The Impact of the Galileo Signal in Space in the Acquisition System

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Abstract. This paper is about the impact of the Galileo signal in space on the Acquisition system of a GNSS receiver. The Galileo signal definition presents features allowing improvements of the acquisition and tracking performance, but these differences with respect to GPS must be taken into account in the receiver design phase. In this paper the classical acquisition blocks designed for GPS will be revisited, from a statistical point of view and in terms of performance, looking to the issues that longer codes, BOC modulations and pilot channels will introduce on the Galileo Open Service (OS).

1 Introduction

The first stage of a GNSS (Global Navigation Satellite System) receiver consists in the acquisition of the satellites in view, and in a first rough estimation of the parameters of the Signal-In-Space (SIS) transmitted by each detected satellite. This activity is performed by the so-called acquisition block, which is a system that implements some well-known results of the estimation theory, by using typical signal processing operations, such as correlation, FFT, and filtering. With the advent of the European Galileo system, some modifications in the acquisition stage have to be adopted in order to account the new characteristics of the Galileo Signal in Space (SIS). The main factors which lead to different strategies for the acquisition of the Galileo SIS: are the use of the sub-carrier BOC(1,1), the presence of the secondary code in the pilot channel and the increased rate in the data channel. These new features have been added in order to guarantee interoperability between the new Galileo and the GPS systems and better performance for indoor positioning. However some additional impairments, from the architectural point of view and in terms of performance, in the case of standard localization, have to be paid.

In this paper the typical acquisition blocks used in GPS receivers are described from a statistical signal processing point of view, in order to emphasize the impact of the Galileo SIS format on the different stages of the acquisition operations. Furthermore some modifications to be adopted in order to acquire the Galileo signals are proposed. Since the main task of the paper is to stress the main differences between GPS and Galileo, only the Open Service (OS) case will be considered. The extension to the other cases is in some cases straight forward, in some cases more complex. The main focus of the paper is on the acquisition strategies based on block processing techniques [2], that is the techniques which process simultaneously a block of L samples, as for example the FFT. In fact the presence of the secondary codes in the Galileo SIS impacts on the acquisition methods based on block processing much more than on the methods based on a sample-by-sample processing. The paper analyzes the architectural modifications that have to be implemented in the acquisition block, the additional computational load and the acquisition performance in terms of Receiver Operative Characteristics (ROC's).

The paper is organized as follows: in Section 2 a general model of GNSS signals is exposed; Section 3 provides a theoretical framework for the description of a general acquisition system; in Section 4 the modifications required by the Galileo SIS are discussed whereas in Section 5 some simulations are reported as support for the theoretical results developed in the paper. At the end some conclusions are drawn.

2 Signal Model

The signal at the input of both Galileo and GPS acquisition blocks, in one-path additive Gaussian noise environment, without data modulation, can be modeled as

$$y[n] = \sum_{i=1}^{N_s} r_i[n] + \eta[n] \tag{1}$$

that is the sum of N_s GNSS signals coming from different satellites and $\eta[n]$, the additive Gaussian noise with flat power spectral density (PSD) $N_0/2$ over the receiver band B_r and with power $\sigma_\eta^2 = \mathrm{N_0B_r}$.

Every useful GNSS signal is of the form

$$r_i[n] = A_{IN,i}\, d(nT_s - \tau_i)\, c_i(nT_s - \tau_i)\, s_b(nT_s - \tau_i) \cos(2\pi (f_{IF} + f_{d,i}) nT_s + \theta_i) \tag{2}$$

where

- $A_{IN,i}$ is the amplitude of the ith GNSS signal, whose power is given by $C_i = \mathrm{A}^2_{IN,i}/2$;
- $c_i\,(nT_s - \tau_i)$ is the ith primary spreading code (assumed to be binary) delayed by τ_i and sampled at $f_s = \frac{1}{T_s}$; in the following the dependence from the sampling interval T_s will be omitted and the primary code will be indicated by $c_i\,[n]$;
- $d(nT_s - \tau_i)$ is the secondary spreading code for the Galileo pilot channel and Data in the GPS case;
- $s_b\,(nT_s - \tau_i)$ is the subcarrier, BPSK for GPS and BOC(1,1) for Galileo[1];
- f_{IF} is the intermediate frequency of the receiver;
- $f_{d,i}$ is the unknown Doppler frequency;
- θ_i is the phase of the ith received carrier.

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[1] Galileo code chips are further modulated by a squared sub–carrier, in this paper it is commonly referred as slot the width of the sub–carrier chip

Thanks to code orthogonality the different GNSS codes are analyzed separately by the acquisition block, thus the case of $N_s = 1$ is considered and the dependence from the index i is omitted in the rest of the paper.

3 Acquisition Concepts

The first operation performed by a GNSS receiver is the signal acquisition that decides either the presence or the absence of the satellite under test and provides a rough estimation of the code delay and of the Doppler frequency of the incoming signal. The acquisition system implements some well-known results of the detection and of the estimation theory and different logical and functional blocks take part in the process. In the GNSS literature the exact role of these disciplines and of these functional blocks is sometimes unclear. In this section a general acquisition system is described as the interaction of four functional blocks that perform four different logical operations. The framework developed by using these four elements allows to describe the majority of the acquisition systems, providing an effective tool for comparative analysis. All the acquisition systems for GNSS applications described in literature [1], [3], [4] are based on the evaluation and processing of the Cross Ambiguity Function (CAF) that in the discrete time domain can be defined as

$$R_{y,c}(\bar{\tau}, \bar{f}_d) = \sum_{n=0}^{L-1} y[n]\, c(nT_s - \bar{\tau})\, s_b(nT_s - \bar{\tau})\, \mathrm{e}^{j2\pi(f_{IF} + \bar{f}_d)nT_s} \quad (3)$$

Ideally the CAF envelope should present a sharp peak in correspondence of the value of $\bar{\tau}$ and $\bar{f}_d$ matching the delay and the Doppler frequency of the SIS. However the phase of the incoming signal, the noise and other impairments can ruin the readability of the CAF and further processing is needed. For instance, in a non-coherent acquisition block only the envelope of the CAF is considered, avoiding the phase dependence. Moreover coherent and non-coherent integrations can be employed in order to reduce the noise impact.

