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GNSS Signal Acquisition in the Presence of Sign Transitions

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BIOGRAPHY

Sun Kewen received his Bachelor Degree of Science in Material Science in July 2002 at Hefei University of Technology, China and the Master Degree of Science in Mechatronic Engineering in March 2005 at University of Science & Technology, Beijing, China, followed he received the Master Degree of Science in Electronic Engineering in March 2007 at University of Udine, Italy. At present, he is a Ph.D student in "Electronics and Communication Engineering" at Politecnico di Torino, Italy. Since 2007 he has been with the NavSAS (Navigation Signal Analysis and Simulation) group, at the Navigation Laboratory in Istituto Superiore Mario Boella (ISMB). Currently his research activities are mainly focused on innovative GPS / Galileo signal acquisition and tracking algorithms for GNSS receivers.

Letizia Lo Presti is a full professor of telecommunications in the Electronics Department of Politecnico di Torino, Italy. She got the degree in Electronic Engineering at Politecnico di Torino in 1971. Her research activities are focused on the field of digital signal processing, telecommunication systems simulation, array processing for adaptive antennas, and the technology of navigation and positioning systems. Her teaching activity is mainly focused on signal processing and digital communications. Currently, she is the coordinator of Master Degree courses in Telecommunication Engineering (since 2003), and is a member of the Dean board of the Engineering Faculty in the ICT field. She is the scientific coordinator of the master on Navigation and Related Applications held by Politecnico di Torino.

Maurizio Fantino received the degree in Communication Engineering in 2001 at Politecnico di Torino and a Ph.D degree in Electronics and Communications Engineering in May 2006. At present Maurizio Fantino is a researcher at the Istituto Superiore Mario Boella (ISMB), member of the NavSAS (Navigation Signal Analysis and Simulation) group, at the Navigation Laboratory. His research interests cover the field of localization, navigation and communication. In particular, his work is mainly focused on innovative architectures for high performance GPS and Galileo receivers. The main goal of this activity is the design and implementation of Software Defined Radio Receivers for GPS and Galileo signal in space. Other important areas of interest of his research are the study of the optimization of GNSS signals as well as the analysis of Signal Quality Monitoring strategies for example of Multipath affected signals.

ABSTRACT

The next generation of Global Navigation Satellite Systems (GNSS), such as Galileo [1] and GPS modernization [2], will use signals with equal code and bit periods, which will introduce a potential sign transition in each segment of the signal processed in the acquisition block. If FFT is used to perform the correlations a sign transition occurring within the integration time may cause a splitting of the main peak of the Cross Ambiguity Function (CAF) into two smaller lobes along the Doppler shift axis [3]. In this paper a method to overcome the possible impairments due to the lobe splitting is proposed and validated by simulation.

I. INTRODUCTION

The first stage in the operation of a GNSS receiver is the acquisition of the satellites in view, which provides rough estimates of the parameters, such as code delay τ and Doppler shift f_d of the Signal-In-Space (SIS) transmitted by the satellites. This activity is performed by the so called *acquisition block* and with the advent of the European Galileo system some modifications on it must be

considered. The main factors that lead to the use of different strategies for the Galileo SIS are the use of the $BOC(n,m)$ [1] sub-carriers, the presence of the secondary code in the pilot channel and the higher data rate in the data channel. These new features have been designed to guarantee the inter-operability with the GPS system and better performance for indoor positioning.

The next generation of GNSS systems, such as Galileo [1] and GPS modernization [2], will use signals with equal code and bit periods, which will introduce a potential sign transition in each segment of the signal processed in the acquisition block. If FFT is used to perform the circular correlations a sign transition occurring within the integration time may cause a splitting of the main peak of the Cross Ambiguity Function (CAF) into two smaller lobes along the Doppler shift axis [3]. In general this is a critical aspect in all the acquisition methods where the data are processed in blocks. It is very well known that increasing the coherent integration time improves the acquisition sensitivity, but the bit sign transition limits the achievable maximum performance. Similarly, the acquisition sensitivity could be increased by non-coherent integration, which is less sensitive to bit transitions but presents the side effect of squaring loss [4][5]. In order to mitigate the CAF peak impairments and increase the acquisition sensitivity, in this paper a novel two steps acquisition method is proposed aiming to overcome the problem of the CAF peak splitting. The CAF peak splitting along the Doppler shift axis is cause of errors in the Doppler shift estimation, while, as far as the code phase delay is concerned, this splitting effect produces only a correlation amplitude reduction, but its position remains unchanged along the code delay axis.

The main idea of this proposed method is to take advantage of these two disjoint effects affecting the CAF along the code delay and Doppler shift axes. The code delay is recovered in the first acquisition step, so as to roughly remove the sign transition, while in the second acquisition step the Doppler shift estimate is recovered. In order to speed up both these acquisition steps, the fast acquisition approach based on Fast Fourier Transformation (FFT) has been adopted.

