Electromagnetic Design of an RF-Coil Transceiver for NQR-based Explosive Detection

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Abstract

In the humanitarian demining setting, it is crucial to detect landmines with reliable sensing performance. As Nuclear Quadrupole Resonance (NQR) is an effective method for detecting explosive materials, our group is currently developing the world's first low-cost system for anti-vehicle mines (AVMs) detection. One of the primary parts of the system is its probe sensor transceiver, which comprises an RF-Coil operating in the near-field along with its tank circuit.

In order to adapt to the humanitarian demining setting's functional requirements, cost effectiveness as well as portability are equally important. To this end, the RF-Coil design under investigation comprises a flat spiral inductor constructed from annealed copper tube, which can ensure an overall low weight and low cost while maintaining the required near-field sensing performance for explosive materials detection.

The numerical Finite Element Analysis (FEA) for the electromagnetic design of the coil is conducted with the use of the RF module of COMSOL Multiphysics®. The AC/DC Module's Electrical Circuit Physics is additionally explored for the simulation of the coil's tank circuit in a Multiphysics study.

A lumped port is utilized for voltage excitation, while impedance matching at 3.4 MHz is performed with the use of a lumped capacitative element parallel to the coil terminals. Near-field sensing performance metrics comprise the calculation of the Q-factor with respect to the port impedance magnitude at specific frequency sweeps, the S11-parameters of the port and the assessment of the magnetic field quality distribution at axes vertical to the coil's geometrical plane that belong to the geometrical locus of the target sensing volume. Mesh sensitivity analysis and investigation of optimal geometrical specifications for the optimization of the sensing performance metrics are conducted with the use of parametric sweeps. Additionally, the sensing performance of the coil is relatively assessed in different operational environments, such as the presence of metallic debris and the application of electromagnetic shielding encapsulations. Finally, the FEA results are comparatively validated with an experimental prototype.

Figures used in the abstract

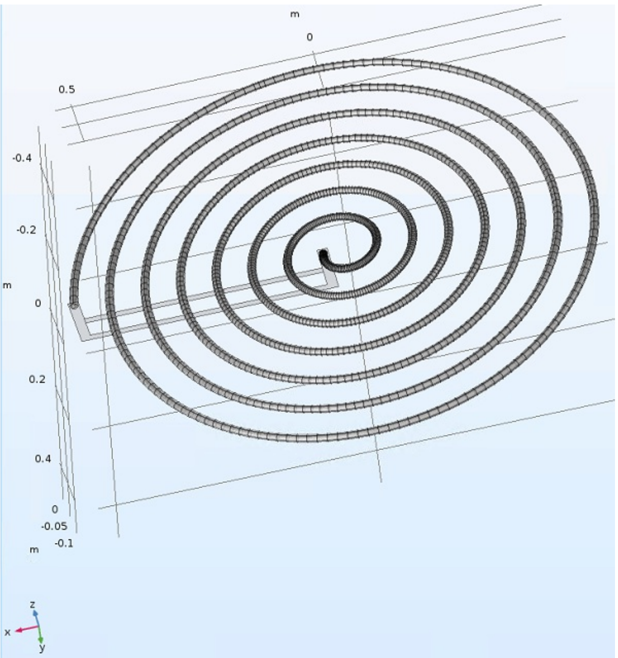

Figure 1: The spiral coil comprises 7 turns of hollow copper tube of an external radius of 8 mm and an internal thickness of 2 mm.