© 2023 IJNRD | Volume 8, Issue 6 June 2023 | ISSN: 2456-4184 | IJNRD.ORG

IJNRD.ORG ISSN : 2456-4184
INTERNATIONAL JOURNAL OF NOVEL RESEARCH AND DEVELOPMENT (IJNRD) | IJNRD.ORG
An International Open Access, Peer-reviewed, Refereed Journal

Performance Analysis of Tracking Algorithm for GNSS Receiver

[1] Tushal Modi*, [2] Ravi Ranjan Singh, [3] Udaiveer Pradhan Singh, [4] Yogendran Murali, [5] Prof Kavita S Guddad,

[1 2 3 4] UG Students, BE (ECE), Electronics & Communication Engg. Dept., Dayananda Sagar College of Engineering, Bangalore
[5] Assistant Professor, Electronics & Communication Engg. Dept., Dayananda Sagar College of Engineering, Bangalore, Karnataka

***Abstract*—This paper involves the study and analysis of tracking algorithm for Global Navigation Satellite System (GNSS). GNSS receivers have become popular and have been used widely in both civilian and military for navigation, timing and other position related applications. In our project, analysis of different tracking algorithm is to be done and based on performance the best tracking algorithm will be chosen. The most suitable signal tracking algorithm for GNSS receivers is to be implemented on the platform of Matrix Laboratory (MATLAB) simulation. A GNSS receiver's job is to locate four or more of the satellites, figure out the distance to each, and use this information to deduce its own location. This operation is based on a simple mathematical principle called trilateration. Acquisition and tracking are synchronization modules of the receiver and their accuracy is very important for exact location so the algorithm is needed to be enhanced and optimized for better accuracy. There are two main tracking loops namely code and carrier tracking loop. Delay Locked Loop (DLL) is used to track code delay or code phase while Phase Locked Loop (PLL) is used to track carrier frequency as well as Doppler Shift. The implementation is done for Global Positioning System (GPS) L1 signal using a standard dataset. Furthermore, it will be executed on Hardware platform by converting the MATLAB code to equivalent C or Python code so that it can be synthesizable on a DSP (Digital Signal Processor)**

Keywords— Global Navigation Satellite System, Delay Locked Loop, Phase Locked Loop, Global Positioning System

I. Introduction

Global Navigation Satellite Systems (GNSS) provide satellite-based radio navigation systems coverage over the Earth. This system usually uses satellites placed on medium Earth orbits (MEO) with an approximate altitude of 20000 km above the Earth's surface. Satellites in Medium Earth orbit (MEO) and Low Earth orbit (LEO) are often deployed in satellite constellations. A satellite constellation is a group of artificial satellites working together as a system. They will provide communication, enable global monitoring of Earth, and enhance space observation. The GNSS is comprised of three segments: Satellite constellation, operational control segment (OCS) and user receiving equipment. The satellite constellation contains the satellites in orbit that provide the ranging signals and data messages to the user equipment. The operational control segment (OCS) tracks and maintains the satellites in space. The OCS monitors satellite health and signal integrity and maintains the orbital configuration of the satellite. The user receiver equipment performs the navigation, timing or other related notation. It performs the calculation of position and provides the timing signals in order to control the operation of the other digital blocks. It also sends the useful information to Display unit.

I. Literature Survey

This paper [1] has presented the performance analysis of acquisition and tracking algorithms for software GNSS receivers. The three acquisition algorithms are compared by using the operation speed. According to the analysis, the smaller Early-Late spacing discriminator algorithm is more precise for Code tracking and more suitable for software GNSS receivers. Moreover, the larger C/No value is more precise for delay lock loop of software GNSS receivers. Results show that satisfactory precision can be achieved if the value of C/No is above 36dBHz.

The objective of this paper [2] is to analyze and find the optimum discriminator function for the code tracking loop in soft-GPS receivers. The delay lock loop (DLL) is a well-known technique to track the codes for GNSS spread spectrum systems. This paper also presents non-coherent square law DLLs and the impacts of some parameters on DLL discriminators such as number of samples per chip, early-late spacing, different C/ No values where C denotes the signal power and No is the noise spectral density, and the impact of with or without front-end device. According to the analysis, the smaller Early-Late spacing is more precise for Code Tracking and more suitable for software GPS receivers. Moreover, the larger C/No value is more precise for delay lock loop of software GPS receivers. Results which have satisfactory precision can be achieved if the value of C/No is above 36dBHz. The arctan discriminator is the most precise one in the possible Costas Discriminators used for Carrier Tracking.

