International Journal of Future Generation Communication and Networking
Vol. 14, No. 1, (2021), pp. 705–713

Model Based Design And Implementation Of Coarse Acquisition (C/A) Code Of Irnss Signal On Fpga

E.Srinivas Assistant Professor
M.Mounika, M.Tech (Vlsi System Design)
Anurag University, Venkatapur (V), Ghatkesar (M), Rrdist-501301.
Email:Mouni.Mamidalamounika@Gmail.Com

Abstract

IRNSS is an independent regional navigation satellite system being developed by India. It is designed to provide accurate position information service to users in India as well as the regions extending up to 1,500 km from primary service area boundary. An Extended Service Area lies between primary service area & area by rectangle from Latitude 30 degree south to 50 degree north, Longitude 30 degree east to 130 degree east. This paper is focused on developing a software-based Coarse Acquisition for IRNSS satellites. The main reason for choosing Gold code to generate C/A code is the good auto-correlation and cross-correlation it exhibits. Tracking & positioning of IRNSS device is preceded by acquisition stage which uses C/A Code generator. This paper present the C/A code generation for IRNSS Signals constructed on Matlab Simulink, thereafter Model is converted to HDL Verilog code (Xilinx ISE) and implemented on FPGA.

Keywords: *IRNSS, PRN, C/A.*

I. INTRODUCTION

Indian Space Research Organization (ISRO) is developing Indian Regional Navigation Satellite System (IRNSS) to provide accurate position, navigation and timing throughout India with an operational name NavIC. It extends up to 1,500 km across the boundaries of India and comprises of 7 satellites. Transmission of navigation signals takes place through CDMA on L5 signal using BPSK modulation. IRNSS offers 2 kinds of services – Standard Positioning Service (SPS) and Restricted/ Authorized Service (RS) at L5 band (1176.45MHz) and S-band (2472.5 MHz) frequencies respectively.
The IRNSS System is composed of 3 segments: space segment, ground segment & user segment. The ground segment manages operation of IRNSS & maintenance. Operational responsibilities include constellation status supervision, navigation data upload & orbital parameters modification. The space segment consists of 7 satellites (3 are geostationary orbits and 4 are geosynchronous orbits). The geostationary satellites are located at 83°E, 32.5°E & 131°E and the geosynchronous satellites have longitude crossings of 111.75°E and 55°E. The user segment consists of various types of receivers capable of receiving L5 band and S-band frequencies.

Code acquisition and Code tracking are two stages in the code synchronization task. Code acquisition searches for satellite signal through an uncertainty region until a correct code phase delay and Doppler frequency is found. The main intention of Code acquisition is to detect and match the visible satellites with a locally generated replica to provide the values of matched carrier and code phase of satellite signals. We are focusing mostly on coarse acquisition (C/A) code in acquisition process. The C/A code

ISSN: 2233-7857IJFGCN
Copyright ⓒ2021SERSC

is pseudo random code (PRN) which looks like a random code but it's clearly defined for each satellite's. It is repeated every 1023 bits or every millisecond.

II. SIGNAL STRUCTURE

A. Transmitter

IRNSS satellites transmits two carrier frequencies L5 band (1176.45 MHz) and S-band (2472.5 MHz). The navigation information is transmitted as DSSS which is modulated by a unique PRN sequence belongs to the family of C/A codes of Gold sequence with 1023 bits. Each of these PRN codes are transmitted with the same carrier frequencies through CDMA scheme.
CDMA scheme is used to detect and track a specific satellite C/A code phase and Doppler frequency shift from L5 carrier. CDMA scheme generates replica of PRN sequence and carrier wave at the receiver with identified code phase & Doppler shift which brings down desired navigation message to baseband.