In order to analyze the performance of the proposed method, simulation campaigns have been addressed. The signal selected for conducting this testing activity is the Galileo Open Service (OS) broadcast on E1, where the spreading code is modulated by fake data but with the correct rate. Histogram plots of the estimated Doppler frequency shift and code phase delay are carried out to compare the proposed method with the state of the art acquisition technique. The acquisition performance comparisons have also been addressed by means of the so called Receiver Operative Characteristic (ROC) curves. The analysis results show how the two steps acquisition method outperforms the classical fast acquisition approach, which prove the advantages of the proposed technique when dealing with weak signals and bit transitions and further prove its validity and effectiveness.

II. SIGNAL MODEL

The signal at the input of the acquisition system of a GNSS receiver is generally an intermediate frequency (IF) signal, obtained by down converting a Radio Frequency (RF) signal. The SIS transmitted by a certain given satellite and received at the terminal antenna can be written as

$$r(t) = A_{in} d(t-\tau) c(t-\tau) s_b(t-\tau) \cos(2\pi(f_{IF} + f_d)t + \varphi) \quad (1)$$

where A_{in} is the amplitude of the received GNSS signal, whose power is given by $P = A_{in}^2/2$; $c(t-\tau)$ is the primary spreading code delayed by τ with respect to a local code replica $c_{Loc}(t)$. Denoting with T_c the chip interval, $c(t)$ can be expressed as $c(t) = \sum_k c_k P_{T_c}(t - kT_c)$, where c_k is k th chip of the Pseudo Random Noise (PRN) sequence with chip rate $R_c = 1/T_c$ and $P_T(t)$ is the unitary rectangular pulse with duration T. $s_b(t)$ is the sub-carrier used for the Galileo OS on E1. The navigation data message is indicated as $d(t-\tau)$, f_{IF} is the IF at the output of the front end (FE), f_d is the unknown Doppler shift and φ is a random unknown initial phase. It is known that Galileo is made by the concatenation of a primary and a secondary codes for each pilot channel. The primary code $c(t)$ on E1 is a PRN with the chip rate R_c of 1.032 MHz and a repetition period T_p of 4 ms. The navigation data message is modulated with a data rate of 250 Hz so with a bit duration of 4 ms. This means that there is a potential data sign transition each code period. In a digital receiver the IF signal is sampled through an Analog to Digital Converter (ADC). The ADC generates a sampled sequence $r(nT_s)$, obtained by sampling $r(t)$ at the sampling frequency $f_s = 1/T_s$. From now on the notation $x[n] = x[nT_s]$ will be adopted to indicate a generic sequence $x[n]$ to be processed in any digital platform.

The realistic model of the received signal at the input of the acquisition stage can be written as

$$y[n] = r[n] + \eta[n] \tag{2}$$

where $r[n] = r[nT_s]$ is the signal component and $\eta[n]$ is AWGN with zero mean and variance σ_η^2 equal to $N_0 B_r$ (B_r being the front end bandwidth).

III. CAF EVALUATION BY FFT

By applying the results of the Maximum Likelihood (ML) estimation theory, it is possible to show that the best estimates of the propagation delay τ and the Doppler frequency shift f_d , in the presence of additional white Gaussian noise (AWGN), are based on the maximization of the Cross Ambiguity Function (CAF). In this section the CAF evaluation using the FFT to perform circular correlation is described [6]. This method is extremely efficient because it works on vectors in a parallel way. However this method is sensitive to peak impairments because of bit sign transitions.

In the FFT-based scheme, a signal vector $\boldsymbol{y} = [y[0], y[1], \cdots, y[L-1]]$ of L samples is extracted from the incoming SIS and multiplied by a complex test signal $e^{j2\pi(f_{IF}+\bar{f}_d)nT_s}$, so as to obtain the sequence $q_l[n] = y[n]e^{j2\pi(f_{IF}+\bar{f}_d)nT_s}$. This signal is FFT-transformed and multiplied by the complex conjugate of the FFT transform of the product of the local code replica $c(nT_s)$ and the sub-carrier $s_b(nT_s)$. Finally the inverse FFT transform is made so as to obtain the circular correlation $R_{y,r}(\bar{\tau}, \bar{f}_d)$, which can be written as

$$R_{y,r}(\bar{\tau}, \bar{f}_d) = IDFT\{DFT[q_l[n]] \cdot [DFT[c(nT_s)s_b(nT_s)]]^*\} \tag{3}$$

IV. BIT SIGN TRANSITIONS PROBLEM

The fast acquisition method based on FFT is extremely efficient, but since its intrinsic nature of processing blocks of data, it may suffer from peak splitting impairments due to the presence of bit sign transitions. In case of the Galileo E1 data channel, the bit sign transition could possibly occur in any time interval of 4 ms (equivalent of a single code period).

