DEPENDENCE OF P-BAND INTERFEROMETRIC HEIGHT ON FOREST PARAMETERS FROM SIMULATION AND OBSERVATION

(1)M Lavalle, (2)M L Williams, (3)S Hensley, (1)D Solimini and (4) E Pottier

(1)Tor Vergata University, Via del Politecnico 1, 00133 Rome, Italy
(1)marcolavalle@gmail.com
(2)Fugro-EarthData, 7320 Executive Way, Frederick, MD 21704, USA.
(3)Jet Propulsion Laboratory, California Institute of Technology, 4800 Oak Grove Drive, Pasadena, CA 91109, USA.
(4) University of Rennes 1, 263 Avenue General Leclerc, 35041 Rennes, France.

1. ABSTRACT

Scattering of electromagnetic waves from vegetation is strongly dependent on the frequency of the wave itself. This dependence impacts on the degree of coherence when interferometric acquisitions are performed using a Synthetic Aperture Radar (SAR). At X-band, scattering is predominantly "first-surface", and, in general, the X-band VV interferometric phase centre is anticipated to be close to the top of vegetation canopies. At lower frequencies, such as P-band, HH returns are, in general, more strongly influenced by ground-volume interactions, and the P-band HH phase centre is expected to lie closer to the ground. Thus the difference between the X-band VV digital elevation model (DEM) height and the P-band HH DEM height is related to the height of the vegetation covering the terrain. Indeed this "surrogate" vegetation height has been used in the retrieval of biomass for areas of tropical forest [1]. The GeoSAR dual-frequency, interferometric SAR was developed for wide-area, airborne mapping applications by NASA's Jet Propulsion Laboratory [2] and is now operated commercially by Fugro-EarthData on a Gulfstream II jet aircraft. GeoSAR collects X-band (VV, 9.7GHz) and P-band (HH, 0.35GHZ) interferometric data in single-passes, from which are derived digital elevation models. The combination of wide-area mapping capability and sensitivity to forest height make GeoSAR an invaluable tool for the large-scale estimation and monitoring of above-ground carbon stocks.

Both evidence and theory suggest that volume scattering effects will lift the P-band HH phase centre off the ground somewhat, even though the ground-volume scattering is strong. An example of a raised P-band HH phase centre under forest is given below in Figure 1. In the figure, forested areas next to a river-bend, clearly distinguished in magnitude data, and in the X-band DEM, are also associated with elevated P-band DEM heights in an otherwise flat area. Additional examples are discussed in the full paper. In order to better exploit the surrogate vegetation height measurement available from GeoSAR observations we need to determine the relationship between our usual understanding of tree height, and the X-band/P-band interferometric height difference.

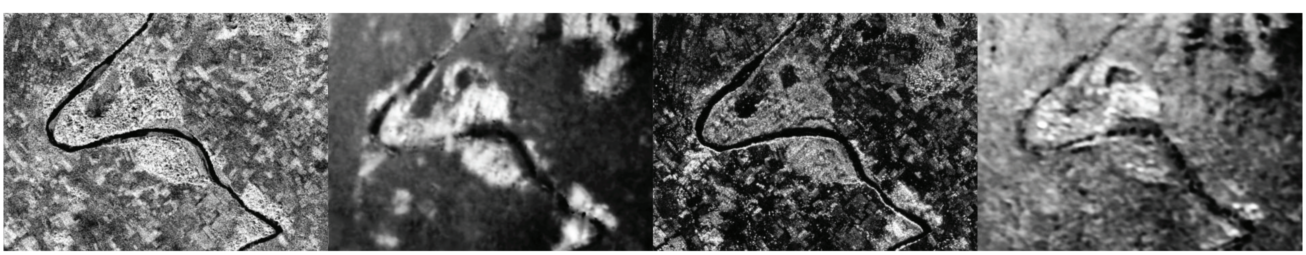

Figure 1. Reading from left: X-band magnitude, X-band DEM, P-band magnitude, P-band DEM. Heights increase from dark-grey to light-grey, X-band and P-band DEM images are not to the same grey-scale.

In this paper we examine the dependence of the P-band HH interferometric phase centre height upon forest and terrain parameters. We develop a simple "random-volume-over-ground" (RVOG) model [3] for P-band GeoSAR observations, and use the model to show how the elevation in P-band HH phase centre height above true ground height is related to the volume-to-ground scattering ratio [4]. This ratio may not be measured directly since direct-ground and ground-volume scattering

terms contribute, in addition to direct-volume scattering, to the total HH backscatter. GeoSAR records cross-polar (HV) returns at P-band (although not interferometrically) and these returns may be dominated by direct-volume scattering, especially for tall, dense, tropical forests. In a random-dipole cloud model of low-frequency vegetation scattering [5] the direct-volume HV backscatter is related simply to the direct-volume HH backscatter. In situations where this condition is appropriate the relationship could be used to estimate direct-volume, P-band HH backscatter from HV backscatter. This in turn could be used to generate a height-correction to the P-band HH DEM using the RVOG model that will bring the P-band HH phase centre closer to the ground. Not only could this procedure permit a better estimate of “bare-earth” height for mapping purposes, but, as a result, the difference between X-band DEM height and volume-corrected P-band DEM height will be closer to a definition of tree height more appropriate for forest biomass recovery: all without using polarimetric-interferometric SAR techniques which degrade spatial resolution.

We demonstrate that our model predicts P-band phase centre elevation magnitudes in accordance with those observed in GeoSAR data for forested areas. We expand this analysis with data simulated using ESA’s high-fidelity forest SAR simulator, PolSARproSim [6], available for download with the PolSARpro [7] tutorial package. The simulator permits us to evaluate the HH volume-to-ground scattering ratio directly, and to relate this ratio both to the HV/HH ratio, and to the variation in P-band HH phase centre height, for a variety of terrain conditions and forest cover parameters. An example of such a calculated variation is shown in Figure 2. Here the volume-to-ground scattering ratio is varied by altering both the soil roughness, and the moisture content of the ground surface below the forest. The P-band HH phase centre is seen to decrease towards ground level (0m) as the volume-to-ground scattering ratio decreases, in keeping with the theoretical model.

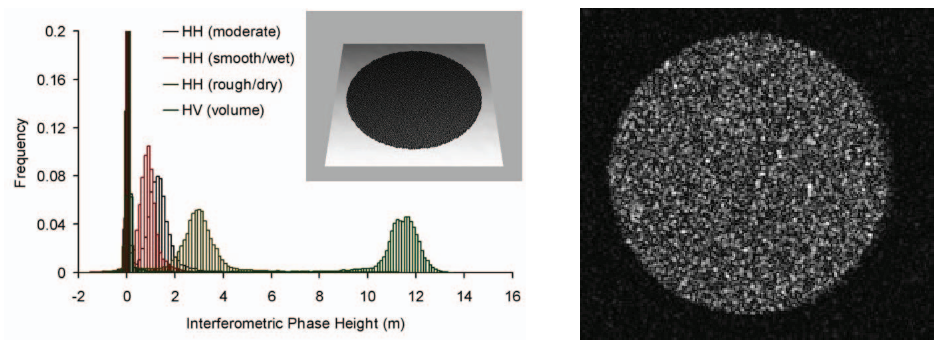

Figure 2. Variation in distribution of interferometric phase height with polarization and surface parameters from SAR simulation (right) for a Scots Pine forest (inset) simulated with PolSARproSim [6].

We examine the volume-to-ground ratio dependence upon forest constitution, and ground properties, including terrain slope, and conclude by discussing the practicalities of calibrating the correction technique with real data.

2. REFERENCES

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