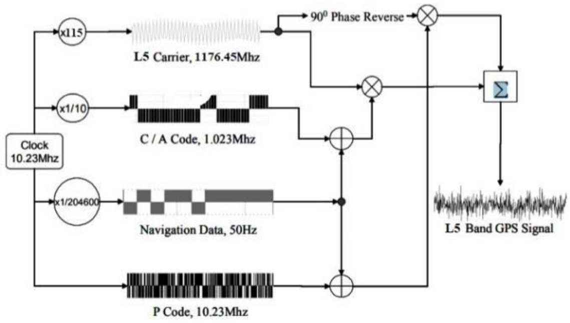
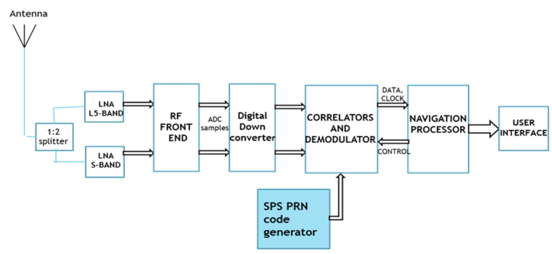


Fig. 1: IRNSS Transmitter

Fig. 1 depicts that the resulting L5 and S-band signals are generated from the same atomic clock with a reference frequency fo= 10.23 MHz. This reference atomic clock provides timing to every other signal generator block in the system. The L5 signal is the resultant of the addition of bitwise XOR operation between C/A code and navigation and bitwise operation between Precision code (P) and navigation message. After their addition, they are modulated into Binary Phase-Shift Keying (BPSK) onto the L5 carrier having a 90 degrees phase offset between them.

B. IRNSS User Receiver

The main objective of the IRNSS user receiver is to acquire signals simultaneously from all the IRNSS satellites using best satellites geometry of configured constellation(s) (w.r.t. GDOP & Signal strength), provide the PNT (position, navigation and time) solution as outputs and display the same. The User Receivers shall have capability to receive IRNSS frequency.



ISSN: 2233-7857IJFGCN
Copyright ⒸC2021SERSC

Fig.2 Block diagram for IRNSS user receiver bands (L5 & S Bands).

Fig. 2 shows the block diagram of IRNSS user receiver which consists of antenna, L5 and S band splitter, RF front end, digital down converter, correlators and demodulator, navigation processor, user interface and SPS code generator.

III. COURSE ACQUISITION (C/A) CODE

Each Satellite (SV) has its individual C/A Code. The C/A Code is also known as the Gold code, the code has good auto and cross correlation properties. The cross correlation of the Gold code is such that the correlation function between two different sequences is low. Every satellite broadcasts a different code, repeating it over and over again. It contains no actual data; it is simply an identifier. These codes are binary, consisting of “zeros” and “ones”. Each individual zero and one is call a chip instead of a bit because they contain no data. They are of a fixed pattern and length that are repeated indefinitely. The C/A code is 1023 chips long with a broadcasting frequency of 1.023 mega hz chips per second. The architecture of a C/A code generator is shown in figure 3 which was developed by using MATLAB Simulink. Two Linear Feedback Shift Registers (G1 and G2) required to generate C/A Code with maximum length of 2^10-1 = 1023 bits. N is chosen to be 10 because PRN code has the data rate of 1023 chips per msec. Initially G1 is all set to “ones” and G2 is set to initial conditions provided in the table

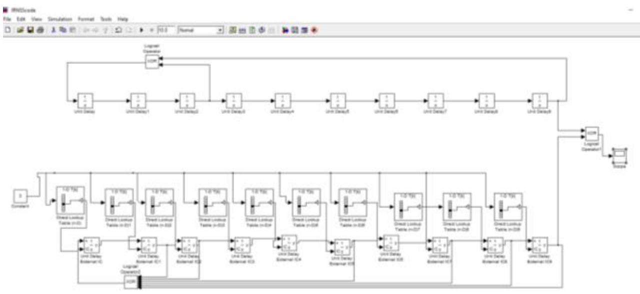


Fig 3. C/A Code Generator

PRN ID	SV Location	L5 –SPS		S-SPS	
		Initial Condition for G2 Register	First 10 Chips in Octal2	Initial Condition for G2 Register	First 10 Chips in Octal2
1	55°E	1110100111	130	0011101111	1420
2	55°E	0000100110	1731	0101111101	1202
3	83°E	1000110100	0713	1000110001	0716
4	111.75°E	0101110010	1215	0010101011	1524
5	111.75°E	1110110000	0117	1010010001	0556
6	32.5°E	0001101011	1624	0100101100	1323
7	131.5°E	0000010100	1753	0010001110	1561

Table 1: Code Phase assignment for SPS Signals

The G1 and G2 LFSRs feedback taps are defined by the generator polynomials

Copyright ⓒ2021SERSC

$$G1(X) = 1+X3+X10$$
$$G2(X) = 1+X2+X3+X6+X8+X9+X10$$

C/A code is generated by taking the exclusive-or output of the G1 LFSR and a delayed version of the output from the G2 LFSR. The delayed effect for the G2 LFSR output is obtained by the exclusive-or of two selected stages from the G2 LFSR. This will work since adding a phase shifted version of a PRN sequence to itself will shift the phase of the code while not changing the code

1) Auto-Correlation

One of the most important properties of the C/A codes is their correlation results. Correlation, in general, measures the similarity of two waveforms or sequences. Autocorrelation measures the similarity between waveform and time-shifts of it-self.

