Evaluation of Performance of Software GPS Receiver using Sub-Sampling and Thresholding

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***Abstract* - Software GPS receiver (SGR) are becoming prevalent because of their flexibility, re-configurability and computational efficiency. Acquisition, pull in frequency and tracking are the main building blocks of SGR design. In this paper, sub sampled version of signal has been processed through these three blocks which effectively reduce processing time. Sub-sampling mainly violets Nyquist criteria. Wide bandwidth of GPS signal set up the sampling frequency very high. The implementation of sub sampling technique followed by thresholding the tracked signal to ± 1 reduce the associated higher chipping rate and henceforth the processing time. The proposed technique decreases sampling frequency (F= 5 MHz) below center frequency (Fcar= 1.25 MHz) of GPS signal. Without loss of original information, signals are recovered. Experiments carried out estimate the computation from 4.2894 sec to 3.0853 sec, 2.178024 sec and 3.468482 sec respectively for sampling frequency F/2, F/4, F/6. This Simulation and real data carried out ensures the fast acquisition and tracking and power consumption.**

Keywords – Evaluation, performance, software, GPS receiver, sub-sampling, thresholding

I. INTRODUCTION

Modern world growing faster with high performance of GPS receiver every day because of rapidly growing research and improved techniques in this area. The Software GPS receiver becomes interesting part for researchers because of its flexibility [1]. Before presenting the most interesting features of the software receiver, will have a look over the entire architecture. A summarizing image of GPS receiver design, hardware and software module is described in Fig. 1. Hardware module compromises RF front end circuit in order to provide intermediate frequency (IF) required for post processing of GPS satellite signals whereas software module decodes each satellite navigation message, and computes the receiver position based on the IF samples provided by the hardware Radio Frequency (RF) front end [2], [3]. Software module offers many advantages over hardware module by allowing different algorithms implementation and simulating them to improve the overall performance of SGR [4], [5].

