

Design and Simulation of IRNSS Receiver in SIMULINK®

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ABSTRACT

Indian Regional Navigation Satellite System (IRNSS) is independently originated, being run and operated by Indian Space Research Organization (ISRO). As of 2016 there are seven satellite being launched and operated named as 1A, 1B, 1C, 1D, 1E, 1F and 1G respectively in the IRNSS constellation. This paper presents MATLAB based SIMULINK models for IRNSS transmitter and receiver design. The PRN code is generated and used in modulation and demodulation of satellite navigation signals for L5 frequency. Further for the same frequency acquisition block is modelled to check which satellite is visible to the receiver and coarse estimation of code phase and carrier frequency is found. Carrier tracking loop is also implemented for fine estimation of acquired data.

Keywords

PRN code generation, IRNSS, IRNSS transmitter, IRNSS receiver, acquisition, tracking.

1. INTRODUCTION

IRNSS is newly invented system involved in the family of satellite navigation system. Based on various consideration it has been proven that IRNSS constellation is completed by 7 satellites. Where in three satellites are Geostationary Earth Orbit (GEO) located at 32.5°E , 83.0°E and 131.5°E with inclination of 29° and other four satellites are Geo Synchronous Satellites with their longitude crossing 55°E and 111.75°E two in each of the plane. IRNSS works for two bands of frequencies they are L5 and S band whose frequencies are centered at 1176.45MHz and 2492.28MHz having bandwidth of 24MHz (1164.45-1188.45MHz) and 16.24MHz(2483.50-2500.00MHz) respectively. This navigation system extends its service area up to 1500km above the Indian land mass. There are services provided by IRNSS they are Restricted Service(RS) which is a authorized one and need to be encrypted and other service is Standard Positioning Service(SPS) is an unauthorized or an open service which is not to be encrypted. This navigation system uses spread spectrum technique called Carrier Division Multiple Access (CDMA) for modulation of signals. In IRNSS two codes are being used, for high accuracy the precision code or simply called the P code which is being used for Restricted Service transmitted at 10.23MHz and the second code is Carrier Acquisition code (C/A code) also called as Pseudo Random Noise (PRN) code which is mainly used to generate SPS signal at the rate of 1.023MHz. In this paper Simulink model for navigation system i.e. IRNSS receiver is presented

2. SIGNAL SPECIFICATION

IRNSS signals are being modulated by BPSK (1) modulation for SPS signals on both L5 and S for Restricted Service BOC(5,2) modulation is used. The transmission data rate of navigation data is 50 samples per second which is 1/2 rate FEC encoded which is being modulo 2 added to locally generated PRN code with chip rate of 1.023Mcps for SPS signals. The PRN code is generated by using Gold codes for SPS signals.

3. IRNSS TRANSMITTER MODEL IN SIMULINK

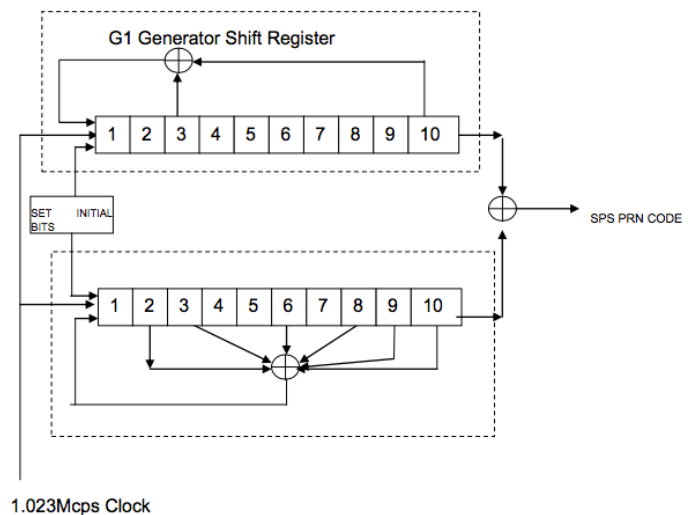


Fig 1: PRN code generation for SPS signal

The IRNSS transmitter is present in the space segment in real life. Figure 2 shows the IRNSS transmitter design in Simulink.

