The importance of detecting unexploded ordnances (UXO) and discriminating them from surrounding clutter objects is well recognized, and so are the scientific and technological challenges. Although detection itself is relatively well established, the discrimination problem is vastly more complex. In this realm, the low frequency electromagnetic induction (EMI) regime – tens of Hertz to a few kHz – presents important advantages and has imposed itself as one of the most promising regime to work at. At such low frequencies, the magneto-quasistatic approximation prevails and the induction regime allows one to neglect the scattering effects from the soil. Hence, a buried UXO can be well modeled by a metallic object in free-space, possibly surrounded by other objects if clutter is present.

For the sake of computation speed, the modeling of the UXO itself is usually based on analytical methods combined with simple numerical solvers. One typical method is the dipole approximation [1, 2], whereby the magnetic field induced by the UXO is modeled as emanating from, typically, three orthogonal dipoles located at the UXO position, and whose moment need to be solved for. This method provides fast and accurate results in many cases, but fails when more complex UXO are involved such as those composed of heterogeneous materials. A more general approach seeks at modeling UXO as spheroidal objects, which require the solution of the Laplace equation in the spheroidal coordinate system. Our group has extensively worked to develop this approach because of its flexibility and accuracy [3].

An important limitation of the spheroidal coordinate system, however, is its restriction to bodies of revolution. Such restriction is not too stringent when modeling UXO (which are most often very close to having rotationally invariant shapes), but it is when modeling clutter which can be composed of arbitrarily shaped objects. In addition, a good clutter model should be able to include many randomly shaped objects, precluding the use of purely numerical methods.

In view of these arguments, we have chosen to develop an ellipsoidal approach for the computation of the induced fields by 3D highly permeable and conducting objects [4]. The ellipsoidal coordinate system is more general than the spheroidal one since it allows for the three axes of the 3D object to be different, while the solution of the Laplace equation is still analytical, written in terms of Lamé functions [5, 6, 7]. In order to avoid having to use the ellipsoidal wave functions for the field expansion inside the object, we use the small penetration approximation [8], by which the normal derivative of the magnetic field inside the object is
dominant over the others (physically implying that the current diffuse into the object and decay fast). This allows to decouple the tangential components and solve them separately, eventually yielding the required solution.

Validating results will be shown during the presentation on both synthetic data and measured data. Synthetic data have been obtained numerically on spheroidal geometries using our analytical spheroidal code, as well as on real ellipsoidal geometries using the method of auxiliary sources. Measured data have been taken on fabricated ellipsoid using the GEM-3 EMI sensor [9] in a controlled environment. Robustness to the sensor position and object orientation will be demonstrated. Finally, the use of our frequency domain data for the prediction of time domain measurements will be discussed.

1. REFERENCES


[6] Pilip M. Morse and Herman Feshbach, Methods of Theoretical Physics, McGraw Hill, 1953, part II.

