PhD Thesis Description

1. Title

DESIGN AND PROCESSING OF GNSS META-SIGNALS FOR PRECISE POSITIONING

2. Supervisors

- Supervisor: **Paul THEVENON (ENAC/SIGNAV) (thevenon@recherche.enac.fr)**
- Co-supervisor: ---
- Participant: ---

3. Description

3.1. Context

Advances in GNSS precise positioning in recent years have mainly focused on the exploitation of carrier phase observations, which provides a cm-level accuracy on the satellite-to-user range estimation but with a carrier cycle ambiguity, which requires specific corrections, clear carrier phase observations and possibly some convergence period. This is the case of the RTK (Real-Time Kinematics) or PPP-AR (Precise Point Positioning with Ambiguity Resolution) techniques. Those techniques are difficult to implement in an urban environment, where the carrier phase tracking is challenging due to surrounding buildings, resulting in frequent cycle slips or even loss of lock of the carrier phase tracking process.

In this study, to increase robustness against known phase impairments in urban environments, we propose to use the code observations from so called meta-signals, leveraging on fusing two or more GNSS signals in an AltBOC like processing at the receiver level. The Galileo E5 AltBOC is a particular case of such meta-signals. AltBOC is a modern signal modulation, coinvented by CNES with an extreme bandwidth of 51.15 MHz, to be compared to the 2 MHz of Galileo E1c signals or the 20 MHz of the Galileo E5a signals. Its large bandwidth exhibits a high ranging accuracy and a strong potential for multipath mitigation. Currently, two constellations are already broadcasting such modulation on the same band: Galileo E5 and Beidou phase 3 B2.

While AltBOC is of prime interest due to its availability in current systems, the study shall also focus on a wider range of innovative modulations encompassed in the term "Meta-Signals". Meta-signals can be defined as signals being emitted on different carrier frequencies at the satellite emitter side, and coherently processed at the receiver side.

3.2. Objective(s)

The aim of the study is to prototype and demonstrate the feasibility and limitations of meta-signal processing in its widest senses, including the particular case of the Galileo AltBOC signal. Simulated signals and real signals will be used for this validation.

3.3. Work Plan

The phases of this thesis are:

1) Investigate advanced signal processing techniques for Meta-Signal modulation,
2) Demonstrate and promote the positioning accuracy of a navigation solution based on meta-signal and on Galileo AltBOC modulation,
3) Optimize the analysed algorithms aiming at assessing an embedded solution for end users, considering two different classes of end-users: autonomous transports (high performance, high reliability need, high precision, available high processing capabilities). And on the other

side, handheld users (for Location Based Services for example), very constraining in terms of processing capabilities.

The 1st phase addresses signal processing and signal design aspects. Indeed, Meta-Signal modulation is known for providing a better code accuracy and improved multipath robustness. Conventional and advanced tracking techniques will be described and characterized for the Meta-Signal family. A particular focus will be put on peak ambiguity resolution techniques, since Meta-Signal auto-correlation functions exhibits multiple peaks. Also, the large bandwidth of Meta-Signals with interleaved independent sub-signals lead computationally expensive to process which leads to high cost of the GNSS chip and high energy consumption. Techniques such as non-uniform sampling, snapshot or sparse sampling, or optimized bi-spectrum meta-signal processing may be helpful in order to reduce the demanding requirements to process Meta-Signals. As such technique may degrade the actual signal waveform or tracking performances, a trade-off study needs to be performed. A combination of different techniques will be used to demonstrate the achievable accuracy of Meta-Signals code-based navigation solutions in real urban conditions. The selected algorithm is expected to answer low computational requirements, high code pseudorange accuracy and robustness against multiple correlation peak ambiguity and multipath.

The 2nd phase is to study navigation solutions using AltBOC code observations. It notably foresees live data collections addressing the autonomous transportation challenges ahead. The experimental part will leverage TAS know-how regarding user segments and based on proven experimental means and expertise (integrated RF/digital front end, multi-frequency bit grabber, antenna array, GPU based software receiver).

The 3rd phase is to support a go to market strategy of the developed algorithms, different optimization processes shall be implemented to take into account the constraints stemming from embedding these algorithms in end users segments, again considering 2 types of users.

The outputs of this study will provide useful insight for the design of new meta-signals in future generations of satellite navigation systems, for example for Galileo 2nd Generation or for a LEO complement of GNSS constellations.

3.4. Keywords

GNSS, signal processing, signal design, precise positioning

3.5. References

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5. Research Unit

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A collaboration with University of Colorado Boulder will be discussed.

6. Proposed Funding

- CNES (Half funding, 1st preselection phase succeeded, final phase needs an identified candidate)
- Thales Alenia Space (private company, half funding, confirmed)
- Other back-up options: ENAC