A Unified Analysis of Radar Interferometry and Polarimetry for the Estimation of Forest Parameters

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The vertical structure of forests is a key input to ecological models of forest succession, growth, and productivity. Radar interferometry is primarily sensitive to the spatial distribution of scatterers [1] while polarimetry is primarily sensitive to their orientation [2,3]. In forests, there are obvious correlations between the spatial distribution of scatterers and their orientation. For example, the largely horizontally-oriented ground surface is at the lowest spatial point in a forest and the more randomly-oriented volume is usually at the top and middle. The dominance of either of these features in the radar backscatter will simultaneously produce signatures in both interferometry and polarimetry. For example, for pure volume scattering, an increase in tree height leads to an decrease in interferometric amplitude and an increase in interferometric phase over the bare-surface signatures. If a ground reflection or ground-volume return contributes even at the 10% level to the received signal, the effect on the correlation amplitude can be of the same order and the effect on the phase can correspond to 5-10 meters of topography. This paper exploits these signatures to simultaneously invert interferometric and polarimetric data from the Boreas Southern Test Site for tree height, surface topography, and other parameters as noted below. The data include TOPSAR interferometry at VVVV, where the first "VV' indicates the transmit-receive configuration at the 1-end of the baseline and the second "VV" indicates the transmit-receive configuration at the 2-end; the interferometric data were acquired at two baselines, 2.5- and 5-m. The polarimetry data include HHHH, VVVV, and HVHV powers, and the complex HHVV cross-correlation (amplitude and phase), where the first two letters indicate the transmit receive configuration of the first member of the polarimetric (baseline=0) cross-correlation and the second two letters indicate the transmit-receive configuration of the second member of the cross-correlation.

A simple forward model, a polarimetric generalization of the approach in [1], describes the interferometric and polarimetric cross-correlations in terms of parameters describing the vegetation and underlying surface. The model assumes a flat ground surface under a largely randomly oriented, statistically homogeneous vegetation. The parameters needed to describe the interferometry and polarimetry include tree height, underlying topography, extinction coefficient, ground dielectric constant (real and imaginary parts), and a parameter describing the ratio of the specular to backscattering characteristics of the volume scatterers. Results for tree height and underlying topography will be compared to ground truth. The correspondence will be made between this approach and fully polarimetric interferometry, in which arbitrary transmit-receive polarization combinations are available [4].

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[3]Ngiehm, S. V., Yuch, S. H., Kwok, R., and Li, F., "Symmetry properties in polarimetric remote sensing," Rad. Sci., 27, 693-711, 1992.
[4] Cloude, S.-R., Papathanassiou, K.-P., ``Polarimetric Radar Interferometry", SPIE Proceedings on Wideband Interferometric Sensing and Imaging Polarimetry, 3120, July 1997.