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GPS Signal Generation for L_1 Frequency using Model Based Design Tools

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Abstract: *The GPS signal is a combination of more than one signal. This paper deals with a model based design technique to implement GPS signal generator for L_1 frequency. It helps in proper understanding of GPS signal structure. SFF-SDR Lyrtech board has been used for this purpose. Once the proper results are obtained, the GPS signal can be down converted for further processing in the GPS receiver.*

Keyword: GPS, Signal Generator, Intermediate frequency.

I. INTRODUCTION

The GPS system is used to find the position of an object across the earth. Signals from a minimum of 4 satellites are required to find the position of an object. These are modulated signals consisting of carrier frequency, the navigation data and the coarse acquisition (C/A) code. Binary phase shift key (BPSK) modulation is used for this signal because BPSK is less susceptible to noise and therefore it helps in maintaining the correct information being passed through the communication channel [1]. Hardware implementation of GPS signal generator for L_1 band has been carried out using Xilinx system generator 9.2. This implementation is being tested on SFF-SDR Lyrtech model which consists of 3 layers. The bottom layer is the DSP layer where all the digital processing takes place. The middle layer is the ADAC MasterIII layer and it is used for analog to digital conversion and vice versa. ADC section of this layer is of 14 bit and can sample up to 125 MHz. Similarly we are using a dual 16 bit DAC that can transmit up to 500 MSPS (interpolated), with 2×, 4× and 8× interpolated filters [2]. The data transfer between FPGA (virtex-4SX35) and DSP is carried out by using TMS320 DM6446SoC Davinci processor. The results

generated are currently being checked for correctness and accuracy. This will lead to indigenous GPS signal generator for L_1 frequency.

II. GPS SIGNAL STRUCTURE

Basically there are two types of GPS signals: the C/A code and precision (P) code. The transmission of P code is not direct but a modified Y code. The P(Y) code is only for military usage. It is not used by the civilians[3]. GPS signals are transmitted by satellites in the radio frequencies (L_1 and L_2) in the ultra high frequency band (500MHZ and 3 GHZ). Common frequency f_o=10.23MHZ is used to derive the radio frequency band signals[3].

$$L1 = 1575.42 MHz = 154 \times 10.23\ MHz \qquad (1)$$

$$L2 = 1227.6 MHz = 120 \times 10.23 MHz \qquad (2)$$

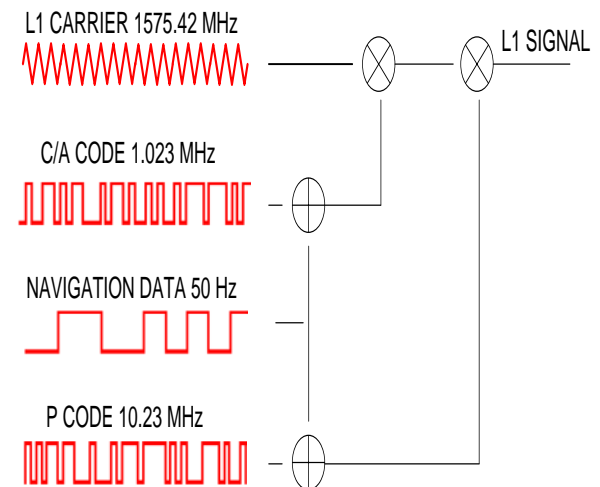We can see the various component signals in a GPS signal as shown in the figure 1 [4].

Fig.1. Various components of GPS Signal

If we observe the signal of a satellite say K, it is given as [5].

$$
\begin{aligned}
S^k(t) &= \sqrt{2Pc}\left(C^k(t) \otimes D^k(t)\right) cos(2\pi f L_1 t) \\
&+ \sqrt{2P_{PL1}}\left(P^k(t) \otimes D^k(t)\right) sin(2\pi f L_1 t) \\
&+ \sqrt{2P_{PL2}}\left(P^k(t) \otimes D^k(t)\right) sin(2\pi f L_2 t)
\end{aligned} \qquad (3)
$$

Where P_c, P_{PL1}, P_{PL2} = Powers of signal with C/A or P code,
C^k = C/A code sequence assigned to the satellite number k, P^k = P(Y) code sequence assigned to satellite number k, D^k = navigation data sequence, f_{L1} and f_{L2} = carrier frequencies of L_1 and L_2.
The C/A code repeats itself every ms and one navigation bit lasts 20ms. So for each navigation bit, the signal contains 20 complete C/A codes. In L_1 frequency, the C/A and P(Y) signals are in quadrant phase with each other [5]. The power levels of GPS signals are as shown [3].

