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## Full Length Article

# Generation and implementation of IRNSS Standard Positioning Signal

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## ABSTRACT

The two sorts of services given by the Indian Regional Navigational Satellite System (IRNSS) satellites are Standard Positioning Service (SPS) and Restricted Service (RS). Both services will be given at two frequencies of L5 (1164.5 MHz) and S (2472.5 MHz) band. The code sequences utilized as a part of SPS are Pseudo Ranging Noise (PRN) codes. They utilize gold codes for navigational data transmission in SPS down-link. PRN sequence code is the secondary code and the gold code is the primary code. The greater part of the global positioning system works on Code Division Multiple Access (CDMA), in which Pseudo Random Code (PRN) sequences are required for the systems. In this paper a study is made on the generation and properties of the PRN codes from the navigational system viewpoint. This paper additionally shows the design and implementation of PRN code on Spartan-II FPGA hardware. The generated SPS PRN code results are approved from hardware with the simulation results and examination of the properties of the PRN codes positively acquired. This paper likewise exhibits the execution analysis and simulation of Auto-Correlation Function (ACF) and Cross-Correlation Function (CCF) properties for PRN sequence. The simulations of SPS PRN codes were completed utilizing the Xilinx ISE test system and MATLAB apparatus. The simulated test outcomes are within the theoretical limits.

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## 1. Introduction

Navigation is precisely ascertaining one's position and planning and following route. It likewise concentrates on monitoring and controlling the movement of a vehicle starting with one place then onto the next. IRNSS (Indian Regional Navigational Satellite System) is ISRO's drive to build an independent satellite navigational system that will give self-governing Geospatial positioning with regional generation by a constellation of GEO and GSO Satellites, which would be under the aggregate control of the Indian Government. The requirement of such a Navigational system is driven by the fact that access to global navigational satellite systems, GPS, is not guaranteed in hostile circumstances [24\*7].

The motivation is to design and create indigenous, independent navigational system under the Indian Government control, catering different needs and giving exact position, navigation and time (PNT) to the client with 20 mtrs exactness. Since GPS is non-civilian and is controlled by different nation's military government, it can scramble our secret information anytime; it is fundamental

and advantageous to have IRNSS, which is under the Indian Government control.

In this project we are producing the IRNSS SPS Signal, which is a modulated BPSK signal with a local carrier frequency of 70 MHz. It is acquired by X-ORing the IRNSS created navigation data and IRNSS produced PRN codes. The issue that happens in satellite while transmitting the navigational data can't be anticipated. So earlier we created an IRNSS SPS signal consolidated with the ISRO produced PRN codes to check whether the information acquired from the satellite is correct or not. This signal is simulated in MATLAB and in ISE simulator utilizing Xilinx implementing the same FPGA kit.

The new civilian signals are the modernization initializations. These new signals are key innovations for dataless channel, improved navigation data message format, code structure and new modulation schemes. This paper concentrated on selection and analysis of the secondary spreading codes for the use in IRNSS [1]. The paper deals with the comprehensive study of GPS space segment and control segment. The specification of GPS service known as SPS ranging signal character is introduced. This paper also illustrates timing, C/A code generation, satellite tracking, frequency planning GPS, navigational message format and technical aspects of working the GPS SPS Standard Positioning System and also its implementation [2].

The paper also guides the design and implementation of PRN code on Virtex-2P FPGA hardware. The results of generation from

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hardware are validated with the simulation results and the properties of the PRN codes are analyzed.

This paper concludes the generation of properties of the PRN codes and the design and implementation of PRN code on MATLAB, Xilinx ISE and Vertex-2P FPGA hardware environments. The results of generation from hardware are validated with the simulated results and also the properties of the PRN codes are analyzed [3]. This paper deals with the generation of GPS signals with FPGA-based Xilinx system generator 9.2. The frequency band L1 is used mainly for commercial civil aviation and other purposes. Once the GPS signals are generated in the simulated laboratory environment, we can test the proper working of multichannel GPS receiver, which is an extension of this project, and after we obtain accurate laboratory results we can go for real GPS signals. The board that has been used for the hardware implementation is Lyttech SFR-SDR board, which has three functional layers. The digital processing layer, the ADAC master 3 layer and RF layer have a transmission and receiving capacity of 1 GHz; this will lead to the development of indigenous digital GPS signal generator using reconfiguration [4]. The proper concept of spreading communication is that it occupies higher bandwidth and hence the power spectral density is lower [5]. The spreading is done by combining the data signal with CDMA, which is independent of the transmitted data message. Spread signals are intentionally made to be much wider band than information to carry noise [5]. Spread spectrum signals use speedy codes that run many times the data rate; these codes will have much higher than the original information. This is done since the actual data timing is still the same but has smaller bit duration codes that are being used. These are nothing but Pseudo Random since they are not the real Gaussian noise and are random. The original source code signal timing is maintained [6].

### 1.1. Code selection computing

In BPSK transmission, data transfer capacity is an immediate capacity of the code chip rate. Code redundancy rate is just given as  $R = \text{Clock rate (chips/sec)} / \text{Code length (chips)}$ .

This regeneration rate decides the line spacing in the RF output range. Henceforth, it is a critical thought in a system design. Another vital standard is that the code's time must be substantial. Table 1 records different code lengths for a 1-Mcps-chip rate. The choice of code rate and code length decides the redundancy's relationship rate to the data baseband and utilization of the system for ranging. The code utilized as a part of an immediate sequence system ought to be balanced for redundancy rate and length such that clamor does not go into the demodulator especially under jammed conditions.