This paper [3] describes the implementation and analysis of acquisition and tracking for GPS software receiver. For signal acquisition, the analysis of three acquisition algorithms is implemented and analyzed. This paper emphasizes on code tracking loop which is also called Delay Locked Loop (DLL). Code tracking loop is implemented and the effect of changing parameters such discriminator spacing and loop noise bandwidth is also described. Among the acquisition algorithms, parallel search in time domain (code delay) is the best for software receiver because of its less computational steps and fastest speed. Two different early-late spacing are tested in this paper and the results describe that the narrower the spacing the greater the accuracy of code tracking discriminators.

II. WORKING

The paper includes the overall working of Global Navigation Satellite System (GNSS) Receiver to get a better understanding of how to implement the tracking algorithm for a software GNSS receiver using the receiver block diagram.

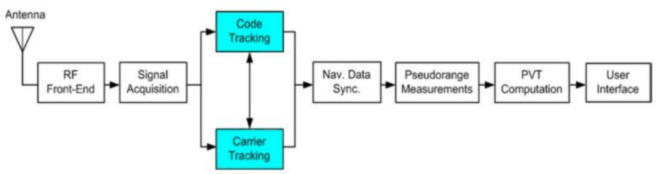

Fig 1. GNSS Receiver

The RF signals of all satellites in view are received by the antenna. The signal received by the receiver is affected by the relative motion of the satellite, causing a Doppler effect. Therefore, the acquisition gives rough estimates of signal parameters: frequency and code phase. The main purpose of tracking is to refine the coarse values of code phase and frequency and to keep track of these as the signal properties change over time. The tracking contains two parts, code tracking and carrier frequency/phase tracking; Code tracking: The code tracking is most often implemented as a delay lock loop (DLL) where three local codes (replicas) are generated and correlated with the incoming signal. These three replicas are referred to as the early, prompt, and late replica, respectively. The three codes are often separated by a half-chip length. Carrier frequency/phase tracking: The other part of the tracking is the carrier wave tracking. This tracking can be done in two ways: either by tracking the phase of the signal or by tracking the frequency. The tracking is running continuously to follow the changes in frequency as a function of time. If the receiver loses track of a satellite, a new acquisition must be performed for that particular satellite.

When the signals are properly tracked, the C/A code and the carrier wave can be removed from the signal, only leaving the navigation data bits. The pseudo ranges (distance between a satellite and a navigation satellite receiver) are computed based on the time of transmission from the satellite and the time of arrival at the receiver. Then the user position and velocity is computed from pseudo ranges and satellite positions and the information finally reaches the user through a display unit or interface.

GPS Signal Working

The GPS signals are transmitted on two radio frequencies in the UHF band. The UHF band covers the frequency band from 500MHz to 3 GHz. These frequencies are referred to as L1 and L2 and are derived from a common frequency, f_0 =10.23MHz: f_{L1} = 154 f_0 = 1575.42 MHz, f_{L2} = 120 f_0 = 1227.60 MHz. The signals are composed of the following three parts:

Carrier: The carrier wave with frequency f_{L1} or f_{L2}.

Navigation data: The navigation data contains information regarding satellite orbits. This information is uploaded to all satellites from the ground stations in the GPS Control Segment. The navigation data have a bit rate of 50 bps.

Spreading sequence: Each satellite has two unique spreading sequences or codes. The first one is the coarse acquisition code (C/A), and the other one is the encrypted precision code (P(Y)). The C/A code is a sequence of 1023 chips.(A chip corresponds to a bit. It is simply called a chip to emphasize that it does not hold any information.) The code is repeated each ms giving a chipping rate of 1.023 MHz. The P code is a longer code ($\approx 2.35 \cdot 104$ chips) with a chipping rate of 10.23 MHz. It repeats itself each week starting at the beginning of the GPS week which is at Saturday/Sunday midnight. The C/A code is only modulated onto the L1 carrier while the P(Y) code is modulated onto both the L1 and the L2 carrier.