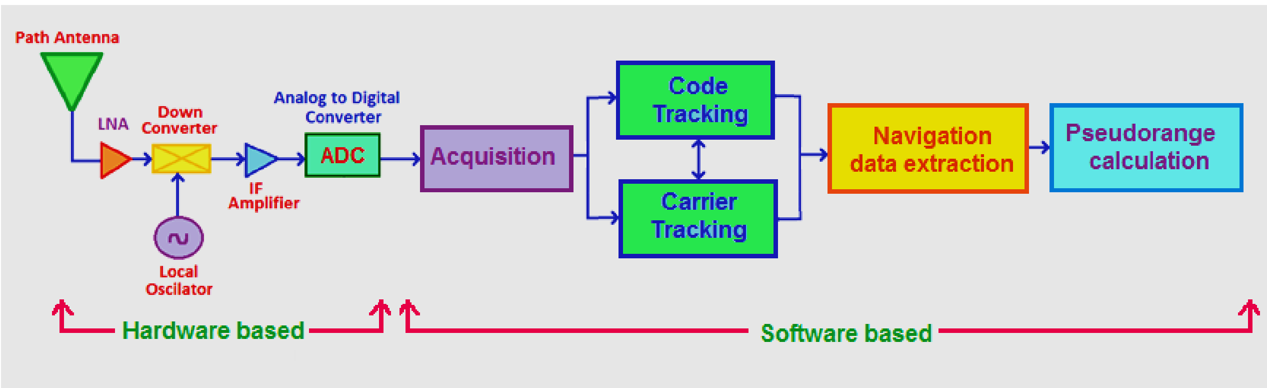

Fig. 1. Basic architecture of GPS receiver

Base band processing of GPS signal is done in main building blocks of Software GPS receiver named as acquisition, pull in frequency and tracking [6]. Implementation of SGR is achievable in highly programming languages such as C/C++, python, LabVIEW, R and Simulink. These attractive choices for implementing GPS engage attention of many researchers, both in academia and industry for future research endeavors. The fundamental concept of acquisition is to find visible satellites and estimates their code-phase and frequency by performing two dimensional search. Acquisition phase starts with input of down converted digital IF signal recorded from the RF front end. It is time consuming process based on FFT-IFFT scheme. This inspires to accept the challenge of reducing acquisition computation time. Tracking rely upon essential principle of phased locked loop between received signal and pre generated stored local C/A code & carrier replica signal received for visible satellite signal acquired from acquisition process [7], [8]. To achieve high performances and fast processing of SGR, lot of efforts has been taken. Acquisition time can be easily reduced with various techniques such as Fast Fourier Transform (FFT), Discrete Fourier Transform (DFT), multi-correlator, eXtended Multi-Correlator, Radix-2 and Radix-4 FFT Algorithms, matched filter, compressive acquisition, Sub-sampled fast fourier transform (ssFFT) [9], [10], [11]. Very little research has been conducted on fast tracking of GPS receiver. Also different research carried out on reducing processing time of SGR [12]. Reduction of computation time is a preferential criterion in SGR which fundamentally depends on less number of computations. We can achieve this only violating essential principle of sampling [13]. Subsampling architectures uses less samples to process as compared to conventional SGR without losing the track of signal. This architectures exhibit several advantages over power savings as compared to conventional method [14]. The receiver achieves a substantially reduce the power consumption and fast processing. Sparse nature of GPS signal in frequency domain makes this possible to happen effectively. Main focus of this research is to apply sub-sampled version of signal to SGR and find out minimum acceptable sampling rate. Computational time can be reduced by applying different sampling frequencies varying from F to F/5 in acquisition, pull in frequency and tracking. The simulations indicate that SGR can be effectively sub sampled with sampling frequency is almost equal to central frequency 1.25 MHz This paper has developed algorithm to achieve quick acquisition and tracking.

This paper is organized as follows. Proposed technique is explained in section II. We further discusses different possibilities of proposed techniques in section III.

II. EVALUATION OF PERFORMANCE OF SOFTWARE GPS RECEIVER

Figure 2-a describes the actual SGR process.

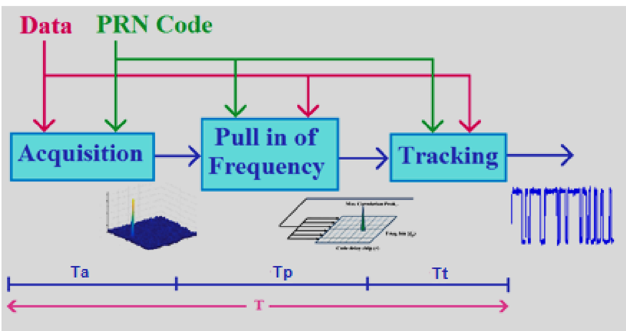

Fig. 2 a. Basic block diagram of SGR

Acquisition Pull in Frequency and tracking are blocks on which performance evaluation going to be done. Pull in Pull in frequency plays very important role as it helps to track signal with accurate value of carrier frequency. After getting pull in frequency value only tracking the signal without an error. Implementation of sub-sampled technique on SGR is shown in Figure 2. b. It also shows the computational times for acquisition, pull-in frequency and tracking as TA, TP and TT. Total computational time is T= TA+TP+TT.

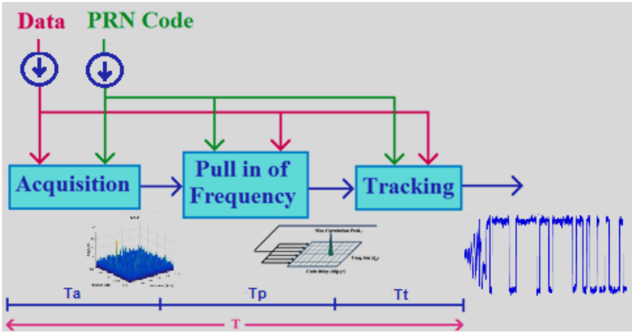

Fig. 2 b. Sub-sampled block diagram of SGR

Pull-in Frequency

The basics concept of Pull in frequency is to achieve finest value of carrier frequency. This process resembles to the acquisition process means it also correlate the incoming signal with locally generated carrier but only it differs in correlation method. Carrier frequency from acquisition output will be used to generate the locally generated signal. Replicas will be generated by adding Doppler shift of the approximately ±5 kilohertz difference to carrier signal obtained from acquisition. These parameters are then used to initialize the tracking loop