A code must be legitimately decided to enhance determination and straightforwardness range resolution issue. The chip rate chosen is a necessary number of code counterbalance that can be utilized to quantify range. Clock rates of 161,875 Hz produce code at rates that are vitally identified with the RF sign rate of propagation. The relationship may be derived as follows: In vacuum Speed of light  $c = 2.997926 \times 10^8 \text{ m/s}$ , 1 nautical mile  $= 1.852 \times 10^3$  meter,

**Table 1**  
Gold code sequence.

Shift register	Gold code size
Stages (n)	$M = 2^n + 1$
10	1025
12	4097
13	8193
15	32769

the clock rate (wavelength = 1 nmi)  $= c/R = 2.997926 \times 10^8 / 1.852 \times 10^3 = 161,875 \text{ Hz}$ . Among the most serious issues in code generation are the following: (1) discovering feedback logic that gives desired code length, and (2) checking code one, a sequence generation has been built to guarantee that it is working appropriately. Tables of input feedback correlations and irreducible polynomials have been created.

## 1.2. Popular codes

### 1.2.1. PN sequence

The pseudorandom noise (PN) sequence is a progression of 1s and 0s that does not have any definite pattern and comprises deterministic sequence of pulse that will rehash after its period, which is the most extreme length sequence. In a legitimate random sequence the bit pattern never rehashes. A pseudo random binary sequence is a semi-random sequence as it seems arbitrary inside of the sequence length, satisfying the needs of randomness, yet the whole sequence rehashes uncertainly. The PN sequence generation is normally a Linear Feedback Shift Register (LFSR). It creates a maximal length sequence of length  $N = 2n - 1$  components. In view of their great autocorrelation two comparable PN sequences can without much of a stretch be staged synchronized, notwithstanding when one of them is debased by noise.

### 1.2.2. Gold sequence

Gold sequences are developed by the XOR of a favored pair of m-sequence with the same timing. They have very much characterized cross-correlation properties and just straightforward hardware is expected to create a vast number of one of a kind codes. Gold code sequences are developed by exclusive or of favored pair of m-sequences with the same timing and same length [1,4]. In gold sequence of length  $L = 2n - 1$ , one uses two LFSRs [7], each of length  $2n - 1$ . On the off chance that the Linear Feedback Shift Register (LFSR) is picked appropriately, gold sequences have better cross-correlation properties [8]. The upside of gold code is in producing bigger number of codes size. Gold and Kasami demonstrated that for certain well-picked m-sequences, the cross-relationship just takes three conceivable values, specifically  $\{-1, -t(n) \text{ or } t(n)-2\}$ . The cross-correlation between the codes is uniform and limited.

$$t(n) = 1 + 2^{\frac{n+1}{2}} \text{ for } n = \text{odd}, t(n) = 1 + 2^{\frac{n+2}{2}} \text{ for } n = \text{even} \quad (1)$$

Here  $t(n)$  depends exclusively on the length of the LFSR utilized. The fact is that, for an LFSR with "n" memory components, gold code family estimate  $M = 2n + 1$ ,  $n$  = shift register stages. The code size increments with expanding the quantity of phase of shift register.

### 1.2.3. Kasami codes

Kasami codes have mainstream use in 3G remote plan. They can be named (1) large Kasami set or (2) Small Kasami set. Small Kasami set has a family estimate of  $(M) = 2n/2$  and period  $= N = 2n - 1$ . Their maximum cross-relationship is  $2n/2 - 1$ . Large Kasami set contains both gold sequence and small sequence of Kasami sequences as subset. Its period is  $N = 2n - 1$ . The greatest cross-correlation is  $2(n+2)/2$ .

## 2. PN-sequence properties and its analysis

The bit stream of '1s and '0s happening arbitrarily is known as PN sequence, with one of a kind properties. The sequence goes about as a source of perspective pattern with known irregular qualities for the examination, optimization and execution estimation of correspondence channels and systems.

**Table 2**

The analyzed results of 7 satellites in L5, S band for balanced property.

Inclination	Satellite number	L5-band	No. of ones	No. of zeros	S-band	No. of ones	No. of zeros
32.5	1	0001101011	480	543	0100101100	513	510
83	2	1000110100	513	510	1000110001	512	511
131.5	3	0000010100	513	510	0010001110	513	510
55	4	1110100111	512	511	0011101111	480	543
111.75	5	0101110010	513	510	0010101011	512	511
55	6	0000100110	545	478	0101111101	512	511
111.75	7	1110110000	513	510	1010010001	512	511

### 2.1. Balance property

Every time the most extreme length sequence is created, the quantity of 1s is constantly one more than the quantity of 0s. The balanced property of 7 satellites is shown in **Table 2**.

### 2.2. Autocorrelation property

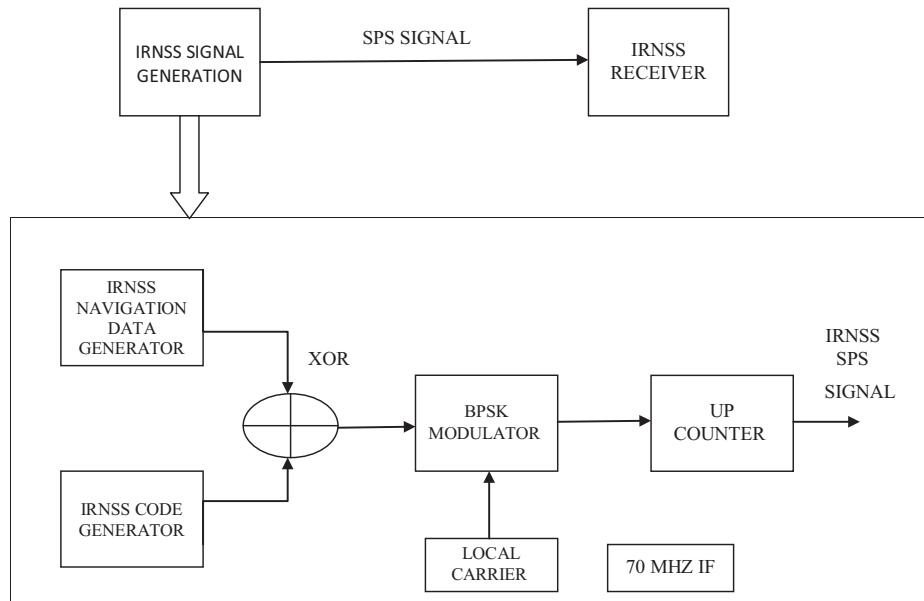
The autocorrelation function  $r(i)$  of any PN sequence of length  $N$  is given by

