ENHANCED ADAPTIVE CARRIER TRACKING LOOP FOR GNSS RECEIVER

A DISSERTATION
Submitted in partial fulfillment of the
requirements for the award of the degree
of
MASTER OF TECHNOLOGY
in
ELECTRICAL ENGINEERING
(With specialization in Instrumentation and Signal Processing)

By
ADARSH MISHRA

DEPARTMENT OF ELECTRICAL ENGINEERING
INDIAN INSTITUTE OF TECHNOLOGY ROORKEE
ROORKEE - 247 667 (INDIA)
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CANDIDATE'S DECLARATION

I hereby declare that this thesis report entitled **ENHANCED ADAPTIVE CARRIER TRACKING LOOP FOR GNSS RECEIVER**, submitted to the Department of Electrical Engineering, Indian Institute of Technology, Roorkee, India, in partial fulfillment of the requirements for the award of the Degree of Master of Technology in Electrical Engineering with specialization in Instrumentation and Signal Processing is an authentic record of the work carried out by me during the period June 2015 through May 2016, under the supervision of **Dr. P. SUMATHI, Department of Electrical Engineering, Indian Institute of Technology, Roorkee.** The matter presented in this thesis report has not been submitted by me for the award of any other degree of this institute or any other institutes.

Date:
Place: Roorkee

Adarsh Mishra

CERTIFICATE

This is to certify that the above statement made by the candidate is true to the best of my knowledge and belief.

Dr. P. SUMATHI
Associate Professor
Department of Electrical Engineering
Indian Institute of Technology Roorkee

ABSTRACT

MATLAB-Simulink is useful tool to analysis the signal processing part of GNSS receiver. Carrier tracking loop (CTL) used in GNSS receiver are closed loop systems, designed from their continuous time transfer function. In this thesis GNSS signals are generated in Simulink by Binary offset Carrier (BOC) and Binary Phase Shift Keying (BPSK) modulation. GNSS signal comprises of PRN code, C/A code, navigation bits and high frequency carrier signal. Transmitted signal is received at GNSS receiver front end down converted to Intermediate frequency (IF) . Digital IF signal is correlated with locally generated code replica, signals are feed into carrier tracking loop each and every information of tracked signal is automatic upgraded by feedback loop filter. In proposed work low C/N0 signals tracked accurately and results are validating the proposed work. Tracking error and jitter is an important parameter to show the tracking performance of Carrier tracking loop. Tracking jitter behavior with low C/N0 GNSS signals has been studied. Hence large variation in input frequency of GNSS signal could be estimated for bi-phase signal of GNSS receiver. Simulation studies demonstrates the suitability of the carrier tracking loop of GNSS receiver. Simulation results are validate the proposed model.

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Above all, I owe it all to Almighty God for granting me health, wisdom and strength.

Adarsh Mishra

Contents

List of Figures

List of Tables

Abbreviations

GNSS	**G**lobal **N**avigational **S**atellite **S**ystem
AGC	**A**utomatic **G**ain **C**ontrol
AWGN	**A**dditive **W**hite **G**aussian **N**oise
BOC	**B**imary **O**ffset **C**arrier
bps	**b**its **p**er **s**econd
BPSK	**B**inary **P**hase **S**hift **K**eying
CTL	**C**arrier **T**racking **L**oop
C/A	**c**oarse **/a**cquisition
C/N0	**C**arrier to **N**oise density
DPLL	**D**igital **P**hase **L**ocked **L**oop
IF	**I**ntermediate **F**requency
L2C	**L**2 **C**ivil
GPS	**G**lobal **P**ositioning **S**ystem
FLL	**F**requency **L**ocked **L**oop

Chapter 1

Introduction

In Global Navigation Satellite System Carrier tracking is very important phenomenon. Now days there is need of accurate position tracking by any navigation system. But due to high receiver to satellite dynamics there is big challenge to design good quality receiver. In 1978 US Department of defense design and developed their own positioning system for navigation purpose. Global positioning system GPS using two basic frequency L1 1575.42 MHz and L2 1272.23 MHz for signal processing services [9].GPS working is comprises of mainly 03 area signal acquisition, signal tracking and provides navigational information. During signal acquisition, the device extracts the satellite vehicle which is under range of GNSS Receiver and determines their Doppler frequency.

During acquisition, the device extracts satellite which is under the range of receiver and determines the initial Doppler rate, Then the initial information passes to tracking loop part where the acquired satellites signals are tracked as long as their quality of signal is not below the threshold points. Discriminator is main part of carrier tracking loop. Mainly two types of discriminators are used in GNSS receiver. Phase Lock loop track the phase of signal give the phase error information to loop and frequency lock loop discriminator provides the frequency error to loop filter. The PLL type of discriminators can track more efficient than FLL type of discriminators [2] however, they have more sensitivity to high dynamics environment i.e. user to satellite motion in comparison to that frequency discriminator [10]. GNSS receiver play a very vital role in area of navigation and space .Its wide range of application include aerospace, agriculture,weather forecasting, civil war ,telecommunication,mobile communication where GNSS receiver act as very useful device,including our cell phone we always on our navigation and tracking mode for live movement. GNSS system is comprises of Global positioning system(GPS), Gallileo and Glonass [7] . GPS ,Gallileo and Glonass systems are run by United States, Europian Union and Russia respectively. GNSS signal is comprises of C/A code, navigation bit and message, P code are modulated by carrier signal thats are in GHz range. Navigation message carrying the position information modulates a GHz frequency carrier signal, that needs to be precisely synchronized to extract the transmitted message. However, severe signal fading and outages, high receiver dynamics may pose constraints on the performance of accurate signal tracking of the transmitted signal [5]. In such cases, a Frequency Locked Loop (FLL) proves advantageous for locking the carrier precisely than the phase locking technique as it performs tracking using frequency and not phase samples. So, problems of narrow bandwidth and due to abrupt phase changes are circumvented [4] . GNSS L1 signal has been found very useful in many applications. GNSS L2 signal is a special signal that is use for defense and some confidential application by government [22] .

1.1 Literature Survey

Coherent reception of GNSS signals requires control techniques for accurate estimation of code and carrier phase [9]. The transmitted signal may experience sudden Doppler offsets, signal fading, blocking and multi-path affecting the signal propagation [2]. A FLL combats severe dynamics and sustained frequency error where phase locking technique may lose track. FLL is proving significant over their PLL counterparts as it can adapt to relatively large frequency offsets ignoring phase changes. [9].Several FLL loop under normal condition but switches to FLL under frequency offsets and other effects due to satellite-user dynamics [3]. In steered frequency PLL presented in the FLL and PLL operate in parallel, with each forcing VCO output frequency to match to reference frequency and signal input, respectively. The structure, thus, eliminates the phase noise of VCO and makes band-width independent of loop parameters [5]. It operates only for small conned region around required center frequency to circumvent problem of locking to unwanted signals and side-bands. Extending frequency tracking to the area of measurement, for direct measurement like grid frequency tracking [6] and indirect measurement such as carrier measurement , are also gaining interest. This concept is extended to frequency adaptive Multiple Second Order loop filter which can calculate the code, carrier, as well as, navigation bits components even under special conditions [7].

The limit of the above two methods is its use to only pure sinusoid. Adapted frequency-locked-loop (AFLL) filter based on a third-order generalized integrator [7] overcomes above difficulty and can reconstruct entire signal that may be composed of N sinusoids by using filter banks. Challenges faced by increasing application poses need for developing application specific methods. A low phase noise FLL is designed using beat method which posses the narrow bandwidth [8]. The proposed FLL is particularly significant for systems requiring external stable reference clock, as in GNSS. In [9], a distributed frequency locked loop is introduced to control the carrier frequencies for wireless communication. The DFLL for cooperative communication using local frequency correction provides improved robustness in distributed networks than a centralized clock [26]. Different automatic frequency control [AFC] loop implementations are discussed in [25]. It examines the noise performance of different discriminators and their compatibility to different signal formats. The designs, however, neglects the effect of discriminator characteristics and choice of loop filter that have significant impact on FLL performance and noise propagation [14]. In[15] a general FLL designed with non-coherent discriminators the effect of carrier to noise density C/N0 is more pronounced [16]. A thorough analysis of discriminator characteristic and loop filter has been discussed in [17] which compare the discriminator based on tracking error variance in presence of thermal noise and across wide signal strength conditions [19]. Loop bandwidth and tracking error variance effect on loop behaviour particularly becomes critical under weak signal conditions where they cannot be correlated easily [18]. Even different optimization techniques for a constant bandwidth FLL loop makes in inappropriate for robust carrier tracking [20] and the need for adaptive loop bandwidth arises. Problem of noise amplification because of non-linear operation on complex inputs limits its use [15]. FLL using kalman based filter, that combines multi-correlation lags of input overcomes the above limitation. A DTFT based approach provides more accurate frequency estimation as compared to traditional FLL [9]. But it suffers from outline effect, due to signal to noise ratio, that is compressed by using median filter [26]. It requires a high order median filter under low SNR. Software defines radio receivers offers an ad-vantages of easy adaptability and reconfigurability [25]. A frequency locked loop based on traditional DLL approach that assist PLL for phase locking is employed in [8]. The rapid phase variation are nullified, improving the transient performance of the FLL-assisted PLL [10]. A FLL for BPSK transmitters that does not adjust frequency before transmission but instead maintains frequency lock while transmitting data and settles during inactivity [23]. This makes it suitable for low power applications. Bit rate higher than settling time is achieved by using nested FLL [15].

1.2 Motivation

The large growth in the availability and need of GNSS enabled cell phone, due to large demand of position ,location and navigation of users in handset and International Telecommunication Union standard rule that mobile manufactures should inbuilt the multichannel GNSS receiver for the global coverage of navigational satellites,In that way the development and design of GNSS receivers tracking algorithms has play a vital role. Developer of traditional GPS receivers have the profits of high performance parts and application specific embedded modules. The current need of GNSS receiver performance has imposed severe constraints on receiver design, requiring low power dissipation and consumption, size and cost .

Now the main aim at designer of handset that they have to design effective front end module that work very effectively even in harsh environment, adoption of softer GNSS receiver is also a very good choice of developers. The critical operating environment of a GNSS mobile hand set, the received satellite signal can be heavily degraded due to multi path and heavily distorted due to several environmental effects and channel performance. In sum up these GNSS receivers problem and environmental effects poses a big challenge to the receiver tracking algorithms and thats why traditional GNSS carrier tracking algorithms fail to provide accurate position and location of particular object.

Hence there big challenge among designers to utilize the available resource and provide the effective result even in harsh environment. There are few question came in author mind: How should the available limited facility afforded by a mobile receiver, be focused upon the task of tracking weak GNSS signals ? Its solution is not so easy. to understand the problem, its each and every parts ,adaptive tracking solution and high yield of receiver design There are few main challenges among designers and manufactures og GNSS receivers-

1. How does a gnss receiver affect the received signal?
2. How do tracking algorithms work under weak signal conditions?
3. How does a gnss receiver affect the tracking algorithms?

In response to these challenges, this thesis attempts to analyze, in detail, the receiver induced losses incurred during the reception of GNSS signals. Subsequently, it considers the influence of consumer grade receiver components on the performance of these tracking algorithms.

1.3 Objectives of Dissertation Work

The objectives of this dissertation work include:

1. Generate GNSS Signal in MATLAB and Simulink.
2. Propose a carrier tracking loop design based on frequency estimation
3. Simulate the GNSS Receiver carrier tracking loop in different inputs and environments.
4. Evaluate the performance of the proposed scheme.

1.4 Organization of Report

This report is organized as follows:

Chapter 2 - It provides an overview of the GNSS transmitter and receiver , its signal structure and the receiver front-end components. Factors causing distortion of the transmitted signal are also discussed.

Chapter 3. The chapter accounts the proposed scheme with description of each component and different parameters used. A brief about each component is discussed. The linearized model has been modeled to demonstrate the behavior of the proposed model.

Chapter 4.Simulation results are summarized in the chapter.

Chapter 5.The concluding results are drawn and some proposals of the work, how it can be further carried forward is included in future scope.

Chapter 2

Basics of GNSS Signals and Receiver

2.1 Introduction

GNSS is a constellation of satellites at fixed orbital planes, where position of a satellite is decided for full area coverage with each site in radius of at-least four satellites. Presently, GPS and the GLONASS are in operation with third system, Galileo, currently un-der development in Europe. All the three systems will be interoperable. Though it was originally intended for military use only but now it has been extended to many civilian applications. GNSS application include both navigation and surveying. Surveying is mainly positioning requiring high positioning accuracies, static observations, and post processing procedures. Whereas navigation includes the determination of position, velocity, and altitude of moving objects. The differences, however, have continued to diminish. GNSS provides precise position information (i.e longitude, latitude and height) anytime, anywhere, and in any weather. Satellite ephemerids are accurately known. The position measurement is based on Time of Arrival measurement i.e. the signal propagation time is measured. Intersection of spherical surface, measurements made using ranging code of three satellite, enables users to know their position anywhere on or above the earth surface. Navigation systems also enable determination of velocity by making Doppler shift estimate. Based on Doppler principle, the relative velocity of user w.r.t satellite may be determined. As satellite position and velocity are known and user position is calculated, the Doppler observable may give velocity vector.

GNSS are one way, space to earth, ranging systems. The emitted signal precisely gives the information about time of transmission for range calculation as well as satellite position and status. The signal characteristics is such to avoid interference and attenuation between signals. Direct sequence spread spectrum (DSSS) modulation is used for GNSS signals. The carrier is modulated by code sequence composed of data message modulated by ranging code. A direct sequence modulated system is one in which modulation signal is a sequence with frequency higher than data rate. It is called spread spectrum because of wider bandwidth after modulation. DSSS is an extension of BPSK. DSSS is preferred as it enables precise ranging by introducing phase inversion on carrier and also enables different satellite to transmit over same carrier frequency using orthogonal code sequence. Different PRN code enables receiver to distinguish among the signals. For above reasons, the transmission of multiple DSSS signals, characterized by different spreading code sequences, on a common carrier frequency is referred to as code division multiple access(CDMA). A brief about the signals composing the GNSS signal structure are discussed in following subsections.