Similar to GPS, one of the available 1 to 7 PRN codes is selected using a constant block. Depending upon the number given, the respective satellite PRN code is selected by the multi-port switch and is given to the EX-OR gate. The other input for this gate is the navigation data generated by the Bernoulli Binary block. The two input signals are modulo 2 added. The modulo 2 added signal is in boolean format and to perform BPSK modulation, this signal needs to be converted to type 'double'.

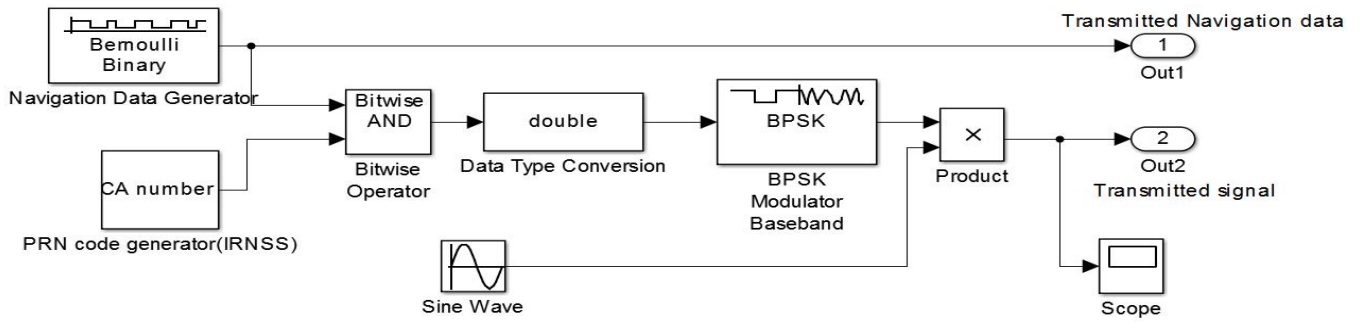


Fig 2: IRNSS transmitter model in SIMULINK

After converting the signal to data type ‘double’, it is fed to the BPSK modulator. After modulating the input signal, the output is multiplied by the carrier signal with the frequency of L5 band, i.e. 1176.45 MHz, generated by the sine wave block. The multiplication is done using a block called ‘Product’. Next the signal is transmitted through the AWGN channel. The sub-sections in this section describe all modules in the IRNSS transmitter in detail.

3.1 PRN code generation

PRN codes, the one selected for SPS signals are similar to GPS signals where in each chips are of length 10 with 1023 chips being chipped at 1.023 Mcps. Two polynomials are used

for SPS code generation, G1 and G2 which may be given as shown below:

$$G1: X^{10}+X^3+1 \quad (1)$$

$$G2: X^{10}+X^9+X^8+X^6+X^3+X^2+1 \quad (2)$$

Each of the polynomial G1 and G2 are similar to that of GPS signal PRN codes which has been realized using 10 bits Maximum Length Feedback Shift Register (MLFSR) as shown in the figure 3. The initial states for G1 register is all set to 1’s since all 0’s is illegal. Chip delays provides the initial states of G2 registers. Final 1023 bits long PRN sequence is found by XORing G1 and G2 with the time period of 1ms in order to generate 1023 PRN sequence [1].