The autocorrelation function of a C/A code is

$$R^{(k)} (\tau) = 1/T\int x^{(k)} (t)x^{(k)} (t- \tau)dt$$

where k is the C/A code for the k^{th} satellite and τ is the phase of the time shift.

The analysis of autocorrelation property of 7 satellites for both L5 band and S band is shown in table-2.

PRN ID	L5-SPS Initial Condition for G2 Register	Maximum Value	Minimum Value	S-SPS Initial Condition for G2 Register	Maximum Value	Minimum Value
1	1110100111	1	-0.0635	0011101111	1	-0.0635
2	0000100110	1	-0.0635	0101111101	1	-0.0635
3	1000110100	1	-0.0635	1000110001	1	-0.0635
4	0101110010	1	-0.0635	0010101011	1	-0.0635
5	1110110000	1	-0.0635	1010010001	1	-0.0635
6	0001101011	1	-0.0635	0100101100	1	-0.0635
7	0000010100	1	-0.0635	0010001110	1	-0.0635

TABLE 2: Result of 7 satellites in L5 and S band for Autocorrelation property analysis

2) Cross-Correlation

Cross-correlation compares given waveform with all-time shifts of a second waveform. C/A code correlation peaks repeat every code period and the correlation interval is two chips. This is a simplified model of the C/A code autocorrelation function as there are shifts which produce non-zero values between correlation peaks. It is important that the cross-correlation of any two C/A codes are minimal for any phase or Doppler shift over the entire code period.

The ideal cross-correlation is defined by

$$R^{(j,k)} (\tau) = 1/T\int x^{(j)} (t)x^{(k)} (t- \tau)dt$$

where i is the C/A code for the i^{th} satellite and j is the C/A code for the j^{th} satellite where $i \neq j$.

Multiple satellites signal are received with different delays and Doppler shifts are not ideal and may cause false acquisitions under certain conditions.

Copyright ⓒ2021SERSC

The analysis of cross-correlation property of 7 satellites for both L5 band and S band is shown in table-3.

CROSS CORRELATION				
PRN ID	L5-BAND		S-BAND	
1 and 2	Maximum Value	Minimum Value	Maximum Value	Minimum Value
1 and 3	0.0616	-0.0635	0.0616	-0.0635
1 and 4	0.0616	-0.0635	0.0616	-0.0635
1 and 5	0.0616	-0.0635	0.0616	-0.0635
1 and 6	0.0616	-0.0635	0.0616	-0.0635
1 and 7	0.0616	-0.0635	0.0616	-0.0635
2 and 3	0.0616	-0.0635	0.0616	-0.0635
2 and 4	0.0616	-0.0635	0.0616	-0.0635
2 and 5	0.0616	-0.0635	0.0616	-0.0635
2 and 6	0.0616	-0.0635	0.0616	-0.0635
2 and 7	0.0616	-0.0635	0.0616	-0.0635
3 and 4	0.0616	-0.0635	0.0616	-0.0635
3 and 5	0.0616	-0.0635	0.0616	-0.0635
3 and 6	0.0616	-0.0635	0.0616	-0.0635
3 and 7	0.0616	-0.0635	0.0616	-0.0635
4 and 5	0.0616	-0.0635	0.0616	-0.0635
4 and 6	0.0616	-0.0635	0.0616	-0.0635
4 and 7	0.0616	-0.0635	0.0616	-0.0635
5 and 6	0.0616	-0.0635	0.0616	-0.0635
5 and 7	0.0616	-0.0635	0.0616	-0.0635
6 and 7	0.0616	-0.0635	0.0616	-0.0635

TABLE 3: Result of 7 Satellites in L5 And S Band For Cross-Correlation Property Analysis

IV. RESULTS

1) PRN Code Generator

The register 2 of PRN component is used to generate 1 KHz clock that is utilized to drive many blocks. First 10 chips in octal – 1300 (0010110000) was generated for satellite 1 by using initial condition for G2 Register is “0000100110” in MATLAB Simulink. Respected results shown in fig 4.