Tracking

Tracking rely upon essential principle of phased locked loop between received signal and pre generated stored local C/A code & carrier replica signal received for visible satellite signal acquired from acquisition process. Same acquisition input samples of down converted digital IF signal recorded from the RF front end has been processed for tracking. The signal has been demodulated by two different code tracking and carrier tracking loops in order to fixed the SGR position. Because of insensitivity to 180 degree phase shift, PLL can be named as Costas loop. Because of insensitivity to 180 degree phase shift, PLL can be named as Costas loop. The another very crucial parameter includes in between acquisition and tracking is pull in frequency which enables accurate tracking.

III. RESULTS AND DISCUSSION

Like acquisition process the same input samples has been used to achieve nearest possible values of code phase and frequency. Search process of acquisition has been carried out with $fc \pm 500\,KHz$ where $fc\ (MHz)$ is carrier frequency of received GPS signal whereas pull in search operation carried out with $fa \pm 5\,KHz$ where $fa\ (MHz)$ is a frequency obtained from acquisition process. Pull in frequency block is necessary to carry out tracking process more precisely. Performance of SGR depends upon fast and precise positioning of user.

Let us discuss the different stages of subsampling:

Stage 1

In stage 1, results obtained are as F= 5MHz and Visible satellite, Sat No= 22, Carrier Frequency, Fcar= 1250500 MHz and Phase delay, Phase=470. Results obtained are shown in Figure 3. For stage 1, Processing time is T=TA+TP+TT is 4.289406 sec.

Stage 2

In stage 2, results obtained are as F= 2.5 MHz and Visible satellite, Sat No= 20, Carrier Frequency, Fcar= 1249500 MHz and Phase delay, Phase=472. Results obtained are shown in Figure 4. For stage 1, Processing time is T=TA+TP+TT is 3.0853 sec. Thresholding signal at +1 to -1 improves signal to noise ratio.

Stage 3

In stage 3, results obtained are as F= 1.25 MHz and Visible satellite, Sat No= 20, Carrier Frequency, Fcar= 1249500 MHz and Phase delay, Phase=472. Results obtained are shown in Figure 5. For stage 1, Processing time is T=TA+TP+TT is 2.178024 sec.

Fig. 5a represent the acquisition of satellite signal. Fig. 5b represent the demodulated noisy signal. This noise is unable to removed by thresholding the signal at +1 to -1. It can be seen from Fig. 5c and 5d. Here the important signatures of signal are missing out. This is reason we are unable to track signal at sampling frequency F=1.25MHz.

Stage 4

In stage 4, results obtained are as F= 1 MHz and Visible satellite, Sat No= 22, Carrier Frequency, Fcar= 1250500 MHz and Phase delay, Phase=475. Results obtained are shown in Figure 6. For stage 1, Processing time is T=TA+TP+TT is 1.753196 sec.

Fig. 6a represent the acquisition of satellite signal. The Fig. 6b represent the demodulated noisy signal. This noise is removed by thresholding the signal at +1 to -1. It can be seen from Fig. 6c and 6d. The signal is tracked with loss of first 100 samples but it is recovered after 100 samples and tracked as before Stage 1. As compare to Stage 4 this is accurate tracking with less time. So we can conclude that with sub sampling frequency F=1.25MHz, few signatures of signal are missing out to cause failure in tracking.

Stage 5

The sub sampling frequency F=1MHz and 5MHz.

The solution of failure of tracking in Stage 4 or also solution of missing out first 100 samples in Stage 5 is to subsample these three blocks at different sampling frequency. Thus Stage 5 subsample the acquisition and pull in frequency at sampling frequency 1 MHz and tracking at sampling frequency 5 MHz.