Table 1. Power Level of GPS Signals

	P	C/A
L1	-133dBm	-130dBm
L2	-136dBm	-136dBm

III.GPS SIGNAL COMPONENTS

A) C/A CODE

The C/A code is one of the important components of the GPS signal. When a GPS receiver receives the signals from different satellites, in order to find out from which satellite the signal is coming the coarse acquisition code is used.
C/A codes are generated by two linear feedback shift registers (LFSR) which are driven by a clock of 1.023MHZ. LFSR generates a maximal length sequence of $N=2^n-1$ elements. Each of the LFSR contains 10 cells, which are initialized with a value of 1. A Gold code is modulo-2 of two maximum length sequences. The feedback is accomplished by using modulo2 adders. The two equations used for LFSRs are [5]:

$$
f(x) = 1 + x^3 + x^{10} \qquad (4)
$$

$$
f(x) = 1 + x^2 + x^3 + x^6 + x^8 + x^9 + x^{10} \qquad (5)
$$

Code phase selector is used for various combinations which give us the code phase of different satellites.
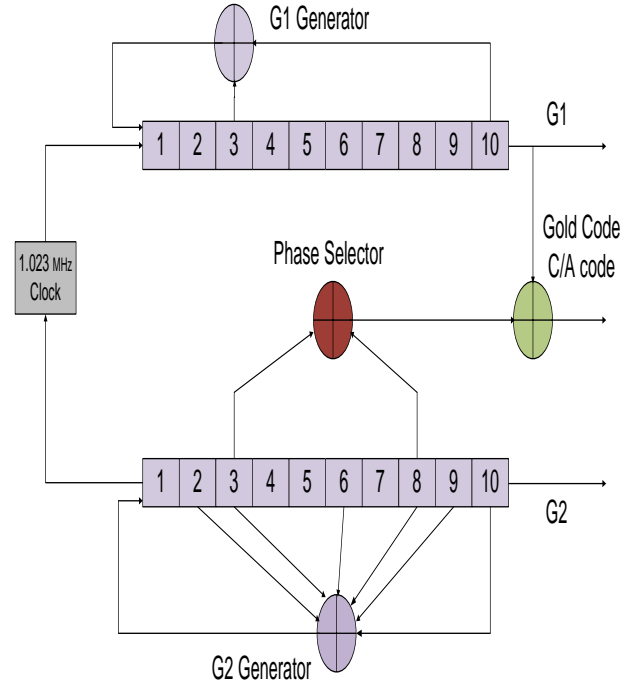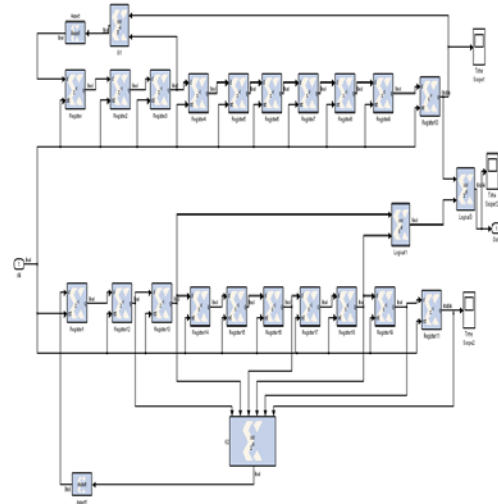

Fig.2.C/A code generator [5]

Fig.3. Logical diagram of Fig.2 in System Generator for C/A code generator implementation.

The above Fig.2 shows the GOLD CODE generator and Fig.3 shows logic or block diagram made by us using system generator 9.2.
In order to find out the signal coming from a particular satellite, the first 10 of 1023 chips are compared with the given set of values. If the matching is correct then signal is coming from that

particular satellite. The following table shows the various combinations of the code phases [5].

Table2. C/A Code Phase Assignment [5]

Satellite ID Number	GPS PRN Signal Number	Code Phase selection	Code Delay Chips	First 10 Chips Octal
1	1	$2 \oplus 6$	5	1440
2	2	$3 \oplus 7$	6	1620
3	3	$4 \oplus 8$	7	1710
4	4	$5 \oplus 9$	8	1744
5	5	$1 \oplus 9$	17	1133
6	6	$2 \oplus 10$	18	1455
7	7	$1 \oplus 8$	139	1131
8	8	$2 \oplus 9$	140	1454
9	9	$3 \oplus 10$	141	1626
10	10	$2 \oplus 3$	251	1504
11	11	$3 \oplus 4$	252	1642
12	12	$5 \oplus 6$	254	1750
13	13	$6 \oplus 7$	255	1764
14	14	$7 \oplus 8$	256	1772
15	15	$8 \oplus 9$	257	1775
16	16	$9 \oplus 10$	258	1776
17	17	$1 \oplus 4$	469	1156
18	18	$2 \oplus 5$	470	1467
19	19	$3 \oplus 6$	471	1633
20	20	$4 \oplus 7$	472	1715
21	21	$5 \oplus 8$	473	1746
22	22	$6 \oplus 9$	474	1763
23	23	$1 \oplus 3$	509	1063
24	24	$4 \oplus 6$	512	1706
25	25	$5 \oplus 7$	513	1743
26	26	$6 \oplus 8$	514	1761
27	27	$7 \oplus 9$	515	1770
28	28	$8 \oplus 10$	516	1774
28	28	$1 \oplus 6$	859	1127
30	30	$2 \oplus 7$	860	1453
31	31	$3 \oplus 8$	861	1625
32	32	$4 \oplus 9$	862	1712
-	33	$5 \oplus 10$	863	1745
-	34	$4 \oplus 10$	950	1713
-	35	$1 \oplus 7$	947	1134
-	36	$2 \oplus 8$	948	1456
-	37	$4 \oplus$	950	1713

