THE PROOF OF CONCEPT FOR 3-CM ALTIMETRY USING THE PARIS INTERFEROMETRIC TECHNIQUE

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1. INTRODUCTION

Since its suggestion in 1993, the altimetric and scatterometric capabilities of the PAssive Reflectometry and Interferometry System (PARIS) [1] have been tested extensively from ground- air- and even space-based experiments. The concept is based in the use of the Global Navigation Satellite System (GNSS) signals reflected off the Earth (Ocean, Ice, Land), in a bi-static radar configuration. ESA has proposed to use the PARIS Interferometric Technique at the future PARIS In-Orbit Demonstrator Instrument (PARIS-IOD) [2]. This is a novel instrumental approach respect to previous PARIS instruments, which obtained the observables through cross-correlating direct and reflected signals against a GPS signal model (or *replica*). The limit of such an altimetric approach was given by the availability of the GNSS codes. The new interferometric technique aligns the direct and reflected signals both in delay and Doppler and computes directly cross-correlation between the received signals (not against replicas of their codes). The principal advantage of this new technique is that in addition to public GPS signals, also encrypted signals can be used simultaneously, increasing the available signal bandwidth and power, and thus the expected precision of the altimetric measurement.

This project contributes to the PARIS-IOD concept trying to demonstrate the suitability of the interferometric technique for altimetric purposes, as well as to study and demonstrate the proposed calibration techniques for the PARIS-IOD instrument. We aim to confirm whether the interferometric technique is capable of measuring GPS signal delay differences with an associted 1 sigma error of 3 cm with 1 second of observation time.

The first step to accomplish the objective of the activity is to build the appropriate receiver, able to perform the direct correlation of the signals. This is being achieved by modifying the existing dedicated full-custom GNSS-reflection receiver GPS Open Loop Differential Real-Time Receiver (GOLD-RTR) [3]. Although the instrument proposed for the PARIS-IOD will have beam-forming antennas, our proof-of-concept instrument will operate with real aperture antennas as we will concentrate our effort on developping the real-time digital signal processing algorithms. The current plan is to have performed initial tests of the system during Spring 2010. They will include two experiments, described below.

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2. SPIRENT SIMULATOR EXPERIMENT

The proposed experiment setup that will allow to determine the capabilities of the PARIS Interferometric Technique is shown in figure 1. The GPS signals are simulated using a GPS simulator equipment. The simulated signals include all visible GPS

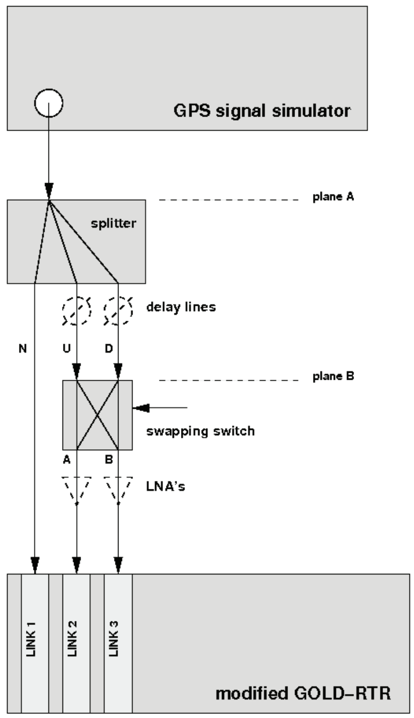

Fig. 1. Proposed experiment set-up using a GPS simulator environment.

signals for a given simulation time, instrument location and dynamics, and one reflected signal, for only one PRN, on a flat surface [4]. These signals are fed into a power splitter and divided into three paths. The first one is injected into link 1 of the modified GOLD-RTR. This first signal is named N (Navigation). Link 1 in the GOLD-RTR receiver is used to obtain standard GPS observables (pseudo-ranges, Doppler, position, time, $\ldots$) using an embedded commercial GPS receiver. The other two GPS signals at the output of the power splitter correspond to the signals acquired by the up (U) and down (D) looking antenna arrays of PARIS-IOD. Phase shifters or delay lines can be used to simulate the effect of the beam-formers in the real PARIS-IOD instrument. Using the switch the U and D signals can be fed into links 2 or 3 using the swapping technique proposed in [5]. Link 2 would correspond to the front-end A and link 3 to front-end B in [5]. The PARIS interferometric technique is implemented by cross-correlating the signals of links 2 and 3. These signals have been aligned in delay and compensated in Doppler before being cross-correlated. LNA's can be placed between the switch and the GOLD-RTR to simulate the presence of an LNA in the real PARIS-IOD.

