ISSN: 2278 – 1323
International Journal of Advanced Research in Computer Engineering & Technology
Volume 1, Issue 5, July 2012

Implementation of Matched Filter Based DSSS Digital GPS Receiver

V.SRIDHAR [1] T.NAGALAXMI[2] M.V BRAMHANANDA REDDY [3] M.SUNITHA RANI[4]

M.RENUKA[5]

[1] Assistant Professor, ECE, Vidya Jyothi Institute of Technology, Hyderabad
[2] Assistant Professor, ECE, Vidya Jyothi Institute of Technology, Hyderabad
[3]Associate professor ,CSE ,SVIST,madanapalle,CHITOOR
[4] Assistant Professor, ECE, Vidya Jyothi Institute of Technology, Hyderabad
[5] Assistant Professor, ECE, Vidya Jyothi Institute of Technology, Hyderabad

[1]varadalasri@gmail.com,[2]nagalaxmi_sept07@yahoo.co.in,
[3]bramhareddy999@gmail.com,[4]blessey.ch@gmail.com[5]renu_404@yahoo.com

ABSTRACT: **The Global Positioning System (GPS) is a satellite-based radio navigation system made up of a network of 24 satellites placed in an orbit by the US Department of Defense. GPS was originally intended for military applications, but now it is freely available to all. For anyone with a GPS receiver, the system will provide location and time. GPS provides accurate location and time information for an unlimited number of people in all weather, day and night, anywhere in the world. The GPS is made up of three parts: satellites orbiting the Earth; control and monitoring stations on Earth; and the GPS receivers owned by users. GPS satellites broadcast signals from space that are picked up and identified by GPS receivers. Each GPS receiver then provides three-dimensional location (latitude, longitude, and altitude) plus the time.GPS receivers incorporate Direct Sequence Spread Spectrum (DSSS) Techniques in their analysis. Traditionally, GPS receiver has been a chip set, consisting of two or more chips. With the advances in Integrated Circuit technology there is a trend towards a single chip solution, which is advantageous in many ways. Such a chip will help integration of a variety of applications from cell phones to wrist watches. It involves a high level of design integration. In this digital GPS signal receiver for a system on chip application is designed using VHDL aiming for FPGA synthesis. The digital GPS signal receiver takes data in digital form and performs the demodulation and dispreading of C/A code and outputs the navigational data bits. Various communication sub blocks such as C/A code generator, BPSK demodulator, correlator and threshold detector are modeled in VHDL and simulated using Modelsim. A four channel receiver is to be modeled and tested with four satellite signal mixed input added with AWGN (Additive White Gaussian Noise).All the modules functionality is verified with Modelsim simulator. Xilinx ISE tools are used for FPGA synthesis, Place & Route and timing analysis. Spartan 3E development board with Chipscope Pro tools is used for on chip analysis and debugging.**

Keywords: GPS, DS-SS, AWGN, BPSK, FPGA

I . INTRODUCTION

Global positioning system is an advanced navigation and positioning system used today for various applications. These vary from GPS guided missiles for precision bombing in the military, to peace time and civilian uses, such as navigation, treasure hunt hobbies, and agriculture.

Exploration has been important to mankind which has resulted in discovery of continents and new worlds. In ancient times, navigation was based on the planetary and stellar positions. This changed to the use of magnetic compass in the medieval times up to very recent in the past. Such alternatives always had their disadvantages and misgivings when dealing with hostile weather conditions, for example, foggy conditions, reduced visibility, thereby hindering navigation. With the development of satellites and improvements in radio signal transmission and reception, these were used for the navigation purposes as well as for positioning. The advantage of using radio signals is that they are immune to the weather effects. Earlier systems included LORAN (Long-Range Navigation), OMEGA to guide aircraft and ships.

LORAN was restricted to the United States and Britain. OMEGA was a truly globally available positioning system. The use of satellites in positioning and navigation was first applied in TRANSIT (Navy Navigation Satellite System), a project developed at the Applied Physics Laboratory at Johns Hopkins University. The Doppler frequency shifts of the signals transmitted by satellites were used to determine the satellite orbit. The receiver on the earth could determine its position from the knowledge of the satellite orbit and the Doppler shift measurement of the frequency. Global Positioning System, in short GPS, is a product of the United States Department of Defense. Intended for military purposes, especially precise positioning for ammunition, it has been demonstrated that it could be used for civilian purposes as well. Its utilization has been demonstrated correctly during the two Gulf war’s where precision guided missiles have found target with a high probability destroying enemy positions.

The target's co-ordinates are loaded in the computer of the missile which is guided by the satellites.

Apart from these military advantages civilian applications too such as navigation and surveying have found use for GPS.Connected Car is a more recent example of how GPS can be used as a navigation aid in co-ordination with other applications and frameworks such as Microsoft .Net Framework, Bluetooth etc. It can be used as a guide in new places. GPS has been used also to land an airplane in adverse weather conditions. A GPS measurement can have an error of 5-10 m (uncorrected) or up to 1m discrepancy (using WAAS and DGPS). Agriculture also has found use of the GPS - to control the distribution of the chemicals and fertilizers. In conjunction with Geographic Information System (G.I.S), GPS has found more use in tracking animals, humans, and knowing the seismology of the earth at a given place. Further advances in GPS signal reception could lead to indoor coverage, in downtown areas, and under trees etc., where the reception is low. This is what helps GPS to be a part of the emergency services. In this class of applications, another popular one is pervasive computing-location awareness. GPS presents a solution to this end in mobile communication electronics.