In stage 5, the results obtained are as F= 1 MHz and 5MHz.Visible satellite, Sat No= 22, Carrier Frequency Fcar= 1250500 MHz and Phase delay, Phase=475. Results obtained are shown in Figure 6. For stage 1, Processing time is T=TA+TP+TT is 3.468482 sec.

Fig. 7a represent the acquisition of satellite signal. The Fig. 7b represent the demodulated noisy signal. This noise is unable to remove by thresholding the signal at +1 to -1. It can be seen from Fig. 7c and 7d. In this case also the first 100 samples are not recovered in tracking.

TABLE 1: SIMULATION RESULTS OF SUB SAMPLING OF DIFFERENT FREQUENCIES

	Sampling Frequency	**Acquisition Results**	**Pull in frequency Results**	**Tracking Results**	**Total Time (Sec)**
Stage 1	F=5MHz	Sat no=22 Fcar=1250500 Phase=470 TA=0.102527	Fp=1250250 TP=0.730232	TT=3.456647	T=4.289406
Stage 2	F=2.5MHz	Sat no=20 Fcar=1249500 Phase=236*2 TA=0.045616	Fp=1249750 TP=0.413948	TT=2.113844	T=3.0853
Stage 3	F=1.250MHz	Sat no=20 Fcar=1249500 Phase=118*4 TA=0.029483	Fp=1249750 TP=0.275340	TT=1.873201	T=2.178024
Stage 4	F=1MHz	Sat no=22 Fcar=1250500 Phase=95*5 TA=0.021174	Fp=1250310 TP=0.212589	TT=1.519433	T=1.753196
Stage 5	F=1MHz and F=5MHz	Sat no =22 Fcar=1250500 Phase=95*5 TA=0.020087	Fp=1250250 TP=0.212589	TT=3.468482	T=3.468482