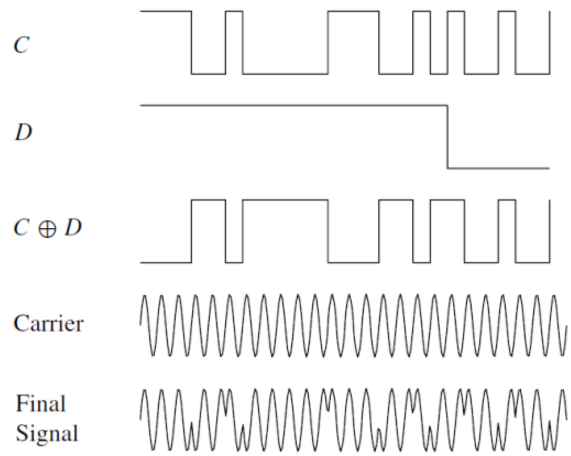

Fig 2. GPS Signal

III. METHODOLOGY

The main purpose of tracking is to refine the coarse values of code phase and frequency

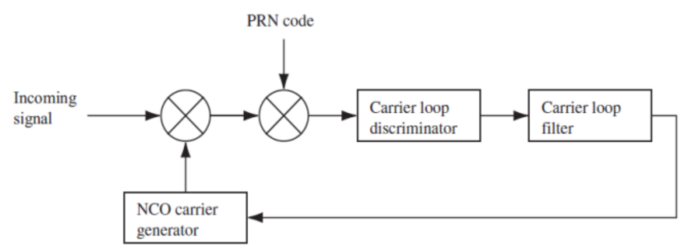

Fig 3. Basic Carrier Tracking Loop

In many cases, carrier tracking is achieved through the utilization of a phase lock loop (PLL), in which the initial two multiplications eliminate both the carrier and the PRN code from the input signal. The carrier loop discriminator component is employed to detect any phase discrepancy in the replica of the local carrier wave. The resulting phase error, obtained from the discriminator's output, undergoes filtering and serves as feedback for the numerically controlled oscillator (NCO). Consequently, the NCO modifies the frequency of the local carrier wave, bringing it close in precision to the input signal's carrier wave.

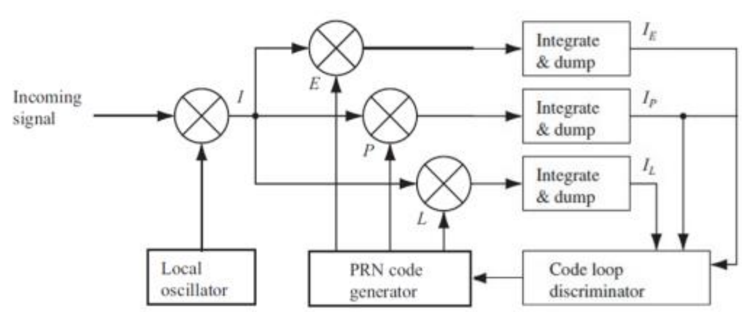

Fig 4. Basic Code Tracking Loop

Code tracking is commonly achieved through the utilization of a delay lock loop (DLL), where three replicas of the local codes are generated and correlated with the incoming signal. These replicas are known as the early, prompt, and late replicas, respectively, and are typically spaced half a chip length apart. The initial step involves converting the incoming signal to baseband by multiplying it with a precisely aligned local replica of the carrier wave. Subsequently, the signal is multiplied by the three code replicas. These replicas are generated with a nominal spacing of ±1/2 chip. After the second multiplication, the outputs from the three replicas are integrated and discarded.
The resulting integrated values indicate the extent of correlation between the specific code replica and the code within the incoming signal. The correlation outputs, namely IE, IP, and IL, are then compared to determine which one exhibits the highest correlation.

As we can observe in Fig1 i.e. the GNSS receiver block diagram we can see that there is a coherent mutual dependence between the code tracking and the carrier tracking blocks. Hence this inter-dependency leads us to merge these two blocks into one single block thereby forming the core system of the methodology this paper aims to propose which is shown in the following block diagram.

