Electromagnetic Induction (EMI) Response from Conducting and Permeable Spheroidal Shells

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Broadband electromagnetic induction (EMI) methods are promising in the detection and discrimination of subsurface metallic objects such as unexploded ordnance (UXO) [1]. In previous works [2–4], we have presented the EMI solution for prolate and oblate solid spheroids under arbitrary excitation. This paper extends these anlayses to include spheroidal shells with a hollow cavity enabling the computation of the EMI response from hollow metallic objects such as needles, spheres and disks. It is expected that these hollow geometries will more closely resemble actual UXOs therefore leading to more accurate detection and discrimination.

We give an exact analytic formulation for the EMI response of a conducting and permeable prolate and oblate spheroidal shells. This formulation is based on the separation of variables in spheroidal coordinates. We assume that the medium surrounding the spheroidal shell is poorly conducting and only weakly magnetic. Thus, in the frequency range of interest, ~20Hz–30kHz, volume and surface effects from the surrounding medium may be conveniently ignored by approximating the background wavenumber $k_2 \approx 0$. This is in contrast to higher frequency subsurface detection techniques such as ground penetrating radar (GPR) in which case scattering must be accounted for due to the nonzero wavenumber of the background medium.

Numerical results for the far-field response from both prolate and oblate spheroidal shells for varying elongations and relative permeabilities are presented as a function of size parameter. These results are compared and contrasted to results for solid spheroids in limiting cases to validate the method. Results are presented as real (in-phase) and imaginary (quadrature) relaxation curves normalized to the high frequency limit. Results indicate that EMI responses from spheroidal shells differ in resonance frequency, crossover point, and DC dipole magnitude when compared to solid spheroids.

REFERENCES

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