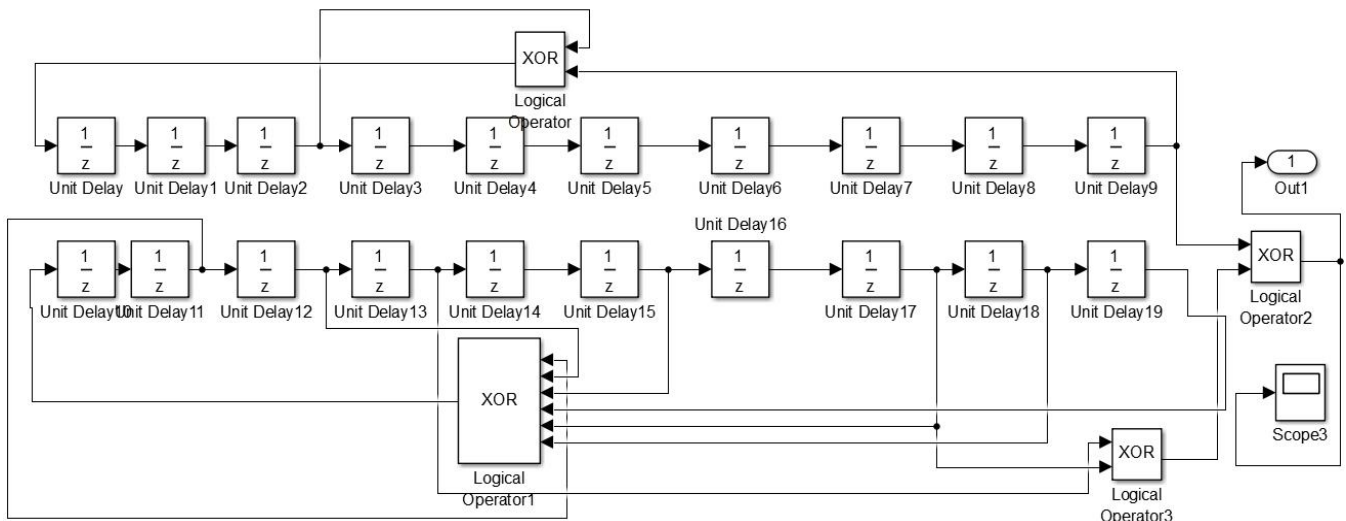


Fig 3: PRN code generation

The initial condition for G2 register and first 10 chips in octal and binary form is as shown in the Table 1 below. These polynomials are modeled using delay blocks in Simulink. As shown in the table, the initial conditions are set for the G2 polynomial [4]

Table 1: Code Phase Assignment for IRNSS L5-SPS Signals

PRN ID	SV Location	Initial condition for G2	First 10 chips in octal	First 10 chips in binary
1	55°E	1110100111	130	0001011000
2	55°E	0000100110	1731	1111011001
3	83°E	1000110100	713	0111001011
4	111.75°E	0101110010	1215	1010001101
5	111.75°E	1110110000	117	0001001111
6	32.5°E	0001101011	1624	1110010100
7	131.5°E	0000010100	1753	1111101011

The 7 PRN codes are connected to the Multi Port Switch as shown in figure 4. Using the constant block one of these 7 PRN codes can be selected and sent to the further blocks in the transmitter. The internal circuit of 'IRNSS PRN code generator' is shown in figure 4.

