Lab Session 3: GNSS Spreading Codes

Laboratory on Generation and Analysis of GPS and Galileo Spreading Codes | **LAB BRIEFING**

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Generation of codes and correlations

Objective:

The goal of this lab session is the implementation of a **MATLAB library** (set of functions) able to generate the spreading codes and to prove their properties.

Notes:

- this lab consists of 5 incremental steps foreseeing few tasks each
- use the **+1/-1 convention** to represent spreading codes: XOR $\bigoplus \rightarrow$ AND $\cdot$
- consider both **GPS L1 C/A** and **Galileo E1b** signals

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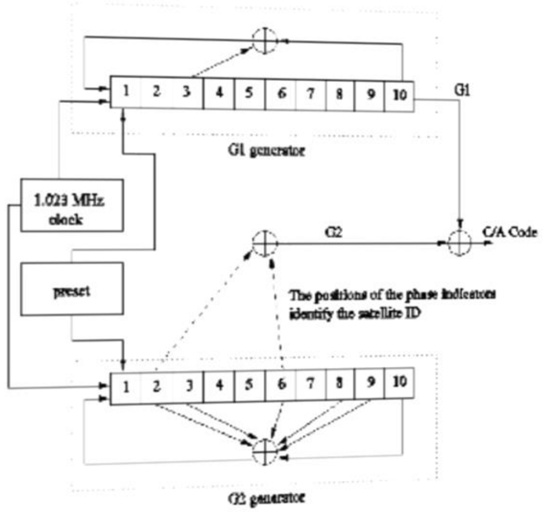
Theory recall… GPS Signal In Space (SIS)

GPS C/A code generation

- Two sequences generate all the C/A codes for the satellites
  - **G1**: $1 + x^3 + x^{10}$
  - **G2**: $1 + x^2 + x^3 + x^6 + x^8 + x^9 + x^{10}$
- Each satellite is characterised by a different shifted version of G2
- The delay effect of the G2 output is obtained by ex-or of selected positions of two taps,
- This is possible thanks to the properties of the m-sequences that the sum of a sequence and of a shifted one is another shift of the same sequence

C/A Code generation



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GPS SVs spreading codes

Satellite ID	PRN Code	Phase Selector
1	1	2 – 6
2	2	3 – 7
3	3	4 – 8
4	4	5 – 9
5	5	1 – 9
6	6	2 – 10
7	7	1 – 8
8	8	2 – 9
9	9	3 – 10
10	10	2 – 3
11	11	3 – 4
12	12	5 – 6

Satellite ID	PRN Code	Phase Selector
13	13	6 – 7
14	14	7 – 8
15	15	8 – 9
16	16	9 – 10
17	17	1 – 4
18	18	2 – 5
19	19	3 – 6
20	20	4 – 7
21	21	5 – 8
22	22	6 – 9
23	23	1 – 3
24	24	4 – 6

Satellite ID	PRN Code	Phase Selector
25	25	5 – 7
26	26	6 – 8
27	27	7 – 9
28	28	8 – 10
29	29	1 – 6
30	30	2 – 7
31	31	3 – 8
32	32	4 – 9
-	33	5 – 10
-	34	4 – 10
-	35	1 – 7
-	36	2 – 8

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Step 1: generation of GPS codes

TASK 1

Write a Matlab function able to generate the chips of the 32 **Gold sequences** used by GPS L1 C/A signals.

notes:

- $m = 10$ for GPS L1 C/A gold codes;
- Initial state is "all -1s".

TASK 2

Verify that each sequence is $p = 2^m - 1$ chips long and that it contains $2^{m-1} - 1$ {+1s} and 2^{m-1} {-1s}.

TASK 3

Check that the codes are correct, by comparing your results with the codes reported in the GPS ICD. In TABLE 3-IA (pages 6-7), the first 10 Chips of each C/A code are reported in Octal format.

Note:
The GPS **Interface Control Document** (ICD), can be download from: https://www.gps.gov/technical/icwg
Table 3-Ia. Code Phase Assignments from **IS-GPS-200**

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Step 2: GPS codes properties

TASK 1

Compute and plot the **normalized linear and circular auto-correlation** of one of the codes generated at **Step 1**.
Hint: for the linear auto-correlation consider a non-zero delay to better observe the peak .

TASK 2

Verify that **circular auto-correlation** assumes the following values:

$$\left\{1, -\frac{1}{p}, \frac{-\beta(m)}{p}, \frac{\beta(m)-2}{p}\right\} \text{ with } \beta(m) = 1 + 2^{\left\lfloor\frac{m+2}{2}\right\rfloor}.$$

TASK 3

Compute and plot the **normalized linear and circular cross-correlation** between two different codes generated at **Step 1**.

TASK 4

Verify that **circular cross-correlation** assumes the following values:

$$\left\{-\frac{1}{p}, \frac{-\beta(m)}{p}, \frac{\beta(m)-2}{p}\right\}$$

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Step 3: generation of Galileo codes

TASK 1

Download and load the **Galileo E1b** memory codes (file on the portal `GalileoCodes.mat`).

TASK 2

Plot the **linear** and **circular** **auto-correlation** and **cross correlation** functions as in **Step 2**.

TASK 3

Compute the ratio in dB between the maximum amplitude of the **cross correlation** auto-correlation function and its highest side peak (absolute value), for GPS L1 C/A and Galileo E1b codes and comment the results.

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Step 4: generation of the code local replica

In order to correctly perform correlations, a GNSS receiver must generate a local replica of the code, sampled at the sampling frequency of the front-end.

TASK 1

Write a Matlab function able to resample the despreading codes generated at **Steps 1 and 3**, for a desired GPS and Galileo satellite, declared as follows:

```
function codeOut = generateLocalCode(codeIn, samplingFreq, chipRate)
```

where:

- `codeIn` is an array containing a period of one of the despreading codes, as generated in **Steps 1 and 3** (sampled at one sample per chip);
- `samplingFreq` is the sampling frequency of the RF front-end (in Hz);
- `chipRate` is the rate of the despreading code chips (in Hz);
- `codeOut` is the generated code to be used for signals correlation.

Step 4: generation of the code local replica

How many samples per chip are generated?

How long is the code in samples?

How long is the code in seconds?

How long is the code in chips?

In the case of Galileo, generate the BOC(1, 1) modulation by adding the subcarrier.

Consider the following parameters:

- sampling frequency: 16.368 MHz
- chip rate: 1.023 MHz

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Step 5: codes in time and frequency

TASK 1

Plot the generated codes in **time and frequency domain** (use the pwelch function) and comment the results obtained.

TASK 2

Compare in the same figure the GPS and the Galileo BOC(1,1) codes spectra and comment the results.

TASK 3

Compare in the same figure the **circular auto-correlation** of **one code period** for GPS and Galileo BOC(1,1) codes.
Hint: observe the behaviour in one code chip around the maximum peak.

Do not forget to properly set the axes labels and units in your plots!

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