When the envelope of the averaged CAF is evaluated the system can take the decision on the presence of the satellite. Different detection strategies can be employed for the decision: some strategies require only the partial knowledge of the CAF implying an interaction among the acquisition elements. The detection can be bettered by using multitrial techniques that require the use of CAF's evaluated on subsequent portions of the incoming signal.

In Fig. 1 the general scheme of an acquisition system is reported highlighting the presence of the four blocks

- CAF evaluation;
- Envelope and Average;
- Detector;
- Multitrial;

and of their possible interactions.

In the following these four blocks are discussed, with particular emphasis to the first two that are the more affected by the new Galileo SIS's.

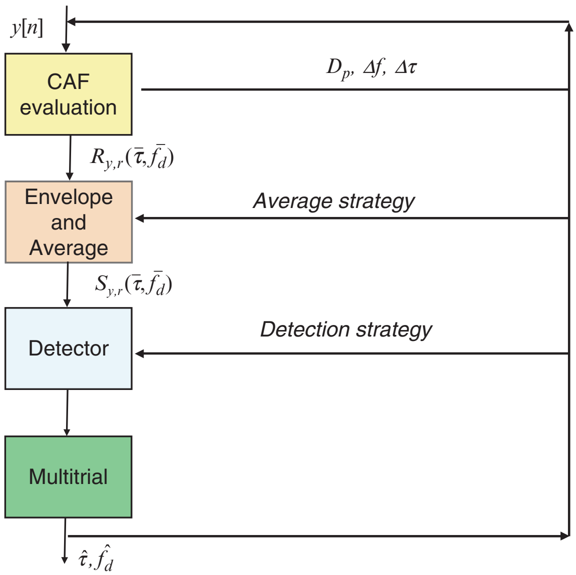

Fig. 1. Functional blocks of an acquisition system.

3.1 CAF Evaluation

In the acquisition systems described in literature different methods of evaluating the CAF are presented. They give the same (or approximately the same) results and the choice of the method mainly depends on the hardware and software tools available for the receiver implementation. The local generation of the test signal

$$\bar{r}[n] = c(nT_s - \bar{\tau})\, s_b(nT_s - \bar{\tau})\, e^{j2\pi(f_{IF} + \bar{f}_d)nT_s}$$

can be done in different ways. It is important to notice that the part of the test signal containing the code and the subcarrier, that is $c(nT_s - \bar{\tau})s_b(nT_s - \bar{\tau})$, can be obtained starting from a local code (including the subcarrier) of the type

$$c_{Loc}[n] = c(nT_s)\, s_b(nT_s)$$

with $n \in (0, L-1)$ and by applying a circular delay to the samples of $c_{Loc}[n]$. This is possible when the periodicity of the incoming code is a submultiple of the integration time L. In the actual implementation this circular delay should be done also taking into account the problem of the incommensurability constraint on the sampling frequency [6]. In fact this constraint alters the perfect periodicity of the samples of the incoming code $c(t)$, allowing the Delay Lock Loop (DLL) to work properly even if the number of samples per chip is very low. On the contrary the effect of the incommensurability on the detection and estimation operations of the acquisition block is slightly disturbing. In practice this effect is negligible since the purpose of the acquisition block is to perform only a rough estimation of the delay and Doppler frequency.

A macro classification of classical acquisition methods can be done as it follows.

- **Method 1: Serial scheme.** In this scheme a new CAF is evaluated at each n instant. The input vector **y** can be updated instant by instant by adding a new input value and by discarding the former one. To avoid ambiguity, in this case the notation $\mathbf{y}_n = [y(n)\ y(n-1) \ldots y(n-L+1)]$ will be adopted. With this approach the delay $\bar{\tau}$ moves throughout the vector $\mathbf{y}_n$ at each new instant. Therefore the local code c_{Loc} $[n]$ is always the same and the CAF is given by the expression

$$R_{y,r}(\bar{\tau}, \bar{f}_d) = \sum_{m=0}^{L-1} y[\bar{\tau} - L + m + 1]\, c(mT_s)\, s_b(mT_s)\, e^{j2\pi(f_{IF} + \bar{f}_d)mT_s} \tag{4}$$

It is quite easy to verify that this approach is equivalent to move the delay of $c_{Loc}[n]$, as the mutual delay between $c_{Loc}[n]$ and the received code is the unknown of interest. In Fig. 2 the serial scheme is reported, each value of the CAF is evaluated independently without using any block strategy. The term F_D indicates the quantity $(f_{IF} + \bar{f}_d)\,T_s$.