$$r(i) = \begin{cases} 1 & \text{for } i=0 \\ -\frac{1}{N} & \text{for } |i| \leq N-1 \end{cases} \quad (2)$$

**Table 3**

The analyzed results of 7 satellites in L5, S band for auto-correlation property.

Satellite number	L5-band	Maximum value	Minimum value	S-band	Maximum value	Minimum value
1	0001101011	0.0723	-0.085	100101100	0.0771	-0.0752
2	1000110100	0.083	-0.0723	1000110001	0.0713	-0.0889
3	0000010100	0.0742	-0.0723	0010001110	0.0859	-0.0752
4	1110100111	0.082	-0.0732	0011101111	0.0762	0.0791
5	0101110010	0.0859	-0.0781	0010101011	0.083	-0.0859
6	0000100110	0.0781	-0.0771	0101111101	0.0762	-0.0762
7	1110110000	0.0723	-0.0732	1010010001	0.0811	-0.0791

**Fig. 1.** Block diagram for PRN code generation.

The auto-correlation [9] has been investigated for both L5-band and S-band for all the 7 satellites shown in **Table 3**.

### 2.3. Correlation property

Correlation is the closeness between two sequences. 'Cross-correlation' results when the two sequences analyzed give diverse qualities, and when they are the same they result to 'autocorrelation' [10].

Numerically, the correlation between two sequences  $x(k)$  and  $y(k)$  as a period's component delay  $m$  is communicated as

$$R(m)_{xy} = \sum_{k=0}^{L-1} x(k)y(k+m) \quad (3)$$

The digitalized bit sequence of relationship comparison that is a correlation equation can in this manner be composed as

$$R(m) = \frac{\text{aggregate number of one's}}{\text{aggregate number of bits}} \quad (4)$$

These three properties make PN sequences productive for discourse/speech encryption. Especially because of the third property, adjoining bits relationship turns out to be extensively less, consequently making the PN sequences more compelling to be utilized as a part of systems like CDMA. Accordingly, helpful PN sequences must have great auto-relationship and cross-correlation properties and additionally keeping up some randomness properties.

## 2.4. Welch bound

Designing codes enhanced for any of the potential application is basically unthinkable; utilizing code-driven metric is more proper. This is the motivation behind why the Welch bound has picked up significance lately as a suitable metric for assessing PRN codes. The Welch bound is the hypothetical least of the greatest estimation of cross-relationship that can be acquired for a given code length L inside of a sequence of M codes [3].

The Welch bound for a sequence of K sequences with every sequence of length (N, K) is characterized as

$$\phi_{\max} \geq \sqrt{\frac{N-K}{NK-K}} \quad (5)$$

The cross-correlation has been investigated for both in-band and out-of-band for all the 7 satellites, and the most extreme least values have been acquired and appear in **Table 4**.

Such a bound is no more achievable when  $N > K$  ( $K+1=2$ ) for genuine cases. Note that, in the continuation, here and there we might speak to double sequences utilizing zeros and ones and as a part of different cases +1 and -1s. The proper mapping is that the zeros are mapped to +1s and ones are mapped to -1s.

## 3. Proposed architecture for SPS PRN code generation

For satellite-based navigation system the proposed architecture for the PRN code generation [11] is shown in **Fig. 1**.

The navigational signals transmitted on every carrier frequency are incompletely synchronized because of the diverse equipment ways relating to every sign. Every satellite's navigational message contains parameters depicting the timing predisposition. A client beneficiary uses these parameters to process the clock correction for every observation.

An illustration for PRN code generation [12] for satellite-based route in GPS is considered. For Standard Positioning Service (SPS) GPS sign comprises the Navigational Data stream of 50 bps blended with C/A code, which is balanced utilizing a carrier frequency of 1575.42 MHz (L-band). The chipping rate of C/A is 1.023 MHz with a code time of 1.023 ms. The bits acquired after spreading the information with PN sequence can be shown in NRZ format, this sign is then utilized for BPSK adjustment of a sinusoidal carrier of 1575.42 MHz. Thus, the  $i^{\text{th}}$  satellite of GPS-SPS sign can be represented as

$$S_{GPS,SPS}^i(\omega_c, t) = A(C_i(t) \oplus D_i(t)) \cos(\omega_c t) \quad (6)$$

where A, the carrier frequency;  $C_i(t)$ , C/A code for the  $i^{\text{th}}$  satellite;  $D_i(t)$ , navigational information for the  $i^{\text{th}}$  satellite; and  $\omega_c$ , L1 carrier with frequency of 1575.42 MHz.

The total of two maximal length sequences of length  $2n - 1$  is utilized, taking their modulo-2 value to build a gold code; to identify with each other in a fitting way two sequences are needed. A brief clarification for gold codes hypothesis is past the extent of this thesis. A great synopsis about this is found in the appendix of Spilker (1996) [13].

