Knowledge of subsurface characteristics such as permittivity variations and layering structure could provide a breakthrough in many terrestrial and planetary science disciplines. For Earth science, knowledge of subsurface and subcanopy soil moisture layers can enable the estimation of vertical flow in the soil column linking surface hydrologic processes with that in the subsurface. For planetary science, determining the existence of subsurface water and ice is regarded as one of the most critical information needs for the study of the origins of the solar system.

The subsurface in general can be described as several near-parallel layers with rough interfaces. Each homogenous rough layer can be defined by its average thickness, permittivity, and rms interface roughness assuming a known surface spectral distribution. As the number and depth of layers increase, the number of measurements needed to invert for the layer unknowns also increases, and deeper penetration capability would be required.

To nondestructively calculate the characteristics of the rough layers, a multifrequency polarimetric radar backscattering approach can be used. One such system is that we have developed for data prototyping of the Microwave Observatory of Subcanopy and Subsurface (MOSS) mission concept. A tower-mounted radar makes backscattering measurements at VHF, UHF, and L-band frequencies. The radar is a pulsed CW system, which uses the same wideband antenna to transmit and receive the signals at all three frequencies. To focus the beam at various incidence angles within the beamwidth of the antenna, the tower is moved vertically and measurements made at each position. The signals are coherently summed to achieve focusing and image formation in the subsurface. This requires an estimate of wave velocity profiles.

To solve the inverse scattering problem for subsurface velocity profile simultaneously with radar focusing, we use an iterative technique based on a forward numerical solution of the layered rough surface problem. The layers are each defined in terms of a small number of unknown distributions as given above. An a priori estimate of the solution is first assumed, based on which the forward problem is solved for the backscattered measurements. This is compared with the measured data and using iterative techniques an update to the solution for the unknowns is calculated. The process continues until convergence is achieved. Numerical results will be shown using actual radar data acquired with the MOSS tower radar system in Arizona in Fall 2003, and compared with in-situ measurements.