**Understanding resonant, electrically-small induction coils for near-field non-destructive evaluation of material properties**

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The characterization and evaluation of materials through non-destructive methods is essential for many industries in determining the structural integrity of critical components. One such technique employs electrically-small magnetic dipole coils for near-field sensing of electrically conducting materials through inductive coupling mechanisms. For many applications high frequency (>3 MHz) operation is required to achieve appropriate sensitivity. At these frequencies parallel LC electrical resonance, traditionally a complicating factor, has been shown to significantly enhance measurement sensitivity due to a resonance distortion phenomenon related to changes in material properties (*R.R. Hughes et.al., NDT&E Int, 2014*). However, before reliable measurement and material property inversion techniques can be made viable, an accurate understanding and model of the behavior of electrical resonance in electrically-small inductive coil sensors must to be realized. This paper presents and discusses the theory and results from a study simulating and experimentally characterizing the behavior of electrical resonance for inductive sensors coupled to electrically conducting materials.

Materials under test can be represented as lossy secondary transformer circuits with unknown resistive and reactive components that are not easily defined analytically due to the near-field deviation from the plane-wave approximation (*H. A. Wheeler, The radiansphere around a small antenna, Proceedings of the IRE, 1959*). Instead an experimental characterization study has been performed and a multi-dimensional optimization method implemented to determine the unknown secondary circuit parameters based on principle metrics of the experimental resonating impedance spectra (resonant frequency, impedance maxima and resonance peak FWHM). The authors conclusively demonstrate that a relatively simple transformer circuit model is sufficient to accurately simulate the frequency spectra of a material coupled resonating inductive coil. They go on to use this method to evaluate the relationship between electrical resonance and physical variables such as coil geometry, proximity, material conductivity and material discontinuities (i.e. defects) to inform and develop a material property inversion model based on electrical resonance distortion effects.