ADVANCED PARIS ALTIMETER BASED ON WAVEFORM DELAY COMPENSATION

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1. ABSTRACT

The possibility to measure with high accuracy the mesoscale ocean topography is of primary importance for the oceanographers, meteorologists or climatologists in order to improve understanding of ocean circulation, ocean bathymetry, eddies, tides and Earth climate models.
Over the last years, conventional radar altimeters have provided huge amount of data and observation of many ocean features. However, since they are based on observing the ocean on a small footprint along nadir-looking direction, classical altimeters such as TOPEX/Poseidon, Jason, or ESA RA and RA-2 are not able to provide high spatial-temporal sampling, absolutely necessary to map properly ocean mesoscale features, unless deployed in ad-hoc constellations. The wide swath ocean altimeter has been envisaged as a potential solution to increase spatial-temporal sampling; however it is a very complex and costly solution [1].

In this context, over the last years the PARIS (Passive Reflectometric and Interferometric System) technique has attracted more and more interest as a low-cost complementary passive remote sensing tool to conventional active instruments for ocean altimetry and many other applications [2]. PARIS is a very wide swath altimeter, capable of reaching 1000 km swath or even more, depending on orbital altitude, as it picks up ocean-reflected (and direct) signals from several GNSS satellites, up to 12 tracks when Galileo will be available.
Due to the global coverage and the multi-static nature of this technique, a low-Earth-orbiting PARIS instrument would allow high spatial-temporal sampling of the Earth surface. For these reasons PARIS has been identified as a very promising complementary technique with respect to conventional radar altimeters in order to address mesoscale altimetry detection [3][4]. The precision requirement in order to properly perform mesoscale altimetry is generally considered as 5cm height precision over a spatial extent of maximum 100Km [3].

However, one of the major disadvantages of this technique is due to the characteristics of the currently available and planned navigation signals. Indeed, transmitted signals power and bandwidth are the most important parameters driving the performance of an altimeter, either radar, PARIS based, either mono-static or bi-static.
Currently transmitted navigation signals show significantly reduced power and bandwidth with respect to conventional altimeter ones. This implies poorer altimetry precision, accuracy and resolution per pulse.
Several studies and results from airborne experimental data have predicted that a space based PARIS receiver exploiting GPS C/A code cannot meet ocean mesoscale altimetry requirements, even adopting maximum reasonable instrument dimension. Analyses in [2],[5],[6] have presented estimation of PARIS altimetry precision adopting GPS signals. The proposed analyses adopt different estimation methods but the results are completely congruent.
On the other hand, the exploitation of a GPS P-code like signal (which presents wider bandwidth, and, in turn, better performance) is on the limit of fulfilling the mesoscale requirements for a spatial resolution of 100Km [6].

For this instrument, height measurement precision improvement would allow fully meeting the mesoscale altimetry requirements, obtaining more reliable and robust data and increasing the spatial sampling of the ocean with respect to that achievable with the current PARIS reference processing.

Generally speaking, three major parameters determine the precision performance of PARIS altimeter: the signal-to-noise ratio (SNR), the TX GNSS bandwidth and the signal-to-speckle ratio (SSR). The first two depend principally on system parameters such as transmitted power and bandwidth, TX and RX antennae gain, receiver thermal-noise figure, coherent integration and orbit altitude.
GPS modernization plan includes an increase of transmitted power and bandwidth, at the same level to that planned in Galileo system. This aspect will certainly improve the link budget with respect to the SNR.
Therefore the self fluctuation of the received pulse, also called “speckle” or “fading” noise is the dominant source of height measurement error for a PARIS altimeter. Extensive incoherent averaging of received pulses is always applied in PARIS altimeter in order to improve SSR and, in turn, height measurement precision. On the other hand, incoherent averaging reduces spatial resolution, therefore it can be applied within the limit of 100Km ocean patch as outlined in mesoscale altimetry requirements. For instance, for a PARIS satellite at an orbit altitude of 500Km, incoherent averaging can be adopted as maximum within a time window of approximately 15 seconds, corresponding indeed to a path length of 100Km travelled by one the specular reflection points.

In the last years, for conventional radar nadir-looking altimetry, the delay/Doppler processing has been proposed in order to improve the altimetry precision as well as the spatial resolution [7]. The delay/Doppler technique is essentially based on the exploitation of the pulse-to-pulse coherence within the transmitted pulse trains. The technique is based on a coherent along-track processing of the received pulses in such a way to produce different altimetry waveforms for different along-track Doppler bins which correspond to contiguous zones over the ocean surface, illuminated by the full 3dB antenna beam-width. All the produced Doppler waveforms are then exploited for height estimation. This allows increasing the number of independent looks with respect to conventional incoherent radar altimeters, thus reducing the speckle degradation, with no expenses for the spatial resolution.

Being the transmitted GNSS signals intrinsically coherent, this paper proposes the adoption of an adaptive delay/Doppler processing technique for a bistatic passive altimeter based on GNSS signals (i.e. PARIS altimeter), which achieves better altimetry precision than currently possible with conventional processing.
The paper introduces in detail the proposed processing and the major differences and peculiarities with respect the delay/Doppler processing adopted in conventional radar altimeters.
Numerical analyses are presented in order to compare the performance of the proposed processing with respect the conventional one, for different mission scenarios.
It will be shown that a PARIS altimeter based on delay/Doppler could achieve height precision improvement up to the 50% with respect to the conventional processing, adopting for example, GPS P-code like GNSS transmitted signals.

2. REFERENCES

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