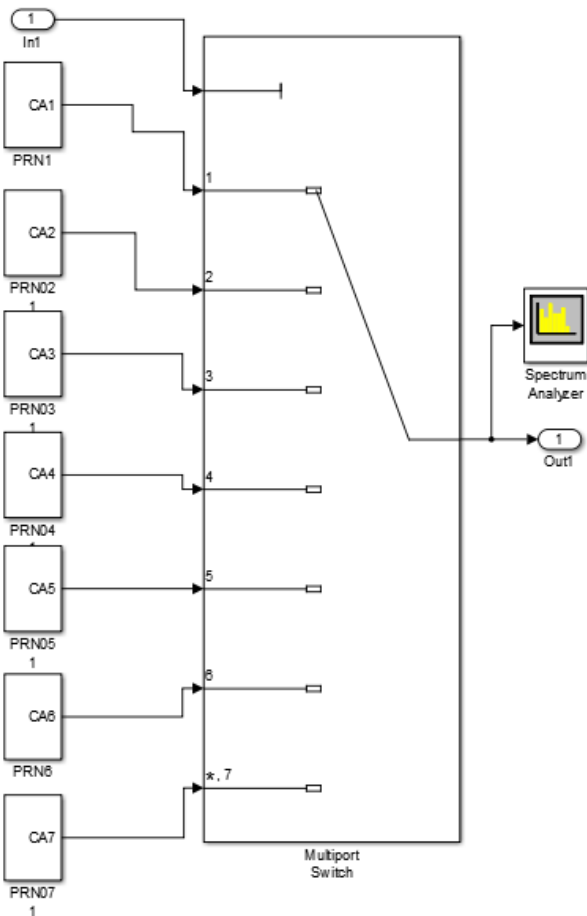


Fig 4: PRN Code Generation for Seven IRNSS Satellites

3.2 Navigation Data Generation

The navigation data for this paper are considered as random data generated from the 'Bernoulli Binary generator' block. In real life, the IRNSS navigation data master frame comprises of four sub-frames. Each sub-frame is 600 symbols, transmitted at 50 samples per second. Each sub-frame has a 16 bit Sync word followed by 584 bits of interleaved data. The information in navigation data is almost the same as in GPS. The information is mainly divided into two parts: primary navigation parameters and secondary navigation parameters. Along with these two parameter sets, an idle pattern, containing alternating zeros and ones is transmitted in the data of the navigation sub-frames.

3.3 BPSK Modulation and Transmission

In IRNSS, the Standard Position Service (SPS) signal is modulated on both L5 and S bands using BPSK modulation. Navigation data with a bit rate of 50 bps are modulo 2 added to the PRN code. This CDMA modulated code, modulates L5 and S carriers at 1176.45MHz and 2492.028 MHz, respectively. The BPSK modulated signal is sent to the channel block to be transmitted to the receiver. BPSK modulation uses two phase changes for carrier signal based on whether the input data is 0 or 1. This modulation is more robust as it has less probability of error. This is because the

distance between the symbol points in the constellation is larger than any other PSK modulation.

4. IRNSS RECEIVER MODEL IN SIMULINK

The IRNSS receiver design is similar to the GPS receiver. Figure 5 shows the implementation of the IRNSS receiver in Simulink. The received signal is first fed to the BPF to attenuate all frequencies except the required L5 frequency. This band passed signal is given to the product block to be multiplied with the local generated carrier signal.

After multiplying, the output is given to BPSK demodulator. Next, BPSK demodulation for the received signal is performed, i.e. data streams of negative ones and positive ones are transformed to zeros and ones. This data stream is given to an acquisition module to acquire the satellite number. After determining the number, the respective PRN code is generated from the local PRN generation module. The received signal and locally generated PRN codes are modulo 2 added to extract the navigation data. The following subsections give detailed explanation of all modules present in the IRNSS receiver.

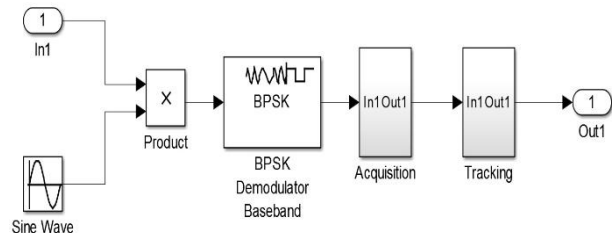


Fig 5: IRNSS receiver model in Simulink

4.1 BPSK Demodulation

BPSK demodulation is the next block after the received signal is filtered using BPF. The signal generated by the Sine Wave Generator is multiplied with the received signal using a Product block. Using the BPSK Demodulator block, the data stream is reconverted to the zeros and ones.

