High Integrity GNSS Receiver for Ground Based Mobile Applications

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Thanks to decades of standardization and receiver development efforts, civil aviation GNSS receivers are available. They come with integrity, an essential feature for civil aviation operations, and can be widely used todays, provided the numerous GBAS and SBAS approaches published worldwide.

Obviously, the civil aviation community is not the only one seeking for integrity. This feature is also essential for any other transportation system, where safety of life is involved. GNSS procedures have not yet been defined for such usages, but need to be.

The main objective of the “Récepteur Intègre” (High Integrity Receiver) project, conducted by Thales Alenia Space for the CNES, is to propose an Integrity concept for ground based mobile applications and to demonstrate the performances of the proposed concept with real world data. As opposed to aviation context, land mobile positioning namely in urban areas and/or under foliage suffers propagation disturbance (multipath and shadowing). The strong multipath (non Gaussian error) and reduced satellite visibility represents the main integrity challenge in such areas.

The first step has been the design of the integrity concept and of the experimental demonstrator. This step took benefit from past studies conducted by the CNES, Thales Alenia Space and M3 Systems. This paper describes the work that has been done in the frame of the “Récepteur Intègre” project, from concept definition to receiver testing in operational conditions.

Integrity determination techniques that allow providing a QoS indicator to the user have been studied for decades. The quality indicator can be defined as a protection level provided together with the position. State of the art techniques that cover algorithms able to detect and identify faulty measurements are documented in several papers [1-5].

Standard RAIM has been initially designed for civil aviation. Its use for ground applications has been widely studied these last few years, with always a strong limitation found in the definition of nominal and threat models, as well as the setup of the probability of occurrence of the threats [6]. As a consequence, RAIM application to ground users often results in large protection levels or high missed integrities due to the inadequate over bounding of local effects in the nominal model.

Unlike SBAS receivers, the “Récepteur Intègre” does not only use data from a large external system associated with local error models, but also process all the information available at the signal processing stage of the receiver so as to monitor the local environement and assess its real impact on the receiver raw measurements. Thanks to this approach, the “Récepteur Intègre” integrity concept is expected to be valid for any kind of environment.

Focusing on the land application use case, [7] proposed a new methodology to provide with PVT QoS characterization better than what can be currently achieved with the aforementioned techniques. To this end, the multiple GNSS constellations, the multiple frequencies, as well as KPI elaborated along the signal processing chain of a GNSS receiver were considered.

Especially, in order to detect multipath and mitigate the induced pseudorange error, a multicorrelator based (MC) maximum likelihood discriminator [8] is used. In addition to the induced error mitigation, as soon as a multipath is detected, the corresponding measurements are overweighted in the PVT+I computation, leading to improve both the accuracy and the bounding of the actual position error.

Fig. 1 illustrates the PVT horizontal error using the EKF algorithm in [7] and several code tracking discriminators. White dots represent a simple EMLP (Early Minus Late Power) discriminator, blue dots represent the MC when the multipath detection is not activated and finally green dots represent the MC when the multipath detection is activated. The improvement on the positioning accuracy is clearly visible in this example. However, short NLoS are still an issue and might cause biased positioning and missed integrities. The improvements and new signal processing scheme with respect to [7] and [8] will be presented in the full version of this paper. They take advantages of signal diversity in a multi-contellation context and of frequency diversity (using a multi-frequency single antenna) or of space diversity (using a single frequency array of antennas such as in [9]).

Figure 1: Comparison of PVT horizontal error given by different discriminators.

Experimental campaigns were conducted in urban and railway contexts in order to assess the performances of the proposed concept in terms of PVT accuracy and integrity.
The urban data collecting system consists in:

- RF capture systems to record GNSS raw signals (GDAS-2);
- Thales Alenia Space SW receiver GEMS [10] fully instrumented with a MC discriminator [8];
- The live-sky testing platform was provided by GNSS Usage Innovation and Development of Excellence (GUIDE), a Toulousian test laboratory. It embeds a GBOX that provides the reference trajectory based on high grade Inertial Navigation System (INS) and GNSS differential corrections from IGS;

The reference trajectory is then compared to the position computed with the proposed algorithms and methods to calculate the positioning error and evaluate the performances of the algorithms.

The urban experimental data have been collected in Toulouse and the trajectory is illutrated on Fig. 2. An example of covered deep urban area is also illustrated on Fig. 3.

Figure 2: Urban experimental trajectory.

Figure 3: Example of deep urban area.

A part of the railway experimental trajectory is illustrated on Fig. 4 and the performances of the proposed solution on this trajectory are illustrated on Fig. 5 in a single antenna – single frequency – multi-constellation context (Galileo – GPS – Beidou – Glonass). This campaign has been run in the frame of the GEOFER project co-funded by the SNCF, "La Région OCCITANIE" and the CNES with the support of GUIDE. On this dataset, the final HPE at 95% is 1.63m and the HPL at 95% is 22.81m. No missed integrity was observed.

Results for both trajectories making use of the frequency diversity or of the space diversity will be presented in the paper.

Figure 4: Railway experimental trajectory: Toulouse-Rodez line.

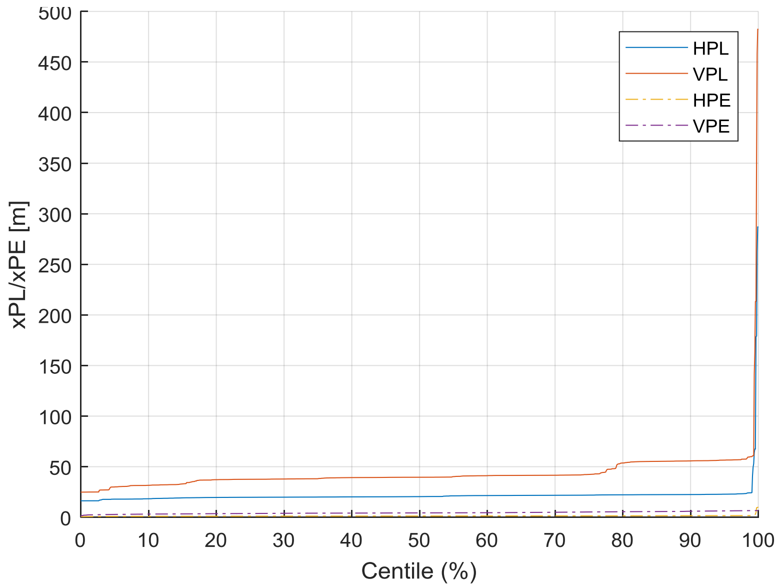

Figure 5: Example of error and protection level distributions in the Railway environment.

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