On the Low-frequency Modeling of Coupled Obstacles Buried in Earth-like Medium

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The work considered here focuses onto the characterization of homogeneous volumetric obstacles buried in a Earth-like homogeneous or half-space medium in the induction regime. Fields of application are in the magnetic probing of natural or artificial objects buried in subsoil at some distance from the air/soil interface.

By characterization, it is meant identification of number, locations and main electrical and geo- metrical features of these obstacles. The latter are assumed to be penetrable with somewhat higher conductivity than the one of the embedding medium (more resistive cases are also worthwhile). A typical obstacle geometry is the versatile yet simple ellipsoidal one and degenerate shapes. Usually one could assume two (or a small number of) such obstacles with different semi-axes and conductivities, somewhat close (in terms of the skin depth) to one another and lying in the near-field of a (vertical) magnetic dipole or a (horizontal) electrical current loop (the source), the magnetic field induced by the electromagnetic interaction being collected nearby at several locations along a borehole (within the Earth) or on a planar surface (above the Earth interface) and possibly at several frequencies variations of impedance of coil receivers could be considered as well.

The first step is to put together a proper modeling tool of the interaction. One is considering, inspired in that matter by earlier work for a single obstacle, G. Perrusson *et al*. Conductive masses in a half-space Earth in the diffusive regime: Fast hybrid modeling of a low-contrast ellipsoid, *IEEE Trans. Geosci. Remote Sens.* **38** 1585-1599 (2000), the extended Born approximation allied to traditional low-frequency asymptotics fields and all pertinent quantities are expanded in positive integer powers of (jk), k complex wavenumber of the exterior medium.

Thus, one is able to express the secondary electrical currents within the obstacles as volume integrals of products of source-independent depolarization tensors times primary fields, the coefficients up to power 3 in (jk) of the said tensors being expressed in closed-form for ellipsoidal shapes in their eigen co-ordinate systems, the coefficients of the primary fields being known or having been derived lately as well up to pertinent orders in both homogeneous and half-space cases for the sources indicated above.

Then, further simplification comes from the fact that, when the obstacles are small enough, the quantities which matter are the tensor coefficients at their centers times their volumes. Since the electrical excitation field at the center of one given obstacle appears as the sum of the primary field and the field due to all other obstacles, one easily arrives at a set of linear equations which yield the total electrical currents at every center (with closed-form solution for two obstacles); the magnetic fields they radiate or (via reciprocity) variations of probe impedances follow. Since all quantities are expanded into powers of (jk) coefficients of the series expansions are obtained in practice. Notice that one has to carefully book-keep all needed changes of coordinate systems from an absolute one to those of the ellipsoidal obstacles.

In this contribution, one will show how the machinery (a version of Lax-Foldy theory of multiple scattering, refer, e.g., to H. Braunisch, Methods in Wave Propagation and Scattering, PhD Thesis, MIT (2001), for a pure magneto-quasistatic development), can be worked out and how numerical results it provides compare with those from brute-force approaches and other approximations in various configurations. Time permitting, and depending upon the pace of the present investigation, retrievals of those obstacles using a differential evolution method will be considered briefly.