B) DOPPLER FREQUENCY

Doppler frequency is the change in the observed frequency of a source due to the relative motion between the source and the receiver [6]. Since we are considering L_1 signal, the maximum Doppler frequency can be calculated as [3]:

$$fdr = \frac{fr*V_{dm}}{c} = 4.9kHz \qquad (6)$$

Where $f_r = 1575.42MHZ$

$$c = 3 \times 10^8 m/sec$$

And V_{dm} (maximum Doppler velocity) is given as[3] :

$$V_{dm} = \frac{(Vs \times r_e)}{r_s} \qquad (7)$$

$$= \frac{3874 \times 6368}{26560} = 929 m/sec$$

Where,

r_e = radius of earth

r_s = Average radius of the satellite orbit

V_s = velocity of the satellite which can be calculated as

$$Vs = r_s \left(\frac{d\emptyset}{dt} \right) \qquad (8)$$

$$= 26560 \times 1.458 \times 10^{-4} m/sec$$

Where

$$\frac{d\emptyset}{dt} = 2\pi / (11 \times 3600 + 58 \times 60 + 2.05)$$

$$\approx 1.458 \times 10^{-4} rad/sec \qquad (9)$$

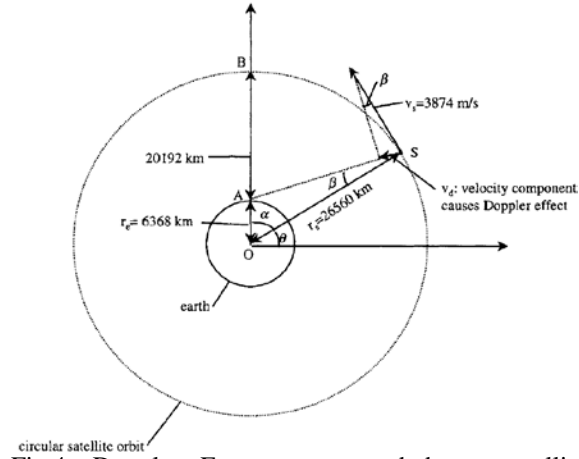The Doppler frequency can be calculated from the following figure4 [3].

Fig.4. Doppler Frequency caused by a satellite motion

So, for stationary object maximum Doppler frequency shift is ±5KHz, for moving object it is ±10KHz. For the C/A code the Doppler frequency is 3.2Hz which can be calculated as [3]:

$$f_{dc} = \frac{(f_c \times v_h)}{c} \qquad (10)$$

$$= \frac{1.023 \times 10^6 \times 929}{3 \times 10^8} \approx 3.2 Hz$$

For moving objects, the Doppler frequency shift for C/A code is 6.4Hz.

C) NAVIGATION DATA

The navigation data gives information about the satellite orbits. The navigation data bit is a bi-phase coded signal with a rate of 50 bps. The time taken for transfer of one navigation data is 20 ms while that for C/A is 1ms.So we can say that in one navigation data there are 20 C/A codes, all having same phase. The GPS data format is shown in figure5 [3].

The navigation data consists of 1500 bits divided in 5 sub frames. Each sub frame has 300 bits. Each sub frame is divided into 10 words of 30 bits each. The sub frames 1, 2 and 3 are same while sub frame 4 and 5 are different in data. One sub frame lasts 6 sec, so one frame lasts 30 seconds and one complete navigation message lasts 12.5 minutes.
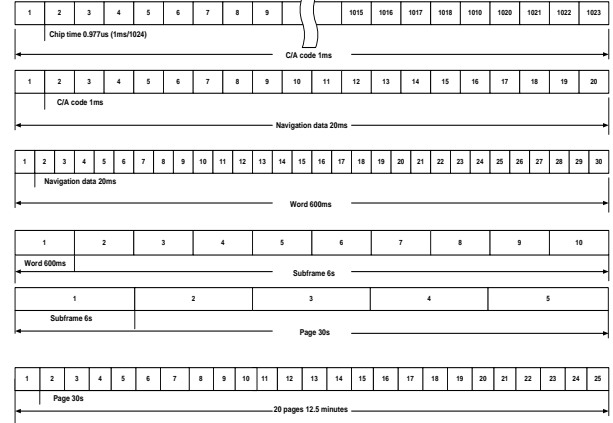