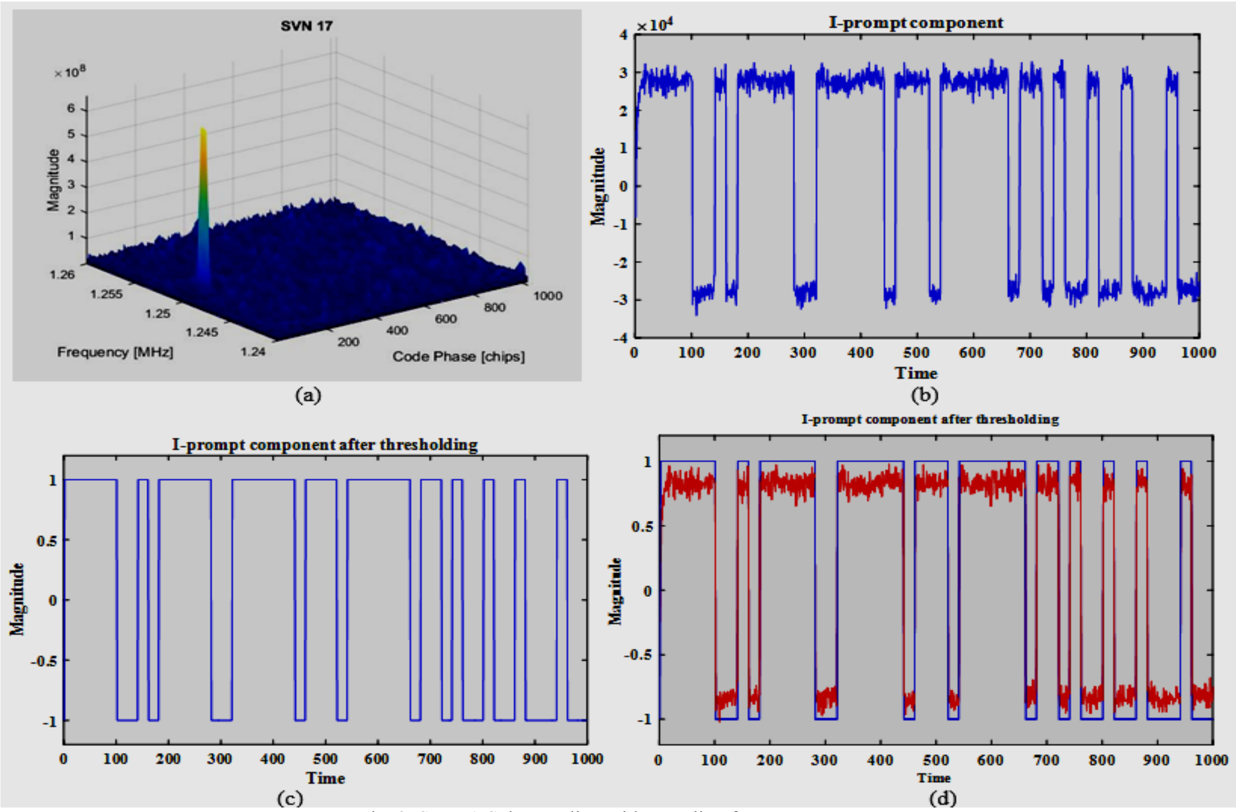

Fig. 3. Stage 1-Sub-sampling with sampling frequency 5 MHz.

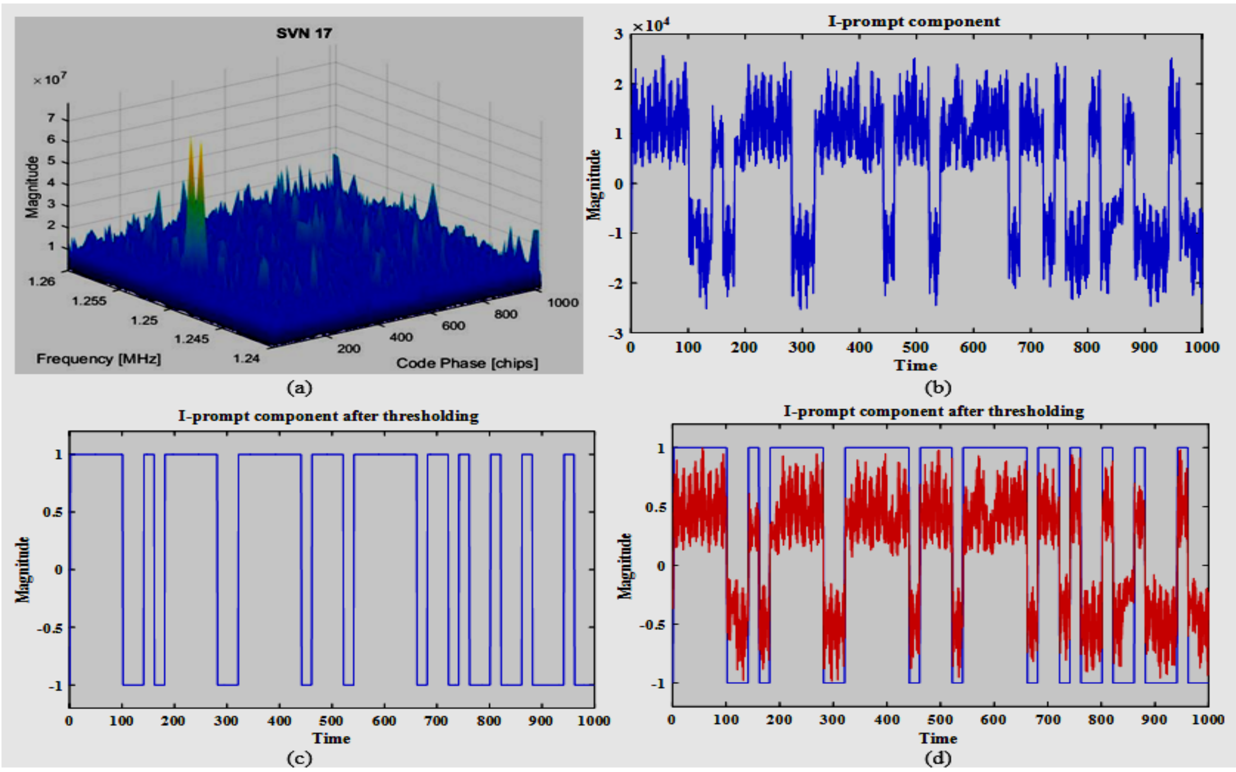

Fig. 4. Stage 2-Sub-sampling with sampling frequency 2.5 MHz.