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2.2 GNSS Signal Transmitter

GNSS Signal are mainly transmitted by using BPSK and BOC modulation technique.From the 1992 US GPS signal was using BPSK method ,but in 2002 German Scientist J.W. Betz invented a advance version of BPSK sub carrier modulation technology known as Binary offset Carrier Modulation. Generally we called then modernize GNSS(GPS, Galileo) signal.

2.2.1 Binary offset Carrier Modulation

Binary Offset Carrier signals are sub carrier-modulated PRN codes, similar to Manchester coding. The BOC sub carrier signal is a square-wave with a frequency of an integer- or integer-and-a-half multiple of the code chipping rate and either a sine or cosine phase relative to the code. BOC modulation is described in the form BOC(m,n) while m and n represent the sub carrier and code rates respectively, normalized to the GNSS base frequency of 1.023MHz [10]. Compare the description of the GPS C/A signal which is a BPSK signal that is, BPSK with a processing (code) rate of 1.023MHz. BOC signals offer several benefits over the code-only spread-spectrum signals used for GNSS BOC modulation allows improved frequency sharing between signals, since the BOC signals sub carrier splits the central lobe of the spectrum: BOC and non-BOC signals are able to share a common center frequency [26]. BOC signals raise the cross-correlation noise less than if new signals with the same modulation were added to constellations transmissions. The wider equivalent bandwidth and spectral separation of the lobes of the signal also increases the signals robustness to jamming and narrow band interference [8].

2.2.2 Ranging Code

Each satellite generates its own unique ranging code or pseudo random noise(PRN) code sequence. The PRN code or spreading code is a nite sequence of bits, often periodic, that is known to the intended receiver. Precise ranging requires accurate reproduction of the spreading code sequence by user and satellite receiver through some digital means [4]. So, rectangular pulses with amplitude changing between 1 and -1 is used. The minimum time between transition is called the chip length. Reciprocal of chip length denotes chipping rate and is proportional to bandwidth. So, length of chip code [15] may be given by Tp = Tc

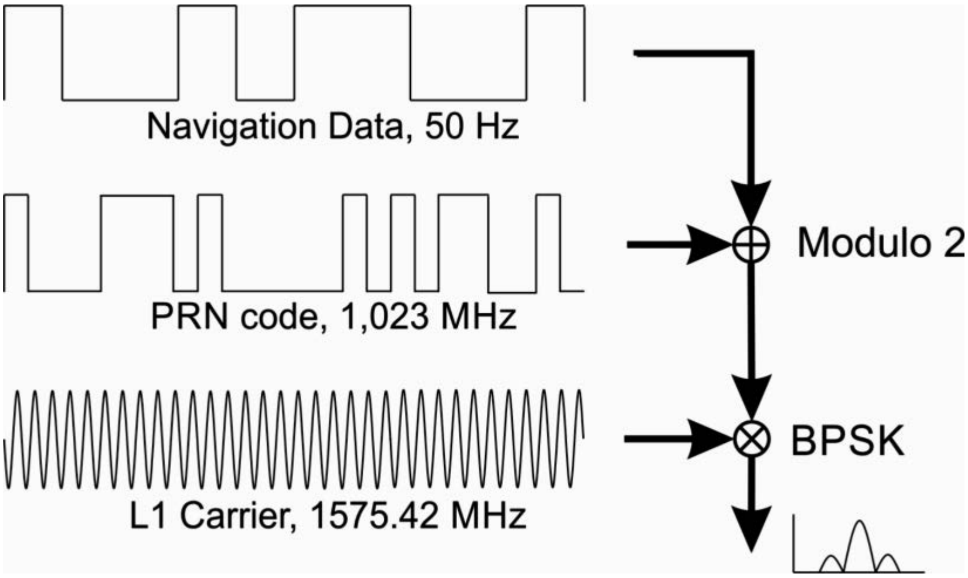


Figure 2.1: GNSS Signal Modulation Scheme [4].

where Nc is number of chips per sequence. The data bit length is greater than Tp. Modulation of data message by PRN code spreads the signal power to wider bandwidth [21]. Although inefficient for data transmission, but it offers advantages of run time measurement, demodulation of low power signal, reduces interferences and enables CDMA technique [7].

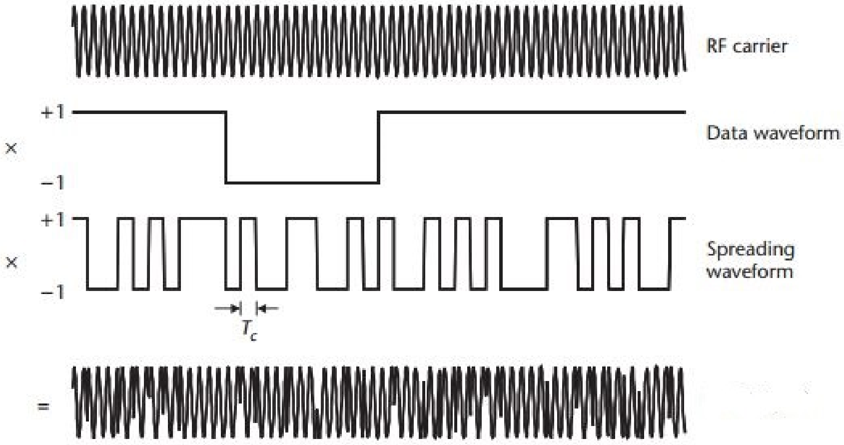


Figure 2.2: GNSS modulated signal [10]

2.2.3 PRN Code

PRN codes are generally generated using Linear feedback shift registers. A feedback loop is formed by feeding XOR of some of the present states as input. Longer is the code better is the correlation properties obtained [4]. Codes like Gold code, truncated

Gold code etc. with better cross-correlation and auto-correlation properties are also developed. Different modulation and multiplexing techniques that provide improved signal tracking with broadcast of signals without interference over same channel are being developed. Improved processing technique, thus, are required.

2.2.3.1 Generation of C/A Code

Coarse acquisition code signals are digital codes .thats are generate by use of two 10 bit Linearly Feedback shift register. GNSS C/A codes are kind of pseudo random noise sequence popularly known as gold sequence code. G1 and G2 are two maximum length 10 bit LFSR govern by a standard clock frequency 1.023 MHz. Generally n bit shift register generate 2^n -1 length of sequence. G1 and G2 are 10 bit shift register hence maximum length of sequence generate by $2^{10} - 1 = 1023$ bits [10] [26]. Its recommend that initialize all the sates with ones. C/A codes are generate by two G1 and G2 LFSR governed by polynomial given below in equation 2.1 and 2.2 respectively.

$$G_1(X) = 1 + X^3 + X^{10} \tag{2.1}$$

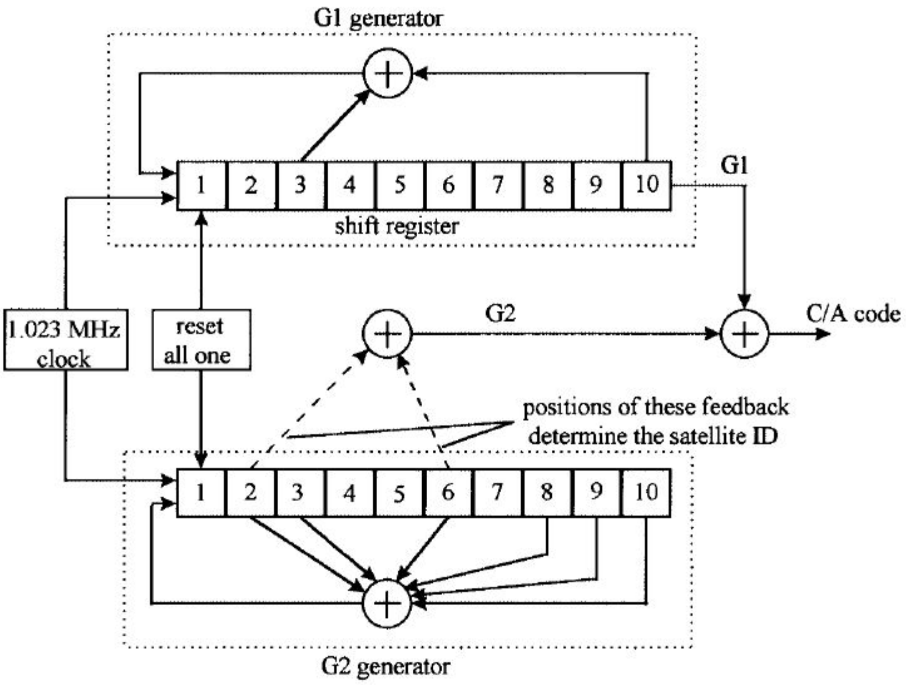
$$G_2(X) = 1 + X^2 + X^3 + X^6 + X^8 + X^9 + X^{10} \tag{2.2}$$

The output of the G2 LFSR for each C/A code is delayed by the modulo-2 addition of two code phase selection bits specific for each satellite.

The C/A code is generated by the exclusive or operation of the output of the G1 register polynomial and the delayed output of the G2 feedback shift register.Figure 2.3 is schematics the way we generate the C/A code for a particular satellite.

2.2.4 Carrier frequency

Technical requirements of the transmitter and receiver, service requirements and propagation effects bearable decides the carrier frequency band used allotted by International Telecommunication Union (ITU). Higher the frequency band used less is ionospheric delays and higher the antenna gains. However, atmospheric attenuation, increased Doppler uncertainty and other design constraint may limit the maximum frequency. For GPS, L1 carrier with frequency 1575.42 MHZ and L2 carrier with frequency 1227.60 MHz contain navigation signals [14].



8

FIGURE 2.3: GNSS C/A Code generator [4]

2.2.5 Navigation message

The navigation code contains information about satellite position and time of transmission. It may also include auxiliary data for communication to other links and also correction factors to range measurements may also be embedded [26]. After code and carrier wipe off from received signal, the data message is decoded in the navigation processor to get satellite position details. It computes time, velocity and position information using code phase and Doppler measurements. The GPS navigation message is transmitted in five 300-bit sub frames with each sub frame composed of ten 30-bit words 21. The receiver checking for deterministic information, performs de-interleaving, error correction and finally extracts the original message.

The transmitted signal is actually electromagnetic wave. Different physical process, mostly frequency dependent, affect its propagation through the space [25]. The signal may experience reflection, refraction and absorption during its propagation resulting in signal attenuation and fading. Ionospheric scintillation, particularly by solar phenomena should be kept in mind. Interference due to other electromagnetic waves also affects the signal power [7]. Therefore, receiver design should accommodate for the loss of signal and track the code and carrier effectively to decode the embedded information. The following section gives a brief overview of the receiver design with role of FLL in it [3].

GPS signals are mainly two types: the coarse/acquisition (C/A) code and precision P(Y) code. Now a days, the C/A code is used for civilian applications while the P(Y) code is reserved for defense application and restricted services [26]. The main aim of our GNSS receiver is that to track the C/A code and carrier signal accurately. The GPS signals are transmitted on two different frequencies: L1 (1575.42 MHz) and L2 (1227.6 MHz) [21]. These frequencies are synchronized with a fundamental clock frequency fo = 10.23 MHz clock related as follows -

$$L1=1575.42 \text{ MHz} = 154^*\text{fo MHz}$$

$$L2=1227.60 \text{ MHz} = 120^*\text{f0 MHz}$$

Since the focus of this GNSS receiver design is on civilian applications, so only the acquisition and tracking GPS signals t L1 frequency are studied in detail.Fig 2.4 shows the spectrum of GPS C/A code and Galileo BOC signal spectrum.,BOC signals have advantage over BPSK signal that two main lobes shifted just away from centered frequency.

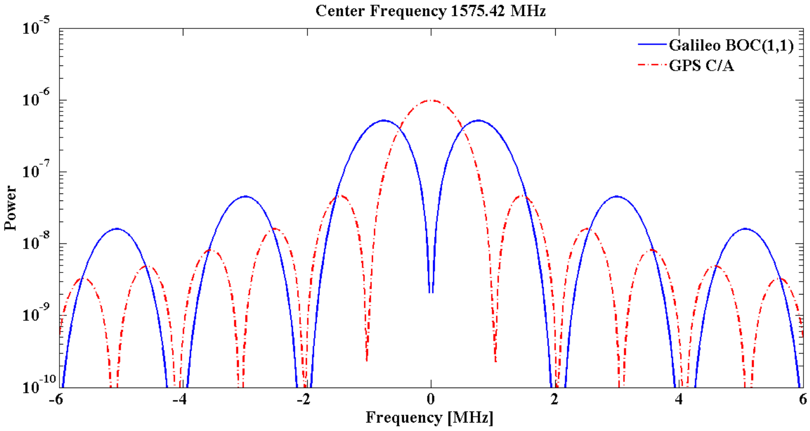
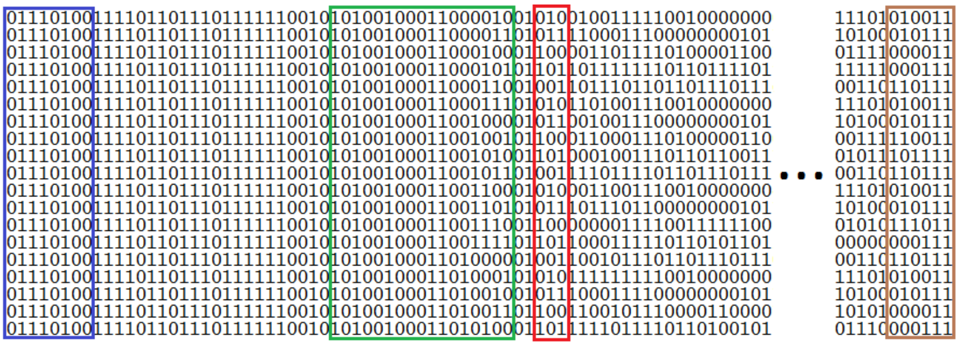


Figure 2.4: Power Spectrum of GPS C/A and BOC(1,1) Signal

In figure 2.5 frame of GPS signal is shown ,its comprises of ephemeris data,navigation bits,Coarse acquisition code and carrier signal .At the receiver end same satellite code is generate by receiver synchronize with satellite clock with fundamental frequency fo =1.023 MHz.