The C/A codes are considered as the pair of maximal-length sequences developed by utilizing polynomials G1 and G2 that are produced [14], where G1 and G2 are given by

$$G1 = X10 + X3 + 1 \quad (7)$$

$$G2 = X10 + X9 + X8 + X6 + X3 + X2 + 1 \quad (8)$$

The modulo-2 whole of the G1 sequence and a deferred variant of the G2 sequence give the gold codes with every satellite number that designates an alternate postponement amount of quantity. Since

**Table 4**

The analyzed results of 7 satellites in L5, S band for cross-correlation property.

Satellite number	In-band cross-correlation		S-band	
	Maximum	Minimum	Maximum	Minimum
1 and 2	0.0801	-0.0859	0.0791	-0.0791
1 and 3	0.0801	-0.0762	0.084	-0.084
1 and 4	0.0908	-0.0801	0.0742	-0.0742
1 and 5	0.0762	-0.0771	0.082	-0.082
1 and 6	0.0791	-0.0811	0.0732	-0.0732
1 and 7	0.082	-0.0869	0.0781	-0.0781
2 and 3	0.0898	0.0791	0.081	-0.083
2 and 4	0.0781	0.0732	0.0908	-0.0898
2 and 5	0.0762	0.082	0.0771	-0.0801
2 and 6	0.0869	0.0859	0.0781	-0.083
2 and 7	0.0811	0.0869	0.0752	-0.082
3 and 4	0.0771	0.0771	0.0859	-0.0811
3 and 5	0.0908	0.0742	0.0723	-0.0771
3 and 6	0.0752	0.0801	0.0801	-0.083
3 and 7	0.0762	0.0791	0.0791	-0.0781
4 and 5	0.0781	0.0811	0.0791	-0.0762
4 and 6	0.0771	0.0771	0.0791	-0.0811
4 and 7	0.0781	0.0811	0.084	-0.082
5 and 6	0.0801	0.085	0.0771	-0.085
5 and 7	0.0781	0.0752	0.0752	-0.082
6 and 7	0.084	0.0752	0.0771	-0.0771
Out of band cross-correlation				
Band and satellite number	Maximum	Minimum		
L5-band satellite 1 to all satellites of S-band	0.085 0.0742 0.0771 0.0801 0.082 0.0781 0.0713	-0.0791 -0.0742 -0.0781 -0.0811 -0.0791 -0.085 -0.083		
L5-band satellite 2 to all satellites of S-band	0.0771 0.085 0.0723 0.0801 0.0811 0.0859 0.0781	-0.0742 -0.0859 -0.0889 -0.0811 -0.0732 -0.0732 -0.0732		
L5-band satellite 3 to all satellites of S-band	0.0957 0.0723 0.0752 0.0752 0.0928 0.0713 0.0703	-0.083 -0.083 -0.0781 -0.083 -0.0791 -0.0771 -0.0762		
L5-band satellite 4 to all satellites of S-band	0.082 0.0801 0.0801 0.0879 0.0713 0.0723 0.0928	-0.0752 -0.0801 -0.0859 -0.0791 -0.084 -0.0781 -0.0947		
L5-band satellite 5 to all satellites of S-band	0.0821 0.0742 0.0801 0.085 0.0742 0.0801 0.085	-0.0801 -0.0791 -0.0791 -0.0781 -0.0752 -0.0791 -0.0781		
L5-band satellite 6 to all satellites of S-band	0.0791 0.0781 0.0713 0.0801 0.0781 0.0791 0.0781	-0.0801 -0.084 -0.0781 -0.0791 -0.0752 -0.0791 -0.084		
L5-band satellite 7 to all satellites of S-band	0.0771 0.0801 0.0791 0.0898 0.0752 0.0771 0.0801	-0.083 -0.0723 -0.0781 -0.0889 -0.084 -0.0723 -0.0762		

there are 1024 unique sequences of codes, just 513 codes are adjusted codes where the quantities of 1s and 0s vary by 1; the sequence of adjusted codes is acquired by appointing codes to specific satellites. In the wake of producing 1023 pseudo-random binary chips, the G1 and G2 generators will be reset to 1. On account of GPS, two distinct taps of the 10-bit G2 register are included in this manner, permitting the most extreme of 45 unique codes to be created. Generally utilized alternative methodologies are to reset a predefined introductory estimation of G2 register rather than 1s, or to incorporate a programmable delay that postpones G2 to reset until a predefined number of chips in the sequence have passed. The benefit of these routines is that they not just allow all the 1023 codes in the family that must be produced, they likewise make usage more straightforward and simpler.

