Theory for Polarimetric Interferometry

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While extensive forward and inverse modeling efforts have been focused on monostatic radar backscatter and bistatic power returns, recent advances in interferometric remote sensing utilizing electromagnetic phase information necessitate the development of mathematical models and computational algorithms for interferometric data interpretations and especially for interferometric inversion problems. We develop a unified electromagnetic wave model to determine multipolarization interferometric signatures together with monostatic and bistatic scattering characteristics of geophysical media. The approach is to describe heterogeneous geophysical media with a stratified multilayered configuration. Vector wave equations are derived from Maxwell's equations for the layered media. Integral equations are cast from the wave equations to solve for electromagnetic fields under the distorted Born approximation subject to boundary conditions at medium interfaces. Dyadic Green's functions are used to account for multiple wave boundary interactions including multiple transmissions, refractions, reflections, and differential phase and attenuation of ordinary and extraordinary waves propagating downward and upward in anisotropic layered media.

Interferometric radar measurements are realized by transmitting electromagnetic waves to a targeted area and recording scattered waves with two different receivers, or by repeating monostatic measurements twice over the same area with a small displacement of the radar between the two overpasses. In the theory, we derive correlations of scattered fields for all polarization combinations in the linear basis at two different observation points above the layered media with spectral densities describing the scatterers. For the first observation point taken at the incident or transmitted field location, the theory is a unified treatment of: (a) monostatic scattering by taking ensemble averages for scattered field correlations at the first observation point, (b) bistatic scattering by ensemble averages at the second point, and (c) interferometric scattering by cross-ensemble averages at the two points. For a case of repeated overpasses, a similar methodology is applied but with incident waves transmitted from two different locations. Multifold integrations for polarimetric backscattering, polarimetric bistatic, and polarimetric interferometric scattering coefficients are carried out over spatial and spectral domains with the complex residue theorem for different characteristic wave types in anisotropic media. The theory intrinsically accounts for the interferometric phase, radar resolution cell, baseline decorrelation, rotation decorrelation, polarization diversity and depolarization effects, and characteristics of geophysical media. We also formulate a generalized correlation tensor M, which characterizes all monostatic, bistatic, polarimetric, and interferometric scattering properties including information for differential polarimetry. This tensor contains 16 tensor elements; each has 16 polarization combinations totaled to 256 complex elements in M carrying a large amount of information about the remotely sensed media.