2.3 Propagation Effects

Propagation of the transmitted satellite signal from an orbital altitude of 20,000 km to 24,000 km to an earth base receiver station cause signal degradation. Amongst these



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0111010011110110111011111110010101001000110000100101001001111100100000000       11101010011
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0111010011110110111011111110010101001000110101000110111110111101101001 01       01110000111
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Figure 2.5: Binary Frame structure of GPS Signal [4]

effects are signal attenuation, distortion and dilation. Some of these effects, and their manifestation in the received signal parameters of are discussed here.

2.3.1 Received signal Power

A number of factors influence the signal power, Pi, available to the GNSS receiver.Whilst the transmitted power at the satellite is approximately 27 W [25], the power incident on the antenna of an earth based receiver, even for a LOS signal, will be of the order of 0.2 pW (-159 dBW) [5].The factors which dictate this power loss include the satellite antenna gain, the free space propagation loss and the gain of the receivers antenna. The gain of the satellites antenna is a measure of the ability of the antenna to focus the transmitted power towards the earth.

2.3.2 Multi path

Unfortunately, the propagation of the GNSS signal through urban and indoor environments does not simply incur an attenuation of the signal power. Generally, the received GNSS signal includes a LOS signal and a number of non-line-of-sight (NLOS) signals [25]. These signals are ones which have been reflected off nearby obstacles one or more times before reaching the antenna. An example of the propagation of a signal in an urban environment is illustrated in Figure 2.6

2.4 GNSS receiver design

The main aim of a GNSS receiver is computing the accurate location and movement of the user or at least provide some parameters which can be provide these data. For this

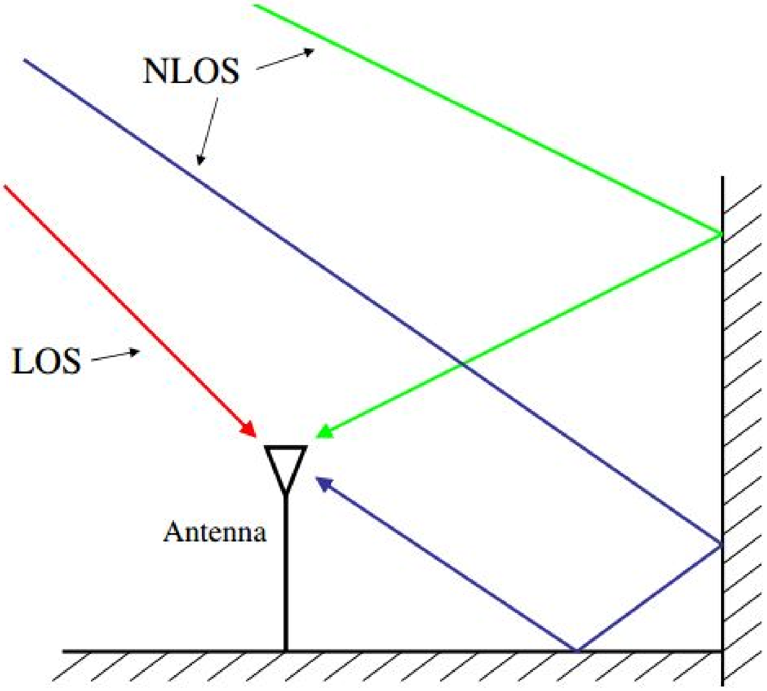

FIGURE 2.6: Multipath Propagation of GNSS Signal [25]

TABLE 2.1: Typical signal attenuation caused by propagation through various building materials. All data sourced from [21]

Material	*Thickness (mm)*	*Attenuation (dB)*
Glass	6	1.19
Glass2	13	2.8
Glass3	20	3.5
Lumber	40	3.9
Plywood Brick	20	2.79
Brick forced Concrete	203	31
Masony Block	406	17.5
Reinforced Concrete	203	33.0

work, the received signals at receiver front end must be received and properly tracked. After successful acquisition and tracking , navigation bits can be extracted and use in the calculation of specific application like position,velocity and time of user.

For this purpose, the received signals at antenna must be acquired and tracked. After

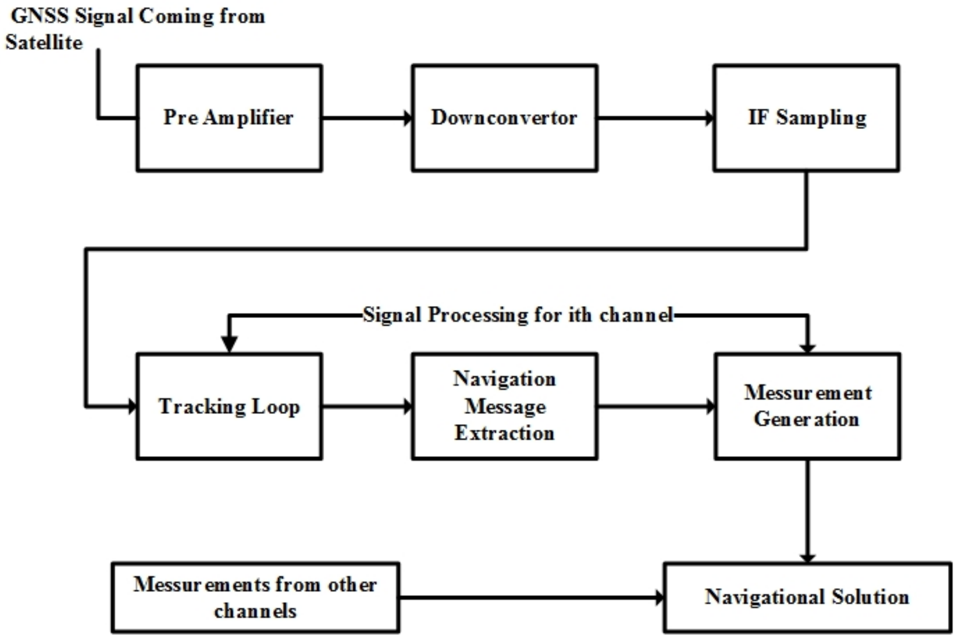

Figure 2.7: GNSS receiver structure [19] .

tracking, navigation message can be extracted and utilized to generate some measurements that are useful in computing the navigation solution. The final goal of a GNSS receiver is computing the position and velocity of the receiver or at least providing some measurements which can be used to compute these values. For this purpose, the received signals at antenna must be acquired and tracked [19]. After tracking, navigation message can be extracted and utilized to generate some measurements that are useful in computing the navigation solution.

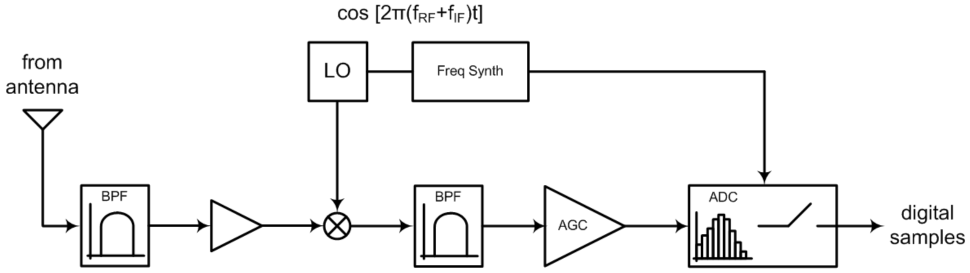

Figure 2.8: GNSS receiver's front end structure.[19]

Figure 2.7 illustrates a block diagram of a GNSS receiver. The received signals at antenna are very weak in power hence they are amplify up to a certain level,so their quality is not degraded then high frequency signals are down converted to inter mediate frequent and a local carrier signal is also generated at this instance .Further down converted signal is sampled and then properly quantized with suitable quantizer. Digital signals then pass through tracking loop where in phase and quadrature phase component of signal is extracted. Now a days multi channel receivers are available.

1. Pre Amplifier
2. Downconvertor
3. Intermediate Frequency (IF) Sampler
4. Quantization
5. Signal tracking loop
    - Code tracking Loop
    - Carrier tracking Loop
6. Navigational Solution

The frequency synthesizer (shown in Figure 2.8) provides the time and frequency information of front end channel .High frequency band pass signals are converted into low frequency base band signals.

2.4.1 Pre Amplifier and Filtering

Pre amplifier and filtering blocks main aim to take the decision how can we suppress the unwanted noise signal and amplify weakest important navigation message signal.Its keep in mind that transmission and reception losses should be minimum. Filtering is done accordingly that filter passes a band of signal and reject all signals.So the quality of receiver increases.

2.4.2 Downconvertor

The receiver front end is main responsible for down conversion of the received satellite signal,mainly two approaches are there converts Radio frequency spectrum direct from bandpass to baseband signal or pass the signal to heterodyne receiver ,where a multi stage circuit automatic shift the satellite signal spectrum to Intermediate frequency with appropriate filtering that again convert IF signals to base band message signal.

2.4.3 IF Sampler

Incoming high frequency bandpass satellite signal are band shifted to intermediate frequency base band signal,then this signal sampled accordingly that no information of navigation bit is lost, and quality of signal is not effected.

2.4.4 Quantization

Quantization is a process to convert discrete samples to digital signals.There are many quantization process ,uniform,non uniform,centered and non centered its depends on signal and noise characteristics. Power level of Received satellite signal are low,so quantization treat noise like signal at the input. Depends on the signal condition we can chose quantizer ,when using 2 bit quantization 1.5 dB degradation while 1 bit,increasing to 3.5 dB.

2.4.5 Signal tracking Part

The main aim of GNSS receiver is to synchronize a local replica of transmitted pseudo random noise code by satellite in order to calculate the distance propagate by the incoming signal as accurately as possible. For that, carrier tracking loops are used in a closed loop manner to follow continuously the code and carrier parameters of the incoming satellite signal.These loops are commonly known as as code and carrier tracking loops.

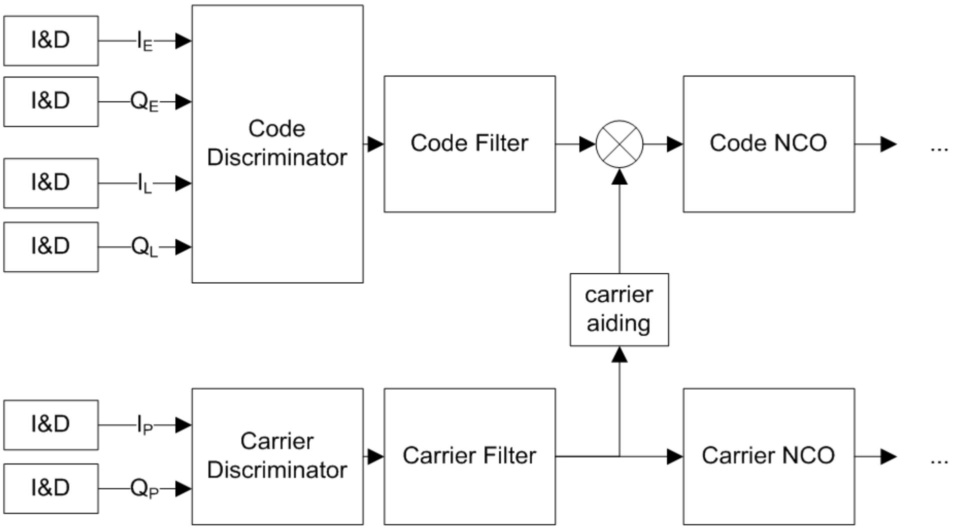

FIGURE 2.9: Block schematics of GNSS receiver signal tracking system.[4]

To extract the useful information from incoming satellite signal GNSS receivers track the signals by replicating the PRN code and adjusting the satellite code signal delay and phase of carrier signal continuously to synchronize with the transmitted signal.In figure 2.9 basic carrier and code tracking architecture shown. The tracking loops include:
Integrate and Dump: Integrate and Dump block extract the in phase and quadrature components from the correlator output of the incoming satellite signal,thats very important parameters to track the signals efficiently.

Discriminators: The main aim of this block to extract the information from correlator output like carrier phase,code delay etc.

Filters: The main aim of the filers to remove unwanted signals like noise and pass the discriminator outputs to track the information..

Numerically Controlled Oscillator(NCO): NCO convert the loop filter results into usable Doppler frequency parameters and code delay that synchronize the incoming signal with local replica. While code tracking loops follow the code delay of the incoming signal using Delay Lock Loops (DLL), carrier tracking loops can be designed to follow either the phase of the incoming signal using Phase Lock Loops (PLL), or the Doppler frequency of the incoming signal using Frequency Lock Loops (FLL). Nevertheless, receivers may implement both FLLs and PLLs:[16] this decision, together with the dimensioning of all the components within the tracking loops, is part of a series of trade-offs conducted during receiver design.