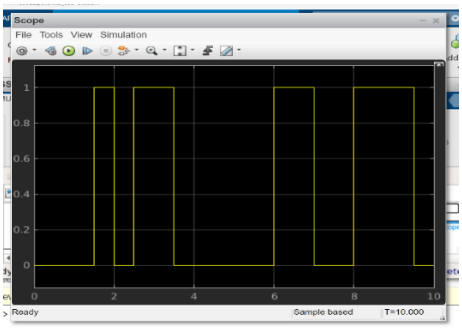


Fig 4. Output of IRNSS C/A code generator for 1st Satellite

First 10 chips in octal – 1753 (1111101011) was generated for satellite 7 by using initial condition for G2 Register is “0000010100”. Respected results shown in fig 5.

ISSN: 2233-7857IJFGCN
Copyright ©2021SERSC

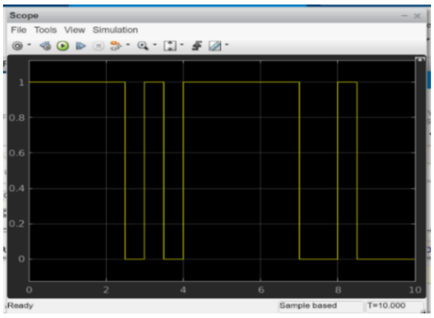


Fig 5. Output of 7th Satellite

1.1 Cross correlation and auto-correlation

A normalized and simplified autocorrelation function of a typical C/A code is shown in figure 6.

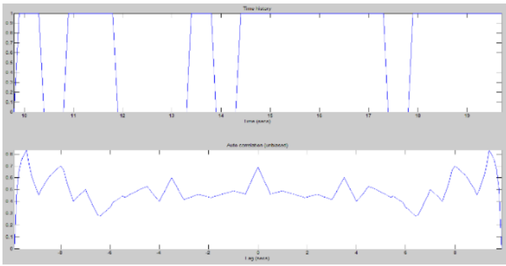


Fig 6. Autocorrelation output for 4th satellite

The output of the autocorrelation is maximum when shift in the second signal is minimum and it's at peak when the shifted signal exactly matches the original signal.

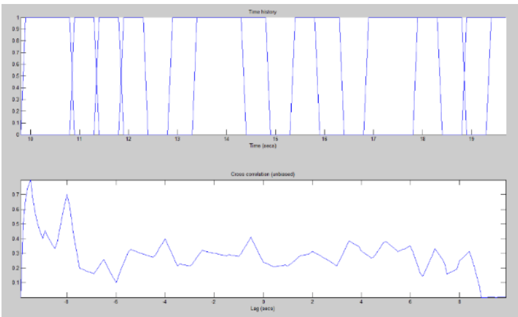


Fig 7. Cross-correlation output for 3rd & 6th satellite

Copyright ©2021SERSC

International Journal of Future Generation Communication and Networking
Vol. 14, No. 1, (2021), pp. 705–713

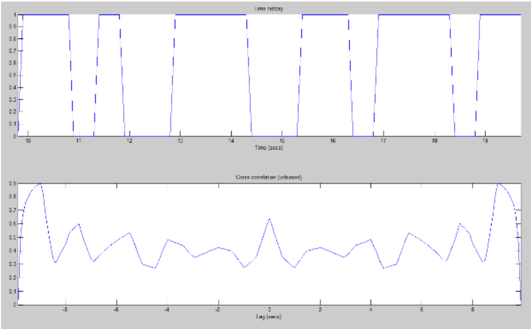


Fig 8. Cross-correlation output for 3rd &3rd satellite

The plot of the corresponding cross-correlation function is obtained with the matlab code shows that for this case n=10, we have t(10) = 26+1=65 and the only three values for the cross-correlation function of the preferred Gold sequences will be:{-1, -65, 63} and after normalizing this three values we can see in fig, the cross-correlation function values obtained correspond to the predicted ones. Figure 7 & 8 depicts cross-correlation of the two signals which are shifted from 0 to 1023 bits.