It is possible to show that the sign transitions do not destroy the possibility of detecting the satellites in view, but there might be an error in the selection of the estimate pair $\hat{p} = (\hat{\tau}, \hat{f}_d)$, where $\hat{\tau}$ is the code delay estimate and $\hat{f}_d$ is the Doppler shift estimate in the acquisition stage. In fact when the local code replica matches the received signal perfectly, the CAF envelope becomes

$$S_{y,r}(\tau, \bar{f}_d) = \left| \sum_{n=0}^{L-1} d(nT_s - \tau)\cos(2\pi(f_{IF} + f_d)nT_s + \varphi)e^{j2\pi(f_{IF}+\bar{f}_d)nT_s} \right| \tag{4}$$

where the term $d(nT_s - \tau)\cos(2\pi(f_{IF} + f_d)nT_s + \varphi)$ can be written as

$$b_\tau[n] = p_L[n]d(nT_s - \tau)\cos(2\pi(f_{IF} + f_d)nT_s + \varphi) \tag{5}$$

with the presence of a rectangular window function $p_L[n]$ in the interval $n \in [0, L\text{-}1]$ and with unitary amplitude. In case of bit transition the function $p[n] = p_L[n]d[nT_s - \tau]$ reverses the sign being a two-pulses signal. Equation (4) can be regarded as the Discrete Time Fourier Transform (DTFT) of a sinusoidal function modulated by $p[n]$, which behaves as a sort of subcarrier. The effect on the CAF peak is to split its power into two different smaller lobes.

To show this effect in the acquisition search space we have simulated the Galileo Open Service E1 data channel signal (E1-B) containing navigation data message with the symbol rate of 250 symbols/s, which means that there is a possible bit sign transition at each PRN code period.

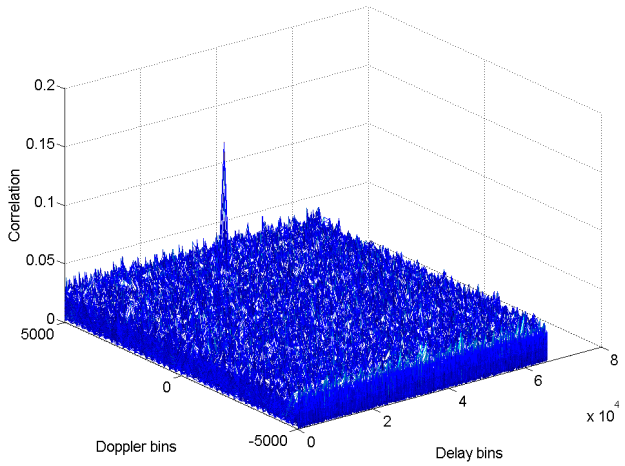

Figure 1: CAF envelope of the Galileo OS signal in the E1 band when no bit transition occurs.

The acquisition experiments have been performed with a Doppler shift f_d of 3500 Hz, a code phase delay τ of 2 ms and a carrier to noise power density ratio C/N_o of 45 dBHz. This C/N_o value represents a relatively optimistic situation, which has been considered to show the CAF peak splitting effect

and then to motivate the modification to the state of the art acquisition scheme. In Figure 1, the CAF envelope is evaluated based on the fast acquisition scheme in case of no presence of bit sign transition.

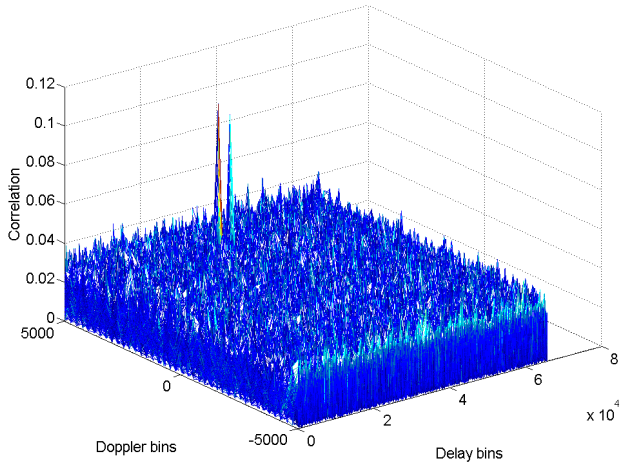

Figure 2: CAF envelope of the Galileo OS signal in the E1 band when a bit sign transition is present.