A lot of research goes into how to make the GPS signal more reliable, visible, and accurate. This system of navigation uses omnipresent radio waves and relative time of arrival of signals to determine positions. The two common frequencies used today by GPS satellites to broadcast are L1 (1575.42 MHz) and L2 (1227 MHz). L1 is primarily a civilian signal while L2 is used for military purposes. L1 is also used by the military and L2 by civilians though the civilians do not have a knowledge of the codes modulating the L2 frequency. From 2005 onwards, GPS satellites will be broadcasting new signals which could help eliminate positioning errors due to Ionospheric effects. The current civilian signals will be boosted by the addition of another civilian signal on L2. From 2008, a new frequency band called L5 will be emitted at 1176.45 MHz which is also a civilian signal. L3 and L4 will carry non-navigation information for the military.

2. Spread Spectrum Techniques:

There are several techniques currently in use for generating Spread Spectrums. These include Direct Sequence Spread Spectrum (DSSS), Frequency Hopping Spread Spectrum (FHSS), and Time Hopping Spread Spectrum. Each technique differs in its implementation and has certain advantages/disadvantages. In addition to the above, there are a number of hybrid techniques which offer certain advantages over, or extend the usefulness of the other techniques. These hybrids are Frequency Hopped/Direct Sequence Modulation and Time-Frequency Hopping.

2.1.DirectSequence Spread Spectrum (DSSS): The basic principle behind the Direct Sequence Spread Spectrum (DSSS) technique is the modulation of the RF carrier with a digital code sequence. The code sequence utilizes a chip rate, which is much higher than the bandwidth of the data signal and is used directly to modulate the carrier, thus directly setting the transmitted bandwidth.

2.2. FrequencyHoppingSpreadSpectrum (FHSS):

The basic principle behind the Frequency Hopping Spread Spectrum (FHSS) technique is that the carrier frequency is periodically modified (hopped) across a specific range of frequencies. The frequencies, across which the carrier jumps is the spreading code. The shifting pattern is determined by the chosen code sequence (frequency shift key – FSK). The amount of time spent on each hop is known as the dwell time and is in the range of 3ms-100ms.

2.3. Time Hopping Spread Spectrum(THSS):

Time Hopping and FHSS are somewhat similar, but in Time Hopping, the transmitted frequency is changed at each code chip time. Time Hopping can be implemented in two ways. In the first technique, each binary is transmitted as a short pulse, known as a "chirp". The PN generator is used to determine the actual interval in which the chirp is transmitted. By doing this, anyone attempting to intercept the signal will be uncertain as to when the next pulse will be transmitted.

3. INTRODUCTION TO GPS :

Global positioning system (GPS) is an advanced navigation and positioning system used today for various applications. These vary from GPS guided missiles for precision bombing in the military, to peace time and civilian uses, such as navigation and agriculture. The Doppler frequency shifts of the signals transmitted by satellites are used to determine the satellite orbit. The receiver on the earth could determine its position from the knowledge of the satellite orbit and the Doppler shift measurement of the frequency. This system of navigation uses omnipresent radio waves and relative time of arrival of signals to determine positions. The two common frequencies used today by GPS satellites to broad-cast are L1 (1575.42 MHz) and L2 (1227 MHz). L1 is primarily a civilian signal while L2 is used for military purposes.

3.1 GPS Segments

For the GPS to function smoothly there are three important constituents. They are:

1. User Segment (receiving segment)
2. The Satellite constellation
3. ThecontrolSegment

3.1.1 Satellite Constellation: The Satellite Constellation constitutes of 24 satellites at an altitude of about 20,000 km above the Earth's surface. These satellites are arranged in sets of 4 satellites in 6 orbital planes. These orbital planes are inclined to the Earth's equatorial plane at an angle of 55^o . The orbital plane location are defined by the longitude of the ascending node while the satellite location by the mean anomaly. These satellites are at such a height and in such orbits such that there are at-least four satellites visible to a user at any location and at any given time. At a time one can however receive signals from 7 to 9 satellites.

3.1.2 Control Segment:

The Control segment consists of Master Control Station at Colorado Springs, 5 Monitor Stations located around the world to ensure maximum satellite coverage and ground antennas. The functions of the Operations Control Segment include maintaining the satellite orbital position, and monitoring the health of the satellite constellation. The health includes parameters like the power, fuel levels among others. The ground stations make pseudo range measurements by passively tracking the satellites. This updated information called TT&C (Telemetry, Tracking and Command) data. This information for each satellite is uploaded by a ground up link antenna when that particular satellite is in view of the antenna.

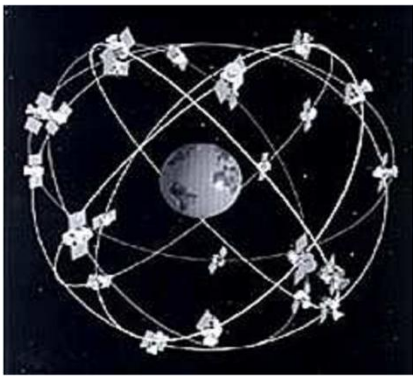

Figure 3.1. GPS Satellite Constellation

3.1.3 User segment

Receives satellite signals and estimates the distance from satellite. Front end antenna and RF unit receives the signal and after sufficient level of amplification, it will be digitized.

The digital GPS receiver applies DSSS correlation technique and extracts the base band data. GPS processor uses minimum four such channels data and calculates its location. Since the location of each GPS satellite is known, the receiver's location can be determined by "triangulating" the distances from several satellites.