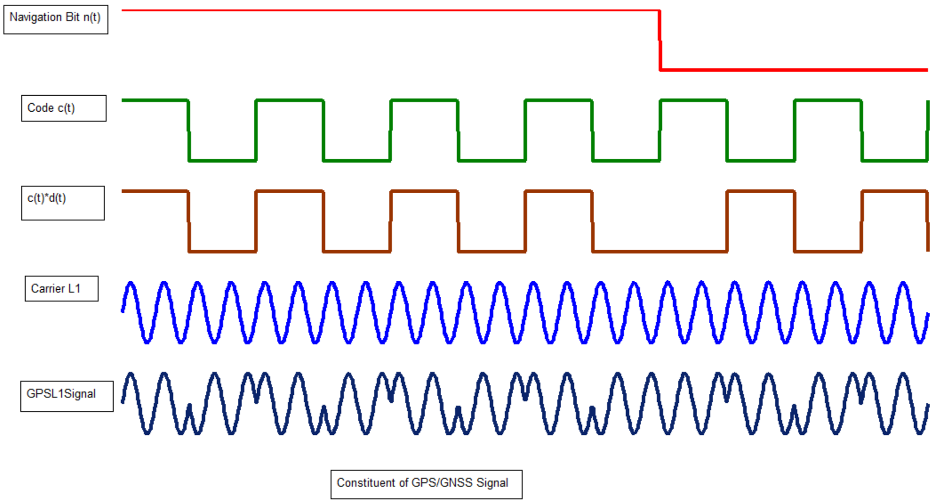

Figure 2.10: Constituent of GNSS GPS Modulated Signal

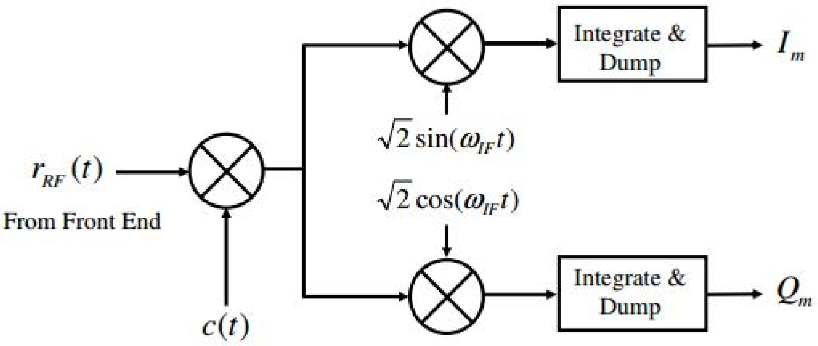

FIGURE 2.11: Block diagram of a typical correlator implementation in a GNSS receiver [22].

2.5 Baseband Receiver Processing

If the receiver has no a priori knowledge of the received code phase then the entire code length must be searched. Similarly, without any estimate of the carrier frequency, all possible Doppler frequency values, combined with any potential oscillator frequency offset, must be searched. Although the carrier frequency and code phase are continuous variables, it is generally not practical that the acquisition Baseband Receiver Processing process perform a continuous search over these variables. Instead, the acquisition need provide only a coarse estimate of these parameters. Having coarsely identified the signal code phase and carrier frequency, a DLL and FLL can be employed to refine these estimates. The receiver, therefore, decimates the search space.

2.5.1 Frequency Lock Loop

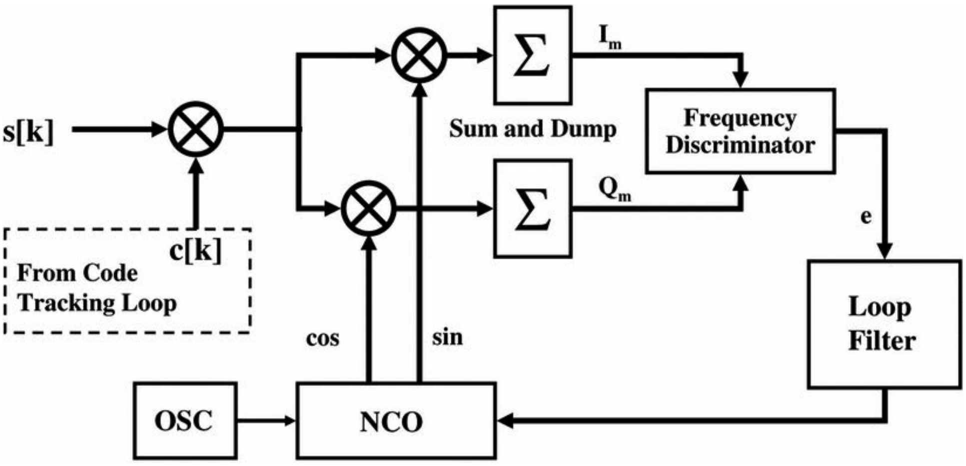

FIGURE 2.12: Block diagram of Frequency Locked Loop [19]

As discussed previously, parameter tracking in a GNSS receiver is a recursive process. To track (or, at least, to attempt to track) the received signal carrier frequency, the FLL will utilize the current set of correlator values. By applying a suitable transformation or mapping to these values, in the form of the carrier frequency discriminator, the FLL will produce an estimate of the difference between the signal carrier frequency and the local replica carrier frequency. This error is then applied to the input of a filter. The function of the filter is two-fold: firstly, as the received signal and, thus, the frequency estimate, is corrupted by thermal noise, the filter is required to provide a degree of noise rejection. Secondly, appropriate design of the loop filter enables estimation of both the instantaneous frequency and, by observing sustained errors, higher order frequency dynamics[23]. Finally, this filtered frequency error estimate is applied to the receiver NCO, to adjust the local carrier frequency for the generation of the next set of correlator values[19]. A simplified block diagram of the FLL is presented in Figure 2.10 [19].Frequency lock loops for GNSS applications can be categorized according to the method by which they estimate frequency error. Frequency estimates can be derived from one of two principles: that of differential power measurement and that of differential phase measurement.The performance of the FLL can be assessed based upon its dynamic performance: its pull-in range and its ability to track carrier frequency dynamics and also upon its noise performance: its ability to accurately track the signal carrier frequency and reject thermal noise. The pull-in range of the FLL is a function of the linear region of the frequency discriminator, which, in turn, is a function of the coherent integration period [7] and must accommodate the residual frequency error of the acquisition stage. In terms of consumer applications, other than the initial transient error induced by the residual error in the acquisition estimate, thermal noise is the primary error source of the FLL, especially as the receiver may be operating in harsh signal environments[2]. A range of closed form approximations to the carrier frequency tracking error variance of the FLL exist, corresponding to a range of different carrier frequency discriminators and under a selection of different assumptions. Primarily, these approximations assume that the discrete update FLL is well approximated by an equivalent continuous update system.

2.5.1.1 Linearized FLL Model

Linear Frequency lock loop z domain transfer function give the idea about stability, where the update rate of the system is T_s . The represent model of linearized Loop Filter provide the information regarding stability and tracking performance of the receiver.

Main interest here are the transfer functions between the thermal noise n^{ω} and the tracking error δ_{ω}, $H^{n}(z)$, denoted Formula, and between the carrier frequency ω and the carrier frequency estimate ω, $H^{\omega}(z)$. These quantities are depicted in a linearized loop model in Fig. 2.13 These transfer functions can be expressed in terms of the loop filter F(z), the numerically controlled oscillator, NCO(z), and the discriminator function, D(z), as

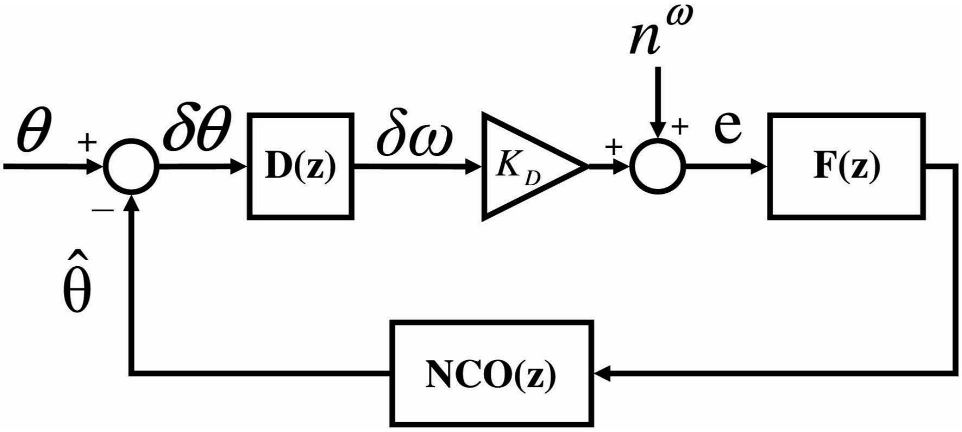

FIGURE 2.13: Block Linearized FLL Model [18]

$$H^{n}(z) = \frac{\Delta\Omega(z)}{N^{\omega}(z)} = \frac{D(z)F(z)\mathrm{NCO}(z)}{1 + K_D D(z)F(z)\mathrm{NCO}(z)} \tag{2.3}$$

$$H^{\omega}(z) = \frac{\hat{\Omega}(z)}{\Omega(z)} = \frac{K_D D(z)F(z)\mathrm{NCO}(z)}{1 + K_D D(z)F(z)\mathrm{NCO}(z)} \tag{2.4}$$

Chapter 3

Proposed Scheme

The Main aim of this thesis is to propose a adaptive carrier tracking loop (CTL) architecture so that the carrier of an incoming satellite signal can be sufficiently tracked in a GNSS receiver. The GNSS signal coming from satellite is in the following form-

$$r(t) = \sqrt{2P}d(t)g(t)\cos(\omega t + \theta) + n(t) \tag{3.1}$$

where P is power of signal ,d(t) is binary data , g(t) is spreading signal,ω is signal frequency θ is phase of incoming signal and n(t) is additive white Gaussian noise with power spectral density No/2

In a GNSS receiver, the incoming signal samples are collected in blocks for signal detection, acquisition, and tracking. To this end, let T_s be the integration interval, Formula be the sampling interval, and assume that T=mT_s for some integer m. A vector of size M can be obtained every T for further processing. At the time epoch kT, the resultant vector bears the following form

Fundamental concept of frequency and phase tracking of GNSS signal is based on following basic operation. Phase and frequency discriminator are heart of tracking engine and play a very important role in GNSS receiver.The following basic block diagram explain basic operation-