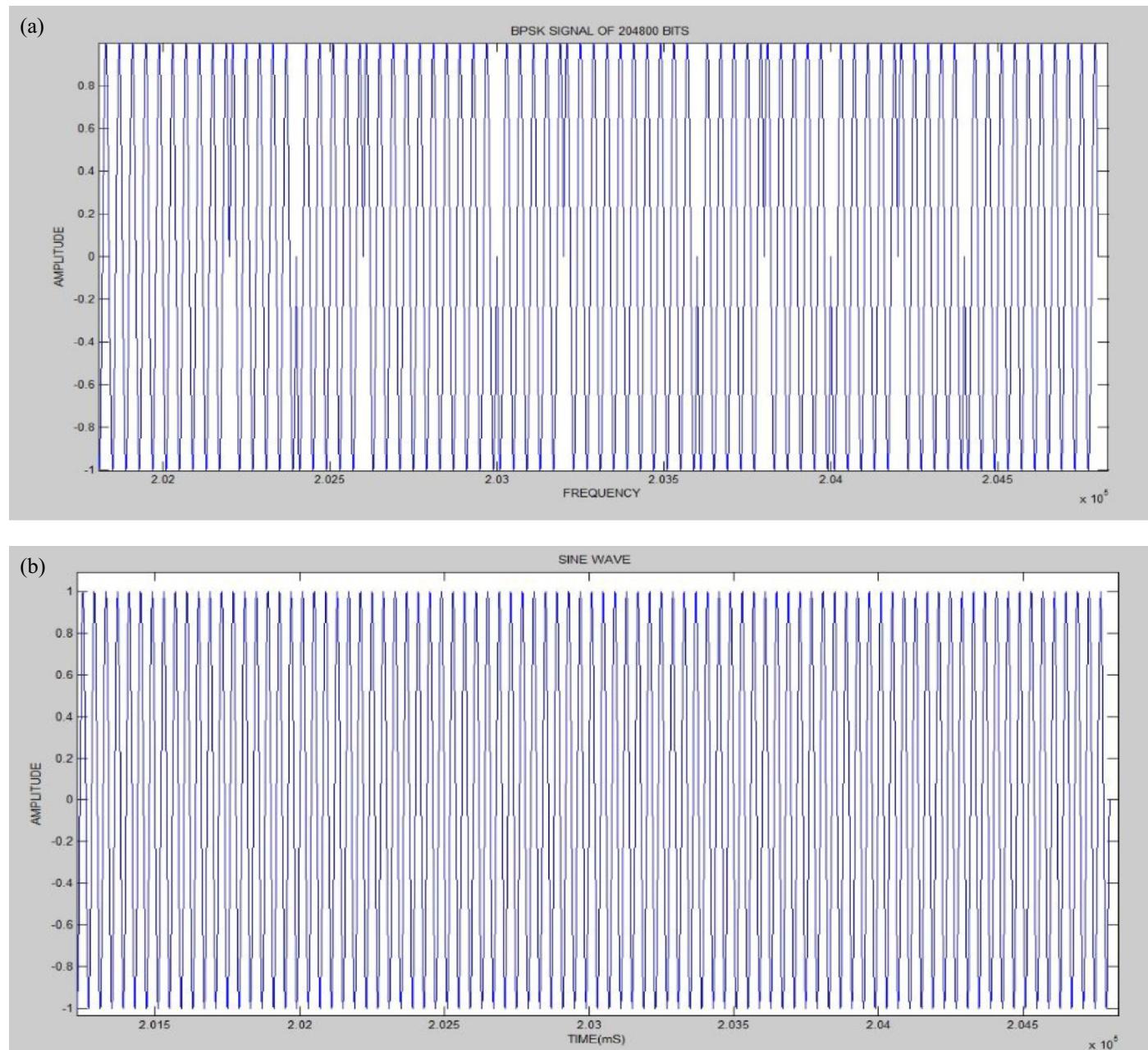
All the 7 satellites have mixed bag of code stage assignments to create the pseudo random noise codes [15]. The different properties

specified from the created PN sequence in Section 3 are performed and are confirmed. The balanced property is checked for all the seven satellites. The auto-correlation and cross-relationship qualities acquired for the created PRN code are spoken to with the waveforms produced.

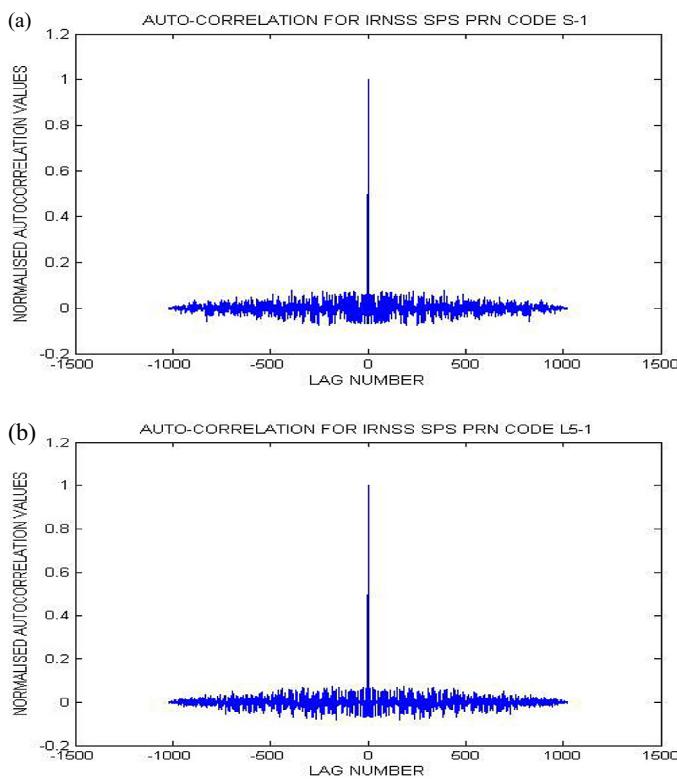
#### 4. Simulation results and analysis

Three distinct languages have been utilized to analyze the SPS PRN code waveforms [16], where MATLAB result demonstrates the produced BPSK waveform, Verilog result indicates 1024 SPS PRN binary waveform, and VHDL code is done to execute on a SPARTAN-II (pq208) FPGA unit.

The PRN code generation and examination has been done utilizing MATLAB and Xilinx ISE simulation. All MATLAB, VHDL and



**Fig. 2.** (a) BPSK Signal obtained for Satellite-1, L 5-Band; (b) 19-Mega hertz sine wave.



**Fig. 3.** (a) L5-Band, Satellite-1; (b) S-Band, Satellite-1.

Verilog codes have been utilized for the PRN code generation. The outcomes are given in the following figures.

**Fig. 2a** shows the obtained BPSK modulated signal by X-ORing the navigational data and the generated SPS PRN code, which is then multiplied by the carrier signal of 19 MHz, as shown in **Fig. 2b**, to obtain a CDMA signal.

**Fig. 3a and b** demonstrates the generation of 1023 chips of PRN code of auto-correlation property. It is clear from the figure that the auto-correlation peak is obtained at the definite chip rate in MATLAB Simulink software.