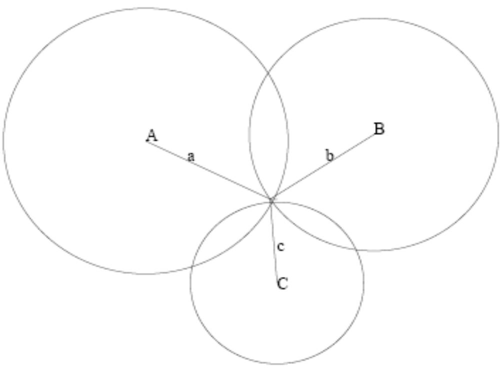

Figure 3.2 Triangulation

3.2 GPS Receiver Channels

The signal processing for satellite navigation systems is based on a channelized structure. This is true for both GPS and Galileo. This chapter provides an overview of the concept of a receiver channel and the processing that occurs. Figure 3.3 gives an overview of a channel. Before allocating a channel to a satellite, the receiver must know which satellites are currently visible. There are two common ways of finding the initially visible satellites. One is referred to as *warm start* and the other is referred to as *cold start*.

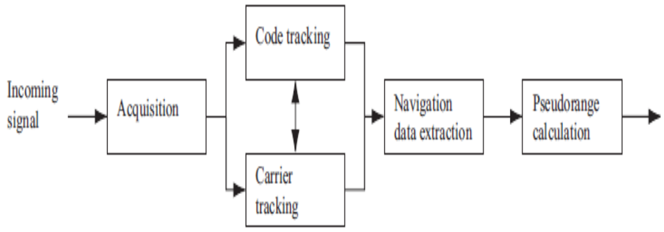

Figure 3.3 One receiver channel. The acquisition gives rough estimates of signal parameters.

Theseparametersarerefinedbythetwotrackingblocks.A ftertracking, the navigation data can be extracted and pseudo ranges can be computed.Warm start In a warm start, the receiver combines information in the stored almanac data and the last position computed by the receiver. The almanac data is used to compute coarse positions of all satellites at the actual time. These positions are then combined with the receiver position in an algorithm computing which satellites should be visible. The warm start has at least two downsides. If the receiver has been moved far away since it was turned off (e.g., to another continent), the receiver position cannot be trusted and the found satellites do not match the actual visible satellites. Another case is that the almanac data can be outdated, so they cannot provide good satellite positions. In either case, the receiver has to make a cold start.

3.2.1 Synchronization

It is the process of matching the locally generated spreading signal with the incoming
spread spectrum signal. Synchronization is a two step procedure:

1. Acquisition and
2. Tracking.

3.2.2 Acquisition

An acquisition search through all possible satellites is quite time-consuming. That is, in fact, the reason why a warm start is preferred if possible. The purpose of acquisition is to identify all satellites visible to the user.

3.2.3 Tracking

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 accuracy of the final value of the code phase is connected to the accuracy of the pseudo range computed later on. The tracking contains two parts, code tracking and carrier frequency/phase tracking

ISSN: 2278 – 1323
International Journal of Advanced Research in Computer Engineering & Technology
Volume 1, Issue 5, July 2012

3.3 GPS Signals

The GPS signal is a Direct Sequence BPSK spread spectrum signal represented as:

$s(t)=A(t)c(t)d(t)\sin(2\pi(fo+\Delta f)t+\varphi+\Delta\varphi)$

where

A(t): amplitude of the transmitted signal

c(t): pseudo-random code(C/Acode of the satellite1.023 MHz)

d(t): navigation data stream (50 Hz)

f_0: carrier frequency of the transmitted frequency (1.575 GHz)

Δf: frequency offset due to relative position change

φ: original carrier phase

Δφ: carrier phase offset

4.1 GPS Reception system

The following figure gives the block diagram of digital GPS reception system

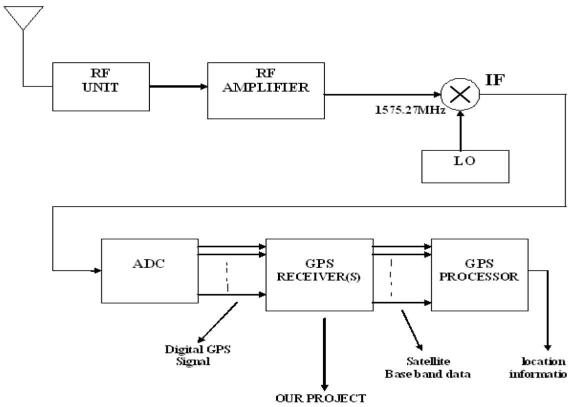

Figure 5.1 Block diagram of GPS reception system

It is to be observed that in GPS to broadcast are L1 (1575.42 MHz) and L2 (1227 MHz).L1 is primarily a civilian signal while L2 is used for military purposes. In commercial GPS receivers the antenna and front end antennas and RF units are tuned to the L2 frequency. After mixer stage the signal is down converted to some intermediate frequency. The exact intermediate frequency value changes from design to design. Then this signal is digitized using ADC with appropriate sampling rate. In our simulation we are assuming this sampling rate is 65472 KHz such that there are 64 samples per every one PN sequence bit which are generated with 1023 KHz frequency. The block with title "**GPS receiver"** in the above block diagram is the scope of the project. The digitized signal is taken in the GPS receiver and after correlation the satellite navigational data (with data rate of 1 KHz) is produced. The internal blocks of digital GPS receiver are discussed in next section.

