GPS Receiver Using RTL-SDR

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Abstract*– *GPS receivers provide very precise Pulse Per Second (PPS) signal. Designing a GPS receiver with low cost device to simulate a real time GPS scenario is a critical issue. Here, we use a simple low-cost method of time synchronization using RTL-SDR receivers to calculate the position. First, we show the data logged from RTL-SDR with both I and Q signal representation. Then, sky plot and both PLL and DLL data are represented and show the results after filtering. Finally, a precise location for the receiver is shown in UTM system.

I. Introduction

The Global Positioning System (GPS) is a Constellation of Earth orbiting satellites maintained by the US DOD for the purpose of defining geographic positions. The system transmits radio signals that can be used by GPS receivers to calculate position, velocity and time anywhere on earth, any time of day or night. The first Block I GPS satellite was launched in 1978 [1]. The GNSS Galileo E1 and GPS L1 links are centred at 1575.42 MHz, and this band is covered by the E4000 tuner IC. The GNSS-SDR software receiver can be configured to use the RTL2832U as a real-time signal source, thus providing a low-cost option to build a real-time software-defined GPS L1 receiver [2].

RTL2832U can be adopted to provide a low-cost GPS receiver. A common method to synchronize space separated receivers is to tune these receivers into a frequency of a known transmitter. By cross-correlating the received data the time difference between two receivers can be calculated and from the known receivers and transmitter location a precise time synchronization can be achieved [3]. Unfortunately, such solution is not always possible. In many cases the receivers can be placed several hundred kilometres away from each other with no common transmitter that would be in range of both receivers. In such situations a GPS time signal (a Pulse Per Second output is commonly available on GPS receivers) can be used to synchronize multiple receivers in time with nanoseconds accuracy [4]. A low cost RTL-SDR dongle has allowed many people to step into the world of software radios and digital signal processing. With a price of several dollars it is a great device for multiple receivers experiment.

On the other hands, as it was originally designed as a consumer DVB-T receiver it doesn't contain any synchronization input and exact moment of the start of the sampling cannot be precisely determined. A cheap and reliable way to precisely synchronize records from multiple RTL-SDR receivers would allow creation of a collaborative distributed network of receivers for Time Difference of Arrival (TDOA) measurements for passive localization of various transmitters like airplanes, satellites, etc [5].

Software Defined Radio (SDR) has no single, unified, globally recognized definition. Slightly different interpretations exist among the actors in the field. Adding to this, a variety of related terms has been proposed and is used to variable degrees. These include Software Based Radio [6], Reconfigurable Radio, Flexible Architecture Radio [7]. The main parameter in the various interpretations and the related terms, is how flexibly the radio waveform can be changed through changing software and without modifying the SDR Platform.

II. Application of RTL-SDR

In this section, some application of RTL-SDR are described and discussed briefly.

A. Tracking aircraft positions like a radar with ADSB decoding[8]: The RTL-SDR can be used as a super cheap real time air radar. Modern planes use something called an ADS-B (Automatic Dependent Surveillance-Broadcast) Mode-S transponder, which periodically broadcasts location and altitude information to air traffic controllers. The RTL-SDR can be used to listen to these ADS-B signals, which can then be used to create an aircraft radar system.

B. Partial Discharge Detection for Wideband Spectrum Sensing[9]: RTL-SDR (Software Defined Radio) based spectrum analyser has been proposed in order to provide a potentially low cost solution for PD detection and monitoring. Initially, a portable spectrum analyser has been used for PD detection that was later replaced by an RTL-SDR device. The proposed schemes exhibit promising results for spectral detection within the VHF and UHF band.

C. A Practical Approach to Spectrum Analyzing[10]: demonstrate a RTL-SDR based spectrum analyzer which can be used proficiently as an alternative of existing hardware spectrum analyzer. This approach will lessen the complexity of analogue hardware system with the higher tractability of software based filtering and demodulation techniques. As RTL-SDR devices are quite cheap (Approximately 20$) and small sized, this system also offers cost effectiveness with provision of portability. An experimental study was conducted with suitable conditions to examine the feasibility and efficiency of the proposed system. The outcome of experimental result

III.RTL-SDR: GPS DECODING AND PLOTTING

The RTL-SDR can be used to receive, decode and plot Global Positioning System (GPS) data in real time. To do this the RTL-SDR must be connected to a GPS antenna. Extremely cheap $5 or less active GPS antennas with SMA connectors, as shown in Figure 1. These GPS antennas contain a small ceramic patch antenna, a low noise amplifier and a GPS filter. In order to power the LNA in the antenna, it is required to have an RTL-SDR with bias tee.