- **Method 2: FFT in the time domain.** In this scheme the vector **y** is extracted by the incoming SIS and multiplied by $e^{j2\pi(f_{IF} + \bar{f}_d)nT_s}$, so obtaining a sequence

$$ql[n] = y[n]\, e^{j2\pi(f_{IF} + \bar{f}_d)nT_s} \tag{5}$$

for each frequency bin. At this point the term

$$R_{y,r}(\bar{\tau}, \bar{f}_d) = \sum_{n=0}^{L-1} ql[n]\, c(nT_s - \bar{\tau})\, s_b(nT_s - \bar{\tau}) \tag{6}$$

assumes the form of a Cross-Correlation Function (CCF), which can be evaluated by means of a circular cross-correlation defined by

$$\tilde{R}_{y,r}(\bar{\tau}, \bar{f}_d) = \mathrm{IDFT}\,\{\mathrm{DFT}[ql[n]]\,\mathrm{DFT}[c(nT_s)\, s_b(nT_s)]^*\} \tag{7}$$

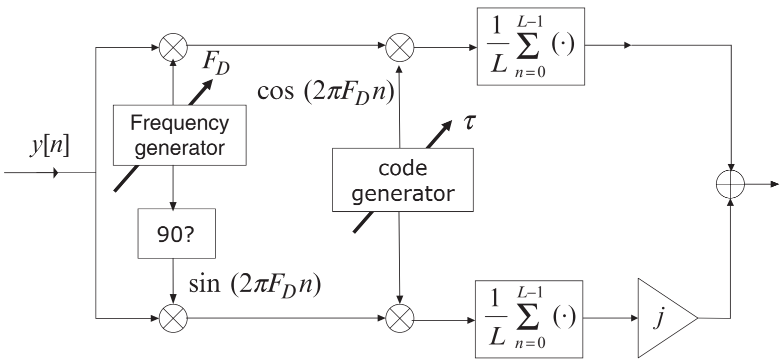

Fig. 2. The serial acquisition scheme: the CAF is evaluated independently for each value of $\bar{\tau}$ and $\bar{f}_d$.

where DFT and IDFT stand for the well-known Discrete Fourier Transform and Inverse Discrete Fourier Transform. It is easy to show that the CCF and the circular CCF coincide only in presence of periodic sequences. This is the case when $\bar{f}_d = f_d$, except for the noise contribution and a residual term due to a double frequency ($2f_d$) component contained in the term $ql[n]$. In the other frequency bins the presence of a sinusoidal component could alter the periodicity of the sequence. The proof of this is out of the scope of this paper.

– **Method 3: FFT in the Doppler domain.** In this scheme (Fig. 3) a vector y can be extracted by the incoming SIS instant by instant, as in the method 1, and multiplied by $c_{Loc}[n]$ so obtaining a sequence

$$q_i[m] = y[\bar{\tau} - L + 1 + m]\, c_{Loc}[m] \tag{8}$$

for each delay bin. A similar result can be obtained by extracting an input vector y every L samples, and multiplying it by a delayed version of the local code $c_{Loc}[n]$. As mentioned before, this delay is obtained by applying a circular shift to the samples of $c_{Loc}[n]$. At this point the term

$$R_{y,r}(\bar{\tau}, \bar{f}_d) = \sum_{m=0}^{L-1} q_i[m]\, \mathrm{e}^{j2\pi(f_{IF} + \bar{f}_d) m T_s} \tag{9}$$

assumes the form of an inverse Discrete-Time Fourier Transform (DTFT). It is well known that a DTFT can be evaluated by using a Fast Fourier Transform (FFT) if the normalized frequency $(f_{IF} + \bar{f}_d)\,\mathrm{T_s}$ is discretized with a frequency interval

$$\Delta f = \frac{1}{L}$$

in the frequency range (0, 1), which corresponds to the analog frequency range $(0, f_s)$. The evaluated frequency points become

$$\bar{f}_d T_s = \frac{l}{L} - f_{IF} T_s$$

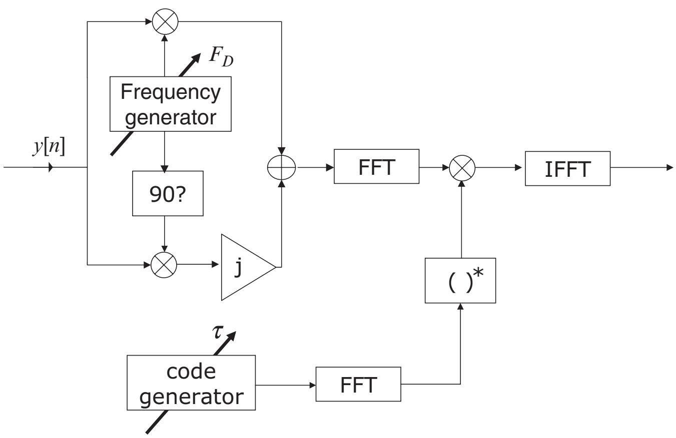

Fig. 3. The time parallel acquisition scheme: the CAF is determined by using a circular convolution employing efficient FFT's.

and the CAF can be written as

$$R_{y,r}(\bar{\tau}, \bar{f}_d) = \sum_{m=0}^{L-1} q_i[m]\, e^{j\frac{2\pi}{L}lm} \tag{10}$$

With this method the support of the search space along the frequency axis and the frequency bin size depend on the sampling frequency f_s and on the integration time L. If the same support and bin size used in methods 1 and 2 have to be used, the integration time has to be changed, and some decimation (with pre-filter) has to be adopted before applying the FFT. This modifies the input signal to be processed and the comparison among the methods will be affected by the signal modifications. Notice that the maximum peak loss in the Doppler frequency domain is not any more a free parameter with this method, since it is ruled by the FFT constraints, as it is shown in [2, 5]. If it is necessary to mitigate this effect some zero padding techniques can be used, at the expenses of some interpolation loss. In Fig. 4 the frequency domain acquisition block is reported. An integrate and dump block followed by a decimation unit is inserted in order to reduce the number of samples on which the FFT is evaluated. This operation reduces the computational load but introduces a loss in the CAF quality [2, 5].