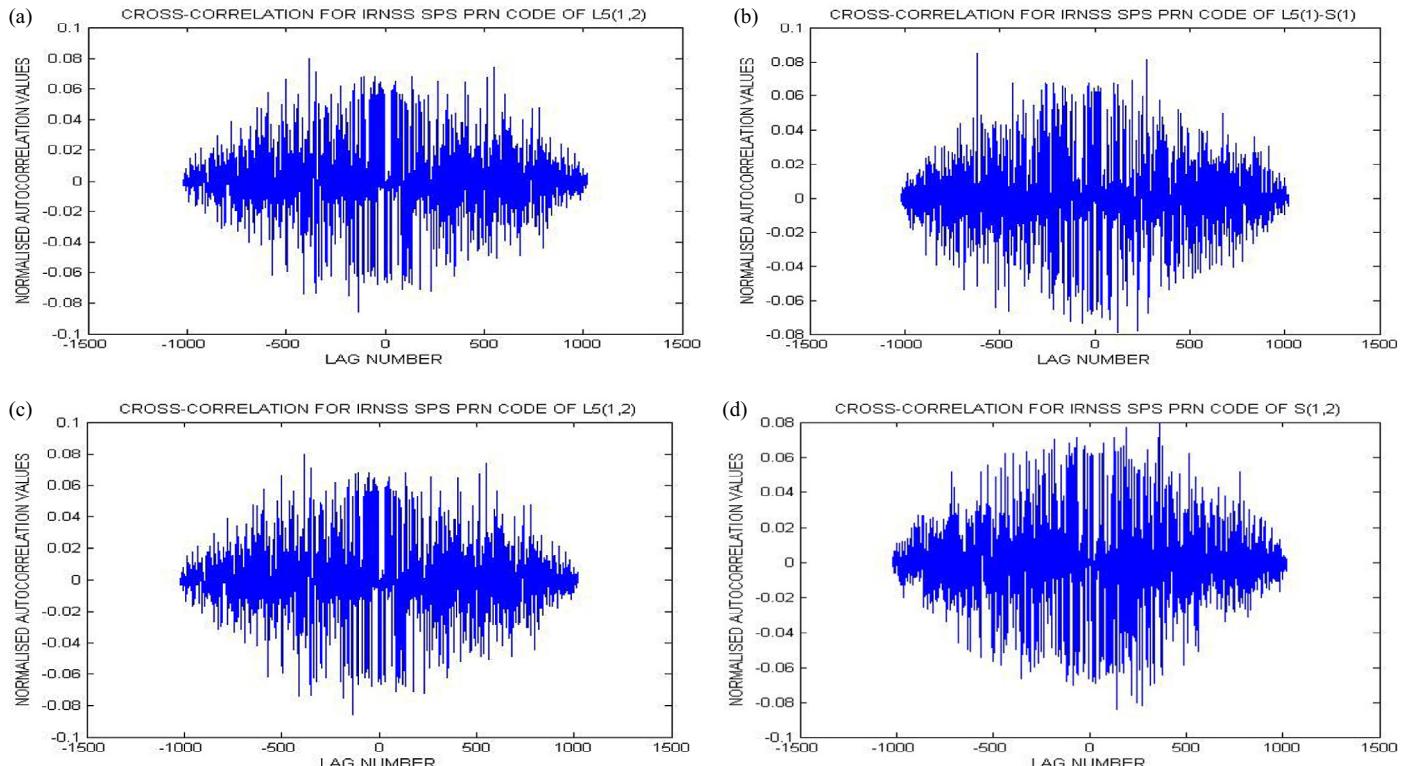
**Fig. 4a-d** shows the generation of two 1023 chips of PRN codes and their cross-correlation. From the definition, PRN codes are not finished orthogonal, but rather are semi-orthogonal. This component is plainly demonstrated in the cross-correlation plot, which demonstrates different peaks all through the chip range.

**Fig. 5** shows 1023 SPS PRN code of Satellite-1, L5-Band that is obtained by X-ORing the initial values of G1 and G2, respectively, in a shift register. These 1023 bits differ for the initial conditions of G2 shift registers depending on the satellite number and band.

