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Phase Coherence Change Detection via Circular Uniformity Test Applied to GNSS-Reflectometry

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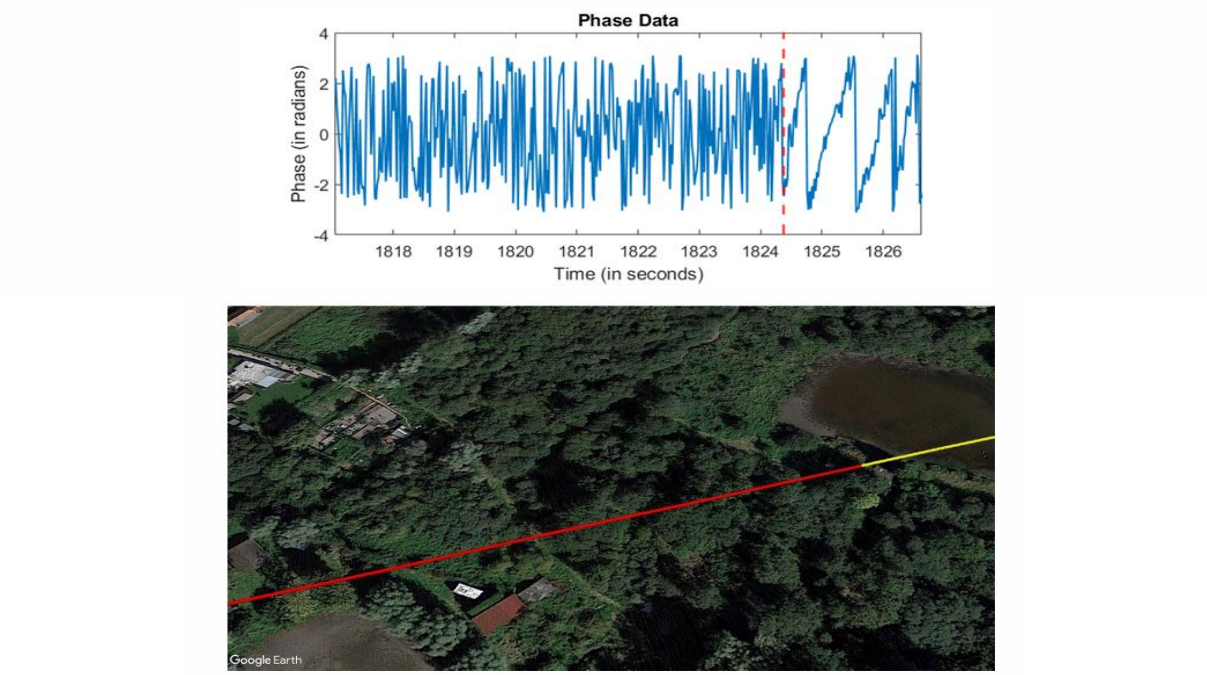
This research focuses on the analysis of carrier-phase coherence in airborne GNSS-Reflectometry (GNSS-R) signals for remote sensing applications. The objective is to detect changes in the reflected GNSS phase to identify variations in surface characteristics, such as transitions between smooth and rough terrain. Unlike classical reflectivity or amplitude-based approaches, this study considers the circular nature of phase data and its sensitivity to surface coherence [1].

To address this, we propose an offline Bayesian change point detection method tailored to the statistical properties of phase signals. The model assumes that the carrier-phase noise follows a Von Mises distribution [2] and applies a Bayesian framework to jointly estimate the change points and the parameters of each stationary segment [3]. The estimation is performed by minimizing a penalized contrast function, where phase parameters are extracted from the spectral representation of the excess Doppler, computed in an open-loop tracking configuration.

The proposed method is first validated on synthetic GNSS phase data, demonstrating high accuracy in detecting known transitions. It is then applied to real GNSS-R measurements acquired during airborne campaigns conducted in the northern region of France [4]. The results confirm the ability of the approach to distinguish between coherent reflections over smooth surfaces, such as water bodies, and non-coherent reflections over rough terrain. The change points are consistently localized, and the coherence levels are quantified through the estimated concentration parameters of the Von Mises model.

This work contributes a novel phase-based framework for change detection in GNSS-R, offering new perspectives for surface characterization and environmental monitoring using reflected GNSS signals [5].



Références :
[1] S. G. Anderson, Y. Wang, and Y. J. Morton, "Relating GNSS Reflected Signal Coherence to Ice Shelf Surface Deformation and Roughness," IEEE Transactions on Geoscience and Remote Sensing, 2025.
[2] G. Stienne, S. Reboul, M. Azmani, J.-B. Choquel, and M. Benjelloun, "A multi-temporal multi-sensor circular fusion filter," Information Fusion, vol. 18, pp. 86–100, 2014.
[3] S. Reboul and M. Benjelloun, "Joint segmentation of the wind speed and direction," Signal Processing, vol. 86, no. 4, pp. 744–759, 2006.
[4] H. Issa, G. Stienne, S. Reboul, M. Raad, and G. Faour, "Airborne GNSS Reflectometry for Water Body Detection," Remote Sensing, vol. 14, no. 1, 163, 2021.
[5] K. Yu, Theory and Practice of GNSS Reflectometry, Springer, 2021.