The Effects of a Superparamagnetic Ground on the EMI Response of a Target

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Abstract

Introduction

Electromagnetic induction (EMI) sensors have a long history of success in finding visually obscured metal objects [1]. Over the past decade, metal detector technology has improved resulting in increased detection rates. These improvements have also increased detection of unwanted items such as nails, bullets, shrapnel and other conductive battlefield debris. Advanced EMI sensors typically use a range of frequencies and provide an increased discrimination capability between buried landmines and metal clutter [2]. A simple circuit model is often used to express the electromagnetic induction response of a target analytically. This analytic model produces a response function that contains unique characteristics based on the target's electromagnetic properties.

Soil's electromagnetic properties adversely affect the performance of EMI sensors. Severe soil conditions can cause the soil's response to drown out the target's response. Das has shown that the magnetic response from soil largely dominates the electrical response [3]. A well-established model for a superparamagnetic ground assumes a log-uniform distribution of magnetic relaxation constants resulting in a magnetic susceptibility of the form [4]:
χ_((ω))=χ_dc (1-1/ln(τ_2⁄τ_1) *ln (iωτ_2+1)/(iωτ_1+1))
Where χ_dc is the static (dc) value of the magnetic susceptibility, ω is the angular frequency, i=√(-1) and τ_1 and τ_2 are the lower and upper bounds of the magnetic relaxation time constants, respectively. This model provides the magnetic susceptibility of soil as a function of frequency.

Use of COMSOL Multiphysics®

A 3D model of two concentric coils representing a continuous wave metal detector was developed in COMSOL Mulitphysics® version 4.4 as shown in Figure 1. A ring target has a well-known analytic solution which provided a means to verify the model. Magnetic soil was modeled and randomized over a semi-hemispherical volume as shown in Figure 2. Figure 3 depicts the effects of various levels of a superparamagnetic soil on the EMI response of a ring target.

Reference

[1] C. Bruschini, 2002, “A Multidisciplinary Analysis of Frequency Domain Metal Detectors for Humanitarian Demining”, Thesis, Vrije Universiteit Brussel.
[2] W. Scott, Jr., and G. Larson, 2010, “Modeling the Measured EM Induction Response of Targets as a Sum of Dipole Terms each with a Discrete Relaxation Frequency”, in Proc. Of SPIE 7664.
[3] Y. Das, “Effects of Soil Electromagnetic Properties on Metal Detectors”, in IEEE Vol. 44, 2006, 1444-1452.
[4] G. Cross, Y. Das, 2008, “Soil Electromagnetic Properties and Metal Detector Performance”, Terrascan Geophysics, 1-170.

Figures used in the abstract

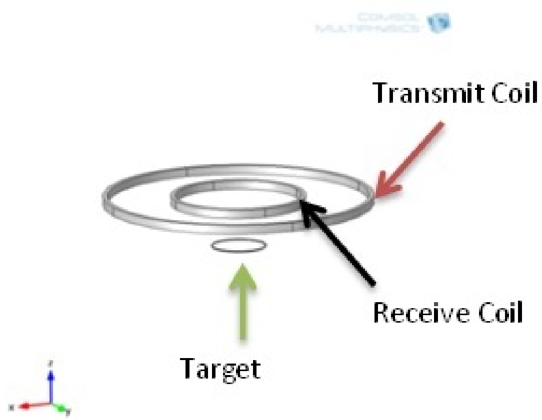

Figure 1: Comsol Modeling Environment.

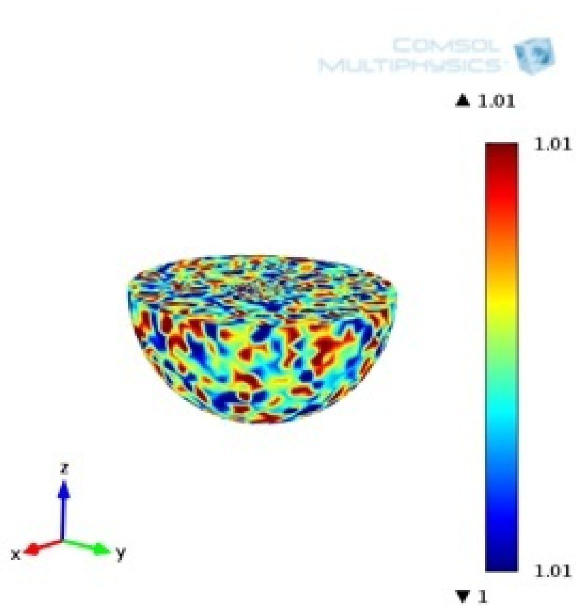

Figure 2: Modeled magnetic soil half-space with a volumetric variability in magnetic susceptibility of 10%.

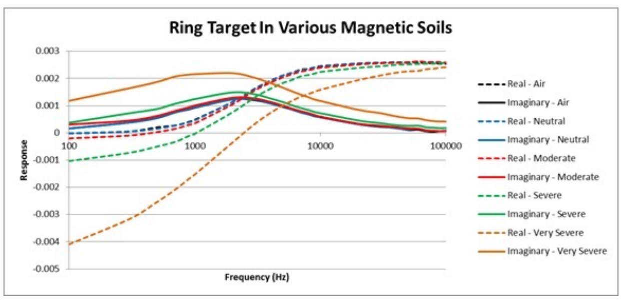

Figure 3: The response of a ring target in various levels of superparamagnetic ground. The target response in air is shown for comparison purposes.