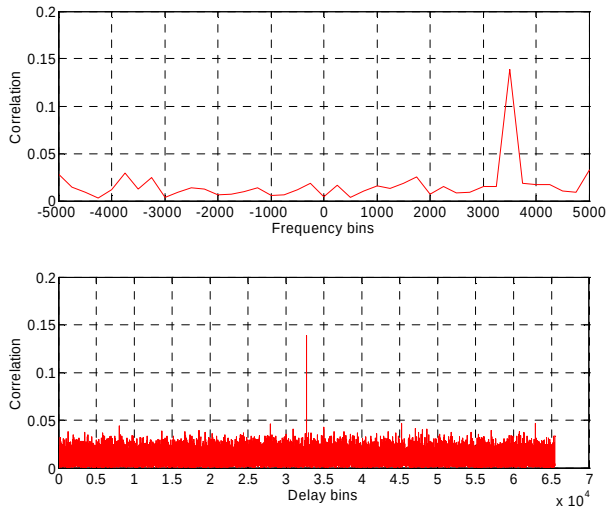

Figure 3: Curves extracted from the CAF envelope in case of no bit sign transition.

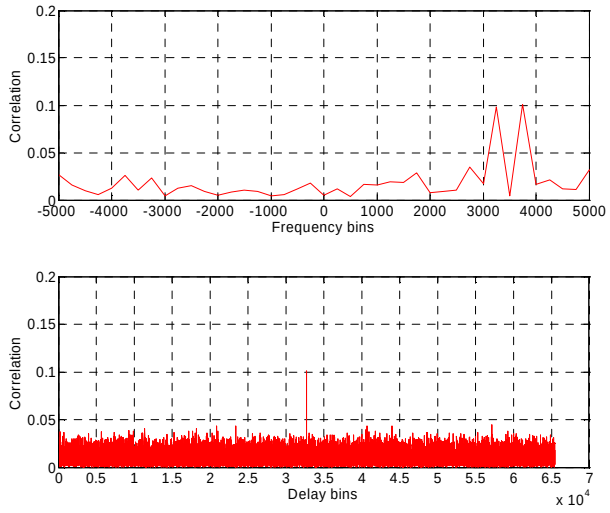

Figure 4: Curves extracted from the CAF envelope in case of with bit sign transition.

When we introduce the bit sign transition to the signal, the splitting effect of the CAF main lobe can be clearly seen in Figure 2. In this case the FFT based fast acquisition scheme suffers much from the peak loss caused by the presence of the bit sign transition.

In Figures 3 and 4 two plots extracted from the CAF envelopes of Figure 1 and Figure 2 are given respectively. The upper curves represent the Cross Correlation Function (CCF) in the Doppler shift domain (which is a energy spectrum) at the correct code delay bin. In Figure 3, it is known that the CAF peak locates its position correctly along the code delay and Doppler shift axes respectively when bit sign transition is not present. When dealing with the bit transition, in the upper plot of Figure 4, it is clearly observed that the CAF peak is divided into two different smaller lobes along the Doppler shift axis. While from the lower plot of Figure 4 it is evident that the bit transition does not impair the CCF in the code delay domain.

V. TWO STEPS ACQUISITION METHOD

In this section, a two steps acquisition scheme is proposed to overcome the problem of CAF peak splitting. The idea is to exploit the fact that the splitting occurs only in the Doppler frequency domain, while in the code delay domain the peak position remains almost unchanged. In the first step the code delay is estimated so as to tentatively align the local code sequence with the data sign transition, while in the second step the Doppler shift is estimated. In other words, the estimated pair $\hat{p} = (\hat{\tau}, \hat{f}_d)$ is obtained in two consecutive steps. The first step aims to get estimated code delay value $\hat{\tau}_1$ by using the FFT-based acquisition method. The Doppler shift $\hat{f}_{d,1}$ is not estimated in this step because it could be erroneous.

Noise reduction techniques, such as coherent integration and non-coherent integration, can be used in order to increase the acquisition sensitivity. The coherently integrated CAF envelope $S_1(\bar{\tau}, \bar{f}_d)$ evaluated in the first step can be written as

$$S_1(\bar{\tau}, \bar{f}_d) = \left| \frac{1}{N_1} \sum_{i=1}^{N_1} R_{i,y,r}(\bar{\tau}, \bar{f}_d) \right| \qquad (6)$$

where $R_{i,y,r}(\bar{\tau}, \bar{f}_d)$ is the i_{th} contribution in the coherent integration process; N_1 is the number of the code periods applied to the coherent integration process in the first step. Non-coherent integration can be used after the coherent integration operation

is made. The non-coherently integrated CAF envelope $G_1(\bar{\tau}, \bar{f}_d)$ can be written as in the following

$$G_1(\bar{\tau}, \bar{f}_d) = \sqrt{\frac{1}{K_1}\sum_{i=1}^{K_1} S_{1,i}^2(\bar{\tau}, \bar{f}_d)} \qquad (7)$$

where $S_{1,i}(\bar{\tau}, \bar{f}_d)$ is the i_{th} coherently integrated CAF envelope in the non-coherent integration process; K_1 is the number of the non-coherently integrated CAF envelopes.

