Radar Backscatter Model to Predict Co-Polarized InSAR Phase Decorrelation due to Layered Medium Effects

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Under the uncorrelated-scattering and perturbation-type assumptions governing surface roughness and volume dielectric fluctuations, we propose a microwave radar backscatter model to understand trends underlying the decorrelation observed in Interferometric Synthetic Aperture Radar (InSAR) interferometric phase measurements formed by two antennas observing a bare (non-vegetated) layered, dielectric medium. In particular, for the co-polarized radar backscatter field returns (*hh* and *vv*), we extend upon past models that typically assume either a homogeneous subsurface or neglect important scattering mechanisms in layered-medium structures when they are quite radar-transparent (i.e., penetrable). Such traditional, homogeneous-subsurface models are applicable for many distributed targets (e.g., partially melted snow, wet and salty soils), particularly at higher frequencies such as X-band, where the penetration of an antenna's radiated electromagnetic (EM) pulse into the subsurface can often be considered negligible. However, this assumption can break down when appreciable EM penetration is expected (e.g., dry snow, dry soils), particularly at lower microwave frequencies such as P-band. The following broader question then arises: How to efficiently and accurately model the effects of radar backscatter from distributed, *layered* dielectric structures on interferometric phase decorrelation? Particularly, which scattering mechanisms are important to include in the model and which can be neglected? Furthermore, how should one appropriately quantify these mechanisms?

We discuss our answers to these questions, both in terms of a mathematical radar backscatter model as well as a physics-grounded justification of why certain mechanisms are included and others are excluded. In particular, we include the effects of rough surface scattering and volume scatter (arising from the weakly inhomogeneous dielectric layers) as do some past InSAR models (including the well-known "spatial baseline decorrelation" effect), however we also include the effects of "multi-bounce" (occurring within dielectric slab layers) in modifying the rough surface backscatter, which can markedly exacerbate interferometric decorrelation via introducing (effective) "image" sources (re-radiators/scatterers) deeply buried within the ground. As far as quantifying these scattering mechanisms, we employ the Fresnel (i.e., specular) planar-interface reflection and transmission coefficients to account for transmission losses and multi-bounce effects, while the Small Perturbation Method (SPM1) and Weak Fluctuation Theory (resp.) account for rough surface scattering and volume scatter arising (resp.). Numerical results will be presented to illustrate key decorrelation trends and highlight the importance of considering layered-medium effects when interrogating them with microwave radars.