Development and Evaluation of a Handheld High Frequency Electromagnetic Induction Sensor

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# Abstract

The remnants, such as Improvised Explosive Devices (IEDs) and land mines, of past and current geopolitical conflicts pose dangers to both civilian and military entities. The IED can be constructed of a wide range of materials including metallic and non-conductive materials. The current methods for detecting include traditional electromagnetic induction (EMI), ground penetrating radar (GPR) and acoustic sensors. Each of these sensing modalities work well to detect some categories of explosive hazards but are not suited for the detection of several types of IEDs and land mines. For an example, traditional metal detectors can only sense metallic targets with considerable metal content which limits the types of buried hazards that can be identified, where-else GPR and acoustic methods are very sensitive and can detect a wide range of materials. However, the latter sensing methods produce high false alarms, generally do not report information regarding the target’s material properties and are sensitive to soil conditions.

Over the past decade, our group has designed, developed, built, and tested a handheld High Frequency Electromagnetic Induction (HFEMI) sensor operating at frequencies between traditional EMI and GPR, specifically from 100 kHz to 10 MHz. This sensor consists of the following components: an FPGA board that synthesizes the transmitted waveform and demodulates the received signal into in-phase and quadrature components; a current amplifier with a 12 dB gain; Two custom-made PCB loops for transmitting and receiving the primary and secondary magnetic fields, respectively. The loops are precisely positioned within a single handheld unit to minimize the primary field while maximizing the secondary field at the receiver. The receiver coil senses and amplifies the secondary magnetic field with a gain of 32 dB. Finally, the instrument uses a windows stick computer for pre-processing and displaying real-time data in the form of in-phase and quadrature signals.

Results have shown that the HFEMI sensor can generate distinct responses for intermediate conductive materials, conductive voids, short wires, and small metallic components. These unique responses can be leveraged as detection and classification features for identifying IEDs, landmines, and other explosive hazards. To fully utilize the system’s capabilities, advanced EMI signal processing approaches must be applied to HFEMI datasets for the detection, localization, and identification of subsurface IEDs and landmine targets. This requires the collection of accurately geolocated datasets. To address this need, this paper presents recent advancements in the sensor, including the integration of a GPS and IMU unit into the data stream. In addition, the geolocated HFEMI dataset collected over IED and landmine targets is illustrated, along with inversion results and a discussion on mitigating soil response effects.