3.2 Envelope and Average

After the CAF is evaluated, the acquisition system has to remove dependence on the input signal phase and to apply some noise reduction techniques. In Fig. 5 three different methodologies are reported. The phase dependence is removed by considering the CAF envelope. If different CAFs are averaged before evaluating the envelope, **coherent integrations** are employed. This kind of integrations provide the best performance in terms of noise variance reduction. In fact before the envelope the noise terms are zero mean gaussian random variables and the coherent integrations average elements that can be either positive or negative. If the average is performed after the squared envelope (Fig. 5, part b), **non-coherent integrations** are used. In this case non-negative random variables are averaged together thus a residual term, due to the noise, still remains. In [5] a deep analysis of the impact of the use of coherent and non-coherent integrations is provided. It is highlighted that the use of coherent integrations impact the Doppler frequency resolution and a greater number of Doppler bin is required for having a constant error on the determination of the Doppler frequency [5]. Thus the required computational load is greater than the one of the non-coherent integrations.

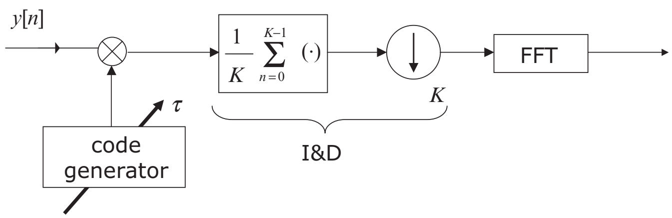

Fig. 4. The frequency parallel acquisition scheme: the CAF is evaluated by using efficient FFT.

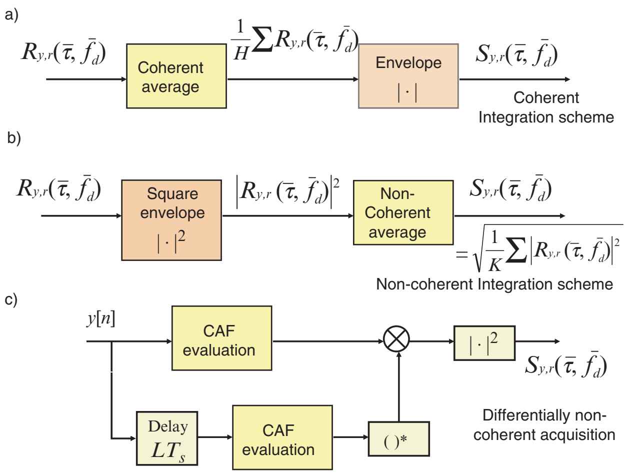

Fig. 5. Different "envelop and average" scheme.

The output of the "envelope and average" block is indicated by

$$S_{y,r}(\bar{\tau}, \bar{f}_d)$$

and two indicators of the system performance are the cell false alarm and detection probabilities associated to $S_{y,r}(\bar{\tau}, \bar{f}_d)$. Each value of $\bar{\tau}$ and of $\bar{f}_d$ defines a cell and the probability that $S_{y,r}(\bar{\tau}, \bar{f}_d)$ is greater than a fixed threshold defines

– the **false alarm probability** if $\bar{\tau}$ or $\bar{f}_d$ do not match the SIS's ones;
– the **detection probability** if the code delay and the Doppler frequency are matched.

When coherent and non-coherent integrations are used the false alarm and detection probabilities assume the following expressions:

$$P_{fa}(V_t) = \exp - \left\{ \frac{V_t^2}{2\sigma^2} \right\} \sum_{i=0}^{K-1} \frac{1}{i!} \left(\frac{V_t^2}{2\sigma^2} \right)^i$$

$$P_{det}(V_t) = Q_K \left(\frac{\sqrt{K}\,\alpha}{\sigma}, \frac{V_t}{\sigma} \right) \tag{11}$$

where V_t is the threshold, $\alpha = \frac{A_{IN}}{2}, \sigma^2 = \frac{\sigma_n^2}{2LH}$, H is the number of coherent integrations, and K the number of non-coherent integrations. Equations (11) and (12) account the fact that coherent and non-coherent integrations can be combined together. In section 5 a comparison between coherent and noncoherent integrations will be provided.

Recently a modified non-coherent detector for signal acquisition referred as differential non-coherent (DNC) has been proposed [8]. This new scheme, whose performance are analyzed in [7] can be easily described in terms of the four functional blocks reported above and its integration strategy is summarized in Fig. 5c. The analysis of this kind of system is out of the scope of this paper, however the modifications necessary for its use with the Galileo SIS can be found in [9].

3.3 Detection Strategy

Once $S_{y,r}(\bar{\tau}, \bar{f}_d)$ is evaluated the system can take the decision on the presence of the satellite. Different strategies can be employed. The detection strategies can control the previous blocks, for example, by requiring the computation of $S_{y,r}(\bar{\tau}, \bar{f}_d)$ only on a subset of the values of $\bar{\tau}$ and $\bar{f}_d$.

In [10] three different strategies are analyzed and compared in terms of system performance.

The introduction of the Galileo SIS does not essentially change the role of this block and the considerations reported in [10] still applies.

