Electromagnetic Wave Scattering from Multi-layered Random Rough Surfaces with Buried Dielectric Object

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Electromagnetic sensing of buried objects in the presence of a random rough interface is a crucial step for subsurface detection problems in general. Most theoreticians and experimentalists agreed that surface roughness constitutes a major source of clutter (i.e., noise) in the received electromagnetic signals. However, due to the complexity of the problem, the ground surface is often assumed to be single layered and *not* multi-layered. This is not the case in the real environment but no work has yet been published on scattering from objects buried beneath multi-layered randomly rough ground. Therefore, the objective of this work is to investigate the scattering of electromagnetic waves from a penetrable shallow object buried in 2-D multi-layered random rough surfaces. It is known that the computational complexity of the scattering problem dramatically increases for the multi-layered rough interface.

A rigorous electromagnetic model has been developed for scattering from inhomogeneous rough ground surfaces. This model is based on the classical equivalence theorem and the method of moments (MoM) that is dramatically accelerated by implementing the Steepest Descent Fast Multipole Method (SDFMM). Four different homogeneous regions are involved in this application; air, dielectric object, upper soil layer and lower soil layer. A tapered Gaussian beam is used to illuminate the multi-layered ground surface. The rough surfaces are characterized with Gaussian statistics for the height and for the autocorrelation function. Since the SDFMM was originally developed for quasi-planar structures where the whole height of the 3-D scatterer should be in the order of one free space wavelength, it is necessary to validate the SDFMM implemented for this application versus the MoM. The relative norm of the error in surface current is presented. The computer memory requirement is plotted versus the SDFMM finest block size for the multi-layered ground with the buried object. It is necessary to mention that the air-ground interface and the underground layer could be flat and/or could be random rough surfaces with different roughness parameters and lossy or lossless soil. Numerical results representing the RCS of the multi-layered ground with the buried object are shown. The effect of the physical characteristics and the surface roughness of the multi-layers are investigated. The thickness of the multi-layer ground is varied to study its influence on the buried object signature.

The results of this work could increase the efficacy of the present subsurface sensing methods by accounting for the multi-layer nature of the rough ground.

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