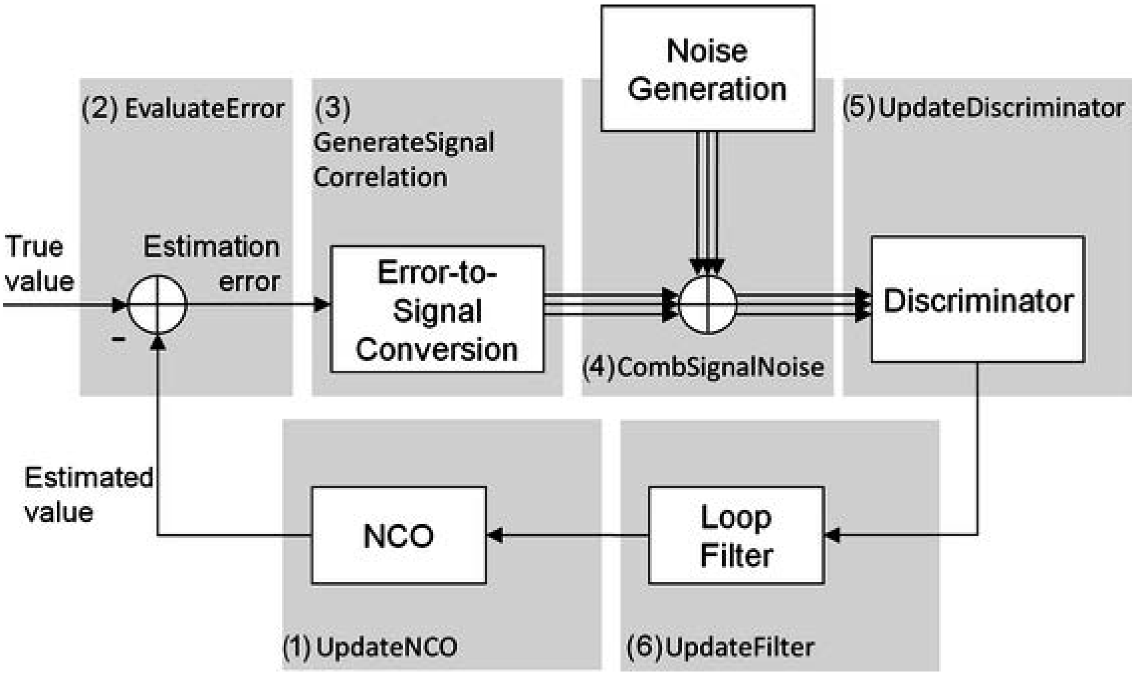

FIGURE 3.1: basic block diagram of carrier tracking operation

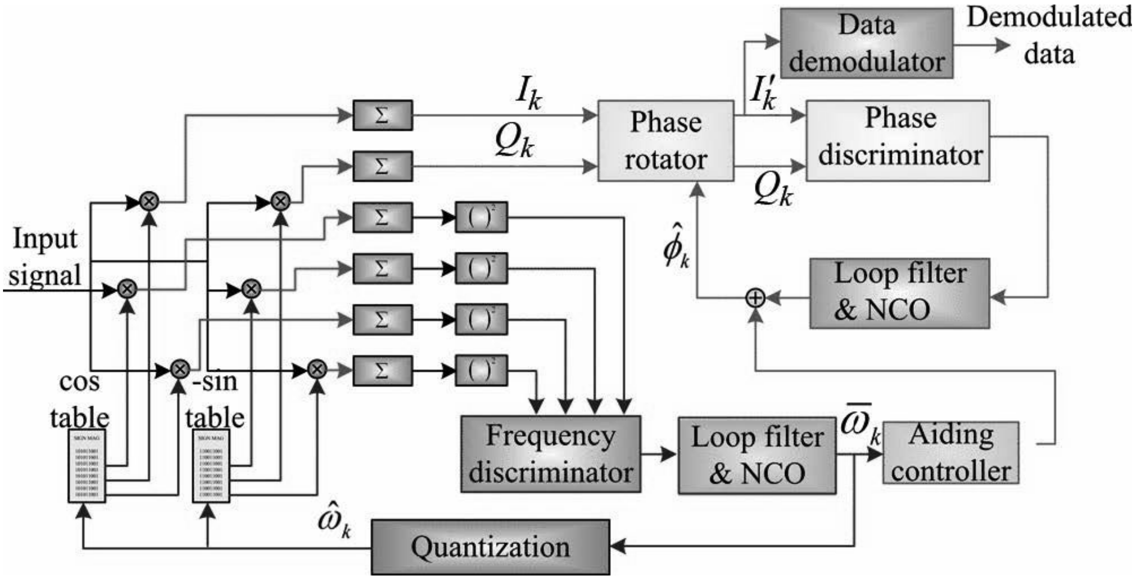

FIGURE 3.2: Carrier and Code tracking schematic of GNSS receiver

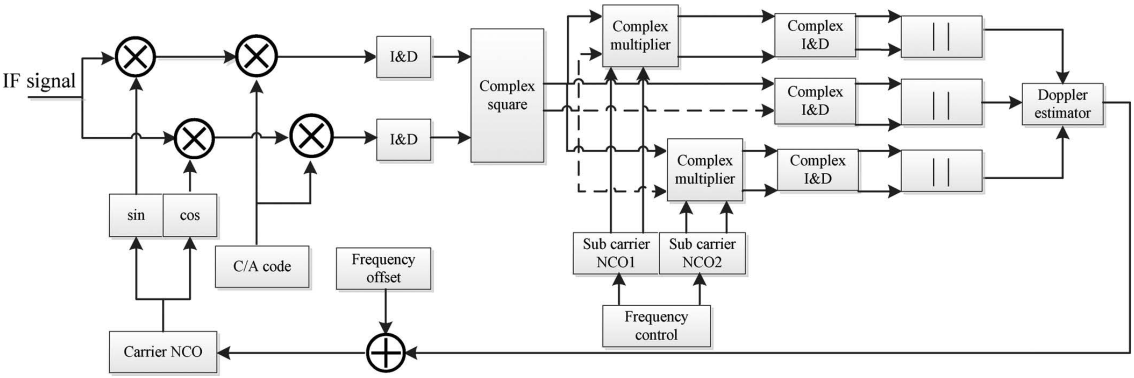

FIGURE 3.3: Block Diagram of the proposed carrier tracking scheme

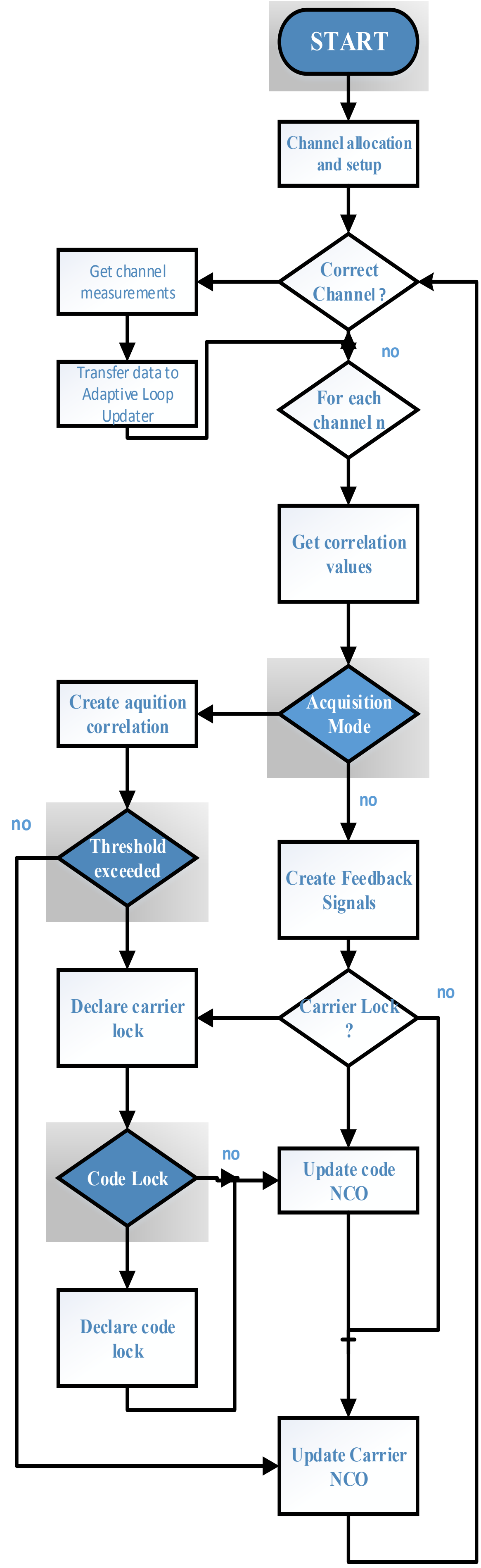

FIGURE 3.4: Flow chart of Adaptive carrier tracking Algorithm

Chapter 4

Results and Discussions

The proposed scheme is simulated in MATLAB ® Simulink environment. Simulation results are validate the proposed scheme discussed in this section.

4.1 Simulation Results

4.1.1 GNSS L1 C/A Transmiter in Simulink

Transmitter of GNSS L1 C/A signal is designed in Simulink environment below the spectrum of sampled C/A code and its power spectrum shown in scope diagram. C/A code are samples at rate of 4.089 MHz. Maximum value is 63.377 dB.From the simulation results,Incoming baseband signal it can be concluded that the proposed Carrier tracking algorithm properly tracked the incoming GNSS signal.PRN code are transmitted at the rate of 10.23bps and at the receiver end local replica codes are generated to synchronize the satellite and receiver clock. BPSK modulated signal is more effected than that of BOC modulated because of two main lobe characteristics.

C/A code have unique properties during correlation peaks are easily detected and provide the accurate carrier and code information to the users. At the receiver end incoming signal is down sample and shifted to intermediate frequency.

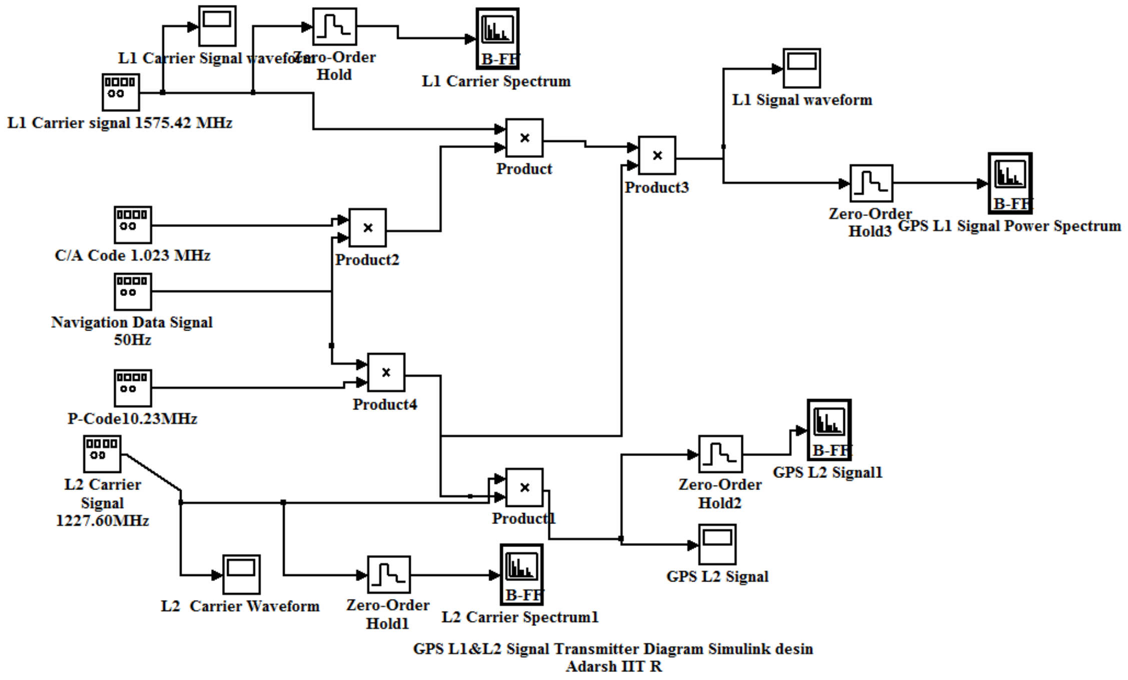

FIGURE 4.1: GNSS Signal Transmitter design (*simulation*)

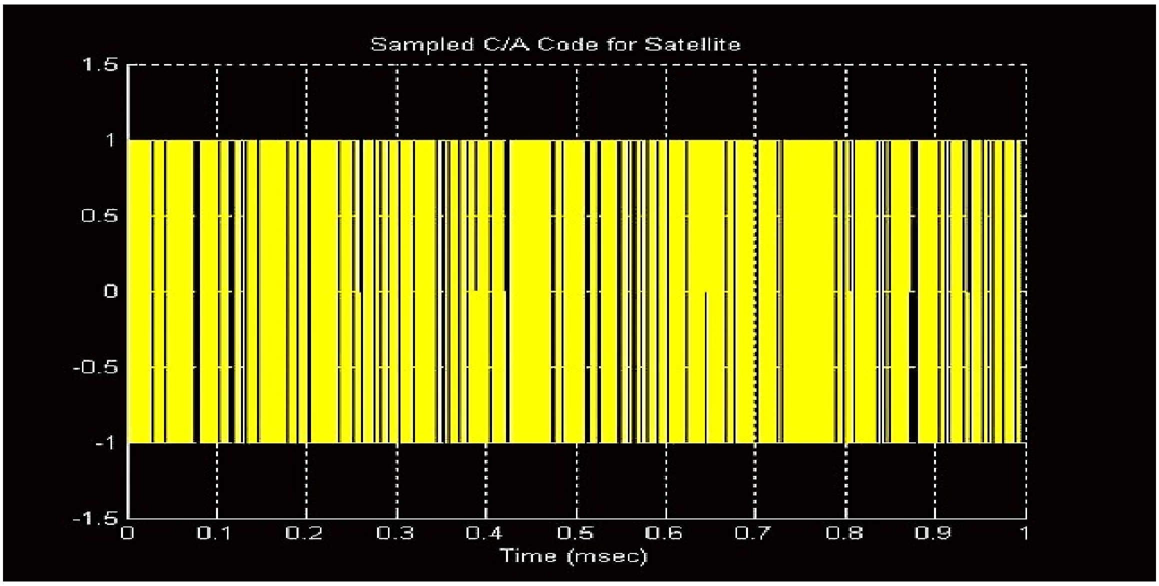

FIGURE 4.2: Sampled GNSS signal (*simulation*)

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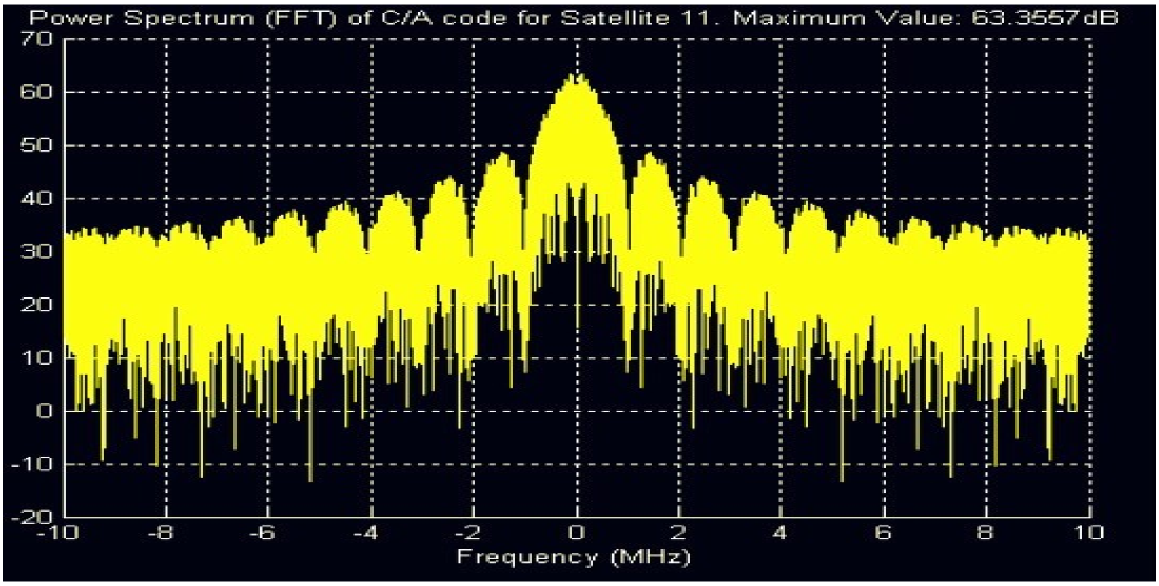

FIGURE 4.3: Spectrum of GNSS Signal at Carrier 1575.42 MHz C/A Signal 1.023 MHz.(*simulation*)

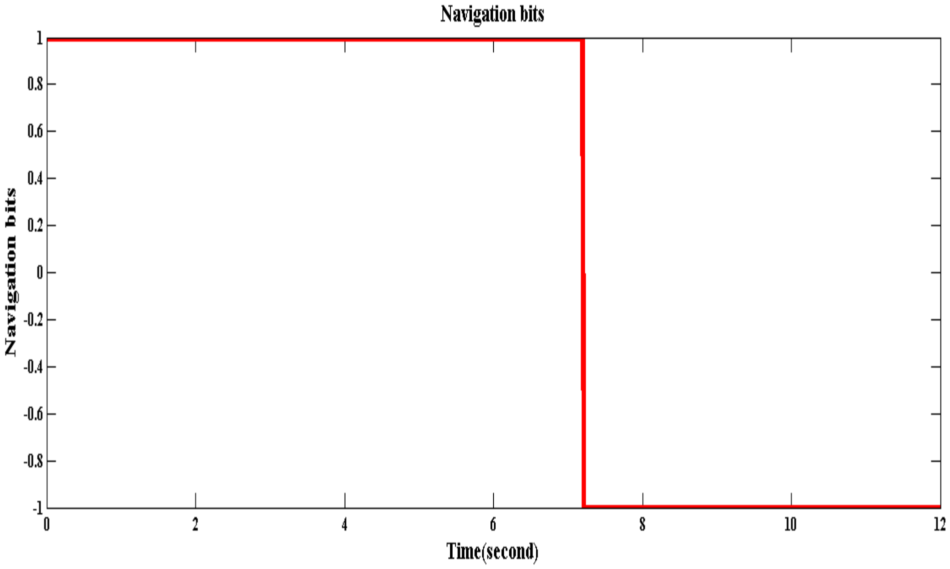

FIGURE 4.4: Transmitted Navigational bits 50 bps. (*simulation*)