4.2 Acquisition

Only after acquisition, the satellite is tracked and the location is determined. Figure 6, shows the Acquisition module of the IRNSS receiver. The received signal and locally generated PRN codes are given as inputs to the Correlation blocks. Output samples of each correlation block are integrated to find maximum correlated signal. The maximum correlated PRN code's index is transmitted to further blocks of the IRNSS receiver module. In the correlation block, correlation between the received signal and locally generated IRNSS PRN codes is performed. As these PRN signals are orthogonal, the correlation is maximum for the PRN code that is used at the transmitter. The correlated samples are added using the integrator method, i.e. each sample is delayed and added to the next sample. This is done for all samples which produces correlation as a number. The same is repeated for all seven PRN codes and given to the 7→1 multiplexer. The output from the multiplexer is given to a maximum block, which outputs the index of PRN that is maximum correlated with the received signal. In this way the acquisition is done at the receiver end.

4.3 Carrier Tracking

The two first multiplications wipe off the carrier and the PRN code of the input signal. The loop discriminator block is used

to find the phase error on the local carrier wave replica. The output of the discriminator, which is the phase error, is then filtered and used as a feedback to the numerically controlled

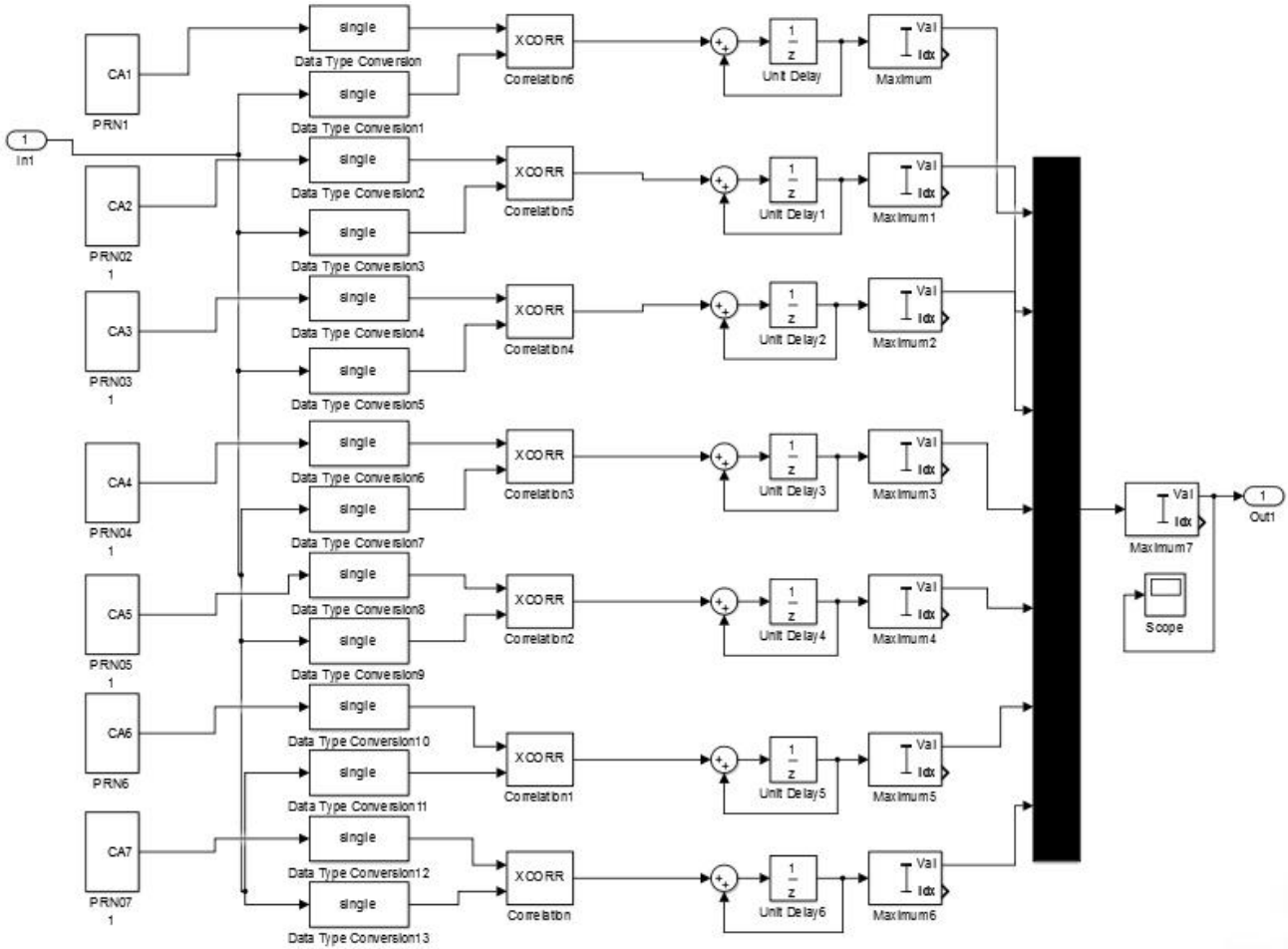


Fig 6: Acquisition module in SIMULINK

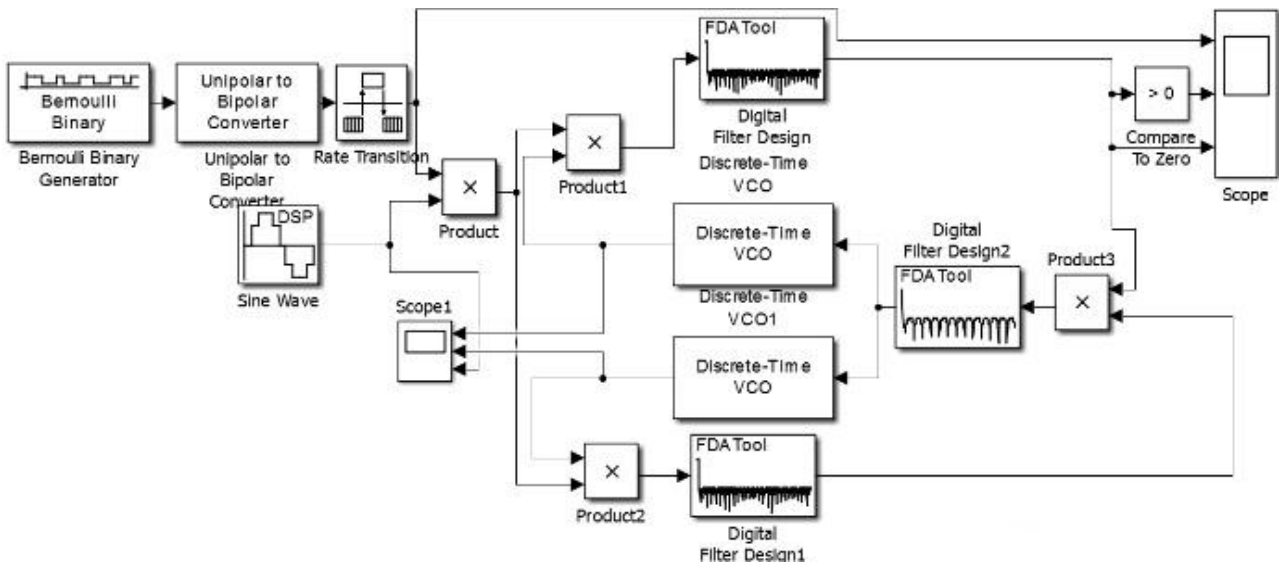


Fig 8: Carrier loop tracking module in SIMULINK

oscillator (NCO), which adjusts the frequency of the local carrier wave. In this way the local carrier wave could be an almost precise replica of the input signal carrier wave. On the point to note, ordinary PLL is sensitive to 180° phase shift.