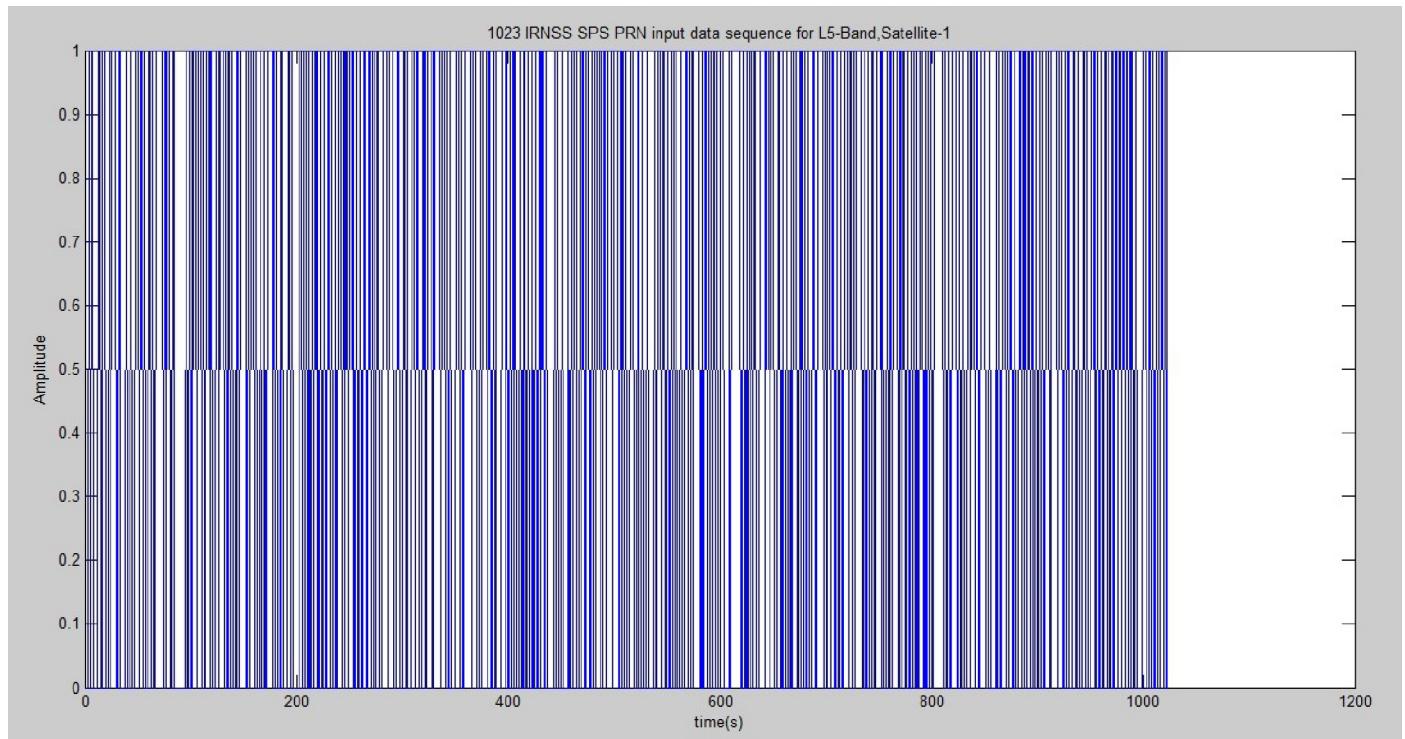
**Fig. 6** demonstrates the generation of PRN code for L5-Band, Satellite-1. In the diagram 'chip' shows the output waveform of 10 octal, which is then used for validating the generated data bits carried out in Xilinx ISE 9.1i environment by utilizing Verilog HDL. The output is obtained only when the respective count input is provided along with the reset input and clock input. Reset input is used as active high.

## 5. Hardware implementation results

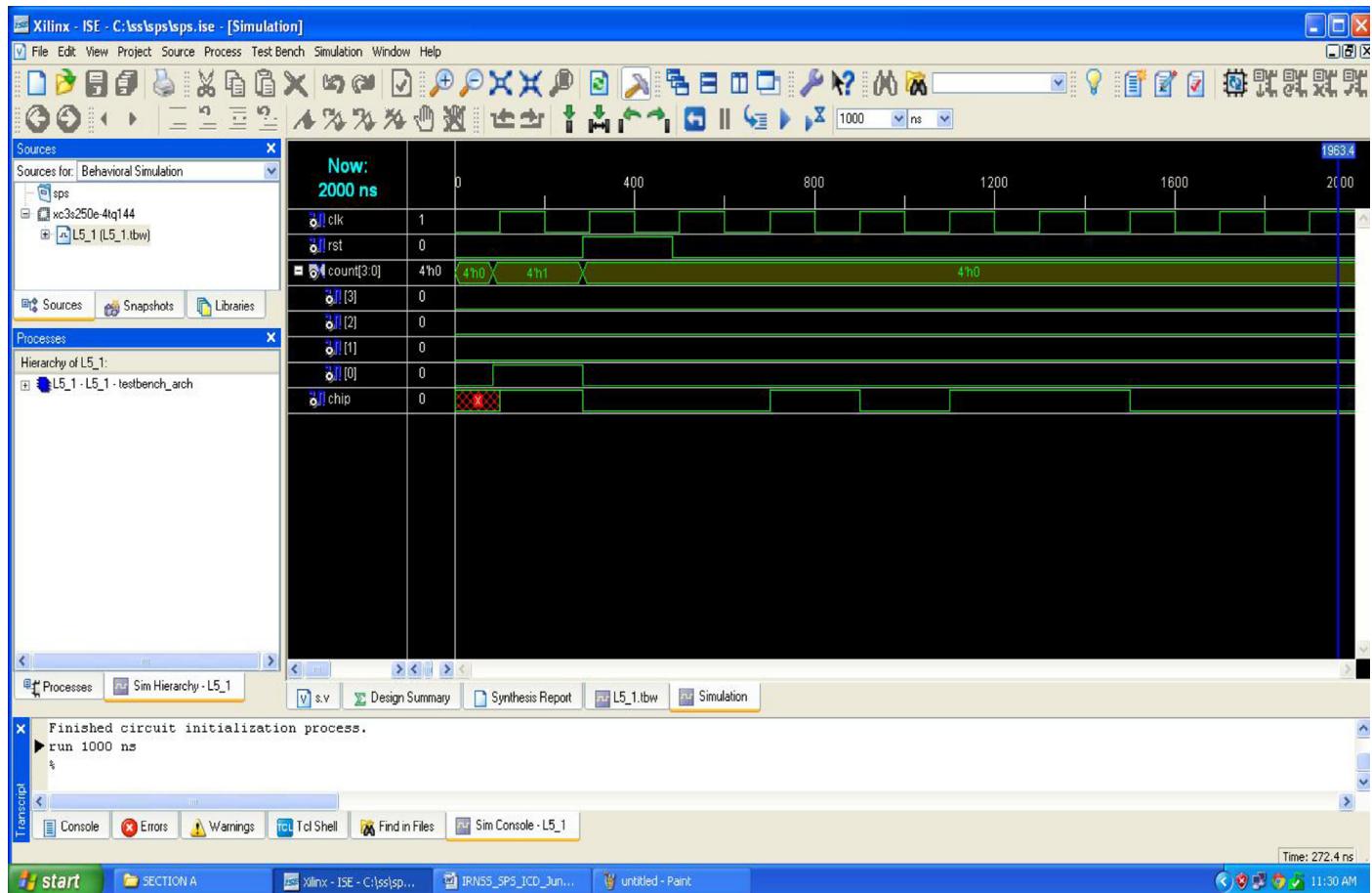
The Xilinx SPARTAN-II FPGA unit is utilized for PRN code generation as a part of the hardware equipment. **Fig. 7** demonstrates the zoomed perspective of Spartan-2 kit, which has been utilized for hardware execution as a part of this project.



