A POLARIMETRIC VEGETATION MODEL TO RETRIEVE PARTICLE AND ORIENTATION DISTRIBUTION CHARACTERISTICS

Maxim Neumann[1], *Laurent Ferro-Famil*[1], *Marc Jäger*[2], *Andreas Reigber*[3], *and Eric Pottier*[1]

[1]University of Rennes 1, SAPHIR Team, IETR Laboratory,
Campus de Beaulieu, bât. 11D, 263 Avenue Général Leclerc, 35042 Rennes, France,
Email: maxn@cs.tu-berlin.de
[2]Berlin University of Technology, Computer Vision and Remote Sensing Group,
Franklinstrasse 28/29 (FR3-1), 10587 Berlin, Germany
[3]German Aerospace Center (DLR), Microwave and Radar Institute
P.O. Box 1116, 82234 Wessling, Germany

1. INTRODUCTION

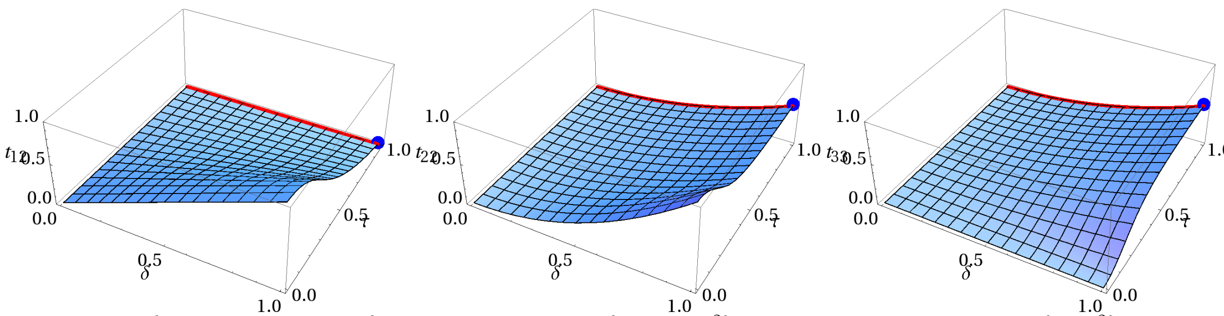
A simple vegetation model for polarimetric covariance and coherency matrix elements is presented. The model aims to represent vegetation characteristics which are observable by radar polarimetry, including the average particle anisotropy, the main polarization orientation of the volume, the degree of orientation randomness in the volume, and the terrain slopes. The decomposition consists, in analogy to the Freeman–Durden model, of volume, surface, and double–bounce scattering components considering all vegetation characteristics. The goal of this approach is to quantify these parameters and to enable their estimation in a remote sensing parameter inversion framework.

A simplified volumetric vegetation layer can be characterized by a cloud of scattering particles whose electromagnetic properties are governed by the probability density functions of their positions, shapes, sizes, dielectric constants, tilt angles and orientation angles (with respect to the polarization plane). The single particle scattering properties are assumed to be independent of position and orientation. Under the hypothesis that particles have an axis of symmetry, the average particle backscattering matrix in eigenpolarizations has a diagonal form, where the polarimetric backscattering behavior can be characterized by a single complex value, the particle scattering anisotropy δ, which describes the scattering properties of an average particle, as perceived by the radar, independently of polarization orientation and scattered power.

The particle anisotropy characterizes the effective shape of the average particle in the polarization plane in dependence of the particle and background permittivities. If the particle permittivity is similar to the background permittivity (i.e. air), the particle anisotropy tends towards 0 independently of the real shape of the particle. If the permittivities are significantly distinctive, one can make the following predictions about the effective particle shapes, assuming simple ellipsoid particles: as $|\delta| \rightarrow 0$, the average effective particle shape approaches an isotropic sphere/disk, whereas for $|\delta| \rightarrow 1$ the effective shape tends towards a dipole. The phase of δ characterizes the average orientation of the scatterers with respect to the reference coordinate system in the polarization plane.