3.4 Multitrial

When a first decision about the satellite presence and a first estimation of the code delay and of the Doppler frequency are available, the system can refine these results. Thus multitrial techniques, based on the use of different $S_{y,r}(\bar{\tau}, \bar{f}_d)$, evaluated over subsequent portions of the input signal, can be employed. Two examples of these techniques are the M on N [1] and the Tong [11] methods.

Multitrial techniques generally do not require the computation of more than one complete $S_{y,r}(\bar{\tau}, \bar{f}_d)$, thus they interact with the other blocks changing the requirements for the subsequent iterations occurring in the process.

4 Galileo Impact on the Signal Acquisition

In this paper the Galileo BOC(1,1) modulation on the L1 carrier is considered. This signal is rather similar to the GPS signal, which can be derived from the C/A code by applying to it a Manchester like coding.

One difference between the GPS and Galileo signals is their bandwidth, since the application of the Manchester coding on the C/A code causes a splitting of the code power spectral density. The single–sided bandwidth, that for the GPS C/A code is B_s = 1.023 MHz, for the Galileo BOC(1,1) signal becomes B_s = 2.046 MHz, as depicted in Fig. 6.

This means that, in order to process the Galileo signal in the same way as the GPS C/A signal, the ADC antialiasing filter must have a single–sided bandwidth twice larger than the corresponding GPS ADC antialiasing filter bandwidth. Therefore, the sampling frequency must be at least twice the GPS C/A code sampling frequency.

The sampling frequency value can be derived also considering that the Galileo BOC(1,1) slot rate is twice the GPS C/A chipping rate. The final result is that every slot of the Galileo BOC(1,1) modulation has a rate twice than the chipping rate of the GPS C/A code signal, i.e. R_{BOC} = 2.046 Mslot/s. This implies that, in order to

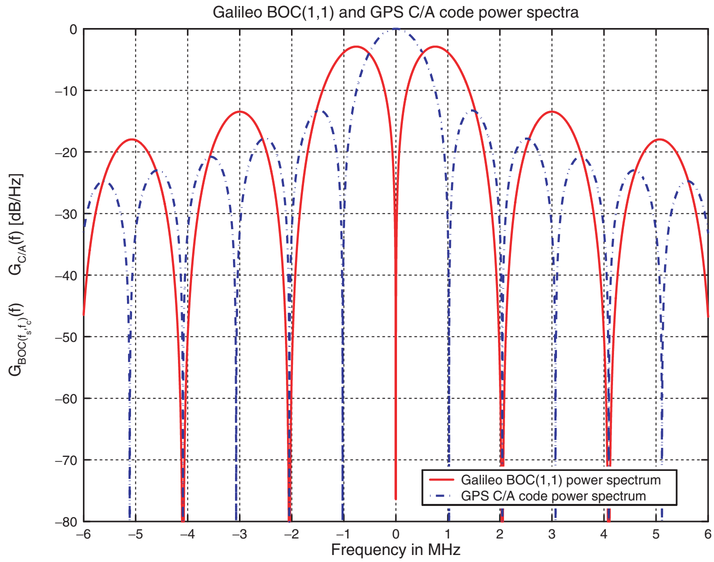

Fig. 6. Power spectral density of Galileo BOC(1,1) code (solid line) and comparison with GPS C/A code (dashed line).

obtain about two samples per BOC(1,1) slot it is necessary to sample the Galileo signal at a rate that is twice greater than the sampling rate of the GPS C/A code.

From the previous considerations it follows that a Galileo receiver can be designed on the basis of a GPS receiver, but the number of samples to process, besides, is accordingly greater than the number of samples processed by the GPS receiver in the same condition of integration time. The global complexity of a Galileo BOC(1,1) receiver is, therefore, slightly increased with respect to the GPS C/A receiver, but the same applies to the acquisition performances, as it will be pointed out in the section devoted to the performance results.

4.1 Secondary Code Transition and Single Period Integration Time

Parallel acquisition in time domain schemes, based on FFT operations, are extremely efficient, but since their intrinsic nature to process blocks of data may suffer of peak miss-detection due to the presence of the secondary code in the Galileo BOC(1,1) pilot channel. In fact, the ranging codes used for the L1F pilot channel are based on the so called tired codes. Tired codes are built modulating a short duration primary code by a long duration secondary code. The secondary code acts exactly as the data transition for the GPS signal and it can be the cause of a sign reversal in the correlation operation over the integration interval. For its natural way to look for all the code shifts over all the possible delays moving along the received signal (Fig. 7), when the correlation is performed on a single period, the serial acquisition scheme is practically insensitive to the secondary code transitions. In fact the main

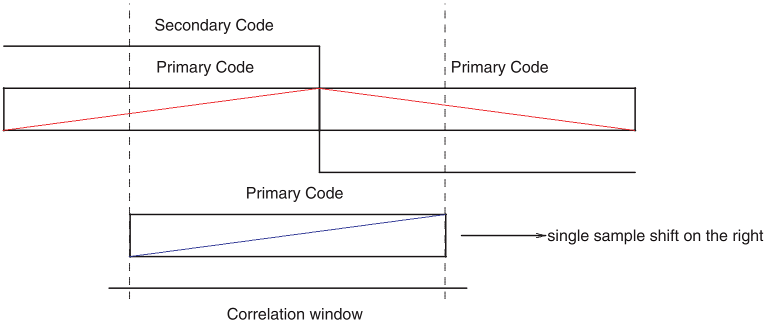

Fig. 7. Circular correlation for serial search scheme with secondary code.

lobe is identified just when the incoming and the local generated codes are perfectly aligned, hence when the secondary transitions are at the edges of the analyzed stream [12].