In the first acquisition step the estimated pair $\hat{\mathbf{p}}_{ML,1} = (\hat{\tau}_1, \hat{f}_{d,1})$

$$\hat{\mathbf{p}}_{ML,1} = (\hat{\tau}_1, \hat{f}_{d,1}) = \underset{\bar{\mathbf{p}}_1}{\operatorname{argmax}} G_1(\bar{\tau}, \bar{f}_d) \qquad (8)$$

is obtained, but only the value $\hat{\tau}_1$ is retained as valid. The value $\hat{f}_{d,1}$ is discarded, as possibly affected by splitting errors (as shown in Figure 4).

In the second step the value $\hat{\tau}_1$ is used to extract a new signal vector aligned with the local code. In this way the effect of the bit transition practically disappears, even if the alignment is not perfect. Coherent and non-coherent integrations can be again adopted in the second acquisition step. The coherently integrated CAF envelope $S_2(\bar{\tau}, \bar{f}_d)$ evaluated in the second step can be written as

$$S_2(\bar{\tau}, \bar{f}_d) = \left| \frac{1}{N_2}\sum_{i=1}^{N_2} R_{i,y,r}(\bar{\tau}, \bar{f}_d) \right| \qquad (9)$$

Similarly, the non-coherently integrated CAF envelope $G_2(\bar{\tau}, \bar{f}_d)$ in the second step can be written as

$$G_2(\bar{\tau}, \bar{f}_d) = \sqrt{\frac{1}{K_2}\sum_{i=1}^{K_2} S_{2,i}^2(\bar{\tau}, \bar{f}_d)} \qquad (10)$$

A new pair $\hat{\mathbf{p}}_{ML,2} = (\hat{\tau}_2, \hat{f}_{d,2})$ is now estimated as

$$\hat{\mathbf{p}}_{ML,2} = (\hat{\tau}_2, \hat{f}_{d,2}) = \underset{\bar{\mathbf{p}}_2}{\operatorname{argmax}}\ G_2(\bar{\tau}, \bar{f}_d) \qquad (11)$$

and only the frequency value is retained. The delay estimate should give now a null value, due to the code alignment performed in the second step. Therefore the delay estimate can be now discarded or it can be used to refine the delay estimation obtained in the first step.

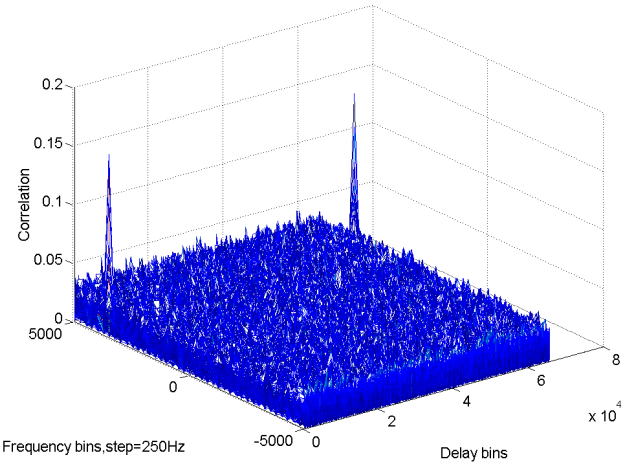

Figure 5: CAF envelope of the Galileo OS signal evaluated by the two steps method for a C/N_o of 45 dBHz with bit transition.

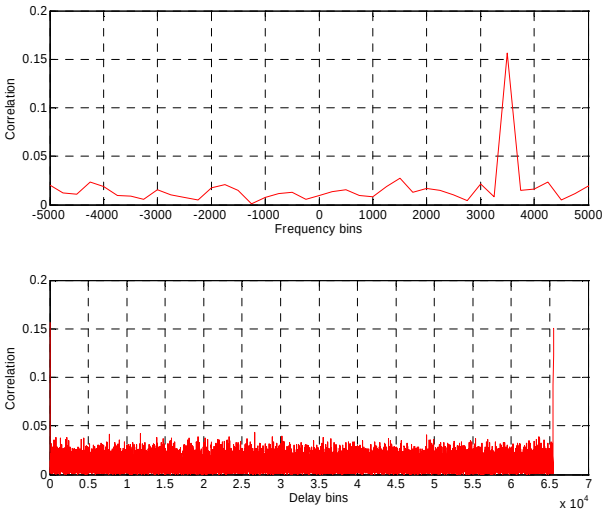

Figure 6: Curves extracted from the CAF envelope evaluated with the two steps acquisition method with bit transition.

