Evaluation of Tomographic SAR Inversion Algorithms for Forest Applications

Victor Cazcarra, Marivi Tello, Matteo Pardini, Kostas Papathanassiou

Since radar signals can penetrate through the vegetation, Synthetic Aperture Radar (SAR) systems can monitor forest parameters and processes. Using advanced imaging processing techniques like SAR Tomography (TomoSAR), 3D imaging capabilities can be achieved [1]. With this, in the next decade, future space SAR missions such as BIOMASS and Tandem-L, will allow to extract 3D information of the forest, at global scale [2] [3].

Once a TomoSAR acquisition is performed, tomographic processing techniques are required to extract the 3D reflectivity of the scene. Several methods for the reconstruction of the 3D reflectivity profiles from TomoSAR data exist in the literature. They all show a different behaviour and performance depending on both the characteristics of the scene and the system acquisition parameters. Besides the linear Fourier beamforming reconstruction, processing algorithms have been proposed to optimize the imaging step. Among them, widely used is the Capon beamforming, based on the minimization of the variance at each height [4]. More recently, methods based on Compressive Sensing (CS) have been proposed and tested in forest scenarios [5]. They achieve better resolution and reduce sidelobes, by exploiting the underlying structure of the data and solving a convex optimization problem. Also, their performance is less affected by the low number of available baselines and by their non-uniform distribution. However, besides a high computational cost, methods based on CS may in some particular situations introduce artefacts. Therefore, the better suitability of one method with respect to another may not be judged regardless of the application for which it is employed and the characteristics of the TomoSAR acquisition system.

For forest applications, the estimation of 3D reflectivity is important for mapping forest structure, in terms of the spatial distribution of canopy layers that needs to be estimated from the reflectivity profiles. Therefore the performance of a given reconstruction algorithm to reflect forest structure variability has to consider its ability to detect unambiguously the presence of a forest layer while remaining invariant to non-structural changes. This involves resolution, but also the capability to reflect weak scatterers. These characteristics will be tested in this paper for Capon beamforming and CS together with radiometric accuracy, stability and polarimetric accuracy.

Furthermore, these characteristics have to be considered with respect to the features of the acquisition configuration, specifically the number and distribution of baselines, the system bandwidth and the size of the multilook employed for the estimation of the covariance matrix. Therefore, the performance of the TomoSAR reconstruction methods will be tested also with respect to key configuration parameters. In order to carry out the comparison between both methods, simulated and real data will be considered. For the simulated scenarios, FORMIND [6] and PolSARpro [7] scenes will be generated for different TomoSAR system configurations. For the real scenarios, a fully polarimetric TomoSAR data, acquired by DLR E- and F-SAR airborne system over different forest sites will be used. Reference data such as lidar, optical images and in situ measurements are also available to discuss the results obtained by the Capon beamforming and the CS approach.

References

[1] A. Reigber and A. Moreira. *First demonstration of airborne SAR tomography using multibaseline L-band data*. IEEE Trans. Geosci. Remote Sens., Vol. 38, No. 5, pp. 2142–4152, Sep. 2000.

[2] Le Toan, T. et al. The BIOMASS mission: *Mapping global forest biomass to better understand the terrestrial carbon cycle*. Remote Sensing of Environment, Vol. 115, Issue 11. pp. 2850-2860, November 2011.

[3] Moreira, A. et al. Tandem-L: *A Highly Innovative Bistatic SAR Mission for Global Observation of Dynamic Processes on the Earth's Surface*. IEEE Geoscience and Remote Sensing Magazine, Vol. 3, Issue 2, pp. 8-23, June 2015.

[4] F. Lombardini and A. Reigber, *Adaptive spectral estimation for multibaseline SAR tomography with airborne L-band data*, Geoscience and Remote Sensing Symposium, 2003. IGARSS '03. Proceedings. 2003 IEEE International, 2003, pp. 2014-2016.

[5] E. Aguilera, M. Nannini, A. Reigber, A Data-Adaptive Compressed Sensing Approach to Polarimetric SAR Tomography of Forested Areas. IEEE Geoscience and Remote Sensing Letters, Vol. 10, No. 3, pp. 543–547, May 2013.

[6] R. Fischer, et al. *Lessons learned from applying a forest gap model to understand ecosystem and carbon dynamics of complex tropical forests*. Ecological Modelling, Volume 326, 24 April 2016, Pages 124-133.

[7] https://earth.esa.int/web/polsarpro/