Simulation of Pulse Induction and Continuous Wave Metal Detectors searching for Landmines

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Metal detectors are the principally used technique for landmine detection. High conductive or magnetic objects are announced by an acoustic signal. Commercial equipments note very fast and accurate smallest changes in the electromagnetic field, which they measure. Nearly all kinds of metallic objects, like e.g. cans and other metallic fragments, generate those changes. Therefore the false alarm rate is very high, it has been reported that in an area, which has to be cleared, about 800-1000 false alarms occurred and three landmines were found.

To reduce this false alarm rate, a project network "HuMin/MD Metal Detectors for Humanitarian Demining: Development potentials of data analysis and measurement techniques" (http://www.humin-md.de) has been funded by the German Federal Ministry of Education and Research (BMBF). Therefore the signal measured at the detector head itself is analyzed. Different and new mathematical methods are developed and tested by the working groups to extract as much information as possible out of the signal.

Our approach is to simulate the signal at the receiver by semi-analytical methods and performing an inversion to find model parameters of the target. We have chosen a semi-analytical approach because it is fast in computation time, which is necessary for a fast inversion procedure. The analytical formulation of the problem restricts the object to simple shapes like a sphere, thin wire ring, and spheroids as prolates and oblates. Vortex currents are induced in these objects and generate a scattered field, which can be approximated by a magnetic dipole. The dipole moment is frequency dependent and is a function of target properties as shape, orientation conductivity and magnetic permeability.

Additional numerical modeling using the commercial software Comsol Multiphysics formerly known as FEMLAB are done to verify the analytical approximations and analyze more complex object shapes as cylinders and the combination of different objects. The numerical and also the analytical modeling consider the mutual induction effects of two objects. Numerical experiments with spheres show that the mutual coupling can be neglected, when the distance between the objects is larger than one sphere diameter.

The electromagnetic induction in the ground has also an influence on the metal detector data. Since the electromagnetic induction is in the low frequency range, the magnetic properties of the soil dominate the signal and the detection of the target becomes difficult.

The simulations have been applied to two commercial metal detectors and have been verified by laboratory and field experiments. The continuous wave system is from Förster with a differential double-D receiver loop and the pulse induction system is from Ebinger with a coincident loop.