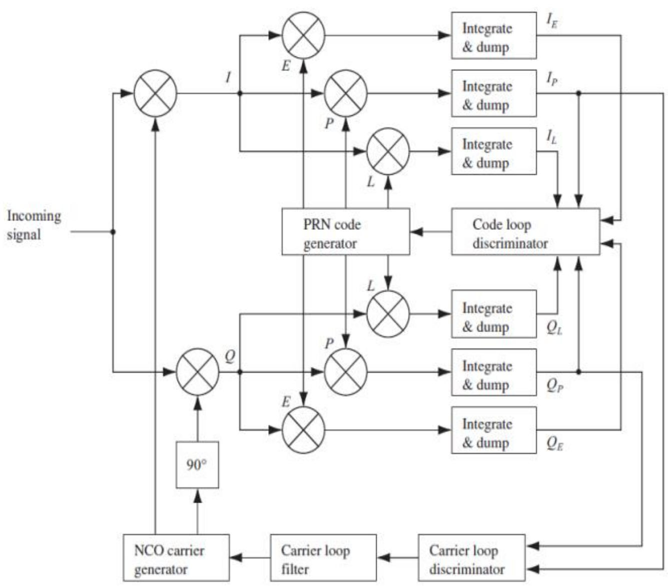

Fig 5. Block Diagram of the Proposed Methodology

The code and carrier tracking loops are working coherently and being mutually dependent on each other. Instead of dividing these two functionalities into two different blocks, they are merged into a combined code and carrier tracking loop. In the combined code and carrier tracking loop, the carrier tracking, Costas loop (PLL), is followed by code tracking, early-late tracking loop (DLL). For the code loop discriminator, the early and late outputs of the in-phase and quadrature arm are used. The prompt outputs of both In-phase and quadrature arm are used in the carrier loop discriminator. The prompt output of the In-phase arm also provides the navigation data.

The tracking module processes its function by using the acquisition results which is stored in a certain structure and GPS sample data at the start condition. Each tracking channel needs acquisition results such as satellite PRN number, code delay value and Doppler frequency. Moreover, output of discriminator is used for tracking loop feedback as input, and stored in memory for navigation module.

IV. TOOLS USED

MATLAB

The platform used for the implementation of GNSS receiver is MATLAB (Matrix Laboratory) simulation.

MATLAB, short for "MATrix LABoratory," is a privately-owned programming language and numerical computing environment developed by MathWorks. It supports various programming paradigms and enables operations on matrices, plotting of functions and data, algorithm implementation, creation of user interfaces, and integration with programs written in other languages.

While MATLAB primarily focuses on numeric computations, it also offers an optional toolbox that utilizes the MuPAD symbolic engine, providing access to symbolic computing capabilities. Additionally, Simulink, an additional package, introduces graphical simulation across multiple domains and facilitates model-based design for dynamic and embedded systems.

As of 2020, MATLAB boasts a user base exceeding 4 million individuals worldwide, spanning diverse fields such as engineering, science, and economics.

V. RESULTS AND DISCUSSIONS

The proposed methodology was implemented for GPS (Global Positioning System) and the following simulation results were obtained.

The three plots given below are the time, frequency domain plot along with the histogram. The time domain plot gives us the signal which has been converted to digital signal from its analog signal source.

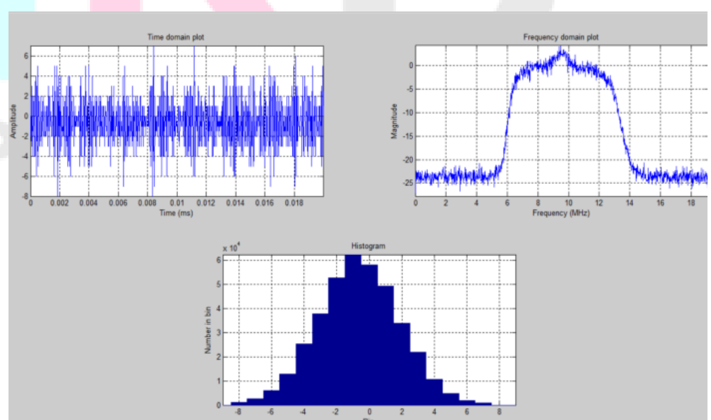

Fig 6.Time and Frequency domain plot along with histogram

The sampling frequency corresponds to the value provided in the parameter list mentioned earlier. The samples obtained in this case are

4-bit samples. In the MATLAB implementation, the data type utilized was 'int8,' representing a signed integer of 8 bits, which is the smallest available data type. However, this choice leads to redundant bits, resulting in increased data memory consumption.

The frequency domain plot provides information about the frequency characteristics of the received carrier signal. The frequency band has a width of 10 MHz. In the plot, a noticeable bulge can be observed at the center of the passband. This phenomenon occurs due to the primary lobe of the sinc spectrum present in the signal itself.

The subsequent plot is a histogram that exhibits similarities to the bell curve, which represents the probability density function of a Gaussian random variable. This resemblance is expected when dealing with white thermal noise.

Presented below are the outcomes of the signal acquisition process. The green indicators signify successful acquisition of the satellite's signal, while the blue indicators indicate unsuccessful acquisition. In total, there are 32 PRN numbers assigned, allowing for the unique identification of signals from 32 satellites without interference. To accomplish this, the DSSS (Direct Sequence Spread Spectrum) technique is employed, utilizing a spreading code referred to as the PRN (Pseudo Random Number) code sequence. This approach ensures minimal interference from other signals operating at the same frequency, enabling accurate signal identification.

