Numerical analysis for water-ice detection using GPR considering temperature dependency of lunar regolith permittivity

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Studies of the presence and nature of water-ice on the lunar subsurface have attracted considerable attention from both scientific and engineering interests. Ground penetrating radar (GPR) is emerging as a variable tool for addressing this issue because of its ability to rapidly map subsurface permittivity structures. The relative permittivity of lunar regolith is known to be influenced by several factors, including bulk density (porosity), chemical composition, and in addition, temperature. Recent research highlights the significant effect of temperature on the permittivity of lunar regolith (Kobayashi et al., 2023).
The top layer of lunar regolith exhibits a complex temperature profile, which in turn results in intricate permittivity structures within the shallow subsurface. However, the response of these structures to GPR measurements remains unexplored. Thus, we perform a numerical analysis that comprehensively considers the effects of porosity and temperature on the relative permittivity of regolith, with a particular interest in the temperature dependence aspect.
Employing the Finite-Difference Time-Domain (FDTD) method, we simulate scenarios that assume the presence of a water-ice layer in the lunar polar regions. Simplifying the regolith composition to consist only of anorthosite, we model the profile of relative permittivity with respect to the subsurface structures influenced by porosity and temperature variations which has reported in previous research (Martinez & Siegler, 2021; Hayne et al., 2017). We also examine the case in extremely low temperature environments in PSRs. Our results suggest that even with low water-ice content, detection of the water-ice layer using UHF band GPR is feasible as long as the depth of the water-ice layer is within the characteristic depth associated with the frequency band.

References:
Kobayashi et al., *Earth, Planets and Space*, **75**, 8 (2023).
Martinez & Siegler, *Journal of Geophysical Research-Planets*, **126**, (2021).
Hayne et al., *Journal of Geophysical Research-Planets*, **122**, 2371-2400 (2017).

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