The CAF envelope in the search space evaluated in the second step ($N_2 = 1$ and $K_2 = 1$) is shown in Figure 5. Two peaks appear now at the correct frequency value (f_d = 3500 Hz). This is due to the fact that the code delay is zero in the second step, and then the typical correlation triangle appears now split at the beginning and at the end of the bin. This result is better highlighted in Figure 6: the upper curve shows that the CAF peak appears at the correct Doppler shift position (f_d = 3500 Hz); the lower curve proves that the local code replica aligns perfectly to the bit transition position in the second step because of the correct recovery of the code phase delay $\hat{\tau}_1$ in the first step.

Since in the ideal case the CAF envelope $G_2(\bar{\tau}, \bar{f}_d)$ in the second step should concentrate its energy only in the correct bins without peak splitting, we can assume that the Doppler shift

estimate $\hat{f}_{d,2}$ obtained in the second step should be correctly recovered and is equal to the real Doppler shift value f_d. We also assume that the code delay estimate $\hat{\tau}_2$ in the second step is correctly located at the beginning or ending position along the code delay axis, that is to say $\hat{\tau}_2$ is equal to 0 or L (Notice that L is the number of the samples in a code period). In order to achieve the correct code delay estimate $\hat{\tau}$, the estimated code delay values $\hat{\tau}_1$ and $\hat{\tau}_2$ obtained from both acquisition steps should be considered. If $\hat{\tau}_1 \leq \tau$, then $\hat{\tau}_2 \leq L/2$ (Notice that τ is the real code delay in the signal), therefore $\hat{\tau}$ can be expressed as $\hat{\tau} = \hat{\tau}_1 + \hat{\tau}_2$; if $\hat{\tau}_1 > \tau$, then $\hat{\tau}_2 > L/2$, therefore $\hat{\tau}$ can be expressed as $\hat{\tau} = \hat{\tau}_1 - (L - \hat{\tau}_2) = (\hat{\tau}_1 + \hat{\tau}_2) - L$. Finally the algorithm to evaluate the estimation pair $\hat{p} = (\hat{\tau}, \hat{f}_d)$ can be summarized as in the following

$$
\begin{cases}
\hat{f}_d = \hat{f}_{d,2} \\
\\
\text{if } \hat{\tau}_2 \leq \dfrac{L}{2} \text{ then} \\
\quad \hat{\tau} = \hat{\tau}_1 + \hat{\tau}_2 \\
\text{else} \\
\quad \hat{\tau} = (\hat{\tau}_1 + \hat{\tau}_2) - L \\
\text{end} \\
\text{if } \hat{\tau} \notin [0, L] \text{then} \\
\quad \hat{\tau} = \hat{\tau}_1 \\
\text{end}
\end{cases}
$$

VI. SIMULATION RESULTS WITH GALILEO E1 SIGNAL

In this section, the behavior of the proposed two steps acquisition strategy is given in terms of histograms of the estimated Doppler frequency shift and code delay. In order to assess the acquisition performance also ROC curves have been addressed so as to compare the proposed method with the state of the art acquisition approach. Simulation campaigns have been performed simulating the Galileo $BOC(1,1)$ signals. In particular, the Galileo E1-B signal with both PRN code and navigation data message has been generated for different values of carrier to noise power density ratio C/N_o, Doppler frequency shift f_d and location of the bit sign transitions along the signal.

The simulation scenario selected for the two steps acquisition assessment in terms of histograms of the Doppler frequency shift and code delay estimates considered a Galileo E1 signal with a code delay τ of 2.5 ms, a Doppler shift f_d of 3500 Hz and a carrier to noise power density ratio C/N_o of 30 dBHz. Six code periods have been coherently integrated ($N = 6, K = 1$) for both the classical fast acquisition approach and the proposed two steps acquisition method. The Monte Carlo simulation experiments have been repeated for 1000 times and the histograms of the estimates of $\hat{f}_d$ and $\hat{\tau}$ are given respectively.

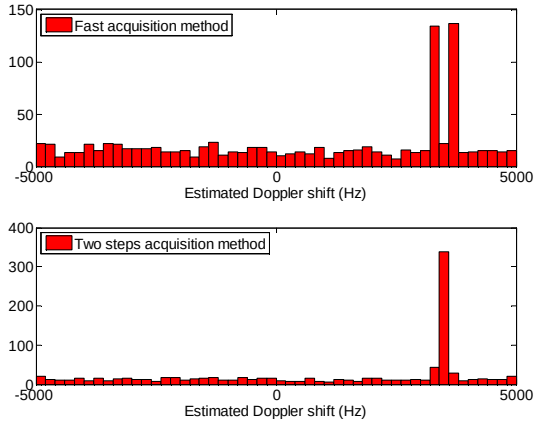

Figure 7: Histograms of the estimated Doppler shifts in two cases: the fast acquisition approach and the two steps acquisition method for a C/N_o of 30 dBHz with bit sign transitions.