**Fig. 4.** (a) L5 and S-BAND, Satellite-1; (b) L5-Band – Satellite-1 and S-Band – Satellite-2; (c) L5 BAND, Satellite-1 and Satellite-2; (d) S BAND Satellite-1 and Satellite-2.



**Fig. 5.** The obtained 1023 SPS PRN data sequence for L5-Band, Satellite-1.



**Fig. 6.** The generation of PRN code for L5-Band, Satellite-1.



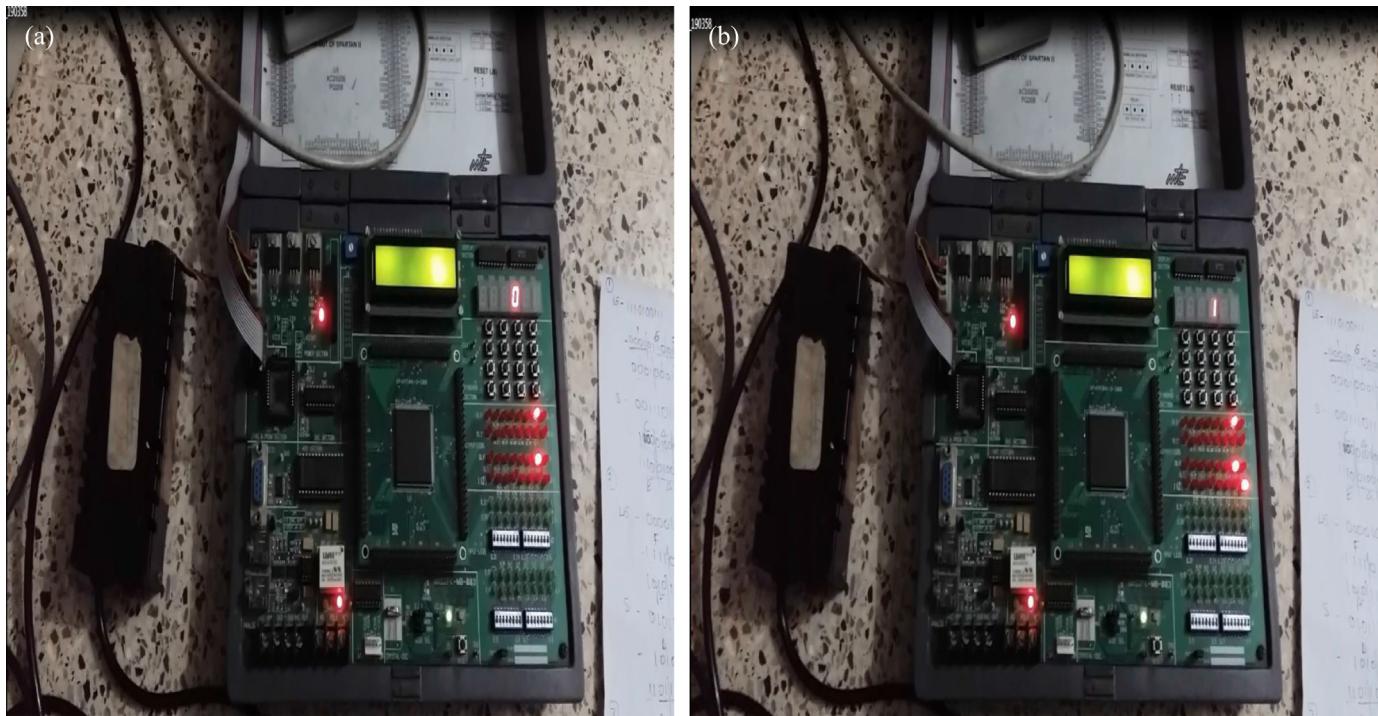
**Fig. 7.** Spartan-2 FPGA unit.

The clock is derived from the internal master clock of an FPGA kit. Out of 32 DIP switches on an FPGA kit, one push button is utilized as reset input (whenever the DIP is high the clock begins and the output on output LED pins can be seen). Out of 32 LEDs, LED-8 is utilized for showing the generated PRN data and LED-9 is utilized for showing the clock delay for every output change.

**Fig. 8** demonstrates the obvious, that programming document has succeeded. The vital User Constraint Files (UCF) were accessible from the user manual of the Spartan-2 FPGA unit. **Fig. 8** demonstrates the one process (generation of programming file) done to acquire the output on hardware equipment. **Fig. 9a and b** demonstrates the PRN code generation in FPGA kit.



**Fig. 8.** Result of programming document succeeded in PC.



**Fig. 9.** (a, b) Logic 1 and 0 output obtained respectively on hardware.

## 6. Conclusion

In this paper a study on generation and properties of Indian Regional Navigational Satellite System Standard positional Signal PRN codes is finished. The consequences of the investigated properties are demonstrated separately in every table that appeared in this paper. This paper introduces the outline and usage of PRN Code on MATLAB, Xilinx 9.1i, ISE Simulator and on Sparton-2 FPGA Hardware environments. Great results have been obtained for generation from hardware equipment as in practical application and are approved with the simulation results.

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