# Study of the orthogonal codes on GPS signals detection.

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*Abstract*— **The process from which a GPS receiver determines its position involves a few stages. One of them implies identifying and tracking the visible satellites using a pseudo random code that identifies univocally the satellite. This process includes huge computing that results in high hardware requirements. Proposed here is a pseudo random number generation method in order to obtain the visible satellites reducing the computation needed on a conventional GPS receiver. The proposed method has been tested using the PRN of the 32 GPS constellation satellites proving that detection can be achieved using up to one-third of the computation needed on the traditional method and reducing the power consumption in the same scale.**

***GPS, PRN, detection, power saving, speed increase,***

## I. Introduction

The way a GPS receiver determines its position implies the following stages: first, the satellites that are visible by the receiver are identified and tracked. Then the delays between the satellite signals are calculated. And finally, when there are at least four identified and tracked satellites, the position of the receiver is computed following an iterative process. While calculate these delays and determine the position from them is a well known software matter, the first stage to discover and track the visible satellites implies a huge computing process resulting in high hardware requirements.

## II. Traditional Methodology

Each of the 32 GPS satellites is identified using a 1023 bits code called Gold Code [2]. The Gold Code is a pseudo random number (PRN) which is modulated in BPSK and transmitted continually by the satellite at 1,575.42 MHz every millisecond in order to be identified. As can be seen in Figure 1, these PRN codes are generated using two shift registers known as G1 and G2. These registers, which have 10 cells, generate two sequences of length 1023 which are modulo-2 added to generate a 1023 bit long code. Every 1023rd period, the shift registers are reset with ones, making the code start over. To make different codes for the different satellites, the output of both registers is combined in a specific manner. The G1 register always supplies its output, but the G2 register supplies two of its states to a modulo-2 adder to generate its output. This selection of states is named the phase selection and this selection determines which code will be generated.

The PRN main feature is that, the correlation with itself gives a very high value whereas the correlations among each others are poor. Using this feature a GPS receiver makes the correlation between the 32 PRN codes stored on its memory and the ones that is capable to receive on its location. Equation 1 presents the correlation function needed to detect a GPS satellite where satn is the satellite number, PRNsatn is the PRN of the satellite and Drx is the received data.

$$a_i = \sum_{j}^{1023} PRN^{satn}_{\mathrm{mod}_{1023}(i+j)} \oplus D^{rx}_i \qquad (1)$$

As each PRN is 1023 bits long, the correlation between two of them implies 1023 x 1023 binary XOR operations. This number must be multiplied by 32 as the receiver must check all the possible satellites. Furthermore, the Doppler effect must be also considered for the L1 carrier. The movement of the satellite and the receiver causes a shift on the received satellite frequency. GPS receivers use 1.0 ~ 3.0 MHz as Intermediate Frequency (IF) which can be shifted by the Doppler effect a maximum of ±10kHz. In order to ensure the receiver does not lose any visible satellite this Doppler frequency margin is scanned on bins of 500Hz. Considering this, the GPS receiver must search each satellite in 41 different frequencies adding some more complexity to the computing. As summary, the total number of XOR operations to determine all visible GPS satellites is 1.373.046.048.

## III. Proposed Methodology

In order to reduce this number, we focus on the fact that 1023 can be divided by 3 obtaining three 341 bit streams. These bit streams are formed by sampling the original PRNsat to a third of the frequency, which means that each 341 bit streams will contain one bit of every three from the original PRNsat sequence. Calling these new bit streams A, B and C, they will be filled as follows:

For a given PRNsat,

PRNsat = [a1, a2, a3, ..., a1023];

There will be three sequences:

A = [a1, a4, a7, …, a1021],

B = [a2, a5, a8, … , a1022],

C = [a3, a6, a9, …, a1023]

From these three sequences a new 341 bit stream can be calculated taking the predominant value of each of their bits, according to the truth table seen on Table 1. This sequence is a new pseudo random code (NPRNsat) which satisfies the same correlation properties of the original PRNsat, and thus can determine whether a certain satellite is present or not saving two thirds of the computation and power needed originally.

TABLE I. TRUTH TABLE TO CONSTITUTE THE NPRN CODES

| A | B | C | F |
|---|---|---|---|
| 0 | 0 | 0 | 0 |
| 0 | 0 | 1 | 0 |
| 0 | 1 | 0 | 0 |
| 0 | 1 | 1 | 1 |
| 1 | 0 | 0 | 0 |
| 1 | 0 | 1 | 1 |
| 1 | 1 | 0 | 1 |
| 1 | 1 | 1 | 1 |

Figure 1 presents the circuit generator for our proposed nPRNSatID. Basically, it is based in the traditional PRN code generator [1] and it includes only three logic gates and three D type flip flops.

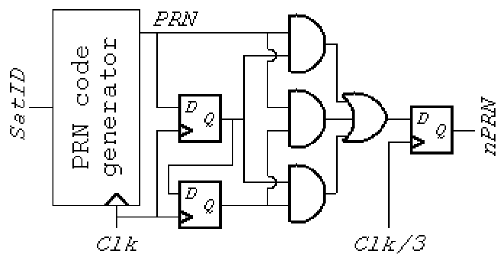


Figure 1. PRN code generator

## IV. RESULTS

Once all the $PRN_{SatID}$ codes are generated, the validity of them is proved. In this sense, the correctness of our proposal is ensured checking the cross–correlation and auto–correlation properties of all $nPRN_{SatID}$. A GPS receiver based in our solution observes $PRN^{A}_{SatID}$, $PRN^{B}_{SatID}$ or $PRN^{C}_{SatID}$ when satellite SatID is visible, the auto–correlation property produces a maximum peak value only when our $nPRN_{SatID}$ is correctly aligned with the observed PRN and noise when is not aligned. The cross–correlation property indicates that when the GPS receiver looks for a non–visible satellite, the receiver only obtains noise.

In the correlation process first, the number of zeros and ones is checked in order to prove there is no more than 60% of any of them on each $nPRN_{SatID}$. Then the number of correlative bits with the same value is checked and found that it is around 50% which is a correct average. Finally every $nPRN_{SatID}$ code generated is correlated with every A, B and C sequence in order to check that the original PRNsat codes correlation properties are still valid. Sure enough, the peak of magnitude appears only when the NPRN code is correlated with the A, B, or C vectors which come from the original PRNsat. Table II shows the maximum, minimum and average value of the peak for the detection case while on Table III the maximum and average noise values are presented for the case that the NPRNsat code is correlated with a bit stream which does not come from the original PRNsat - non detection case -. These results show the feasibility to apply this generation method to the satellite detection saving two-thirds of calculation and power.

TABLE II. MAXIMUM, AVERAGE AND MINIMUM VALUES FOR DETECTION CASES

| Minimum | Average | Maximum |
|---|---|---|
| 133 | 169 | 201 |

TABLE III. MAXIMUM AND AVERAGE VALUES FOR NON DETECTION CASES

| Maximum | Average |
|---|---|
| 67 | 9,782 |

## REFERENCES


[1] [1] "A software-defined GPS and GALILEO receiver", Borre, Akos, Bertelsen, Rinder, Jensen. Birkhäuser 2007.

[2] [2] Ramjee Prasad and Marina Ruggieri, "Applied Satellite Navigation Using GPS, GALILEO, and Augmentation Systems", Artech House Publishers, Apr. 2005