Broadband Analytical Solution of the Electromagnetic Induction (EMI) Response by Spheroidal Objects Under Arbitrary Excitation

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Electromagnetic induction techniques show considerable promise for the detection and discrimination of subsurface metallic objects such as unexploded ordnance (UXO) or some kinds of landmines. Analytical solutions exist for the EMI secondary response (internally induced and externally scattered fields) from conducting and permeable spheroids [1, 3], but their evaluations encounter numerical difficulties for moderate frequencies. A small perturbation approximation (SPA) valid at high frequencies has also been developed [1], but as yet there is no satisfactory solution for intermediate frequencies. We use asymptotic expansions to approximate the spheroidal wave functions for large, complex size parameter c in order to extend the region of validity of the analytical method to moderate frequencies [2]. The broadband, secondary response from prolate and oblate spheroidal objects can then be obtained from a a concatenation of three methods: the original full analytical method for low frequencies, the asymptotic expansion-assisted full analytical method for moderate frequencies, and finally the SPA solution for higher frequencies. As the aspect ratio $e = b/a$ become much greater or much less than unity, solutions become unstable at lower and lower frequencies. However, in the prolate case, the concatenated solutions are within 5% error for $e \lesssim 10$ for relative permeability $mu_r = 1$ and $mu_r = 100$. In the oblate spheroidal case for the same parameter range, this error is achieved for $e \gtrsim 0.1$. These solutions provide a forward model upon which inversion routines could be based. A simple example for finding the position, orientation, and aspect ratio using a Nelder-Mead simplex search method is illustrated.

REFERENCES

1. C. O. Ao, H. Braunisch, K. O'Neill, , and J. A. Kong. Quasi-magnetostatic solution for a conducting and permeable spheroid with arbitrary excitation. *IEEE Trans. on Geoscience and Remote Sensing*, 40(4):887–97, April 2002.
2. B. E. Barrowes. Asymptotic expansions of the prolate angular spheroidal wave function and eigenvalues for complex size parameter. *Studies in Applied Mathematics*. to be submitted.
3. H. Braunisch, C. O. Ao, K. O'Neill, and J. A. Kong. Magnetoquasistatic response of conducting and permeable spheroid under axial excitation. *IEEE Trans. on Geoscience and Remote Sensing*, 39(12):2689–2701, December 2001.

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