Since the FFT system in frequency domain performs a serial search over the code delay and a parallel search in frequency domain, it results insensitive to the code transition as well as the serial search scheme and it can be used in the acquisition of the L1 Galileo primary code.

The fast acquisition scheme computes an entire row of the search space from a block of data by means of FFT operations. Since it is not possible to know if in the data block the secondary code causes a sign reversal or not, this technique cannot be applied without changes. Figure 8 shows, how, the secondary code sign reversal within a correlation window makes it no longer periodic; by consequence, the

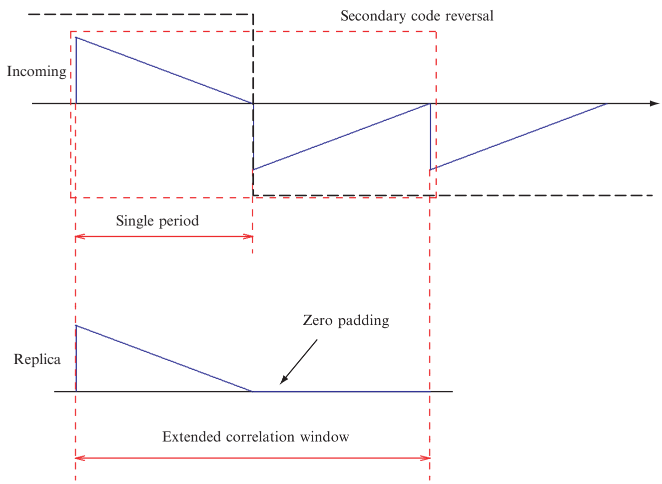

Fig. 8. Linear correlation for fast acquisition scheme with secondary code.

single period circular correlation cannot be used alone to decide the absence or the presence of a signal.

A possible solution to this problem is to conduct a linear correlation as shown in Fig. 8. Two periods of the incoming signal are correlated with a single period of the local code zero padded to fit the correlation window. The zero terms in the second period does not introduce any advantage in terms of noise reduction generally achieved with a longer integration time. The price to be paid for the fast acquisition scheme to achieve such insensitivity is to perform a linear correlation using two code periods, then to use longer FFTs.

4.2 Multiple Period Integration Time

In order to increase the detection probability for a given false alarm probability, a summation over more than one code period can be performed. In this case, the threshold value has to be increased.

The length of a data record used for the summation in an acquisition scheme is limited by two factors, the navigation data or secondary code transitions and the Doppler effect on the spreading code.

The presence of a navigation data or secondary code transitions in the data record causes a spreading effect of the output spectrum and the performances of the acquisition system are degraded. For the GPS C/A signal on the L1 carrier, the navigation data rate is 50 bit/s (see reference [1]), so that the length of a data bit is 20 ms, i.e. 20 periods of the spreading code. The maximum data record that can be used for the coherent summation is, therefore, 10 ms or 10 C/A code periods. In fact, in a 20 ms time interval only one navigation data transition can occur. Then, if there is a transition in the first 10 ms data record, the second 10 ms will be transition free. On the other hand, the sequence length cannot be less than a code period or 1 ms and even in this minimum interval a data transition can occur. In order to guarantee no data transition, the acquisition algorithm should take into account two consecutive data records of equal duration, but less than 10 ms, perform the coherent summation over these two data records and then declare the detection if one of the two envelopes or both of them exceed the threshold. Unfortunately the presence of the secondary code on the Galileo signal does not allow the possibility to perform the acquisition of consecutive pieces of signal, since every period of the primary code is modulated by the secondary short code, then it is not guaranteed the absence of a secondary code transition in the following integration period. By the way, in order to increase the detection probability, a summation over than one code period in a non-coherent way can be applied, accepting the squaring loss due to the square operation performed after the squared envelope.

5 Performance Analysis

The simulations performed to determine and analyze the acquisition systems and their optimum parameters aim to obtain the so–called *Receiver Operative Characteristic*, which will be named with the acronym ROC. This is the graph of the

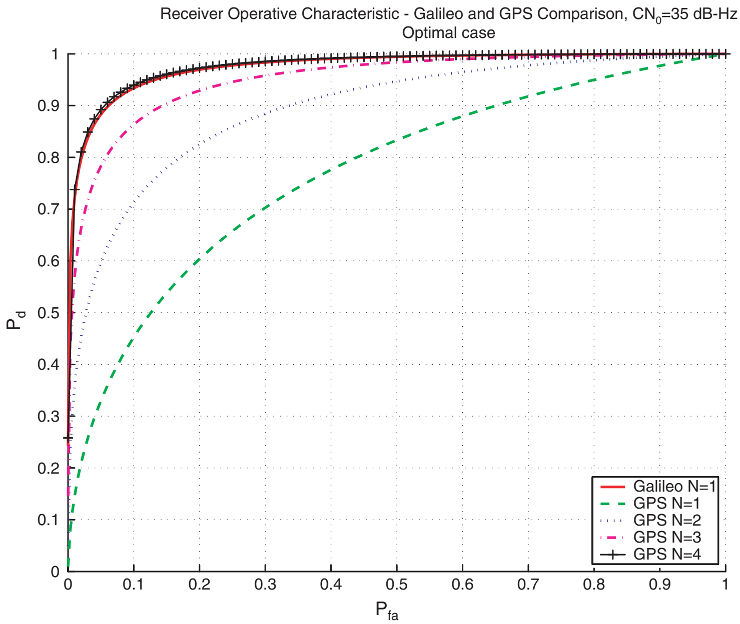

Fig. 9. Receiver Operative Characteristic Comparison, Galielo single period and from one up to five coherent GPS C/A code periods integration time under no losses hypothesis at CN_0 of 35 dB-Hz.

detection probability versus the false alarm probability, or, equivalently, of the missed detection probability versus the false alarm probability. Figure 9 depicts the comparison between the ideal optimal ROC comparison between the single period Galileo L1 signal acquisition and GPS.