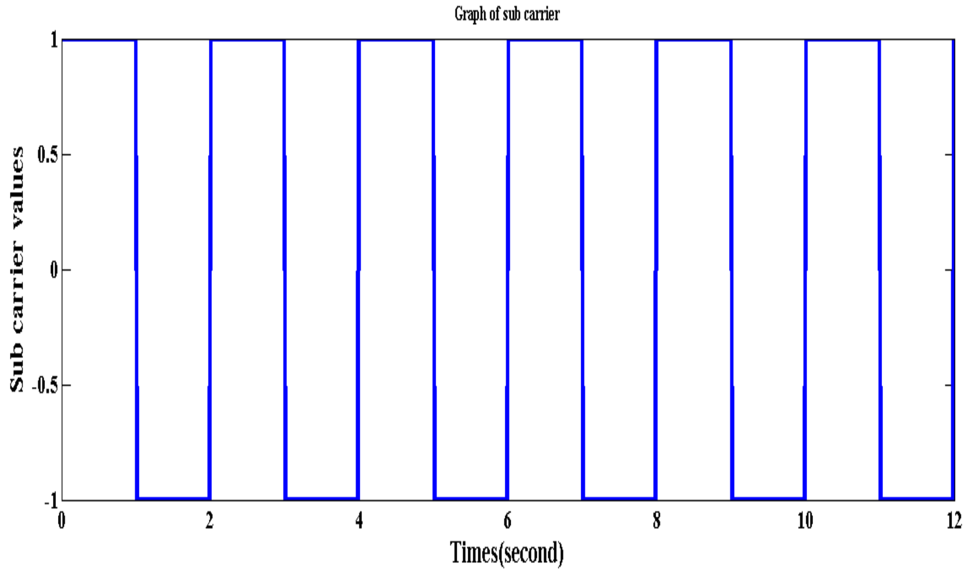

FIGURE 4.5: Sub carrier signal 10.023 MHz. (*simulation*)

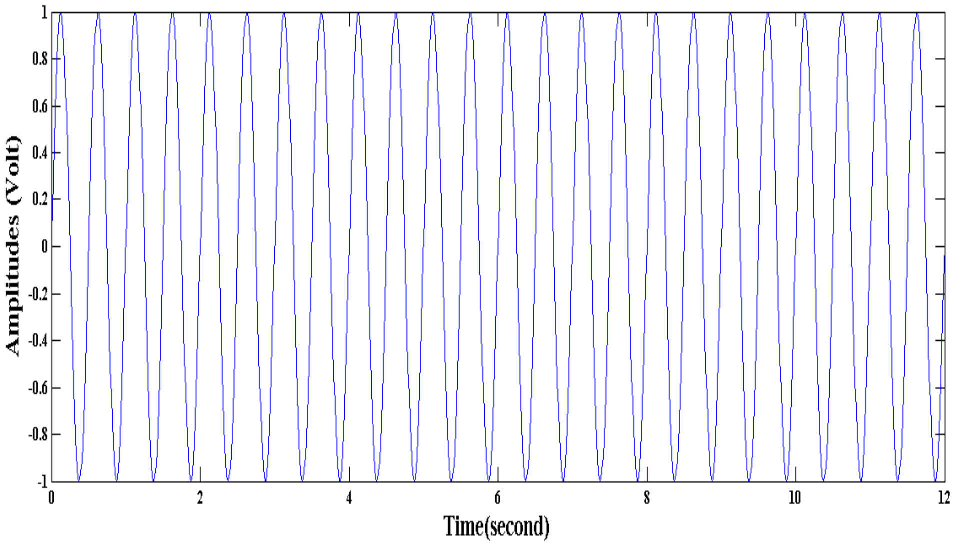

FIGURE 4.6: GNSS carrier signal 1575.42 MHz. (*simulation*)

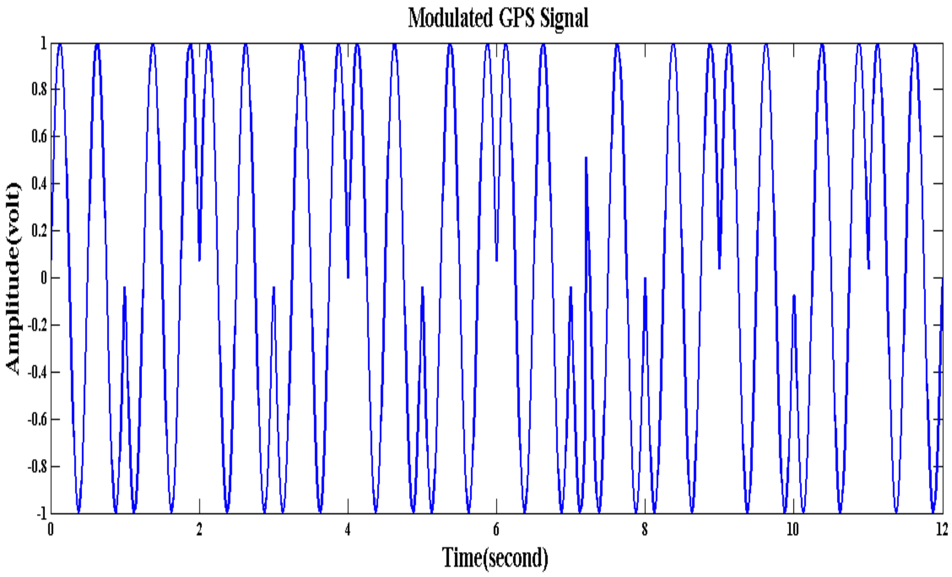

Figure 4.7: GNSS Signal in Space 1575.42 MHz. (*simulation*)

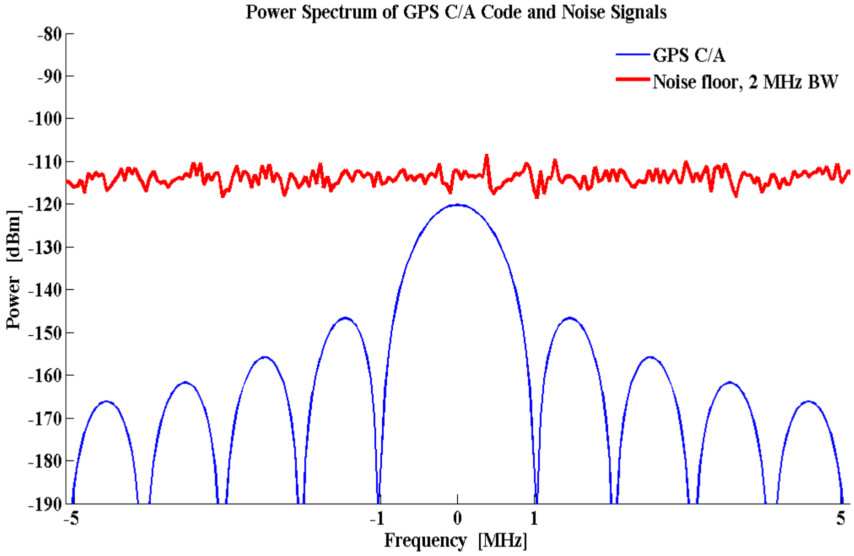

Figure 4.8: Power Spectrum of GNSS Signal in Space (1575.42 MHz) and Noise 2 MHz BW (*simulation*)

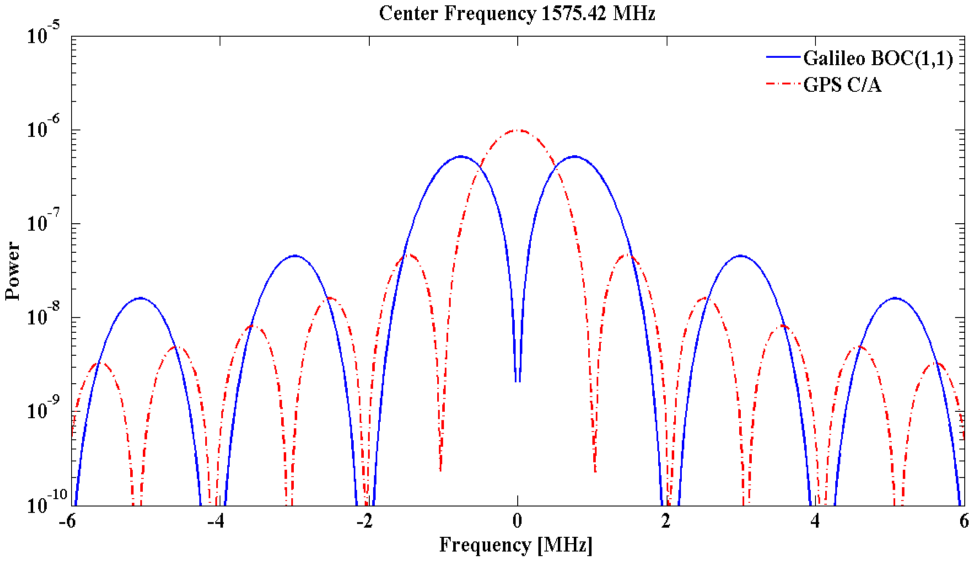

FIGURE 4.9: Power Spectrum of BOC and BPSK modulated GNSS Signal in Space. (*simulation*)

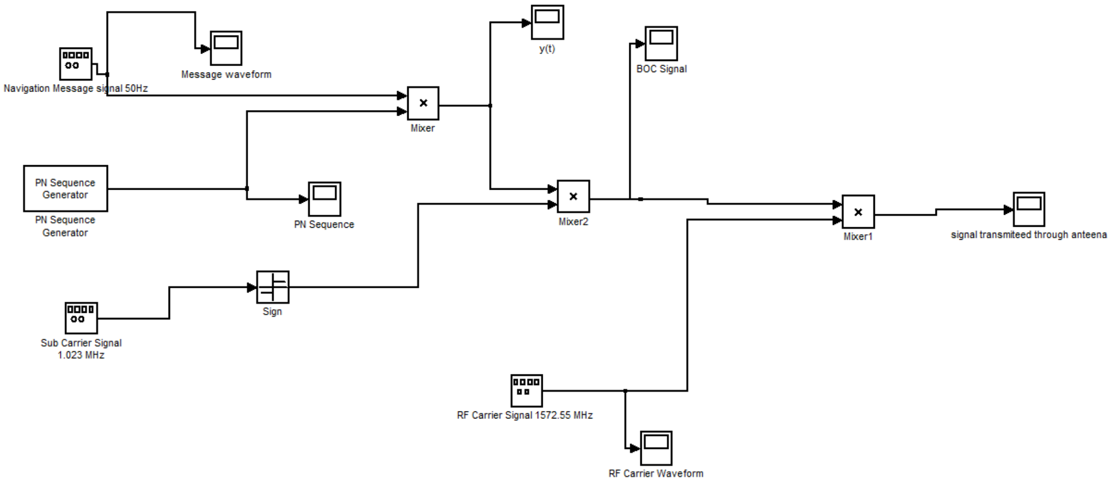

FIGURE 4.10: Simulink model for Binary offset GNSS Carrier signal transmitter.BOC(1,1). (*simulation*)

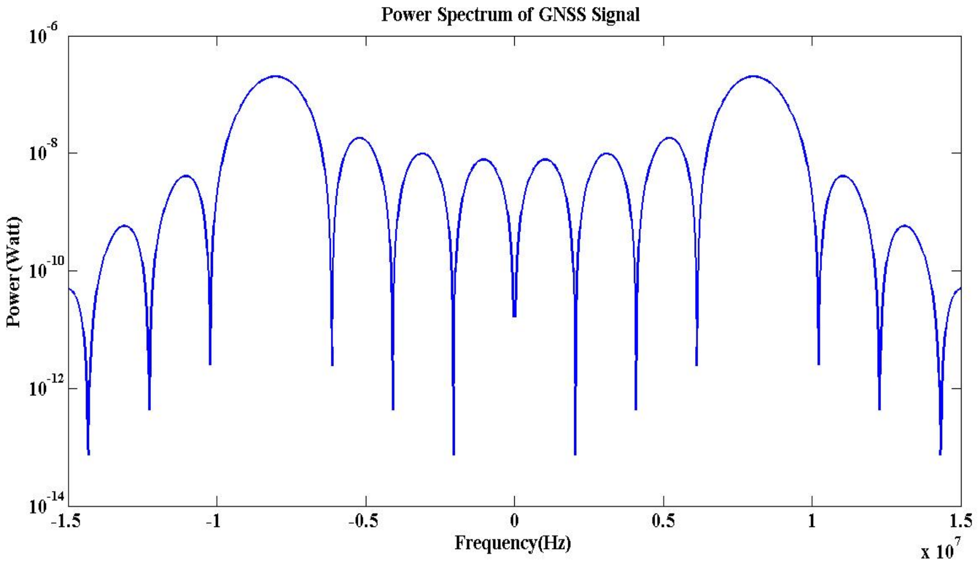

FIGURE 4.11: Power spectrum of Binary offset Carrier signal .BOC(1,1). (*simulation*)

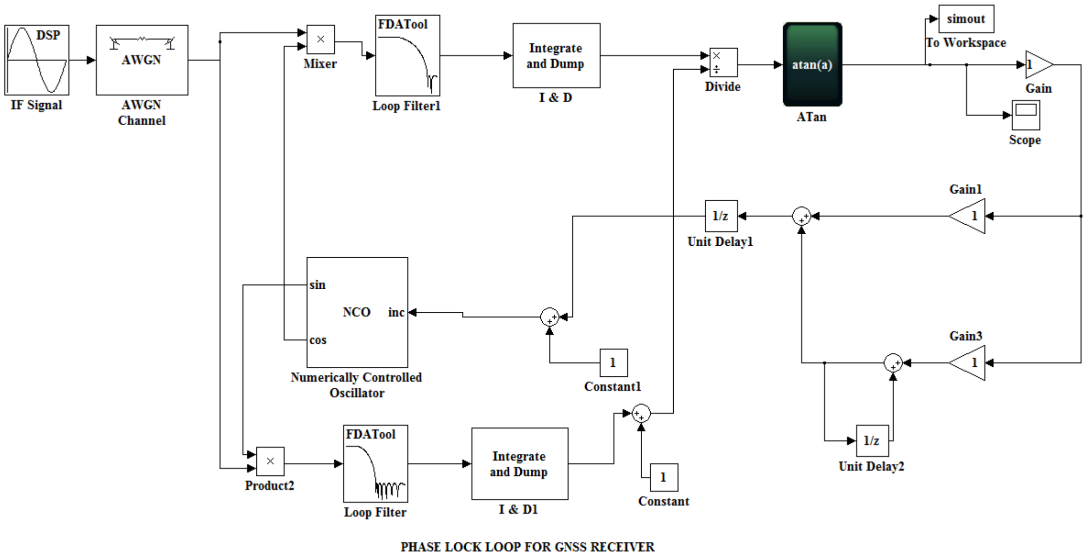

FIGURE 4.12: GNSS Receiver Simulink model for tracking of Signal (*simulation*)