Fig.5. GPS Data Format

IV. MODEL DEVELOPED

We have tried to build signal generator for L1 frequency using Xilinx System Generator 9.2. The model for GPS signal L1 generator is as shown in figure 6. It includes the C/A code generator as an higher abstract block in the figure 6.
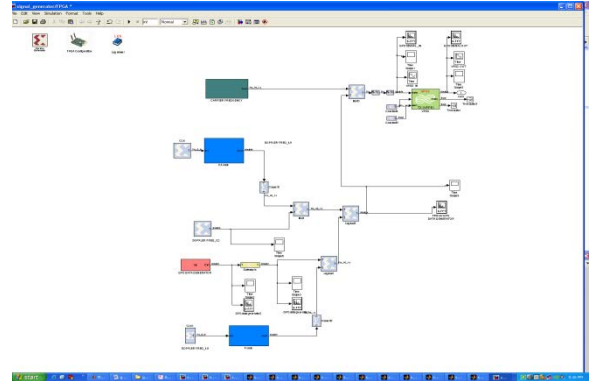

Fig.6. GPS Signal Generator

The entire model has been simulated in the simulink and system generator and implemented on the Lyrtech SFF-SDR board which is shown in figure 7.
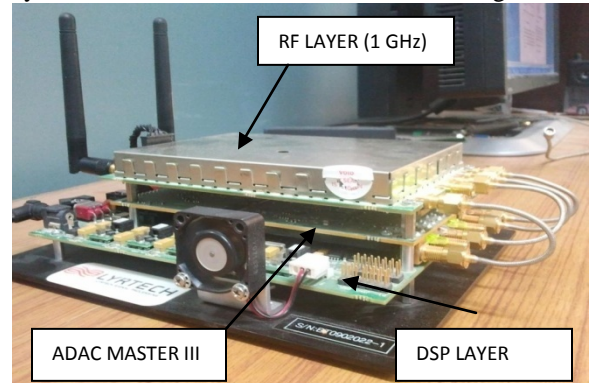

Fig.7. Lyrtech SFF-SDR board

V. RESULTS and FUTUREWORK

Currently the results of GPS signal generator are being verified by implementing them on the hardware (Lyrtech SFF-SDR board) and once accurate results are obtained, further filtering and down conversion of the signal to INTERMEDIATE FREQUENCY will be done as per specific requirement of the Lyrtech SFF-SDR board. The various signals of GPR receiver are shown in Fig. 8 to Fig. 10.

The carrier frequency generated and the output of the signal from the Lyrtech board is shown below in figure8.
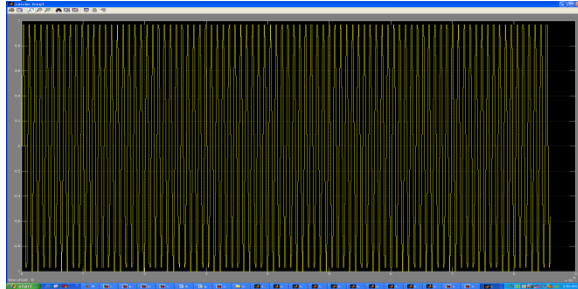

Fig. 8. Carrier Frequency

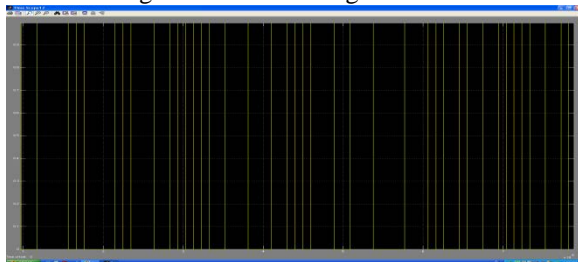The GOLD CODE generator output obtained from the block diagram is shown in figure 9.

Fig.9. Gold Code

The result for the final signal generator of GPS signal L1 which we obtained is shown in figure10. This is after the BPSK modulator.
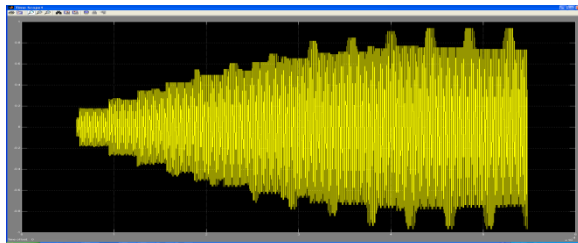

Fig.10. Final L1 GPS signal

We are currently verifying the results and once we obtain accurate results we will go for down conversion of the signal.

ACKNOWLEDGEMENT

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