the signal model. The performance evaluation of the considered system for different environmental conditions is presented using simulations in Section 4. Finally, we draw conclusions and future work in Section 5.

2 Related Works

Most GPS receivers perform a time-consuming two-dimensional search to acquire the signal from satellites because they have no code phase and Doppler shift information. Along with this GPS signals degrade its performance due to the harsh environmental conditions. More interest has taken on the research of indoor positioning. Chansarkar, Mangesh M has evaluated the performance of GPS acquisition for indoor positioning with weak GPS signals where he discusses the practical limitations on time required for long integration during acquisition [5]. GPS acquisition with low SNR values. It takes at least a few seconds even if the almanac is known. High demand for fast-tracking and quickly determining the position, under any environmental condition is the need of the modern society. All the efforts have been made by researchers to reduce the time for GPS acquisition as well as GPS tracking. We can find more research work has been done on GPS acquisition because it's a very simple process of correlating the incoming signal and it also does not require reconstruction as it is required in GPS tracking. The Author Rao M V G has found a novel, simple technique for GPS acquisition named Sub-sampled fast Fourier transform (ssFFT) which is advantageous while designing a low power consumption GPS receiver [6]. M Venu Gopala Rao has further continued his research and they have successfully achieved the GPS acquisition by processing the signal below sampling frequency [7]. This research violets the Nyquist criteria while designing a low power consumption GPS receiver. Ilir F Progri discusses on the high performance of GPS like VBOC signals for a wireless-enabled GPS indoor geo-location and focuses on obtaining a very high accuracy position level accuracy 99.999% of the time and meets the integrity requirements in various applications such as indoors, undergrounds, and in tunnels [8]. G Arul Elango has obtained 96% of probability detection for GPS signals with SNR of -159 dBm. They
have used a pre-filtering technique of reduced rank singular spectral analysis [9]. The optimal subsampling frequency used for this sub-sampled GPS-SDR is 1 MHz whereas the actual sampling frequency is 12 MHz. Figure 1 represents ssFFT based GPS Acquisition which is the fastest algorithm in all acquisition methods having the computational complexity of \( \log(d) \) where 'd' is a sub-sampling factor.

![Figure 1 ssFFT based GPS Acquisition](image1)

Figure 1 represents Compressive Sensing based Sub-Sampling (CS-SS) process. Many researchers has worked on Compressive sensing with different applications [10]. Subrahmanyeswara Rao T J V has obtained the subsampling factor of 0.2 with input SNR 20 dB for wideband signals in wireless communications [11].

![Figure 2 Compressive Sensing based Sub-Sampling (CS-SS) process](image2)

Figure 2 represents GPS acquisition results for different sub-sampling factors varying from 2 to 14 in step size of 2 [12]. The proposed technique decreases sampling frequency \( (fs=11.99 \text{ MHz}) \) below twice of the center frequency \( (fc=1.25 \text{ MHz}) \) of GPS signal by violating Nyquist criteria. Without loss of original information, signals are recovered. Experiments carried out to estimate the computation time of acquisition for different fs varying from 11.99 MHz to 1.99 MHz. The computation time is reduced from 42.894 sec to 30.853 sec, 21.78024 sec and 34.68482 sec respectively for sampling frequency fs, fs/2, fs/4, and fs/6. The below figures are showing the increased presence of noise due to the aliasing effect.

![Figure 3 Compressive Sensing based Sub-Sampling (CS-SS) process](image3)
Proposed Methodology

The subsampling increases noise linearly which can be easily eliminated by thresholding the signal or using filter [13]. This noise does not affect GPS acquisition as visibility of satellite depends upon only on one spike [14]. The computation time decreased as the subsampling factor increases. Figure 4 (a) and (b) represent GPS signal data and its Frequency domain representation for different sampling factors. Figure 4
The accuracy of GPS completely depends on the signal strength which also gets affected due to multipath (reflections with large buildings), troposphere, stratosphere, ionosphere or any electromagnetic interference making GPS unusable in water, dense forest, underground areas causing an error of 5 to 10 meters in positioning [15]. Due to the harsh environmental conditions, GPS signal quality gets highly affected [16]. The proposed methodology is to evaluate the performance of ssFFT based GPS Acquisition in the harsh environmental conditions [17]. All simulation results have been performed using Matlab 2018 platform. GPS signal data for satellite PRN 1 is realized by simulation code. By adding the noise to the available GPS signal, different degraded input signals have been given as an input (with varying signal-to-noise ratio). The GPS signal quality may degrade because of so many factors and it may reach up to -10dB which increases difficulty in computing positioning. GPS receiver in the high dynamics and weak signal environment forces signal to reacquire again which again takes a few minutes [18]. In order to deal with these types of situations ssFFT based GPS acquisition gives the fastest acquisition, 12 times more faster than previous techniques. Here the Sampling Frequency is $f_s=11.999MHz$ and central frequency is $f_c= 3.563MHz$ for satellite PRN = 1.