4.2: Digital GPS signal receiver

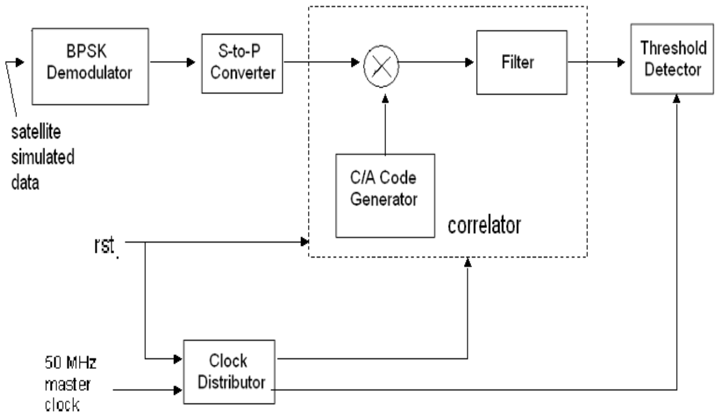

Figure 4.2 Digital GPS signal receiver

The modules in Digital GPS signal receiver are

1. Clock distributor.
2. BPSK demodulator.
3. Serial to parallel converter.
4. Matched filter based Correlator.
5. Threshold detector

4.2.2 :BPSK demodulator

The BPSK demodulator accepts the digital IF signal, and produces an output which will be used by correlator to detect the bit sequence. The block diagram of BPSK demodulator is shown in the below figure.

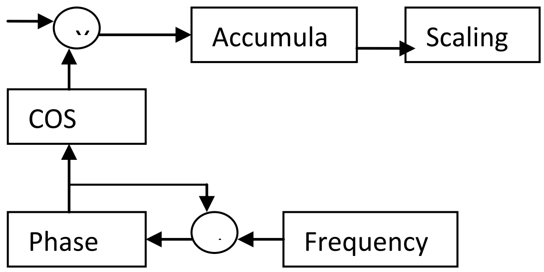

Figure 5.4 BPSK demodulator

4.2.3 Serial to 1023 length parallel word converter

Since the correlator requires parallel data, this block accepts serial BPSK demodulator output and produces parallel output word. The Block diagram of serial to parallel converter is shown in the below figure.

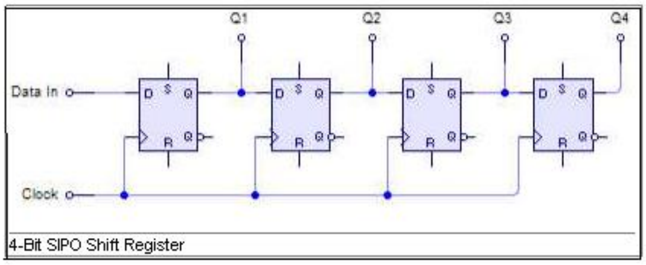

Figure 4.2.3 Serial to Parallel converter

This configuration allows conversion from serial to parallel format. Data is input serially, once the data has been input, it may be either read off at each output simultaneously, or it can be shifted out and replaced

Serial to parallel converter (parallel output is used in parallel correlator)

```
process(rst,clk_1023KHz)
        variable temp_parallel_out:corr_input_data;
begin
        if rst='1' then
                temp_parallel_out := (others => 0);
        elsif clk_1023KHz'event and
clk_1023KHz='1' then
                temp_parallel_out(1022 downto 1) :=
temp_parallel_out(1021 downto 0);
                temp_parallel_out (0) :=
demod_out;
        end if;
        parallel_out <= temp_parallel_out;
end process;
```

4.2.4:Correlator

The receiver component that demodulates a spread spectrum signal; a device that measures the similarity of an incoming signal and a stored reference code. The correlator multiplies the input parallel word (parallel converted BPSK demodulator outputs) with C/A code specific to the satellite. This C/A can be changed accordingly to receive data from different satellite. One can find different types of correlators both analog/ digital and various other forms but our main interest lies in digital correlators, for which we use DSSS based correlators, and hence the project title "Digital GPS Receiver" can be justified.

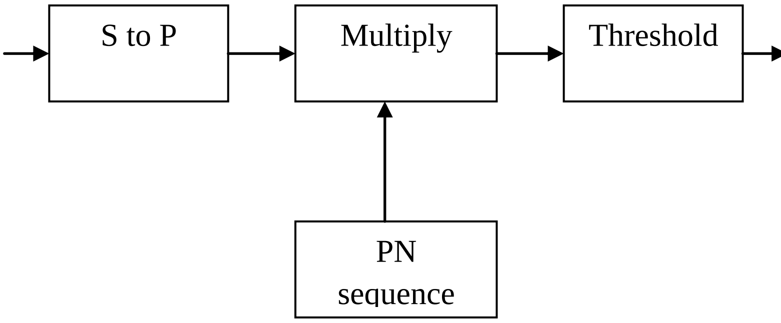

Figure 4.6 Block diagram of correlator

4.2.5 Threshold detector

Threshold detector compares the output of correlator with threshold value and produces detect pulse '1' when ever the correlator output is above threshold value.

```
if(temp_corr_out > threshold) then
        flag_detect <='1';
        if (correlator_out > 0) then
                out_bit <='1';
        else out_bit <='0';
        end if;
        else
        flag_detect <='0';
        end if;
```

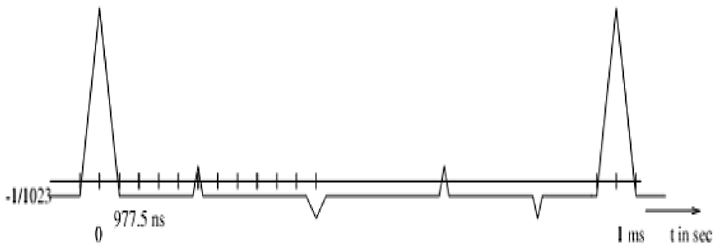

Figure 4.2.5 Typical GPS correlator output

The figure showing the correlator output peaks for every 1 ms. It is correct as the correlator output produces data which is navigational bit which runs with 1023 KHz