Due to navigation bit transitions, a PLL used in a GPS receiver has to be insensitive to 180° phase shifts. Costas loop

5. EXPERIMENTAL RESULTS

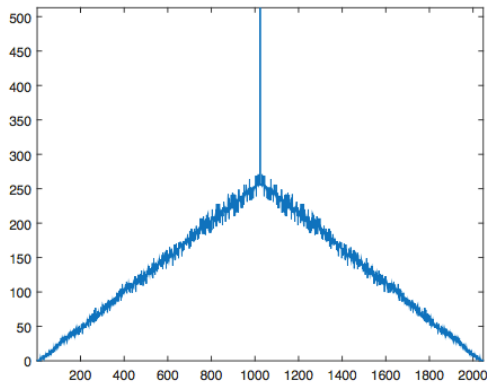


Fig 8: Maximum correlation of PRN1 with received signal

The PRN1 code is used at the transmitter as a ranging code, correlation with PRN1 should be maximum at the receiver. Acquisition module as shown in Figure 8 tries to find out which satellite signal is received. For this it correlates the demodulated signal with all local copies of PRN codes. After the correlation, the maximum correlated PRN code is used to extract the navigation data. The simulated results of carrier loop tracking which was explained in provision section is shown in figure 9.

receiver, after demodulation of the received signal, the Acquisition module tries to find out which satellite signal is received. For this it correlates the demodulated signal with all local copies of PRN codes. After the correlation, the maximum correlated PRN code is used to extract the navigation data. The simulated results of carrier loop tracking which was explained in provision section is shown in figure 9.

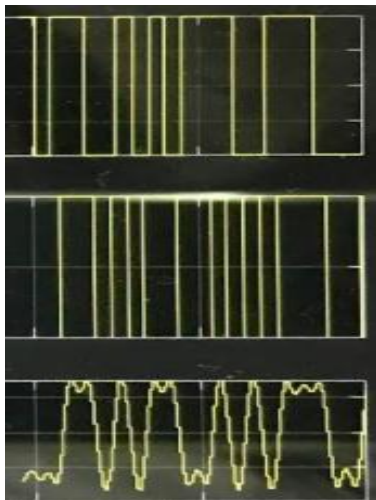


Fig 9: Carrier tracking loop

6. CONCLUSION AND FUTURE WORK

The designed receiver in Simulink can receive signals, find maximum correlated satellite signal using an acquisition algorithm and extract the navigation data. This receiver is a single frequency single channel receiver, i.e. it can receive only IRNSS L5 signals and process them to extract the navigation data. The Simulink model can be further used for preliminary tests and can form a base for making prototype hardware [4]. In the future, a hardware prototype for the proposed Simulink model can be constructed as a next step to this research. There are certainly some features to make this paper more successful. This paper demonstrates only acquisition of the satellite and carrier loop tracking. In future code loop tracking has to be implemented.

7. ACKNOWLEDGMENTS

The author would like to acknowledge gratefully and appreciate the support provided by R.V. College of Engineering, Bangalore for the above project.

8. REFERENCES

- [1] IRNSS Signal-In-Space ICD For SPS Version 1.0, pp. 10-11.
- [2] Kai Borre "A Software-Defined GPS and Galileo Receiver A Single-Frequency Approach" Birkh'auser.
- [3] Virendra Patel "Implementation of GPS L5 Signal using Model based design tool", IEEE, pp. 1-4, March 14
- [4] Terence Zarb "Verification of a VHDL GPS baseband processor using a simulink based test bench generator", IEEE, pp. 327-330, 2010.
- [5] M.N.Venkatash Babu.S "Implementation Of the Modernized GPS Signals L2C, L5 And their Tracking Strategies", Vol. 2, Issue4, IJERA, pp.2148-2152, July-august 2012.