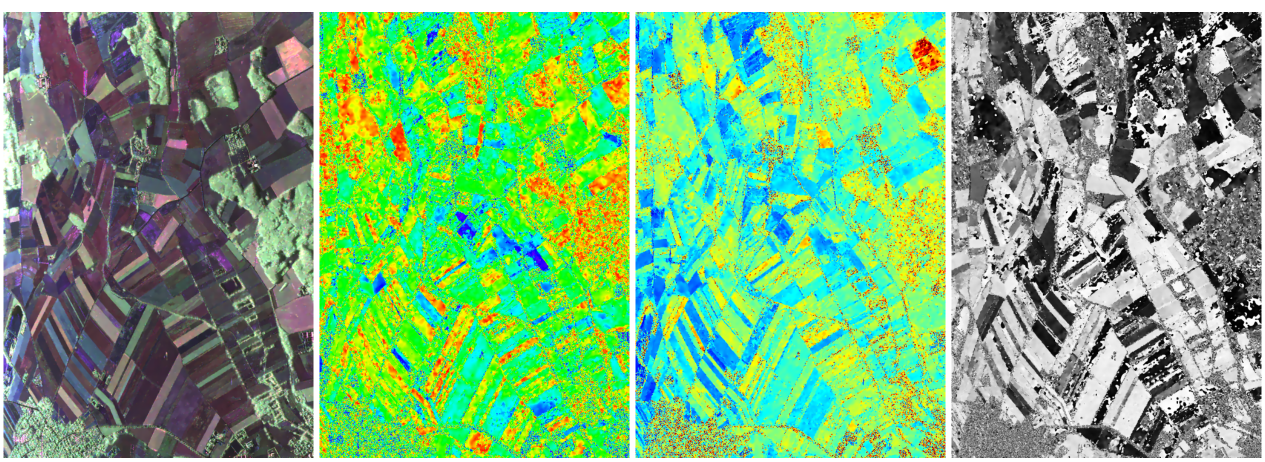
The particle orientation angle ψ in the polarization plane is assumed to follow a unimodal circular distribution $p_\psi(\psi)$ and to be independent from other vegetation characteristics. Under the central limit theorem condition, given a large number of scatterers, the orientations of these scatterers are normally distributed, and follow the von Mises distribution. This distribution is determined by the mean orientation angle $\widetilde{\psi}$ and the normalized degree of orientation randomness $\tau \in [0, 1]$. The derived normalized coherency matrix elements for the volume component in dependence of the average particle anisotropy and degree of orientation randomness are presented in Fig. 1.

Most agricultural and forestry vegetation types can be realistically modeled by a single volumetric layer over the ground taking into account the orientation characteristics, but an extension to multiple layers to model complex vegetation structures is possible. Using additional data sources, such as interferometry (PolInSAR), external DEM, multi–frequency, or multiple incidence angles makes the inversion of the mentioned parameters possible. If the volume component dominates, one can invert these parameters based on SAR polarimetry only. Experimental validation is presented on simulated data as well as on real SAR data acquired by the E–SAR system of the German Aerospace Center (DLR).



(a) $|t_{12}| = \frac{|\mathrm{E}\{(S_{hh}+S_{vv})(S_{hh}-S_{vv})^*\}|}{\mathrm{E}\{|S_{hh}+S_{vv}|^2\}}$ (b) $t_{22} = \frac{\mathrm{E}\{|S_{hh}-S_{vv}|^2\}}{\mathrm{E}\{|S_{hh}+S_{vv}|^2\}}$ (c) $t_{33} = \frac{\mathrm{E}\{|S_{hv}|^2\}}{\mathrm{E}\{|S_{hh}+S_{vv}|^2\}}$

Fig. 1. Normalized coherency matrix elements ($|t_{12}|, t_{22}, t_{33}$) over τ and $|\delta|$. Von Mises distribution of orientation angles. The blue point and the red line correspond to the parameter space of the Freeman–Durden and the Freeman II models, respectively.



(a) Scene in Pauli basis after the application of the J–filter. (b) Degree of orientation randomness τ. (c) Particle anisotropy amplitude. (d) Particle anisotropy phase.

Fig. 2. Example results.