Given below are the results of the signal acquisition process.

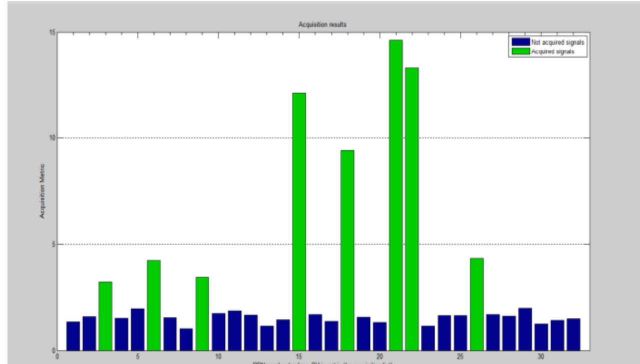

Fig 7.Signal Acquisition Results

The green indicators represent successful acquisition of the satellite's signal, while the blue indicators indicate unsuccessful acquisition. A total of 32 PRN numbers are utilized for signal identification. This approach is necessary to ensure the unique identification of signals from 32 satellites without interference.

To achieve this, the DSSS (Direct Sequence Spread Spectrum) technique is employed, utilizing a spreading code known as the PRN (Pseudo Random Number) code sequence. This technique minimizes interference from other signals operating at the same frequency, allowing for accurate signal identification.

Next, we have the output of the received message decoded from the GPS satellite. In the DLL discriminator, the damping ratio directly impacts the width of the code phase. A higher damping ratio results in a wider code phase compared to lower values. Additionally, the loop noise bandwidth governs the level of noise present in the filter. A larger loop noise bandwidth leads to increased noise within the code tracking loop.

Now, turning to the PLL, a higher damping ratio facilitates faster settling time in the carrier loop and further alignment with the incoming signal. As for the noise bandwidth, larger values introduce more variations in the PLL output.

The correlation result demonstrates the behavior of the PLL in a locked state. Due to the precise carrier replica generated by the PLL, the correlators remain constant over time.

Lastly, the navigation bits represent the most significant message obtained from the GPS signal and have been successfully decoded.

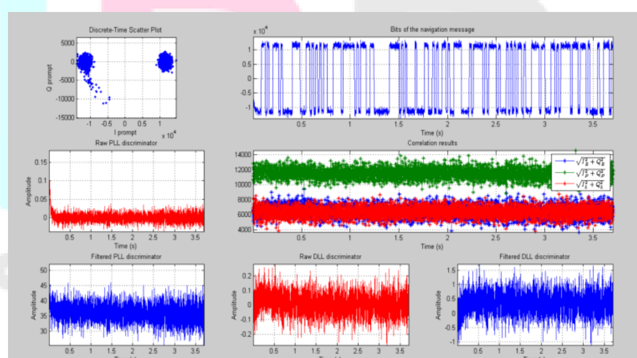

Fig 8.Tracking Results for discriminator spacing of 0.5 chip

On the top left we see the Scatter plot for the navigation message bits i.e. on the top right. In the centre in the second figure on the right we have the correlation results of the Early, Prompt and Late replicas . The central left and bottom three figures represent the Raw PLL discriminator, Filtered PLL discriminator, Raw DLL discriminator and Filtered DLL discriminator respectively.