Since the C/A code length is a quarter the Galileo L1 OS code, the comparison of Fig. 9 is made increasing the integration time used for the coherent autocorrelation function evaluation from 1 ms to 4 ms. As it is possible to see, considering the optimal case, better performance can be achieved increasing the integration time and without considering any correlation loss impairments GPS and Galileo are completely identical when the integration is 4 ms, value which correspond to 4 GPS C/A code periods and a single Galileo L1 OS code period.

Figure 10 shows the same comparison of Fig. 9, but considering the Acquisition impairments due to a rough code alignment in half chip/slot resolution and a coarse Doppler frequency recovery.

It is here remarked how, the correlation loss due to the Doppler shift in the bidimensional CAF evaluation does not depend on the Galileo or GPS signal structure, but only on the integration time used to perform the correlation. Different is the case of the loss due to the code misalignment, which is related to the shape of the correlation function [5]. As it possible to see in Fig. 11, where a comparison of the envelope of the GPS C/A and Galileo L1 OS correlation functions is reported, the Galileo correlation function is narrower than the GPS one. Even though, this

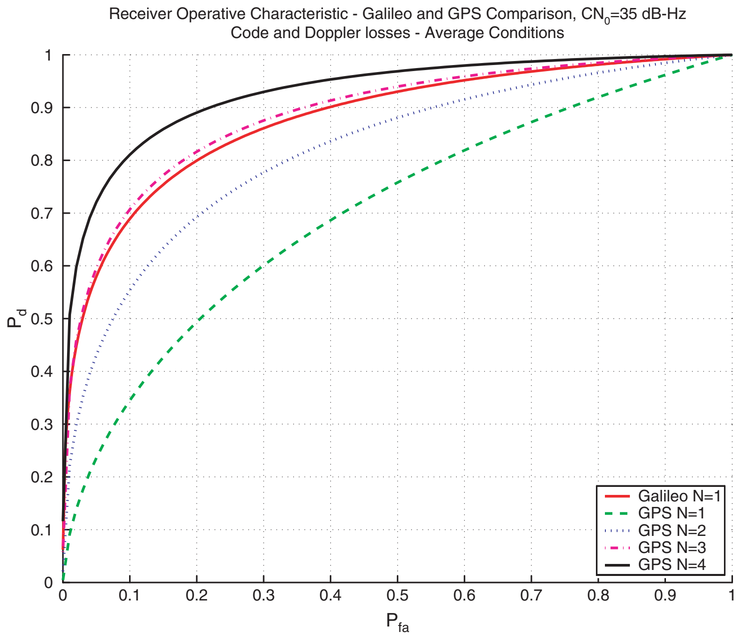

Fig. 10. Receiver operative characteristic comparison, Galielo single period and from one up to five coherent GPS C/A code periods integration time at CN_0 of 35 dB-Hz.

leads to better tracking jitter and multipath rejection performances, it makes the acquisition more challenging with respect to the classical GPS strategies. In fact it is easy to understand that for the same local code displacement the Galileo correlation functions drop faster than the GPS one, with a consequent bigger loss, as it is possible to see in Fig. 10.

Coherent integration over more than a single code period is a common strategy to increase the signal to noise ratio at the detector input in the acquisition of GNSS signals. It has been highlighted how the presence of the secondary codes in Galileo will make the coherent evaluation of the CAF quite difficult and how the required robustness in terms of signal to noise ratio can be achieved by means of non-coherent summation. This strategy, however due to its easily implementation and efficiency is already successfully used to acquire the C/A GPS signal. In Fig. 12 a comparison between the single period Galileo and multi period non-coherent GPS signal acquisition is carried out. As it is possible to outline, better performance can be achieved with the coherent approach, but this requires to reduce the Doppler bin size in order to maintain the same Doppler loss and then increasing the number of analyzed cell in the search space [5]. Moreover, a longer integration time means to increase the samples that must be processed by means of FFT operations, which is surely more cost effective than the non-coherent integration.

The Acquisition system performance can be better appreciated by means of the graph of Fig. 13, where the detection probability for a fixed false alarm probability is plotter versus the input carrier to noise ratio. Due to the long code designed for Galileo and the presence of the secondary codes, the comparison is outlined