5: SIMULATION RESULTS:

5.1 Simulation output of Satellite Selector

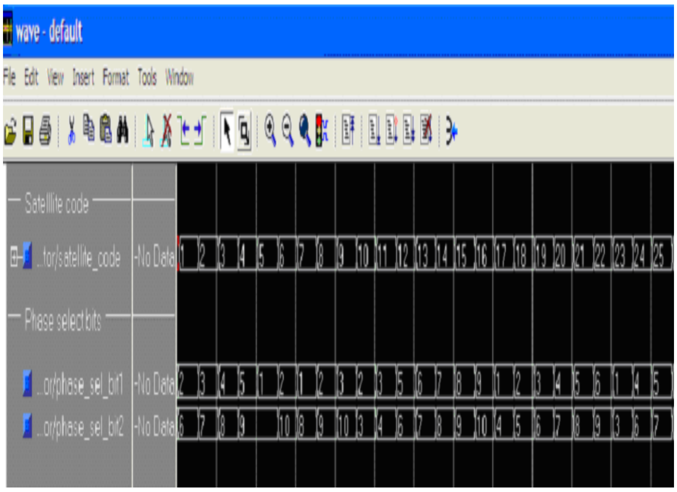

Figure 5.1 Satellite Selector

5.2 Simulation output of C/A Code Generator

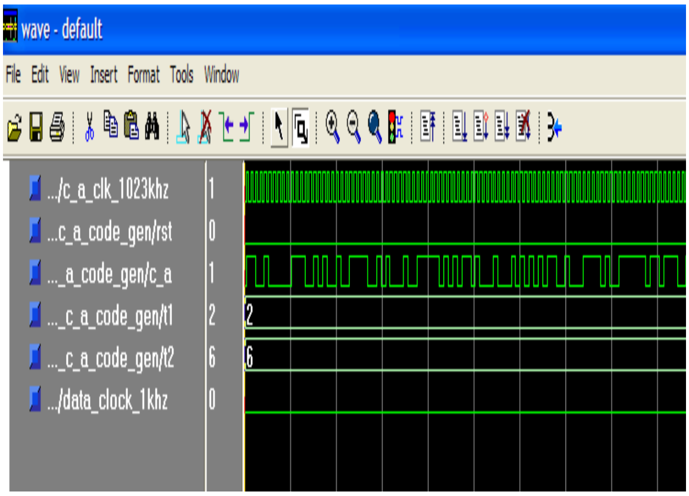

Figure 6.2 Simulated output of programmable C/A code generator

Above figure shows the generated PN sequence for satellite-1.It can be observed that the phase select logic integers are 2 and 6 which corresponds to the satellite-1

5.3 Phase Accumulator

The simulator output for phase accumulator is shown in figure. In the figure the phase accumulator goes from 0 to 63 and again 0(corresponding to true phase sweep from 0 to 360).Correspondingly the BPSK modulated spread signals are generated as per the C/A bits. Total 4 channel signals are shown in the above figure. For each channel the navigational data bit, C/A code bit, resulting digital pattern which is used for modulation and the SS signal with BPSK modulation can be seen. It can be observed when data bit is one the C/A code and the digital pattern used for modulation are same, where as if data bit is zero then C/A code bits complement is used for modulation.

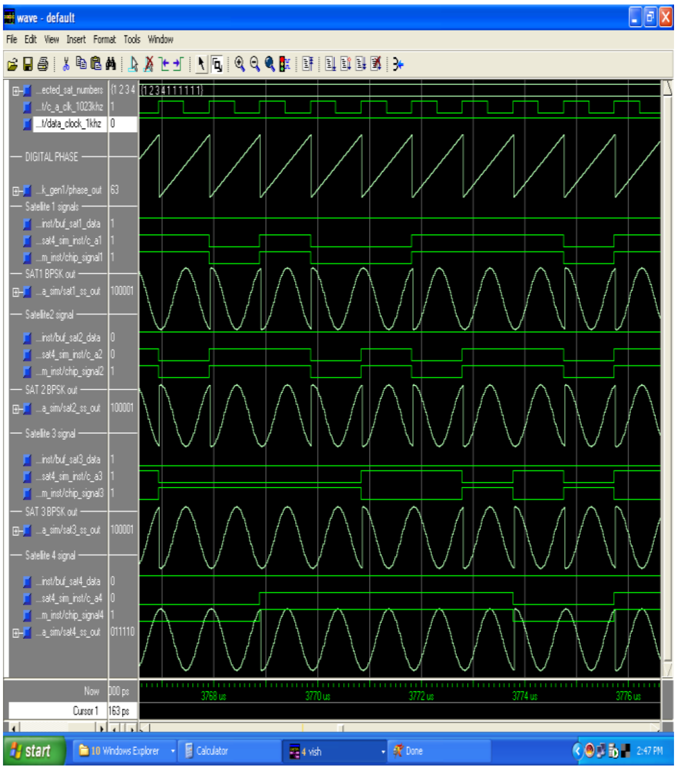

Figure 6.3 Simulation results of phase accumulator

5.4 Simulation output for Satellite data simulator

The top level module satellite data simulator shows the generated SS signals from the four satellites and the sum of all such signals. The bottom waveform is the sum of four satellite spread spectrum signals, which after addition with noise will be used to test the GPS receiver segment.