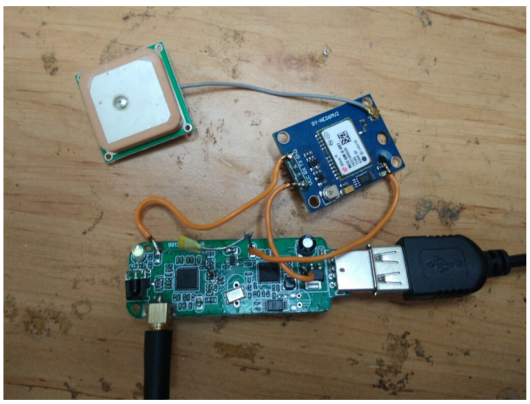

Figure 1 Experimental setup

Our RTL-SDR V3 dongles have this feature built in, but if you do not have a V3 you could also use a homebrew 5V external bias tee module or hack it into a standard RTL-SDR if you desired. Also note that most standard R820T/2 RTL-SDRs fail to receive after a few minutes at frequencies above about 1.3 GHz due to heat issues. Our RTL-SDR.com V3 dongles don't have this problem in most climates thanks to the metal case cooling and improved thermal design.

The main GPS frequency L1 is 1.575420 GHz, but most of this signal is very weak and below the noise floor. The spectrum of GPS received signal is shown in Figure 2.

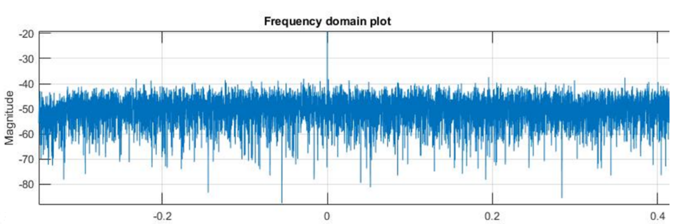

Figure 2 Spectrum of GPS signal

IV. SIMULATION AND RESULTS

In this section, we use a simple matlab code to capture GPS signal and with some processing a position information data capture as in phase (I) and Quadrature phase (Q) data in two different files are generated, as shown in . The data were collected 20th of June 2022, using matlab 2021b.

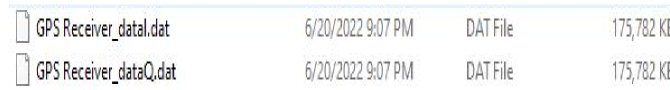

Figure 3 In phase and Quadrature phase received data from GPS satellites

Figure 4 and Figure 5 represent the time domain and the histogram representation for both I and Q signals, respectively.

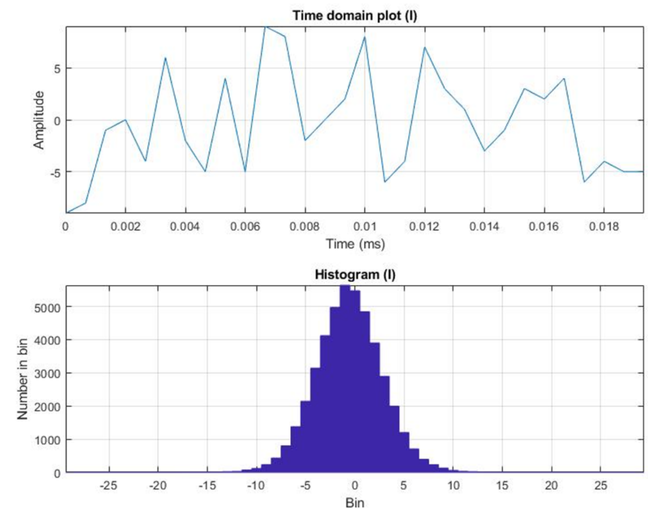

Figure 4 Time domain and Histogram for In phase signal.