3. BRIDGE EXPERIMENT

The set-up for the bridge experiment is shown in figure 2. The experiment set-up uses six antennas (N, U, D, R, $B1$, $B2$). Antenna U is a directive parabolic reflector antenna of about 1m diameter pointing to a fixed direction of the sky, where the selected GPS satellite will transit. The pointing direction of this antenna can be adjusted, but it will not perform any tracking. The antenna N is a hemispherical antenna and is used to obtain navigation observables. The position of this antenna is retrieved using a GPS receiver. This GPS collects data continuously with the objective of retrieving continuous phase information without

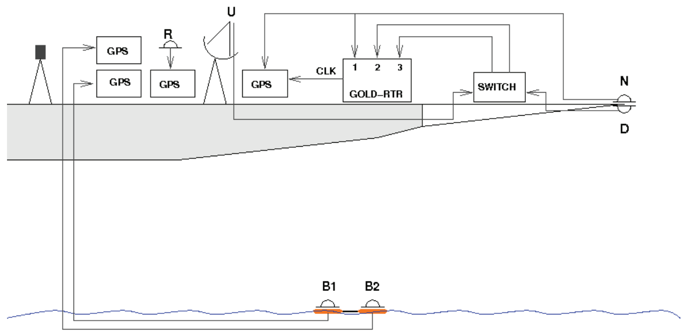

Fig. 2. Set-up for the bridge based PARIS proof of concept experiment.

any jump. This GPS receiver is driven by a common clock reference delivered by the GOLD-RTR. The signal of antenna N is also injected into link 1 of the GOLD-RTR. The signal input into this link is used to drive the internal navigation receiver and derive the necessary signal models. The down-looking antenna D collects the GPS signals reflected on the sea surface. The signals collected by antennas U and D are fed into a calibration switch before being delivered to the GOLD-RTR. Thus, the PARIS interferometric antennas are antennas U and D. It is intended to perform *traditional* model cross-correlations (U, N, D) simultaneously to the interferometric ones.

Independent sea-level measurement will be obtained using two GPS buoys free-floating near the bridge, for cross-comparison purposes. The height of the buoys will be measured with respect to the reference receiver on the bridge using standard GPS processing software, giving 2-3 centimeter accuracy in the vertical.

4. CONCLUSIONS

At the end of Spring 2010, a proof-of-concept instrument for PARIS-IOD based on a full-custom dedicated GNSS-Reflections receiver will have been developed, and the novel interferometric concept tested in two experiments: one using simulated GPS signals, and a second one using real reflected signals obtained from a relatively high bridge over estuary waters. The aim of the activity is to demonstrate PARIS-IOD concept as an altimetric system able to provide 3-cm vertical resolution. The paper will present the instrument and the results of the experiments.

5. REFERENCES

[1] M. Martín-Neira, “A Passive Reflectometry and Interferometry System (PARIS): Application to Ocean Altimetry,” *ESA J.*, vol. 17, pp. 331–355, Dec. 1993.

[2] M. Martín-Neira, S. D’Addio, C. Buck, N. Floury, and R. Prieto-Cerdeira, “The Paris Ocean Altimeter In-orbit Demonstrator,” *Submitted to IEEE Trans. Geosc. Remote Sensing*, June 2009.

[3] O. Nogués-Correig, E. Cardellach Galí, J. Sanz Campderròs, and A. Rius, “A GPS-Reflections Receiver That Computes Doppler/Delay Maps in Real Time,” *IEEE Trans. Geosc. Remote Sensing*, vol. 45, no. 1, pp. 156–174, Jan. 2007.

[4] SPIRENT Communications, “Simulating Multipath. Application Note DAN004-TM Issue 1-00,” Tech. Rep., SPIRENT Communications.

[5] Manuel Martín-Neira, Salvatore D’Addio, and Christopher Buck, “PARIS In Orbit Demonstrator: Part 3 - Geometry, Ionspheric Correction, Instrument Design, On-Board Calibration, Performance,” in *GNSS-R 08 Workshop*. ESTEC, ESA, sep 2008.