1.2 Xilinx Implementation

By using HDL Coder the C/A code Simulink model is converted to HDL Verilog code. HDL Coder generates portable, synthesizable Verilog and VHDL code from MATLAB functions, Simulink models, and Stateflow charts. The output is obtained only when the respective reset input and clock & clock enable inputs. Clock enabled input is used as active high. Respected Simulation results for Verilog C/A code as shown below.

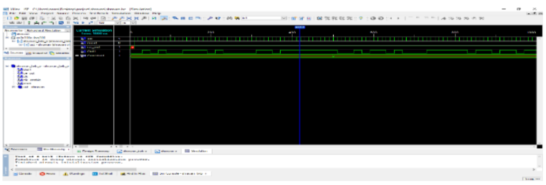


Fig 9. Output waveform of IRNSS CA code for 5th Satellite

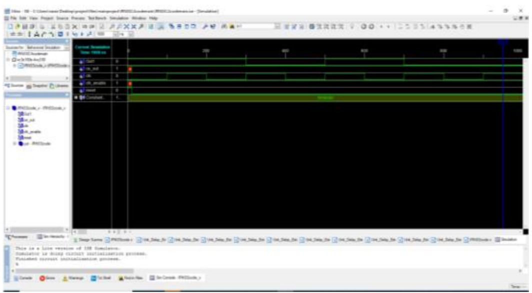


Fig 10. Output waveform of IRNSS CA code for 2nd Satellite

1.3 Hardware Implementation

The FPGA SPARTAN-2 kit is used for PRN code generation in the hardware is represented in the fig 11.

ISSN: 2233-7857IJFGCN
Copyright ⓒ2021SERSC

Fig.11 FPGA Spartan-2 kit

The push button switch provided enter key is utilized as the clock input. The clock was derived from the internal master clock. LED-1 is used for the displaying generated PRN data. Figure 11 shows the LED interfacing on the SPARTAN-2 FGPA kit using in built timer to show the SPS PRN codes generated.

V. CONCLUSION

This paper began with an overview of the IRNSS signal structure with attention to the theories of signal acquisition. We have generated and analyzed the properties of the PRN codes from the navig-ational system viewpoint. We have additionally done the design and implementation of PRN code on Spartan-II FPGA hardware. IRNSS receivers are implemented in either hardware or software. Due to flexibility and low cost, software receivers are preferred over the hardware. The design of PRN code on MATLAB Simulink and Xilinx ISE has been implemented and the properties of PRN codes have been verified using MATLAB & Xilinx.

REFERENCES

[1] "REAL-TIME ACQUISITION AND TRACKING FOR GPS RECEIVERS". *Abdulqadir Alaqeeli, Janusz Starzyk, Frank van Graas,* School of Electrical Engineering and Computer Science

[2] "AVERAGE CORRELATION FOR C/A CODE ACQUISITION & TRACKING *FREQUENCY DOMAIN" J. A. Starzyk and Z.*

[3] Zhu School of Electrical Engineering and Computer Science

[4] *"CODE ACQUISITION AND TRACKING OF IRNSS SIGNALS "Anirudh Lanka, Aishwarya Shivani R., Amoolya* R. Bayari, Suresh Dakkumalla, Shylashree N.

[5] "IMPLEMENTATION OF SIGNAL GENERATION AND MODULATION OF IRNSS L5 BAND SIGNAL INMATLAB SIMULINK" Vijeshree Kadiya, Prof Viral Mehta, Prof Virendra Patel ,Communication system engineering.

[6] "FFT based Acquisition techniques of GPS L2C signals", B.R. Iswariya, H. Nirosh Kumar, ICTACT Journal on Communication Technology, vol. 04, no. 04, pp. 849-853 Dec. 2013.

[7] "Implementation of Acquisition & Tracking Algorithms of Spread Spectrum Signals in high dynamic scenario", Sandip Sudani, Dhaval Upadhyay, Pravin Patidar, International Journal of Current Advanced Research Research, vol. 5, no. 3, pp 643-648, March 2016.

ISSN: 2233-7857IJFGCN
Copyright ⓒ2021SERSC

[8] Department of Space, Indian Space Research Organisation - www.isro.gov.in.

ISSN: 2233-7857IJFGCN
Copyright ⓒ2021SERSC