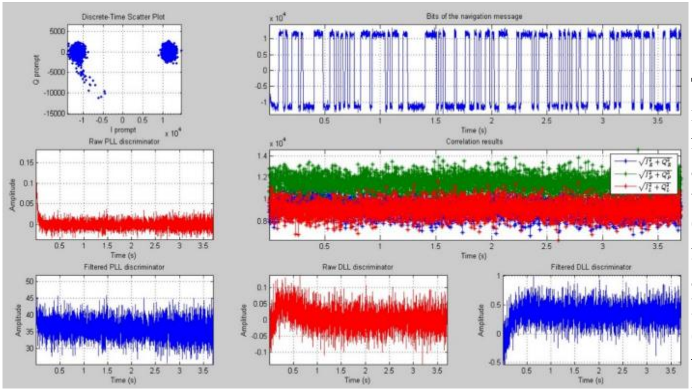

Fig 9.Tracking Results for discriminator spacing of 0.25 chip

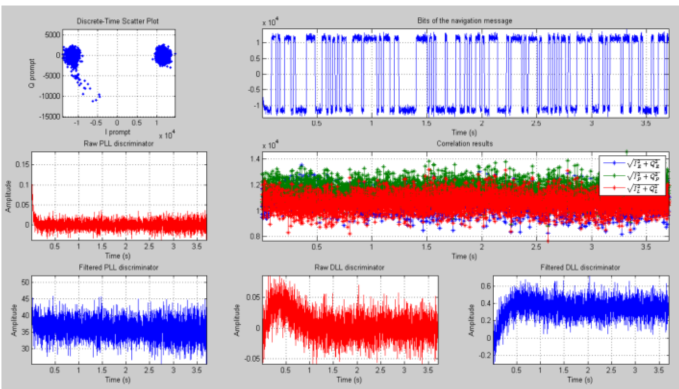

Fig 10.Tracking Results for discriminator spacing of 0.125 chip

The analysis of the impact of parameter changes on the discriminator is performed for code tracking, and it is briefly described. Figure 8 illustrates the unprocessed and filtered outputs of the DLL discriminator for a specific satellite. Initially, various values of discriminator spacing (ds), which refers to the time difference between early and late code, are modified, and the outcomes are depicted in Figures 8,9, and 10, demonstrating filtered DLL outputs with ds values of 0.5, 0.25, and 0.125, respectively. This parameter determines the noise bandwidth in the DLL and the signal's dynamic range. Smaller spacing values can reduce the DLL's tracking dynamic range and tracking error variance. However, excessively small spacing values may hinder the DLL's ability to synchronize with the incoming signal, particularly in the presence of noise (low signal-to-noise ratio).

Results	Carrier frequency
Acquisition	9.5474 MHz
Tracking	9.5475 MHz

From Acquisition the frequency was found to be 9.5474 MHz and after tracking the frequency was found to be 9.5475 MHz for PRN:21 which is precise to the IF of 9.548Mhz.

VI. CONCLUSION

This paper presents the analysis of tracking algorithms for implementation of GNSS software receiver. The simulation results are described by comparing the carrier frequency from acquisition and the carrier frequency value obtained from tracking.

GPS stands for Global Positioning System and is a global navigation system used worldwide for determining the location of an object. It consists of a network of 32 satellites orbiting the Earth, transmitting signals on two different frequencies: L1 (1575.42 MHz) and L2 (1227.60 MHz). The objectives of the work this paper is based on which have been successfully implemented, are as follows- To study the working of Global Navigation Satellite System (GNSS) Receiver and gain insights into how these devices receive and process satellite signals to determine accurate positioning information.

To understand Global Positioning System (GPS) Signal and develop a comprehensive understanding of the signals transmitted by GPS satellites, including their frequencies, encoding schemes, and data formats.

To examine the tracking algorithm and implement it in the platform of MATLAB simulation. This involves analyzing how the receiver maintains and tracks satellite signals to provide continuous position updates, and simulating the tracking algorithm in MATLAB to gain practical insights into its functioning. However, the implementation of the Indian Regional Navigation Satellite System (IRNSS) was not possible due to the confidentiality of the dataset. As a result, the work focused solely on GPS and did not extend to the implementation of IRNSS.

The paper has also successfully achieved its objective by studying the working of a GNSS receiver, understanding the importance for having state of the art receiver technology to maintain the integrity of the information contained in the signal received from our satellites and overcoming factors such as signal attenuation and high dynamics.

These objectives have laid the foundation for further development and future work in the domain.

REFERENCES

[1] Analysis of Acquisition and Tracking Algorithms for Software GNSS Receivers, International Journal of Advances in Electronics and Computer Science, ISSN: 2393-2835 Volume-2, Issue-6, June (2015)

[2] Implementation of Code and Carrier Tracking Loops for Software GPS Receivers, International Journal of Scientific & Technology Research, ISSN: 2277-8616 353, Volume 4, Issue 06, June(2015)

[3] Analysis on GPS Acquisition and Tracking for Software Defined Receiver, International Journal of Electrical, Electronics and Data Communication, ISSN(p): 2320-2084, ISSN(e): 2321-2950 Volume-7, Issue-10, Oct.-(2019)

[4] Digital Satellite Navigation and Geophysics", A Practical Guide with GNSS Signal Simulator and Receiver Laboratory by IVAN G. PETROVSKI, IP-Solutions, Japan TOSHIAKI TSUJII Japan, Aerospace Exploration Agency (JAXA)