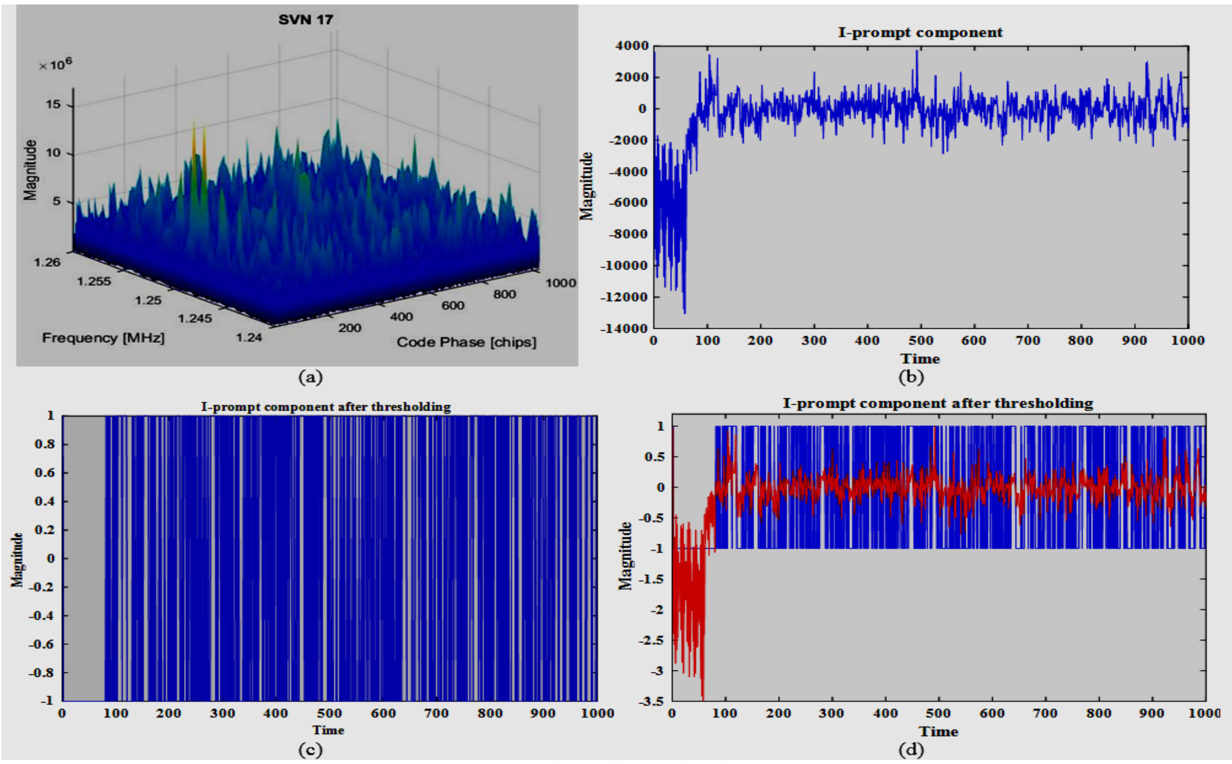

Fig. 5. Stage 3-Sub-sampling with sampling frequency 1.25 MHz.

