Galileo IOV System Initialization and LCVTT Technique Exploitation

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Abstract. Satellite-based navigation systems uses one-way ranging measurements for system orbit estimation and time-keeping, due to its operational advantage when compared with two-way ranging technique, in terms of complexity of ground monitoring stations (completely passive and requiring a simple omnidirectional antenna to track all the satellites in view). However, a sufficient number of simultaneous independent measurements is required to solve the system unknowns: in particular simultaneous visibility of multiple stations by an individual satellite (allowing to separate the ground stations clocks contributions since the SVs clocks disappear), as well as simultaneity of observations from the same monitor stations of a large number of satellites (allowing to recover the SVs clocks parameters, since the GSS clocks drop out) is the key to an effective separation in the solution of the clock contributions from the pseudo-ranges.

In the Galileo IOV phase (consisting of 4 satellites on two orbital planes and a ground network of 20 Sensor Stations), the first condition is clearly fulfilled, however the second condition is not met for a considerable part of the time. If two GSSs do not see simultaneously a single Galileo satellite, they will not be able to estimate their clocks time and frequency drifts, i.e. they will not be synchronized. The free running clocks will essentially enter a holdover mode, were the relative time between the two stations will be slowly drifting as a function of the initial conditions and the stability of the clocks. The ground stations synchronization will gradually degrade with time and when a satellite will rise on the horizon they will be essentially not synchronized to the extent required to carry on a one-way-based Orbit Determination & Time Synchronization (OD&TS).

During the IOV phase, the limited number of satellites available and the peculiar characteristics of the Galileo orbits will make difficult for the Orbit Determination and Time Synchronization to start producing meaningful data, therefore some form of intermediate operational configuration must be sought to help in the OD&TS process initialization.

The paper will address the proposed solution to overcome the problem of Galileo system initialization starting from the intermediate configuration with first 2 satellites (first IOV Launch) up to final IOV Configuration after second IOV launch. The proposed solution will be based on a limited use of GPS to insure the synchronization of the Galileo Sensor Stations, relying on the exploitation of the Linked Common View Time Transfer (LCVTT) Technique, while the Galileo Orbit Determination and SVs clocks characterization will be carried on autonomously and independently by GPS, in a two step process, up to the achievement of the IOV Configuration with 4 satellites, when the nominal Orbit Determination and Time Synchronization process will be operated.
Moreover the paper will address the development of the LCVTT Algorithm, carried on as part of development of the infrastructure aiming to support the Galileo Verification Phase currently under definition as part of Galileo Phase C/D/E1 contract. The algorithm design and implementation will be presented together with the validation carried out (both for LCVTT and MLCVTT) to verify that the synchronization accuracy is adequate to support the Galileo System Initialization.

1 Introduction

Galileo, as the European-controlled world-wide satellite navigation system, is conceived to be the contribution to the next GNSS (Global Navigation Satellite System) system, namely the global infrastructure for the integrated management of the multimodal mobility on world scale (see [1]). Galileo will be an autonomous system but contemporarily compatible and, possibly, interoperable at the maximum extent with other navigation systems, particularly with the GPS system. Galileo will be under the control of a civil authority and will provide basic services at global coverage level for a wide range of applications in different transport domains, like road, railway, air, maritime and personal mobility, and suitable to fulfil various user needs spread over a wide professional areas.

The Galileo Programme is jointly supported by the European Commission and by the European Space Agency and is currently facing its C/D/E1 Phase, focused to the development, deployment and validation of an initial part of the System, known as IOV Configuration, composed of a reduced Space Segment and a reduced Ground Segment compared with the Final Operation Capability (FOC).

The Galileo IOV constellation shall be a sub-set of the Galileo FOC constellation of 30 satellites, comprising four satellites, in two different planes. The Ground Segment will be also a sub-set of the final one and is reported in Table 1.

The IOV reduced architecture has a high impact on Navigation Performance in IOV, leading of course to a degradation on accuracy and availability of navigation solution.

Several are the problems encountered when trying to work with an IOV constellation:

- The lack of measurements associated to each GSS station make difficult to compute a snapshot bias per epoch as currently envisaged for FOC.
- Furthermore, for long intervals of time, the satellites are not in view of the master clock station, and hence all the measurements at those epochs are rejected (more than half the total number of observations), hence degrading the orbit and clock estimations.
- Finally, the Orbit Determination and Time Synchronisation algorithm often fails because the normal matrix cannot be inverted, due to the bad conditioning of the system from the mathematical perspective. This can be sometimes overcome by restricting the a-priori covariance of the clock estimation (that implies constraining the normal matrix).

Moreover, in order to reach its on-line IOV Operation, the System needs to be initialized, as to reach convergence (especially in its Ground Processing, namely Orbit