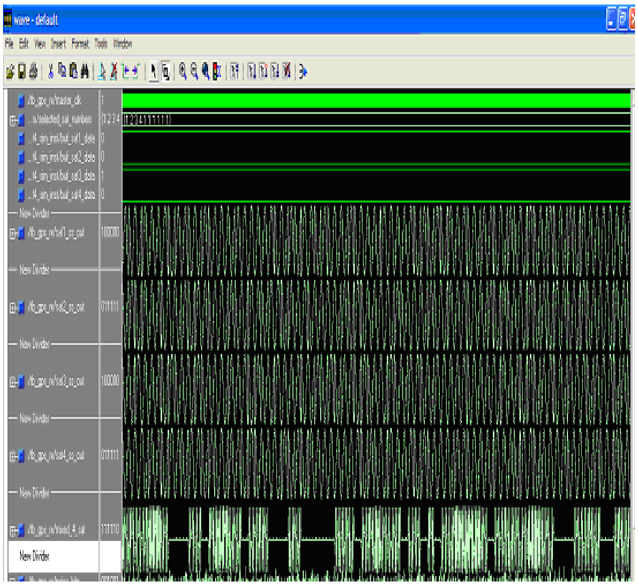

Figure 6.4 Simulation output for Satellite data simulator

5.5 Gaussian noise simulator

This module generates Gaussian noise which is added to simulated data signals and given as input for GPS signal receiver. The simulation output for Gaussian noise simulator is shown in the below figure.

