A Unified Surface Source Model for Discrimination of Subsurface Metallic Objects by Magnetometry and UWB Electromagnetic Induction

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Clean up of land and water from subsurface metallic objects, particularly unexploded ordnance, still remains the number one military environmental problem. This process requires two steps: first a signal from a metallic object has to be detected and second, from the detected signal the object of interest must be distinguished from widespread pieces of metallic clutter. Recent studies have shown that magnetic and time or frequency domain electromagnetic induction (EMI) sensing technologies are the most promising approaches for UXO detection. In EMI the practical depth of penetration of the target by EMI signals is determined by the input frequency and target's conductivity and permeability. Signal clutter due to the dielectric heterogeneity of the surrounding environments or other non-metal material is negligible. Since, most if not all UXOs are metal, or contain substantial amounts of metals, they can easily be detected, but it is extremely difficult to discriminate them reliable from non-hazardous items. In order to overcome the discrimination problem, joint and cooperative (typically magnetic and EMI) approaches have been proposed. In these approaches magnetic and EM forward models have different parameterizations. Therefore when attempting joint or cooperative inversions, constraints imposed by one data set (for example magnetic) on the other (EM) is partially active — because of forward models.

In order to use all information obtained from each data set, this paper presents a unified source model applicable for any combination of magnetic and frequency or time domain EM data, for any sensor configuration and for any input waveform. In this approach, the EMI field from a given object is generated by a reduced set of surface sources: magnetic charges for a dry soil (free space approximation) or magnetic dipoles for relatively high conductivity host media such as seawater. These sources are distributed on a fictitious spheroid, which surrounds the object. First an input primary magnetic field is decomposed into fundamental spheroidal modes. Then, for each input spheroidal mode, a full low frequency EMI problem is solved via the method of auxiliary sources. Finally, for efficiency the EMI responses are reproduced by the reduced (few) set of sources, which is stored inside a library. Once all these processes are completed the full EMI problem for any transmitter/receiver can be easily solved by carrying out a spheroidal decomposition of the primary field and simply superposing the stored modal solutions. In time domain cases the EMI responses from the reduced set of sources are generated from frequency data for different waveforms using the inverse Fourier transform. In this paper, the first comparisons between the proposed model and real data in time and frequency domains will be presented and demonstrated for different waveforms. Finally, the method will be applied to the UXO discrimination problem.