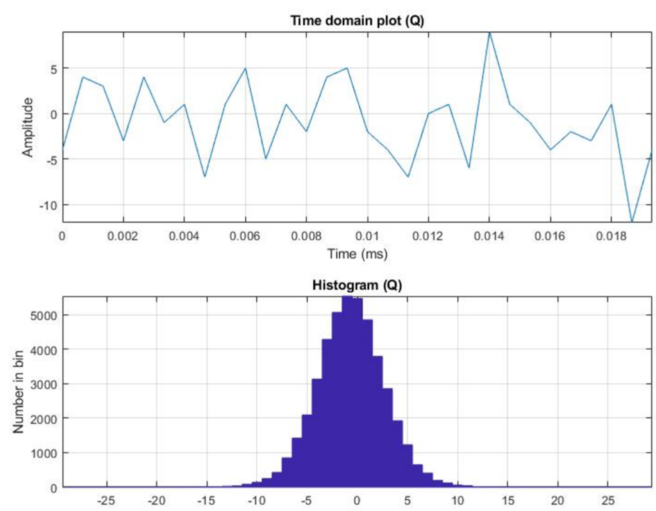

Figure 5 Time domain and Histogram for Q phase signal.

In our algorithm, after the data is captured, an acquisition is performed then tracking PLL and FLI is done to calculate the position. The sky plot for the GPS satellites is shown in Figure 6, only 5 satellites are located (sat. 3, sat. 16, sat. 26, sat. 1, and sat. 7) with mean PDOP 3.5437. The power of the received signal for all satellites located and represented in the sky plot are shown in Figure 6.

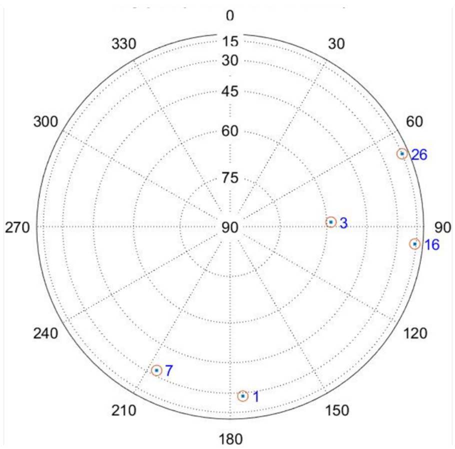

Figure 6 Sky plot with mean (PDOP 3.5437).

Tracking PLL and DLL: after detect satellite that can receive signal from it make phase locked loop and frequency locked loop to this signal to can extract information from signal received, DLL Tracking show that at high carrier to noise ratio make low bit error rate (BER) make it signal more useful to use to extract information.

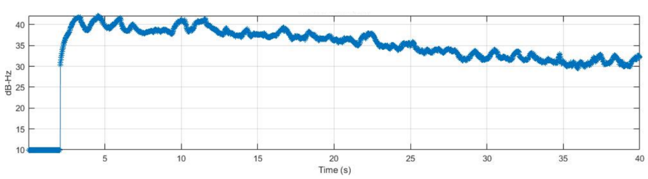

Figure 7 Estimated C/N$_0$

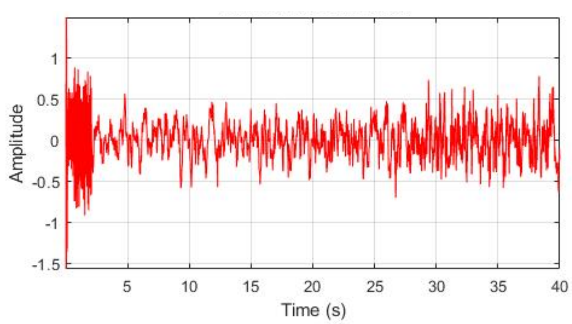

Figure 8 Raw PLL discriminator

In our simulation, we collect the data for only 10 minutes and represent the carrior to noise ratio in Figure 7. And the raw data of the PLL discriminator and the filter PLL discriminator are represented in Figure 8 and Figure 9, respectively.