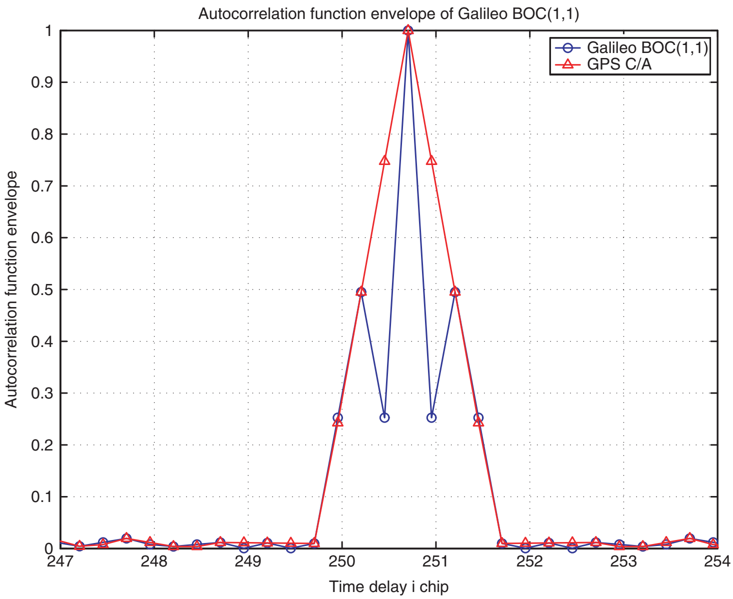

Fig. 11. GPS C/A and Galileo L1 OS envelope autocorrelation comparison for a digital sequence sampled at two samples per slot.

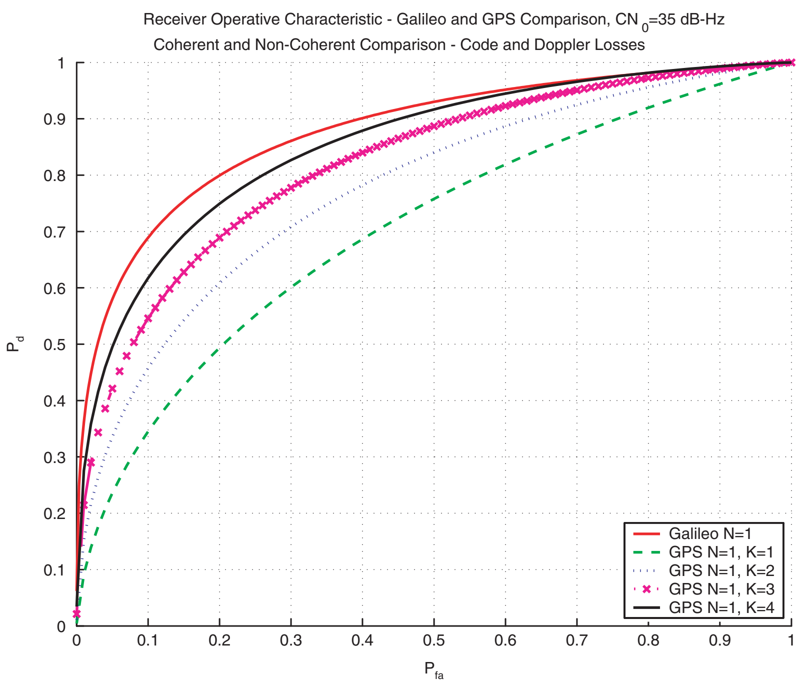

Fig. 12. Receiver operative characteristic comparison, Galielo single period and from one up to five non coherent GPS C/A code periods integration time at CN_0 of 35 dB-Hz.

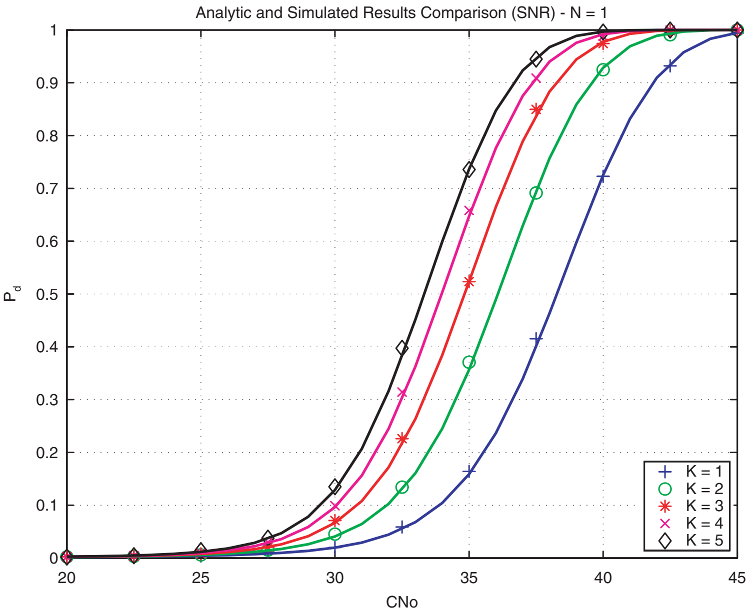

Fig. 13. Comparison for the analytic and simulated results for the Galileo BOC(1,1) signal for a desired $P_{fa} = 10^{-3}$ and from one up to five non-coherent integration times.

varying the integration time from one up to five codes period integrated in a non-coherent way.

It is possible to see how, even though this approach is less performing than the classical coherent one, it is possible to achieve good acquisition performance even at low signal to noise ratio overcoming the secondary code transition problems.

6 Conclusion

The main differences introduced by Galileo with respect to GPS are the presence of a secondary code, which acts in the same way of the GPS navigation data but with a higher rate, the particular shape of the correlation function and the presence of side lobes. The secondary code may introduce a sign reversal in the data record with a reduction of the efficiency of the circular correlation performed by the time parallel acquisition technique; the problem can be overcome by employing a linear correlation with a consequent increment of the system complexity due to the longer number of samples that have to be processed. Moreover, the sign reversal introduced by the secondary code does not allow to increase the integration time in a coherent way. In the paper these issues, coupled to the system performance are analyzed. The main factors to be accounted in the design of a Galileo acquisition block are described and the system performance are studied by means of theoretical curves and computer simulations.

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