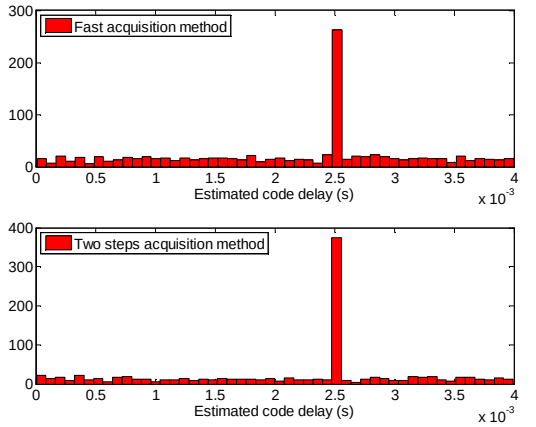

Figure 8: Histograms of the estimated code delays in two cases: the fast acquisition approach and the two steps acquisition method for a C/N_o of 30 dBHz with bit sign transitions.

Figure 7 shows the histograms of the Doppler shift estimates for the classical fast acquisition approach and the proposed two steps acquisition technique. The upper plot of Figure 7 is the histogram evaluated by the classical approach which shows that the Doppler shift estimates deviate much from the correct value (f_d = 3500 Hz) because of the CAF peak splitting. The classical acquisition approach shows inadequate performance when dealing with bit transition problem. The lower plot of Figure 7 is the histogram of the Doppler shift estimates obtained by the proposed acquisition technique, as can be seen that the achieved Doppler

shift estimates much more concentrate around the correct Doppler shift value. This proposed methodology is less affected by the peak splitting effect and outperforms the classical acquisition approach.

Figure 8 shows the comparison of the histograms of the code delay estimates for both described acquisition techniques. The upper histogram of the code delay estimates is evaluated by the classical approach and the lower histogram is achieved by the proposed technique. It is easily known from Figure 8 that the proposed acquisition technique provides much improved detection rate of the code delay estimates over the classical fast acquisition approach.

A more detailed analysis has been performed by evaluating the ROC curve [7], which is the graph of the detection probability versus the false alarm probability, or, equivalently, of the missed detection probability versus the false alarm probability. The presence of bit transitions in the Galileo signals reduces the benefits deriving by coherently extending the integration time, for such a reason in the first acquisition step a combination between the coherent and non-coherent integrations techniques over more code periods is suggested. In the simulation experiments different numbers of the coherent and non-coherent integration code periods have been chosen to compare the performances between different acquisition schemes. Each simulated ROC curve reports the comparison of the performances about different acquisition schemes using the same number of code periods, coherently or non-coherently integrated.

Figure 9 depicts the acquisition performance comparison among three cases respectively: the fast acquisition approach with and without data transition on the signal, and the proposed two steps acquisition method considering sign reversals during the correlation. The simulation has been made considering the coherent integration of two Galileo $BOC(1,1)$ code periods $(N = 2)$, ten non-coherent integration operations $(K = 10)$, a C/N_o of 30 dBHz and a sampling frequency of about 8.21 MHz. The results of Figure 9 show that the two steps acquisition method provides improved acquisition performance in terms of detection probability over the classical fast acquisition approach, when the received signal presents the well known problem of the bit sign transition.

As the value of carrier to noise power density ratio C/N_o increases, less non-coherent integrations are necessary to achieve a reasonable estimation rate for the code delay in the first acquisition step, so to consequently recover the correct Doppler shift in the second step. An example of that is shown in Figure 10 for a C/N_o of 32 dBHz and 2 coherent integration code periods $(N = 2)$ and 6 non-coherent integration operations $(K = 6)$. Similarly to the comparison of Figure 9, Figure 10 highlights how better performance can be achieved by the two steps acquisition method with respect to the classical fast acquisition scheme.

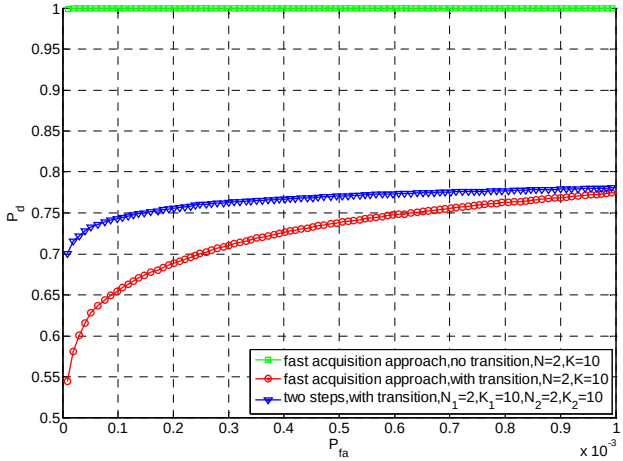

Figure 9: Comparison between the fast acquisition approach and the two steps acquisition method for a case of C/N_o = 30 dBHz, N = 2 and K = 10.