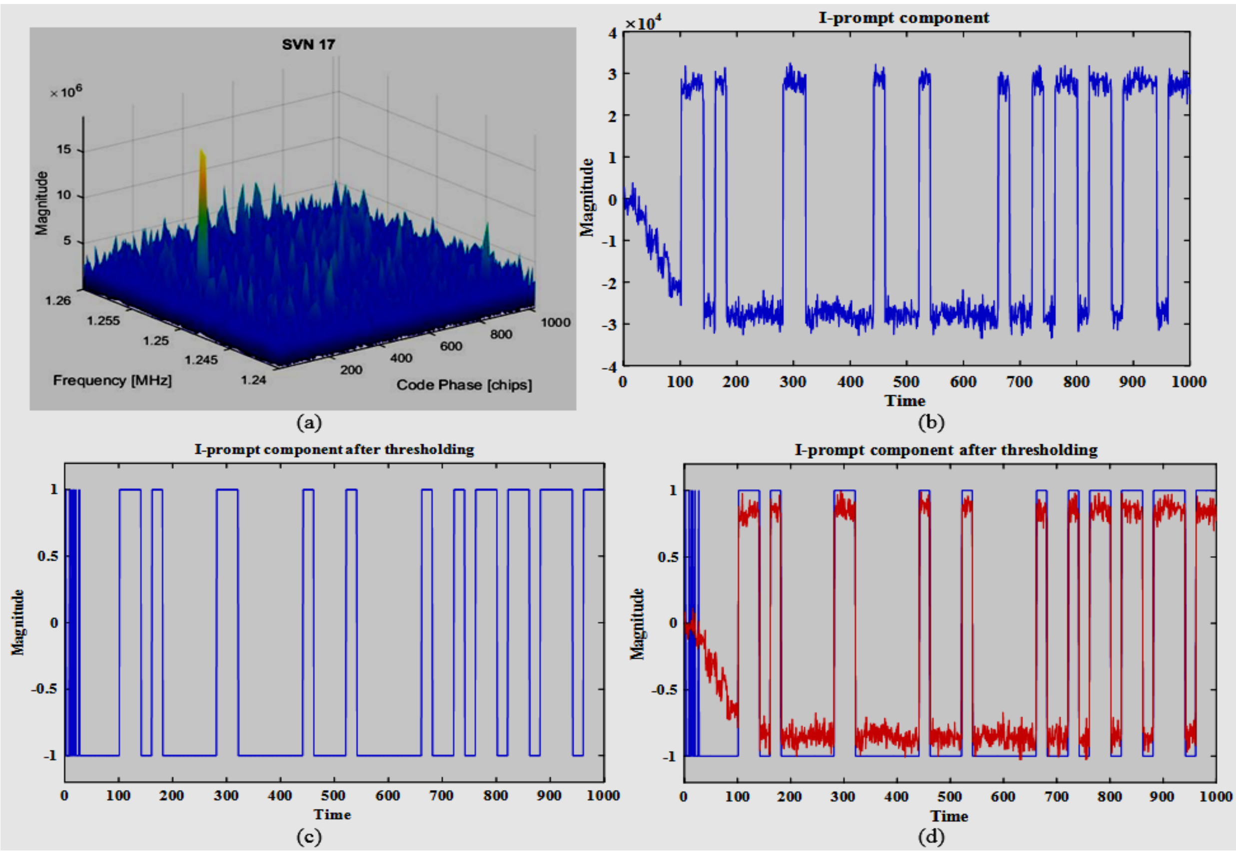

Fig. 6. Stage 4-Sub-sampling with sampling frequency 1 MHz.

