Polarimetric and Interferometric Optimization of Ionospheric Calibration

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With BIOMASS, it was desired to exploit the capability of low-frequency Synthetic Aperture Radar (SAR) to penetrate into volumetric targets such as dense forest, snow and ice. With its long wavelength ($\lambda \sim 69\,\text{cm}$) and quad-pol operation, it has proven to, for example, detect and separate targets below tree canopies (e.g., the ground and tree trunks) while maintaining the interferometric coherence, facilitating the implementation of interferometric techniques such as SAR tomography.

One of the main challenges associated with low-frequency radar is the distortion introduced by the ionosphere, which is seen in both single acquisitions and interferometric pairs. The effects can be grouped mainly into two categories: *Faraday rotation* affecting the polarimetry, and *phase errors* that introduce defocusing of single images, and azimuth shifts (misregistration) and residual phase screens between interferometric pairs. Both types of errors are proportional to the ionospheric free electron content and the wavelength. Small-scale ionospheric irregularities introduce high-frequency Faraday rotation and phase errors, usually referred to as scintillation. It has been proven that it is possible, for example, to use the polarimetry to estimate Faraday rotation and correct for phase errors [1] (this approach has proven to be effective at high latitudes).

However, the Faraday rotation sensitivity to small irregularities decreases rapidly towards mid- and low-latitudes. Then, the problem can be addressed by examining the phase signatures directly. Techniques such as autofocus help correct the impact in single images. In interferometric pairs or stacks, the differential ionospheric phase screen can be resolved by exploiting the induced coregistration errors in azimuth. The two mentioned approaches are based on cross-correlation between image pairs, for which the contrast and content of the scenes highly compromise the performance.

In this work, we exploit the fact that the phase error is common to all polarimetric channels to add redundancy to the observations. This allows us to reduce the uncertainty in retrieving the ionospheric distortion map when a least-mean squares inversion scheme is implemented. Similarly, we also use the multiple passes in the interferometric stacks to attempt to improve the performance of both the single-pass and interferometric corrections, as it was proposed in [2]. Besides regaining coherence and reducing interferometric phase errors, accurate scintillation maps will be valuable for studies that require high-resolution ionospheric imaging.

References

[1] Kim, J. S., Papathanassiou, K. P., Scheiber, R., and Quegan, S. (2015). *Correcting distortion of polarimetric SAR data induced by ionospheric scintillation,* IEEE Transactions on Geoscience and Remote Sensing, 53(12), 6319-6335.

[2] F. Betancourt-Payan, M. Rodriguez-Cassola, P. Prats-Iraola and G. Krieger, *Towards an Interferometric Autofocus for the Estimation of Ionospheric Signatures in Biomass,* EUSAR 2024; 15th European Conference on Synthetic Aperture Radar, Munich, Germany, 2024, pp. 1227-1231.