TOPOGRAPHY EFFECTS ON FOREST RADAR SCATTERING, CONSEQUENCES ON BIOMASS RETRIEVAL

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1. INTRODUCTION

Ground topography under vegetated area can have a significant impact on the radar backscatter signal and thus on the retrieval of vegetation biomass. This paper addresses the comparison between the radar backscatter at P-band from forest over tilted and non tilted ground. This is achieved using the electromagnetic model MIPERS, followed by comparison with past studies (e.g. [1]) and experimental data, in particular those acquired in BIOSAR 2008 campaign over a forest in North Sweden (cf. [5]).

Subsequently, the effect of ground slope on the retrieval of forest biomass based on Pol InSAR coherences is assessed, based first on the standard form of the RVoG (Random Volume Over Ground) model inversion from Pol-InSAR coherences. More specifically the following set of descriptive parameters is concerned : $[\phi_0, h, \sigma, \mu_{hh}, \mu_{hv}, \mu_{vv}]$, that is respectively the ground phase, height, extinction coefficient and polarimetric ground over volume ratios. Finally, in view of the importance of these ground slopes effects, a solution involving a non linear optimization formulation is proposed and its robustness is assessed using simulated coherences.

2. ELECTROMAGNETIC MODELLING AND RADAR OBSERVABLES MAIN CHANGES

Generally, our model MIPERS (Multisatic Interferometric & Polarimetric Electromagnetic model for Remote Sensing) has been designed to simulate Pol-InSAR observables and therefore uses a coherent (especially to preserve the interferometric phase) and a descriptive approach. As far as topography is concerned, the scene geometry takes on particular importance. It can be decomposed into several zones characterized by its own origin $O_{p=1\ldots N}$ and normal vector $\vec{n_p}$. Each patch is derived from the main coordinate system $\mathbf{R_0}$ after a similitude transformation. The latter is defined by the translation $\vec{OO}_p$ and the two Euler rotations $(\vec{z_0}, \alpha_p)$, $(R^{\alpha_p}(\vec{y_0}), \beta)$. Then scatterers are modelled with canonical elements (cylinders and ellipsoids) and arranged as realistic as possible according to the tree description at our disposal (cf. [1]). This distribution is vertically divided by a sufficient number of layers associated to a representative extinction coefficient. Their radar scattering contribution are then coherently added as well as the ground contribution and coupling effects (double bounce between volume and ground). In order to take into account an arbitrary tilted angle, we first compute a scattering matrix (using IEM or FDTD) which relates incident and scattered field in the respective basis $(k^i, v^i, h^i)_{O_p}$ and $(k^s, v^s, h^s)_{O_p}$.

$$\overrightarrow{E^s_p} = \frac{e^{jkr}}{r} \cdot [\mathbf{S_p}(\theta^i_p, \varphi^i_p, \theta^s_p, \varphi^s_p)] \cdot \overrightarrow{E^i_p} \tag{1}$$

$$[\mathbf{S_p}] = \left[\begin{array}{cc} S_{h^s_p h^i_p} & S_{h^s_p v^i_p} \\ S_{v^s_p h^i_p} & S_{v^s_p v^i_p} \end{array} \right] \tag{2}$$

We stress the fact that upperscripts refer to incident or scattered field whereas lowerscript to the zone number (and its own coordinate system). Then, $(\theta^{i,s}_p, \phi^{i,s}_p)$ do correspond to the spherical coordinates of transmitter and receiver position in $\mathbf{R_p}$, which by itself can significantly affect the radiometry (cf. [2]). Then, the scattered field in $\mathbf{R_0}$ verifies eq. 3 where quaternions

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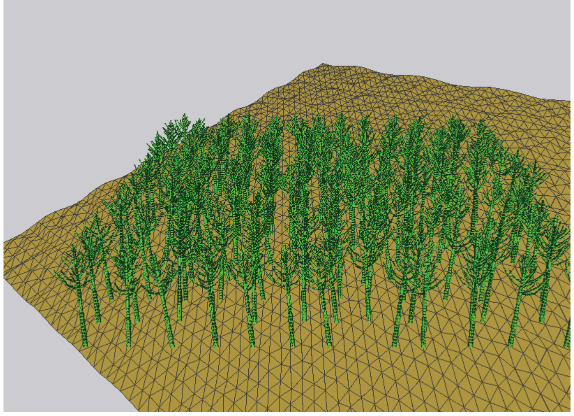

Fig. 1. Graphical output of the simulated forest over a tilted, multifaceted ground.

matrices $[P]$ include azimuth and site rotations ($K_p^{i,s}$ refers to the canonical polarization basis derived from the euclidian R_p one)

$$[P_{R_0}^{K_p^s}]^{-1} \cdot [P_{R_0}^{R_p}]^{-1} \cdot [P_{R_0}^{K_0^s}] \cdot \overrightarrow{E_0^s} = [\mathbf{S_p}] \cdot [P_{R_0}^{K_p^i}]^{-1} \cdot [P_{R_0}^{R_p}]^{-1} \cdot [P_{R_0}^{K_0^i}] \cdot \overrightarrow{E_0^i} \tag{3}$$

from which the $[\mathbf{S_0}]$ expression is straightforward. Significant cross polarization terms can result from this matrix transformation. Besides, the cancellation of this term through polarization basis rotation is a well known method to provide a slope information that is a composite angle for lack of the two Euler ones (cf. [3, 4]). The volume (assumed azimuthally symmetric) and its interaction with the ground is taken into account following the same approach that is from the local coordinate system with the corresponding orientations and radar positions, these transformations will be detailed as well in the full paper. A particular attention is put on attenuation calculations as in the tilted system the media loses its revolution symmetry along the current normal vector and therefore exhibits non null cross polarization extinction coefficients. Instead of computing the latters using forward scattering theorem with the suitable orientations distributions, another set of rotations can produce the same result.

3. CONSEQUENCES ON THE RVOG INVERSION, RVODG FEASABILITY

On account of our simulation results, it turns out that in addition to a significant impact on double bounce, the cross polarization contribution from the ground is also manifest — specifically in the case of azimuthal ground slope — and implies to modify the standard inversion algorithm. Indeed, the HV term from the ground is mostly assumed null so that a simple but elegant linear relationship holds for the coherence dependency on the ground return (cf. [6]). A numerical approach is then preferred using a quasi-Newton method under constraints $\mathbf{D}$ to find the set of parameters X which minimizes the distance between theoretical polarimetric decorrelation and observables :

$$\min_{X \in \mathbf{D}} \|\gamma_{pq} - f^{pq}(X)\| \text{ , with } \quad X = [\phi_0, h, \sigma, \mu_{hh}, \mu_{hv}, \mu_{vv}] \tag{4}$$

The additional μ_{hv} parameter is introduced and the resulting inversion of the RVoDG (Random Volume over Depolarizing Ground) feasibility is assessed according to the Hadamard criteria among which existence and uniqueness conditions are tested with simulated Pol-InSAR coherences.

4. COMPARISON WITH EXPERIMENTAL DATA

The modelling results will be compared with observation using data from the BIOSAR 2008 campaign ([5]). The campaign collected in-situ and airborne SAR data at boreal forests with significant topography in northern Sweden to investigate the effect on forest height estimation and radar backscatter signal variation due to topography. Backscatter intensity at HH, VV, HV and Pol InSAR coherences have been analysed as a function of forest biomass and the effect of topography has been assessed. The paper will present the model data comparison and will discuss on the mitigation of topography effect on the biomass retrieval.

5. REFERENCES

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