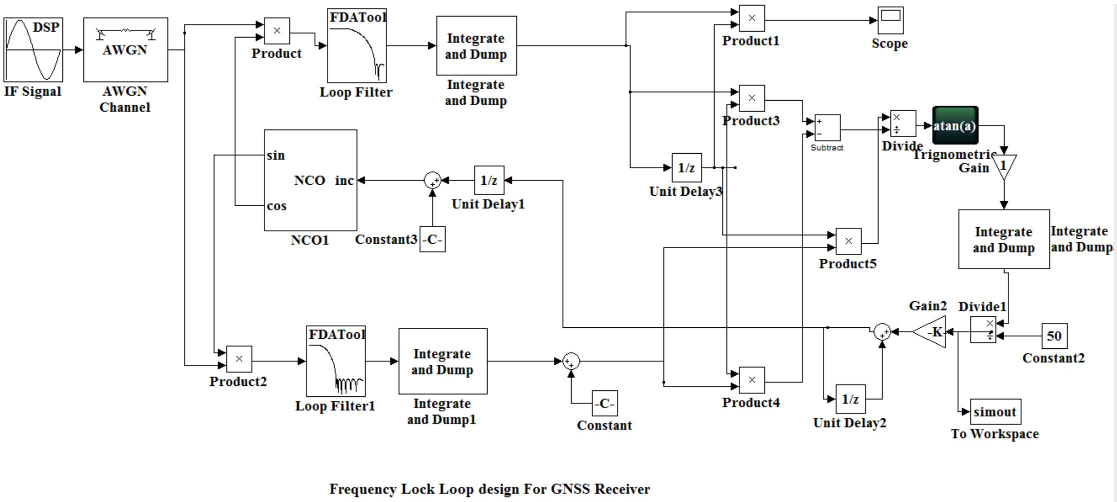

FIGURE 4.13: GNSS Receiver Simulink model for tracking of Signal (*simulation*)

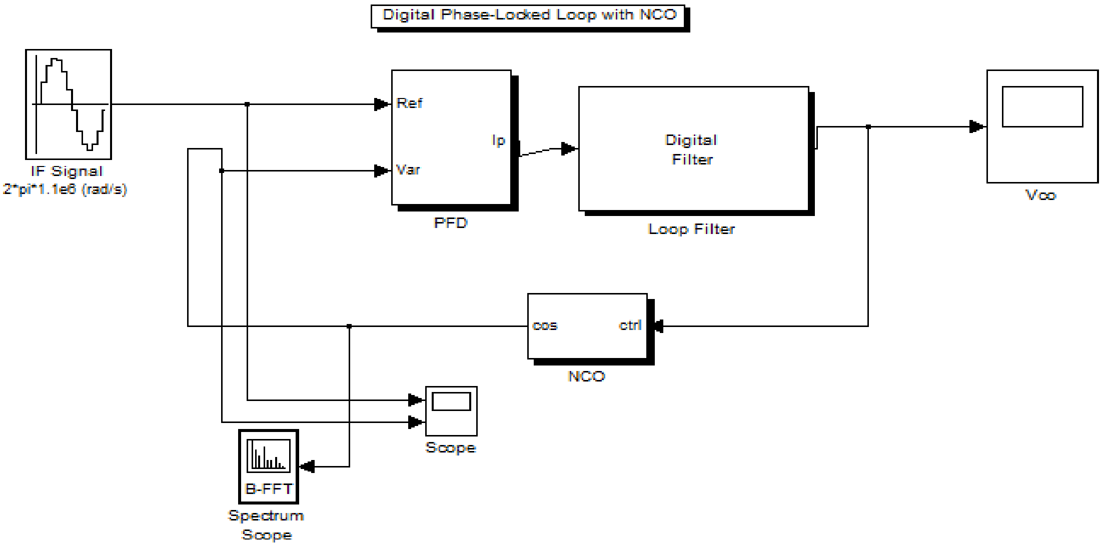

FIGURE 4.14: Carrier tracking loop (*simulation*)

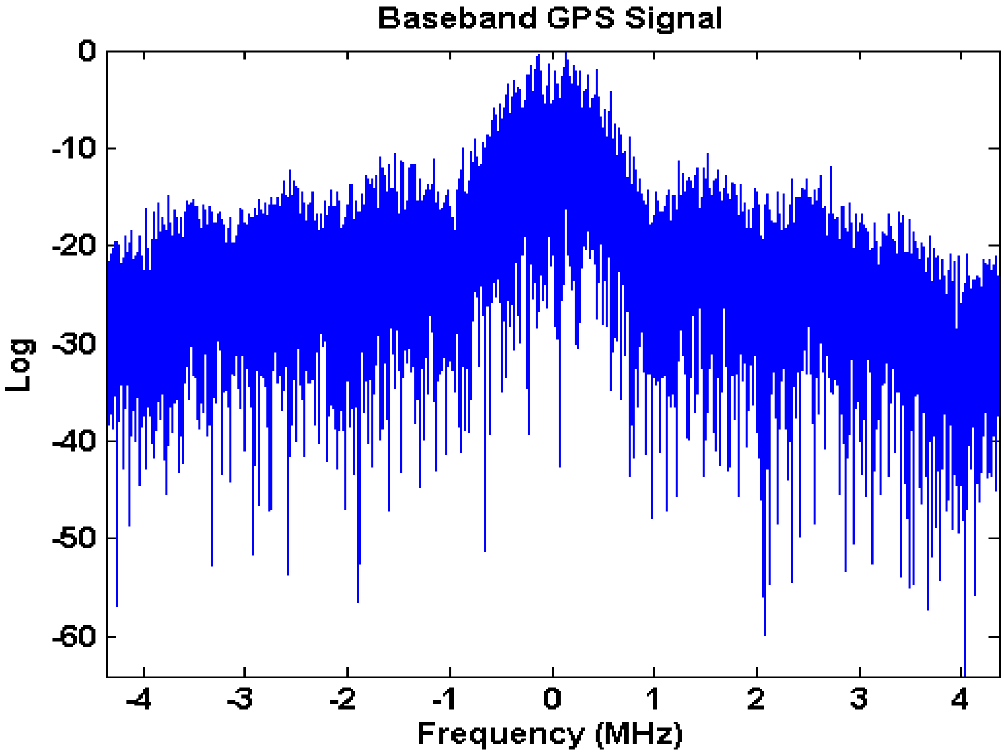

FIGURE 4.15: Baseband spectrum of received GPS signal (*simulation*)

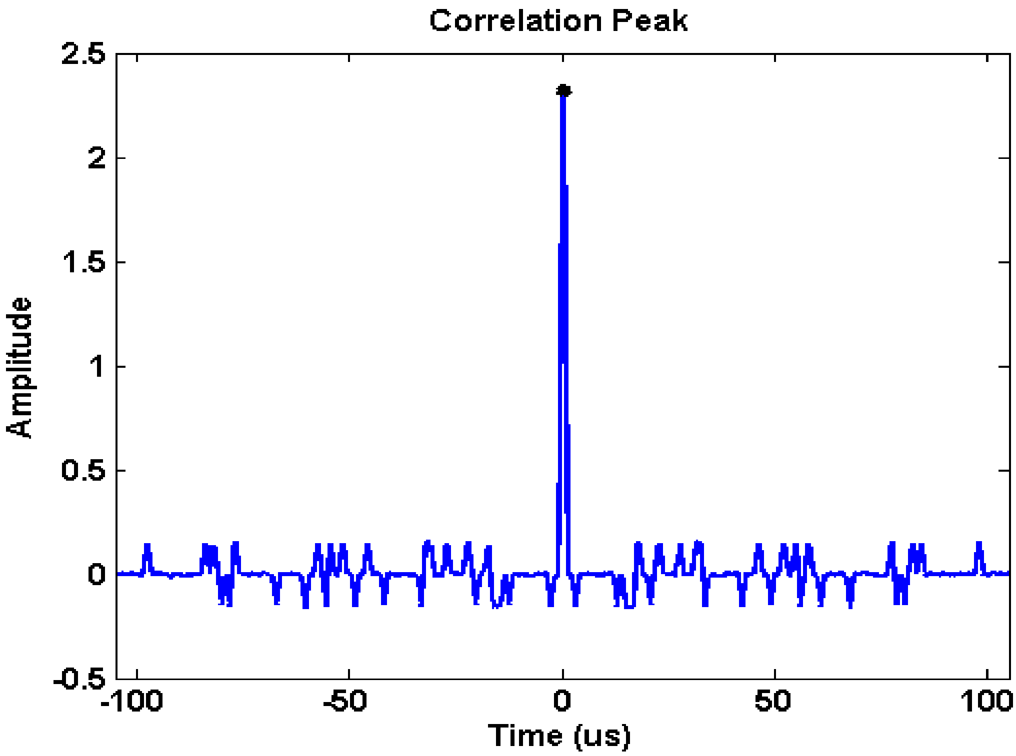

FIGURE 4.16: Correlation of GPS signal (*simulation*)

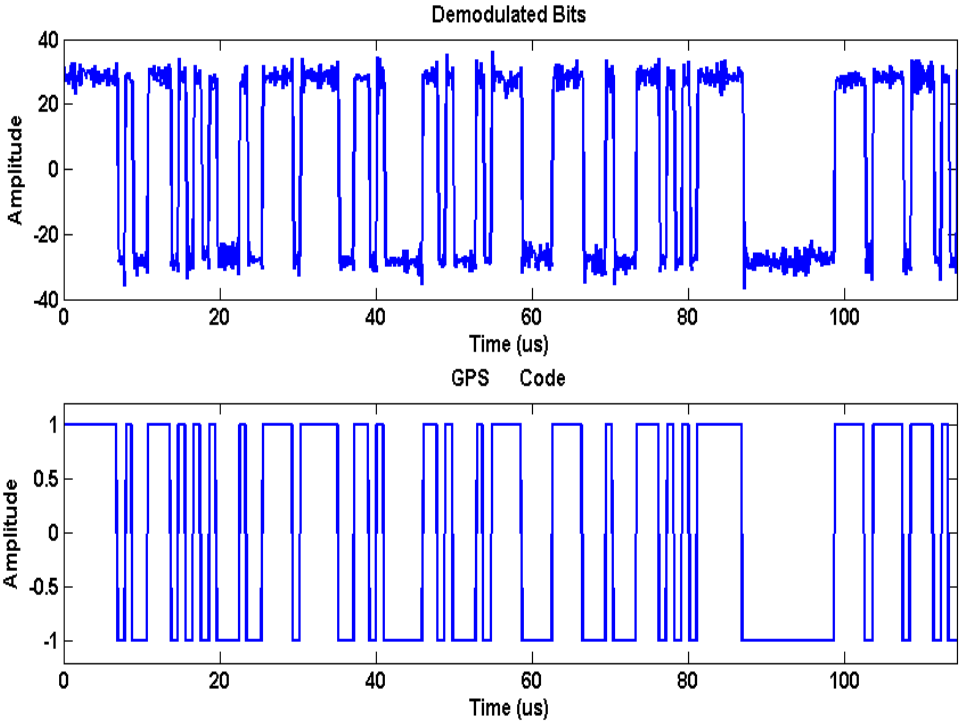

FIGURE 4.17: Navigation bits and GPS C/A code of received satellite signal. (*simulation*)

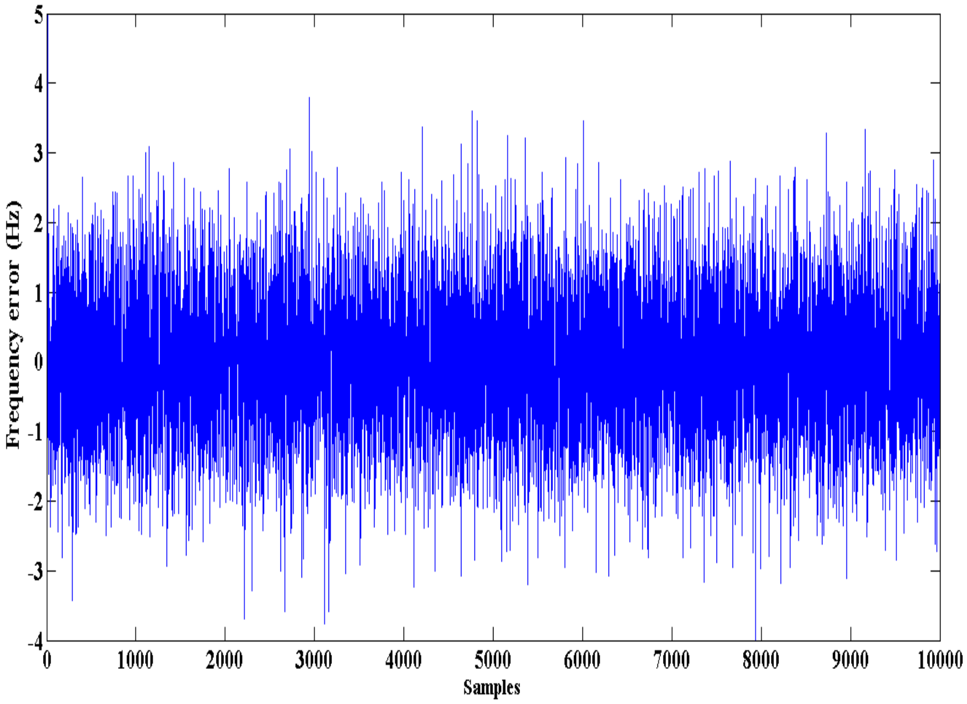

FIGURE 4.18: Frequency error estimation of tracked signal. (*simulation*)

