# Environmental Effects on UWB Electromagnetic Induction Inversion Techniques and Forward Modeling of Unexploded Ordnance

**B. J. Zhang**
Massachusetts Institute of Technology, USA

**K. O'Neill**
Dartmouth College, USA

**T. M. Grzegorczyk and J. A. Kong**
Massachusetts Institute of Technology, USA

This project seeks to understand the effect of environmental factors on electromagnetic induction (EMI) measurements of unexploded ordnance (UXO) and the associated inversion techniques applied on the noisy measurements. The environmental factors include clutter, since UXO sites are highly contaminated with metallic clutter, and ground effects, because soil may be slightly permeable.

EMI measurements were taken of UXO overlaid by a surface dispersion of small metallic clutter pieces. Inversion was done to identify the UXO based on those noisy measurements. This was accomplished by optimizing the match between measured and modeled scattered magnetic fields, using a new generation of fast but accurate forward models. We used differential evolution (DE) to find the optimal match. Inversion is successful when the closest match originates from the correct UXO type out of the library of possible UXO types. For UXO obscured by clutter, it was shown that the inversion was successful for measurements which had signal-to-noise ratios up to 2.5 dB. Generally, a DE population size of at least 50 members and over 100 generations were necessary to achieve successful inversion from noisy measurements.

Furthermore, measurements were also taken of UXO buried in soil. Through analytical approximations of spheres embedded in permeable half-spaces, it was found that for the range of realistic soil permeabilities, all halfspace effects are negligible except for a magnitude offset in the real part of the measured frequency domain EMI signal. We incorporated this offset effect in our forward models and did optimization inversion on the measurements. The inversion was successful for UXO buried at shallow depths.

Lastly, clutter can be approximated as directional dipoles and their combined effect can be incorporated into our forward models along with the soil offset effect. Synthetic data was generated using this forward model. Our optimization inversion was successful using this synthetic data with 20 spheres randomly dispersed over an area of 0.7 by 0.7 meters. Furthermore, this improved forward model allows for Monte Carlo-type simulations to help understand the statistics of clutter noise and investigate ways of suppressing or filtering out that noise in measurements. Further research is also needed to enhance the robustness of our inversion techniques to overcome the environmental effects.