(c) and (d) represents CA code data and its Frequency domain representation for different sampling factors.

Figure 4 (a) GPS signal data and its Frequency domain representation for different sampling factors.
Figure 4 (b) GPS signal data and its Frequency domain representation for different sampling factors

Figure 4 (c) CA code data and its Frequency domain representation for different sampling factors
4 Results and Discussion

In order to evaluate the performance of ssFFT based GPS Acquisition in the harsh environmental conditions, a case study has been done with different sampling rates and different SNR values. The ssFFT based GPS acquisition gives the fastest acquisition, 12 times more faster than previous techniques. Here the Sampling Frequency is $f_s=11.999\text{MHz}$ and central frequency is $f_c= 3.563\text{MHz}$ for satellite ,PRN = 1.

4.1 Case 1 Without Sub-Sampling Information

Without subsampling the signal can capture the signal minimum SNR is -10dB. Figure 5. (a) shows the evaluation of GPS acquisition without subsampling for SNR= 0dB, -2dB, -5dB and -10dB, whereas Figure 5. (b) represents noisy GPS signal data and its frequency domain representation for SNR=-10dB. It clearly represents the degradation of GPS signals due to the harsh environment.
4.2 Case 2 Sub-Sampling Factor 2

With subsampling factor 2 the signal can capture the signal minimum SNR is -8dB. Figure 6 shows the evaluation of GPS acquisition without subsampling for SNR= 0dB, -1dB, -5dB and -8dB.
4.3 Case 3 Sub-Sampling Factor 4

With subsampling factor 4 the signal can capture the signal minimum SNR is -5dB. Figure 7 shows the evaluation of GPS acquisition without subsampling for SNR=0dB, -1dB, -2dB and -5dB.
4.4 Case 4 Sub-Sampling Factor 6

With subsampling factor 6 the signal can capture the signal minimum SNR is -4dB. Figure 8 shows the evaluation of GPS acquisition without subsampling for SNR= 0dB, -1dB, -2dB and -4dB.
**Performance Evaluation of ssFFT based GPS Acquisition in the harsh environmental conditions**

**4.5 Case 5 Sub-Sampling Factor 8**

With subsampling factor 8 the signal can capture the signal minimum SNR is -1dB. Figure 9 shows the evaluation of GPS acquisition without subsampling for SNR = 0.00001dB, 0.0001dB, 0dB and -1dB.
Figure 9. Evaluation of GPS acquisition with subsampling factor 8 for different SNR

4.6 Case 6 Sub-Sampling Factor 10

With subsampling factor 10 the signal can capture the signal minimum SNR is -4dB. Figure 10 shows the evaluation of GPS acquisition without subsampling for SNR= 1.5dB, 1dB, 0dB and -1dB.
4.7 Case 7 Sub-Sampling Factor 12

With subsampling factor 12 the signal can capture the signal minimum SNR is 1dB. Figure 11 (a) shows the evaluation of GPS acquisition without subsampling for SNR= 2dB, 1.8dB, 1.5dB and 1dB. Figure 11. (b) represents noisy GPS signal data and its frequency domain representation for SNR=1dB. It clearly represents the degradation of GPS signals due to the harsh environment.
Figure 11 (a) Evaluation of GPS acquisition with subsampling factor 12 for different SNR

Figure 11 (b) Noisy GPS signal data and its frequency domain representation for SNR=1dB

5 Conclusion

The performances of the ssFFT based GPS Acquisition are compared and evaluated using different Signal to noise ratios (SNR) in harsh environmental conditions. The simulation results show that the considered system can operate continuously without fail even with very weak GPS signals. Same acquisition results have been obtained with SNR values of -10 dB, -8 dB, -5 dB, -4 dB, -1dB, -1dB and 1dB for subsampling factor of 0, 2, 4, 6, 8, 10 and 12 respectively. The proposed algorithm definitely will have a great contribution towards the exact positioning required in various applications such as fisherman, cell phones, missile guidance, vehicle tracking, and disaster management etc.
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References

Biographies

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