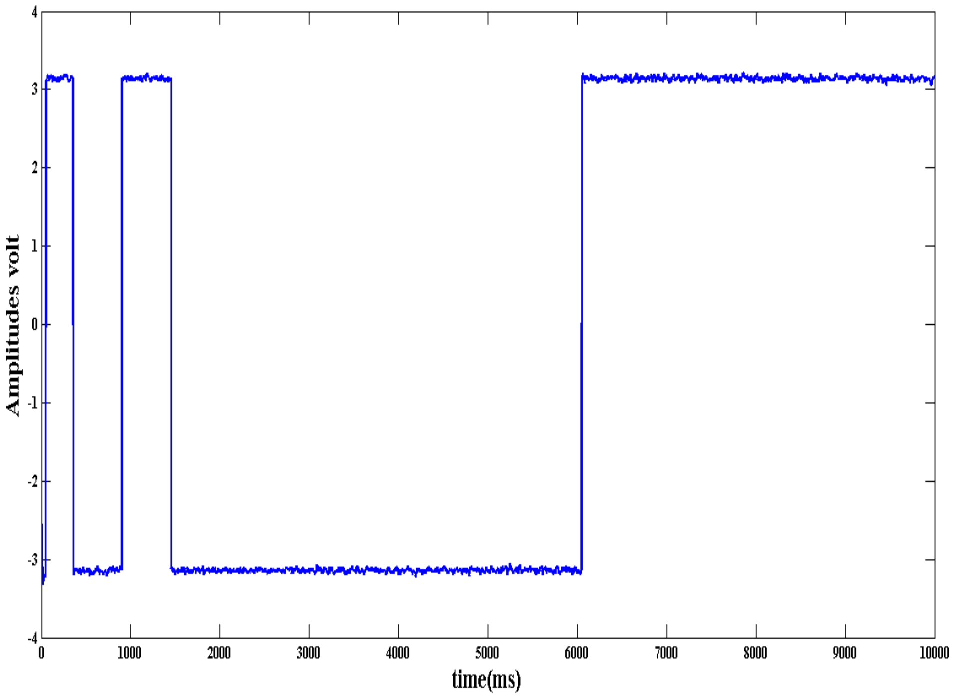

FIGURE 4.19: Estimate phase error in navigation bits. (*simulation*)

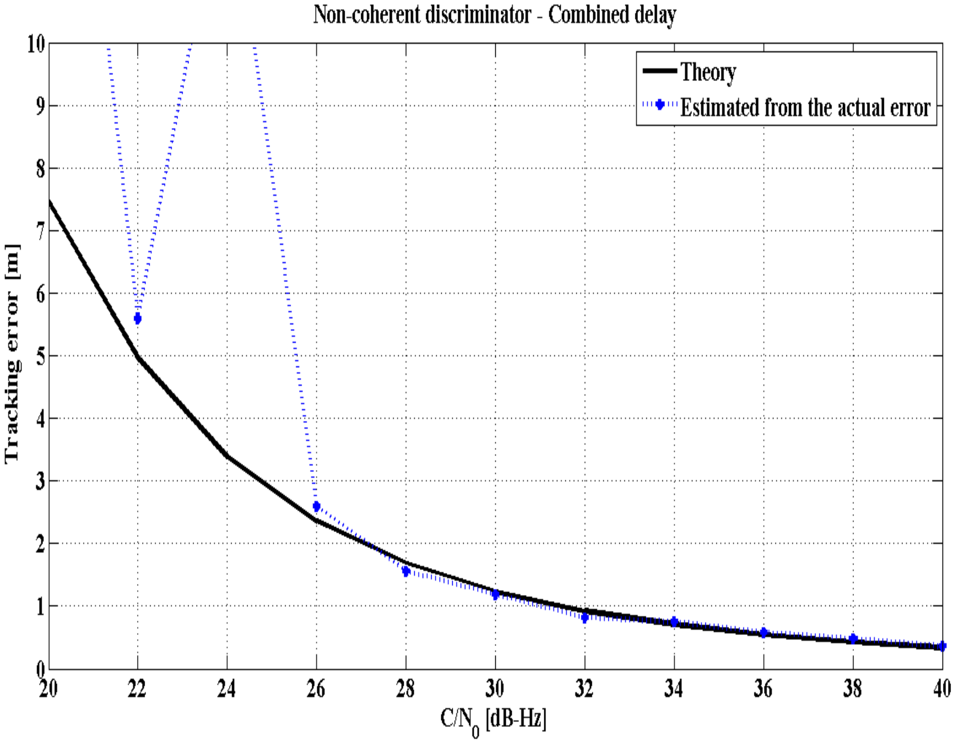

FIGURE 4.20: Tracking error estimation with respect to combined delay. (*simulation*)

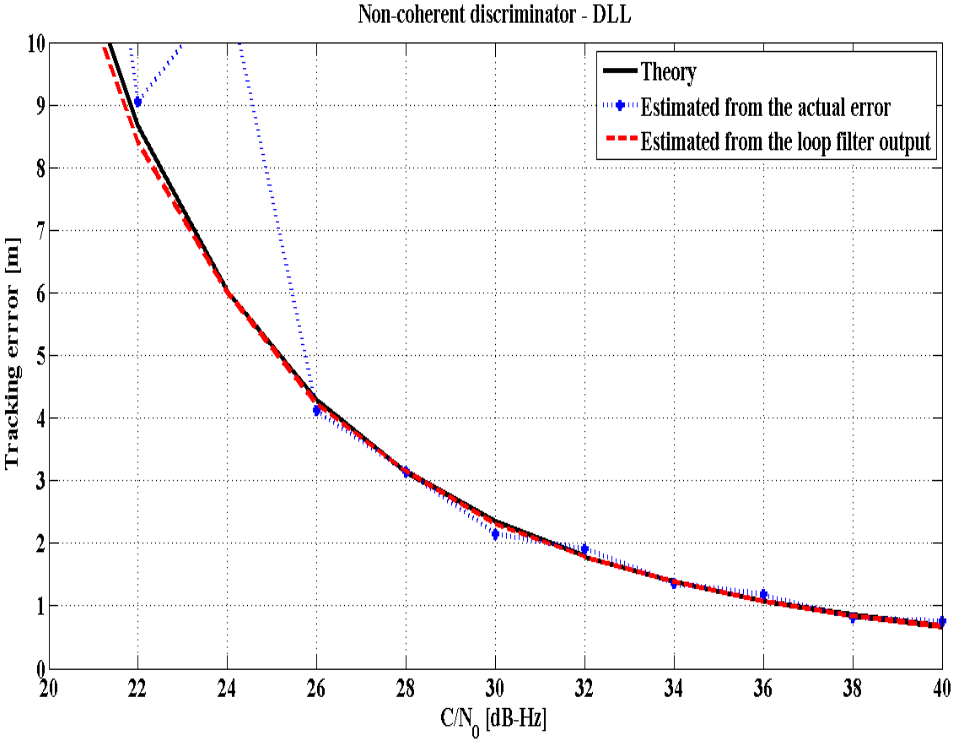

FIGURE 4.21: Non cohrent discriminator output in Delay Lock Loop. (*simulation*)

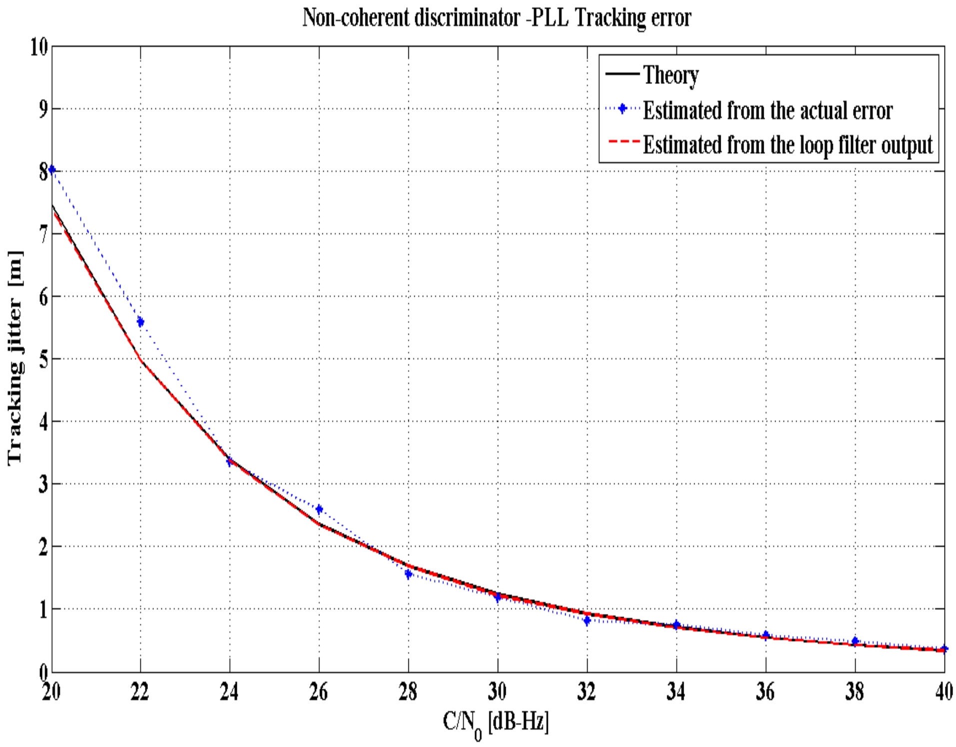

FIGURE 4.22: Non cohrent discriminator output in phase Lock Loop. (*simulation*)

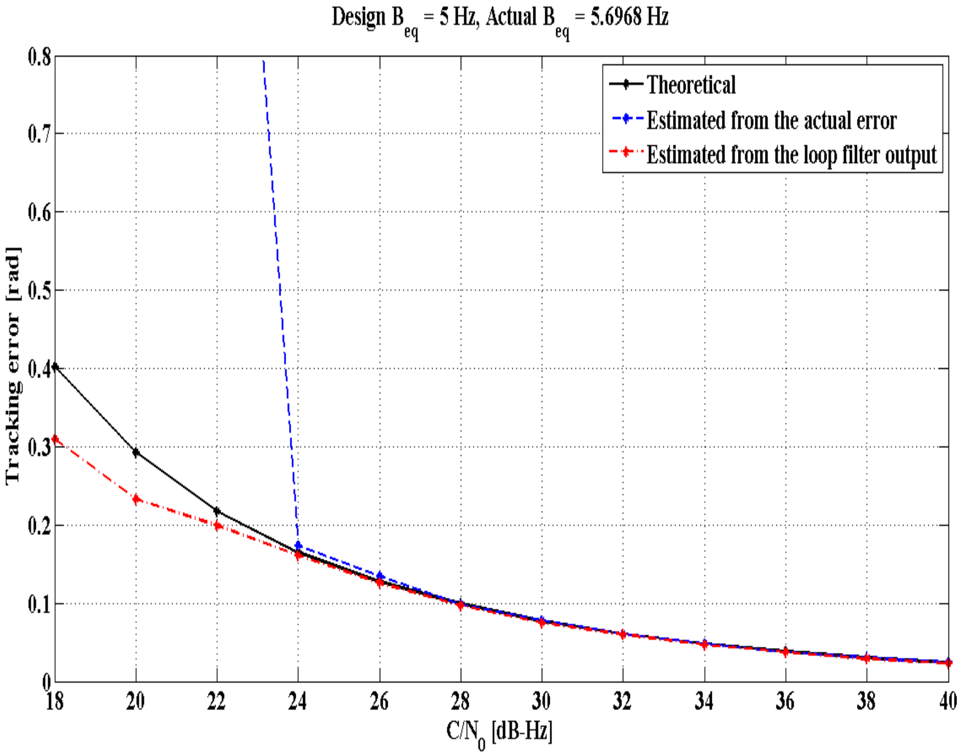

FIGURE 4.23: Response of Optimal BW 5 HZ carrier tracking loop filter. (*simulation*)

Chapter 5

Conclusion and recommendation for future work

This chapter briefly sums up the results and proposes some further research options in the field.

5.1 Conclusion

A frequency and phase error estimation based carrier tracking loop is proposed for GNSS receiver. By using comparative study, suitable parameters values were chosen. The stability factor in the loop response was also analyzed. Chapter 4 give simulation and experimental investigations that prove the suitability of the proposed carrier tracking loop for GNSS receiver. The applied modulated input to the system is

The bi-phase signal received by the GNSS receiver is locked with in-phase component of discrete time Fourier transform to estimate the frequency. Proposed carrier tracking loop provides wide operating range, quick acquisition time, accurate estimated frequency,work under low C/N0 environment. The noise factor on signal input is taken as Gaussian white noise and adaptability of the design to noisy signal is shown through simulation. The above algorithms have been tested on various GNSS sample data, including simulating data and real sampled data provided by PLAN group University of Calagry. The future work consists of detection the satellite navigation message from the carrier and code tracking output and to compute the position,velocity and Doppler shift of the GNSS receiver. This is very important to design the GNSS signal processing as fast as possible, and make the GNSS receiver really useful with respect in any condition, all the proposed algorithms should be able to run in real-time environment and not just simulating mode. Finally after completion, a Generic GNSS receiver design working under low C/N0 condition of GNSS signal is proposed in the Masters thesis work.

5.2 Scope for Future Work

This thesis work may be extended into following applications:

1. The phase changes are detected by analyzing I-channel carrier of PLL that is synchronized to the received signal in present GNSS receivers. The extracted signal is then processed in the navigation processor. In the proposed FLL, the dynamics of the control loop may be utilized for bit extraction. The change in sign of error fe or the value of NCO control input can be used
2. There is need for inter-interoperability of GNSS systems. As an extension of the work, a double stage NCO based scheme may be designed. This would enable simultaneous tracking of carrier waves at different frequency in harsh environment.

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