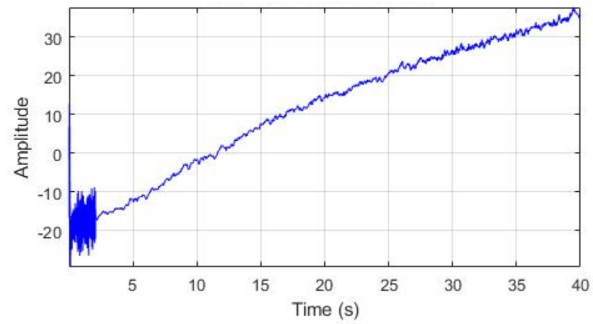

Figure 9 Filtered PLL discriminator

While, the raw data of the DLL discriminator and the filter data of the DLL discriminator are represented in Figure 8 and Figure 9, respectively.

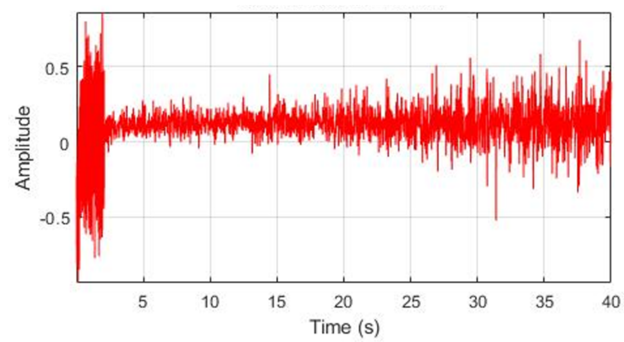

Figure 10 Raw DLL discriminator

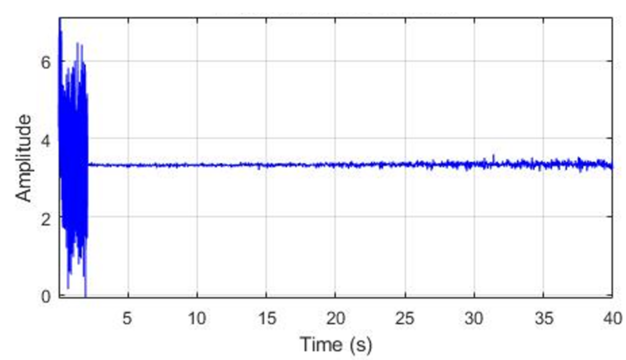

Figure 11 Filtered DLL discriminator

Finally, the location of the receiver is estimated and represented in Figure 12. As shown, the accuracy is varying based on the number of satellites detected.

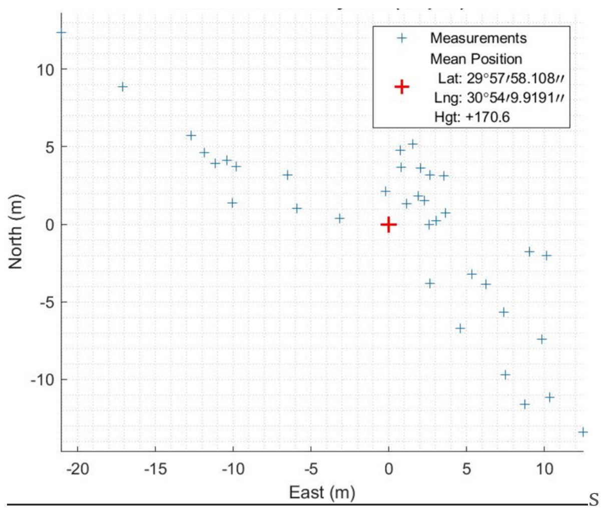

Figure 12 Position in UTM system

IV. CONCLUSIONS

GPS receivers provide very precise Pulse Per Second (PPS) signal. Designing a GPS receiver with low-cost device to simulate a real time GPS scenario is a critical issue. Here, we use a simple low-cost method of time synchronization using RTL-SDR receivers. First, we show how to decode the GPS received signal. Then, a full detailed signal representation and sky plot are shown. Which are used to calculate a precise location for the receiver.

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