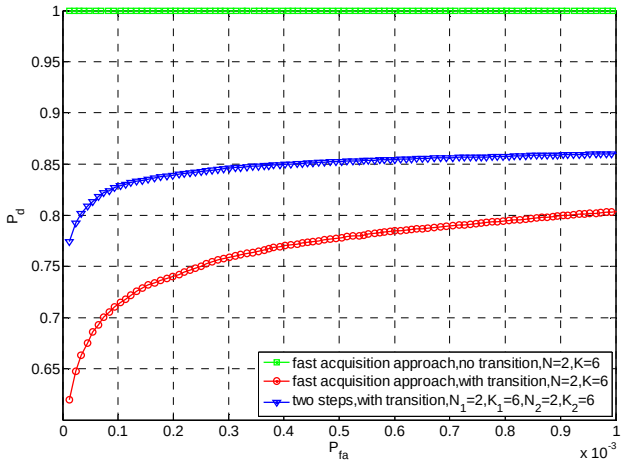

Figure 10: Comparison between the fast acquisition approach and the two steps acquisition method for a case of C/N_o = 32 dBHz, N = 2 and K = 6.

This trend is clearly even more evident for high C/N_o ratios as shown in the comparison of Figure 11 for 38 dBHz. For such a high carrier to noise ratio the first acquisition step is generally able to recover the code delay at which the bit sign transition might occur and initialize the second acquisition step in a proper way. Figure 11 clearly shows like in this case, in real situations, when the bit transitions occur the two steps acquisition method could aid the acquisition phase of a GNSS receiver.

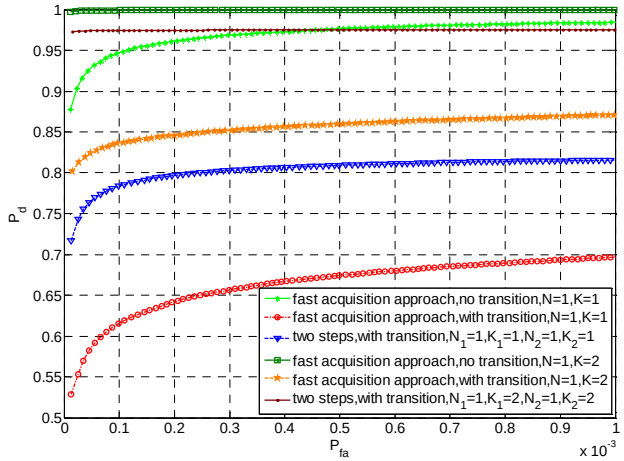

Figure 11: Comparison between the fast acquisition approach and the two steps acquisition method for a case of C/N_o = 38dBHz.

VII. CONCLUSION

The presence of data message or a secondary code which modulates each primary code period reduces the possibility of increasing the integration time in a coherent way, since data or the secondary code may lead to sign reversals during the correlation window. In order to overcome the peak splitting caused by such a sign transition on the CAF, an innovative two steps acquisition method has been proposed and presented in this paper.

A comparison between this proposed two steps acquisition method and the classical fast acquisition approach is carried on by simulation campaigns in terms of histograms of the code phase delay and Doppler shift estimates as well as ROC curves. Those simulations have shown how the sign transition may reduce the detection rate of the classical acquisition scheme in a significant way, while the proposed methodology is less affected.

The simulation results also show how the two steps acquisition method can generally achieve better performance when the signal modulation presents a potential sign transition each PRN period, which is exactly the situation of the Galileo OS signal broadcast on the E1 carrier.

REFERENCES

[1] European Space Agency / European GNSS Supervisory Authority, "*Signal In Space Interface Control Document*", OS SIS ICD, Draft 1, February 2008.

[2] E. D. Kaplan, "*Understanding GPS: Principles and Applications*", 2nd edition, Norwood, MA 02062, Artech House, 2006.

[3] L. Lo Presti , M. Fantino, P. Mulassano and X. Zhu, "Acquisition systems for GNSS signals with the same code and bit rates", *IEEE/ION PLANS Conference*, Monterey, California, USA, May 5-8, 2008.

[4] M. Fantino, "*Study of Architectures and algorithms for Software Galileo Receivers*", Ph.D dissertation, Politecnico di Torino, 2006.

[5] D. Borio, M. Fantino and L. Lo Presti, "Acquisition Analysis for Galileo BOC Modulated Signals: Theory and Simulation", *European Navigation Conference*, Manchester, UK, 7-10 May, 2006.

[6] D. J. R. Van Nee and A. J. R. M. Coenen, "New Fast GPS Code-Acquisition Technique Using FFT", *Electronics Letters*, Vol. 27 No. 2, 17th January 1991.

[7] J. I. Marcum, "A Statistical Theory of Target Detection By Pulsed Radar", *IEEE Transactions on Information Theory*, pp.59-267, 1st December 1947.