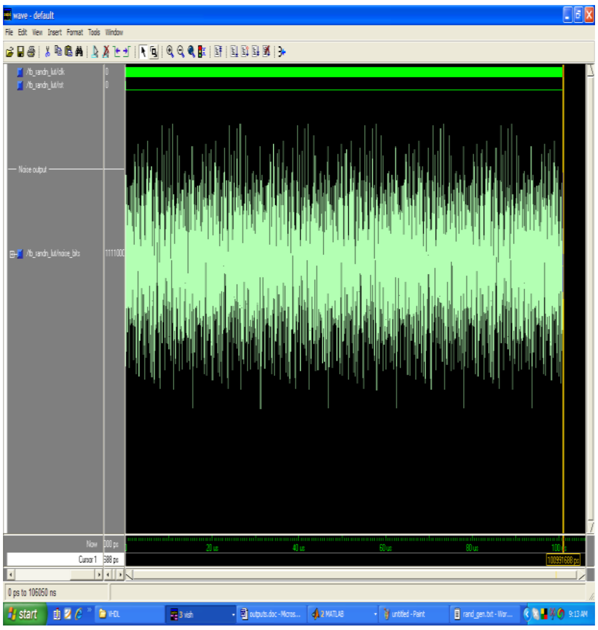

Figure 5.5 Gaussian Noise generator simulation results

6.6 The four satellites SS signal after adding with Gaussian noise

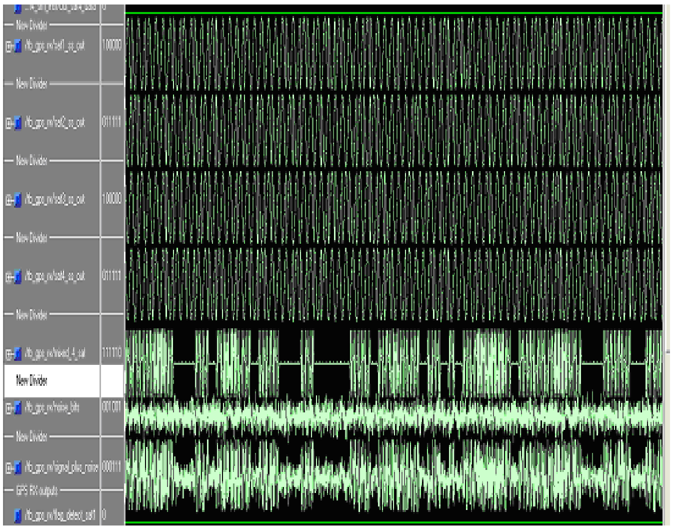

Figure 6.6 The four satellites SS signal after adding with Gaussian noise

5.7 The simulation output of clock distributor

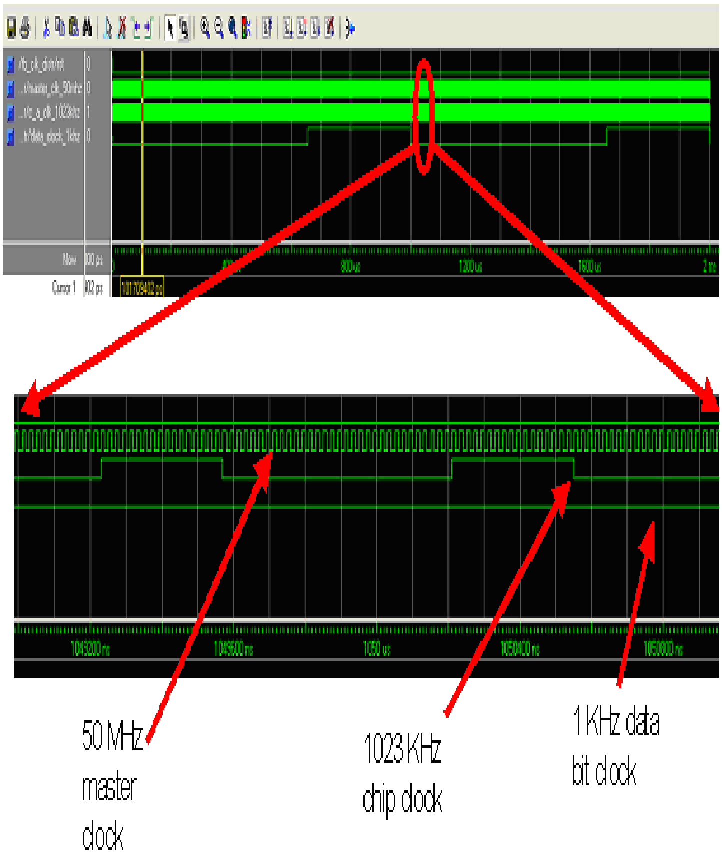

Figure 5.7 Simulation output of clock distributor

5.8 Serial to Parallel converter

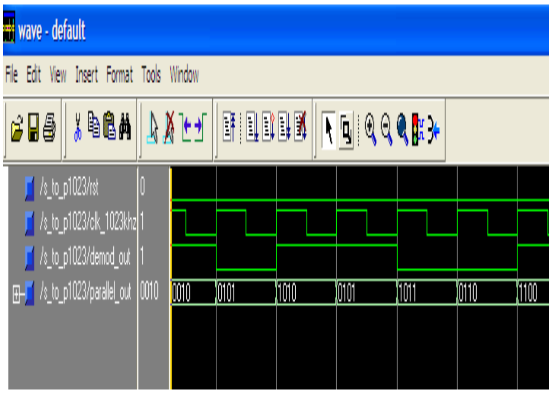

Figure 6.8 Serial to Parallel converter

5.9 Simulation output of Correlator

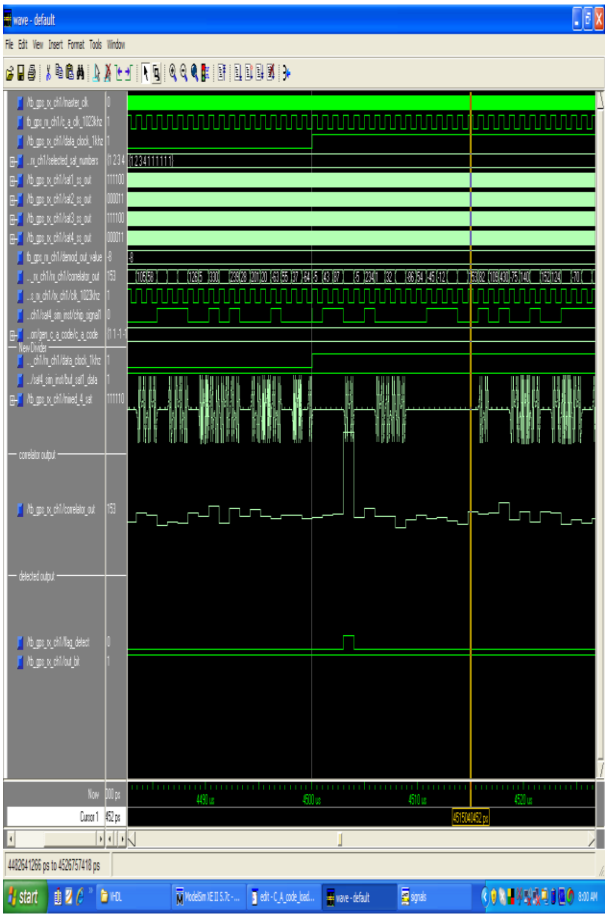

Figure 6.9 Simulation output of Correlator

In the above figure when the correlator output crosses the threshold then the flag detect becomes '1' **.**

5.10 Threshold detector

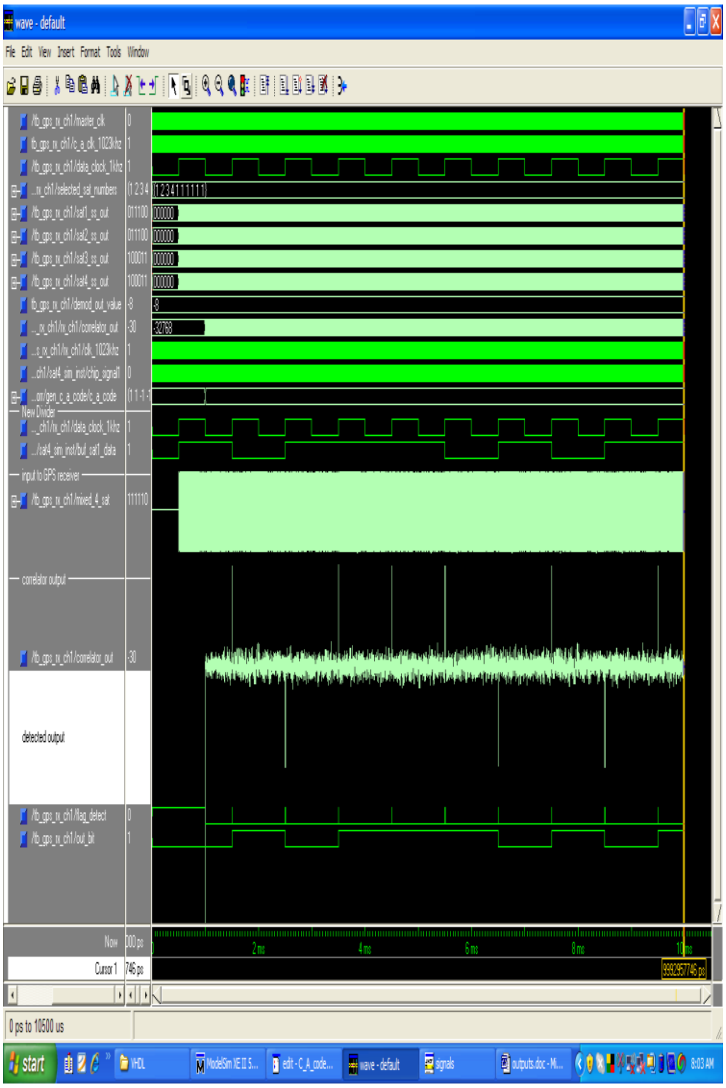

Figure 5.10 Simulation output of threshold detector

In the above figure the receiver outputs at various stages are shown. The noisy waveform with lot of impulses is the correlator output. Whenever the C/A code at transmitter and at the receiver matches each other the correlator produces peak output. If this is a positive peak then it means it is bit 1 and if it is a negative peak means then the output is zero. This is done by the decision device. The decision device output with '1' or '0' is given in the last waveform.