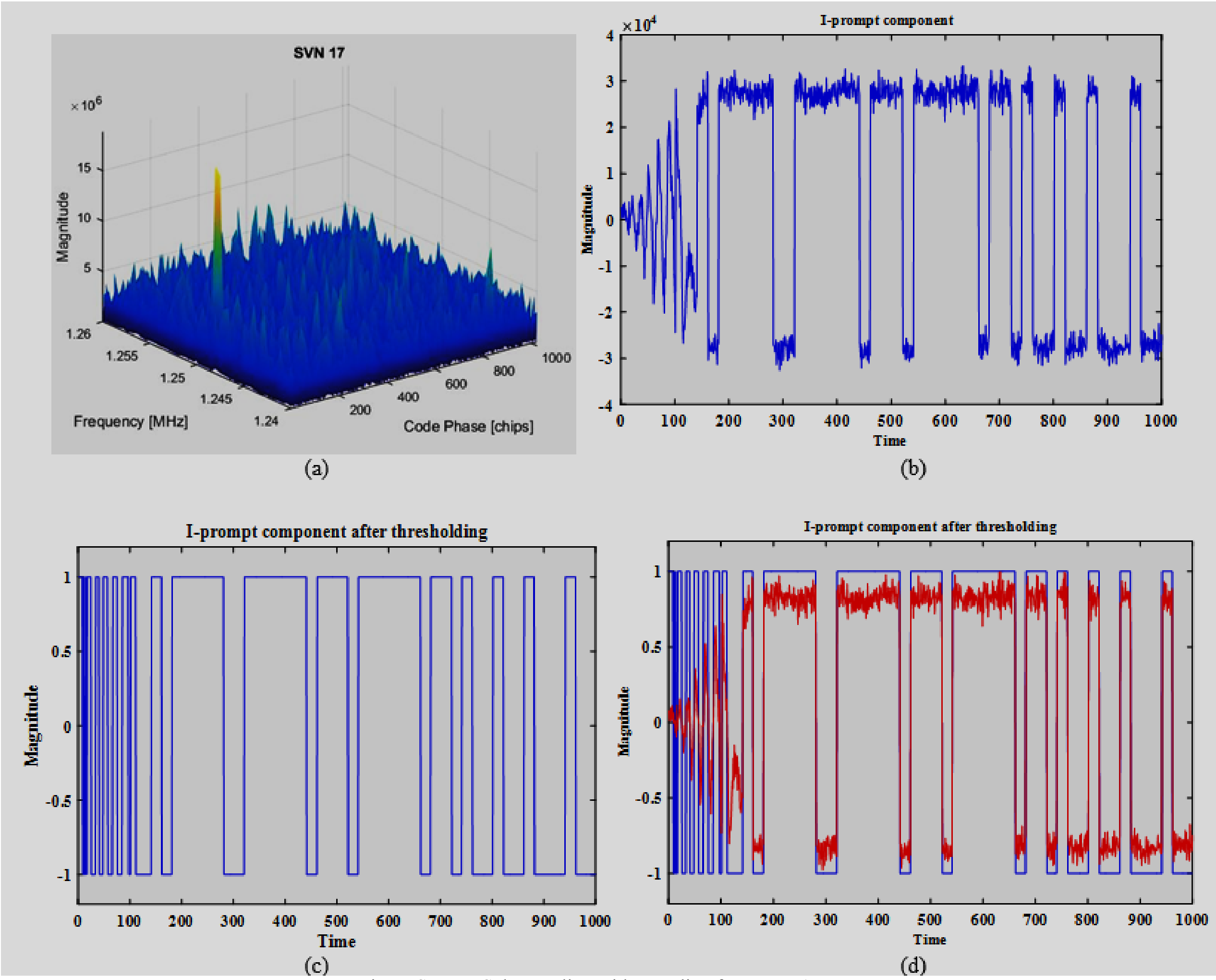

Fig. 7. Stage 5-Sub-sampling with sampling frequency 1 MHz.

IV. CONCLUSION

The implementation of sub sampling technique followed by thresholding the tracked signal to ± 1 reduces the associated higher chipping rate and henceforth the processing time. The proposed technique decreases sampling frequency (F= 5 MHz) below center frequency (Fcar= 1.25 MHz) of GPS signal. Without loss of original information, signals is recovered. Experiments carried out estimate the computation from 4.2894 sec to 3.0853 sec, 2.178024 sec and 3.468482 sec respectively for sampling frequency F/2, F/4, F/6. This Simulation and real data carried out ensures the fast acquisition and tracking and power consumption.

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