VII: CONCLUSION:

This work outlined the implementation of a GPS receiver in time domain. It dealt with VHDL implementation of the digital backend of a GPS receiver. Different functional blocks and communication blocks were implemented as part of this work. The scope of this work was to develop a working code acquiring and tracking module, capable of acquiring a GPS signal and tracking it. Synthetic data was generated at the required rate and modulated the PRN sequence. This transmitted data was demodulated and detected and the expected data was recovered. Thus, a DS/SS receiver was implemented, in time domain, capable of acquiring and tracking a GPS C/A code signal. The receiver implementation assumed a coherent signal acquisition and tracking. This work also dealt with acquiring codes from multiple satellites. It used a dedicated channel for each of the satellites being tracked. Four satellites were continuously being acquired.

For this to be integrated as an independent module, the carrier acquisition has to be performed along with the code acquisition. This module has to be tested on original GPS data to validate it. The entire model has to be synthesized, to be used in conjunction with the tour guide being developed. Low power modes and functionalities have to be incorporated. Newer algorithms to speed up the acquisition times in the time domain could be worked upon. Acquiring data from a greater number of satellites and tracking them simultaneously is another aspect for future research. Integrating this module with the analog front end to achieve proper GPS functionality is a future work. Finally, developing algorithms for using the GPS receiver indoors is an aspect of future research..

VIII References:

[1] P. Misra and P. Enge. *"Global Positioning System: Signals, Measurements and Per formance"*. Ganga-Jamuna Publishers, 2001.

[2] P. Enge. Next Generation GPS Receiver. *http://www.sciam.com/*

[3] Press Release. Single chip GPS Module. *http://www.valence.com/*.

[4] Instant GPS Product Documentation. Single chip GPS Receiver. *http://www.motorola.com/ies/GPS/products.html*

[5] WirelessDevNet.com Press Release. SONY Introduces Industry's First 1-ChipCMOSGPS. *http://www.wirelessdevnet.com/news/2003/dec/15/news1.html*

[6] J. Ashjaee. GPS: Challenge of Single Chip. *http://www.gpsworld.com*

[7] D.M. Akos. A Software Radio Approach to Global Navigation Satellite System Receiver Design. PhD thesis, Ohio University, 1997.

[8] G. Martin and H. Chang. "Tutorial 2 System-on-Chip Design". In Processings of the 4th International Conference on ASIC, pages 12–17, Oct 2001.

[9] U. Kailasam. High Level VHDL Modeling of Low Power ASIC for a Tour Guide. Master's thesis, University of South Florida, 2004.

Authors Biography

V.SRIDHAR working as Assistant professor in **ECE** department at Vidya Jyothi Institute of Technology,Hyderabad from 2009. completed **M.Tech** withSpecialization Wireless and mobile communication systems from vardhaman college of engineering **(AUTONOMOUS)JNTU**,Hyderabad in 2011.he has completed **M.Sc (IT)**from Nagarjuna University, guntur, AndhraPradesh.completed Electronics and telecommunication engineering from vidya jyothi institute of technology,**JNTU** Hyderabad in 2007.His areas of research interests include Wireless and Mobile communications, Digital signal processing, image processing, Telecommunications, communication systems, signal processing.He is LifetimeMember of **ISTE and IETE,IAENG AND SDIWC.**

T.NAGALAXMI working as an Assistant professor in ECE department at Vidya Jyothi institute of technology,hyderabaad from 2008 to till date. And also pursuing **M.TECH(Embedded systems)**,affiliated college by JNTUH. She is having five years of teaching experience.Her areas of research interests are embeddedsystems,VLSI,embeddedandrealtimesystems,digital signalprocessingandarchitechtures,Microprocessor&Micro controller,data communication systems.

M.V.Bramhananda Reddy, Assoc.Professor, in CSE DepartmentTECHNOLOGY(SVIST),SRIVISHVESWARAI AHINSTITUTEOFSCIENCEANDTECHNOLOGY,ANGAL LU,MADANAPALLE ,M.Tech in Computer Science Engineering at JNTU, Kakinada, B.Tech in CSE at JNTU, Hyderabad. He is having seven years teachning experience His areas of interest for doing the research in DATAMINGING, DIGITAL IMAGE PROCESSING, EMBADDED SYSTEMS, COMPUTER NETWORKS AND ARTIFICIAL INTELLIGENCE.

M.SUNITHA RANI working as an assistant professor in ECE department Vidya jyothi instituteoftechnology.hyderabad from 2008.she is pursuing M.TECH (Embedded systems) from nethaji institute of engineering college and technology.affliated JNTUH.she is having four years experience in teaching. her areas of research interests include VLSI,embedded systems, digital signal processing, and microprocessor.

M.RENUKA working as Assistant professor in ECE department vidyajyothi institute of technology hyderabad .she is persuing **M.Tech (VLSI)** from Mahaveer instituteofscienceandtechnologyJNTU,HYDERABAD.She worked as “hardware design engineer” in ECIL from 2007 to 2008.and also she worked as assistant trainee officer in the year 2008 to 2009.her areas of research intrests include VLSI,Embedded systems, EDC and Digital signal processing.