

# Numerical Study of the Scattering of a Short-Pulse Plane Wave By a Buried Sphere in a Lossy Medium

Fabrizio Frezza<sup>1</sup>, Fabio Mangini<sup>2</sup>, Marco Muzi<sup>3</sup>, Paolo Nocito<sup>4</sup>, Endri Stoja<sup>2</sup>, Nicola Tedeschi<sup>2</sup>

<sup>1</sup>Department of Information Engineering, Electronics and Telecommunications, "La Sapienza" University of Rome, Via Eudossiana 18, 00184 Rome, Italy

<sup>2</sup>Department of Information Engineering, Electronics and Telecommunications, "La Sapienza" University of Rome, Rome, Italy

<sup>3</sup>Institute of Advanced Biomedical Imaging, "G. d'Annunzio" University Foundation, University "G. d'Annunzio" Chieti-Pescara, Chieti, Italy

<sup>4</sup>Istituto Superiore C.T.I., Communications Department, Ministry of Economic Development, Rome, Italy

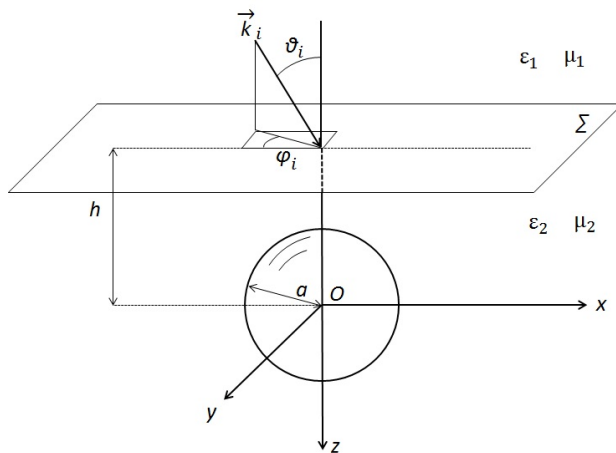
## Abstract

The ground penetrating radar (GPR) is an interesting topic of research that studies the propagation of electromagnetic waves in the earth and the scattering of electromagnetic energy from buried objects for detection purposes [1]. For the study of GPR systems a great variety of numerical methods have been adopted [2]. In this paper, COMSOL Multiphysics has been used to analyze the canonical problem of the scattering of a plane wave by a buried sphere in a lossy medium (Figure 1) with the goal of validating the results obtained by confronting them with data in literature from Vitbeskyi et al. [3] which implements a Method of the Moments (MoM) method. To be consistent with the latter, we choose a perfectly conducting sphere buried in dry clay, with a linearly s-polarized incident plane wave impinging normally to the interface. In addition, in [3], a short-pulse was used as an excitation with a spectrum spanning from 50 MHz to 1 GHz (Figure 2). We use the RF Module's scattered field formulation by specifying the background field analytically. On the other side, the ground material dispersion is implemented in COMSOL by interpolating experimental data [4]. As our problem is frequency dispersive we perform a frequency sweep. In Figure 3, a comparison of the frequency behavior of the scattered electric field component along y (relative component) obtained by COMSOL simulations and the data presented by Vitbeskyi et al. is presented. The field probe is located on the interface level, on top of the sphere center. As we can see, the agreement between the two methods is excellent over the entire frequency range. After the validation of the COMSOL model, we perform some other studies to gain insight in the role of the sphere radius, the distance of the buried sphere from the interface and study the case of a dielectric sphere instead of the perfectly conducting one. In conclusion we can affirm that the simulation data provided by COMSOL is in very good agreement with previously published data. The RF Module is a versatile and efficient tool for the study of the canonical problem of a buried sphere in a lossy medium in different configuration schemes. In future works we plan to use the Transient Electromagnetic Waves Interface for the study of this canonical problem.

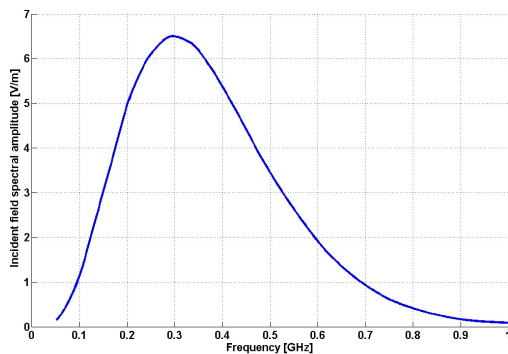
## Reference

- [1] R. W. P. King et al., "The transmission of electromagnetic waves and pulses into the earth," *Journal of Applied Physics*, vol. 39, pp. 4444-4452, August 1968.
- [2] H. M. Jol, "Ground Penetrating Radar Theory and Applications," Elsevier B.V., 2009.
- [3] S. Vitebskiy et al., "Short-Pulse Plane-Wave Scattering from Buried PEC bodies," *IEEE Transactions on Antennas and Propagation*, vol. 44, no. 2, February 1996.
- [4] J. E. Hipp, "Soil electromagnetic parameters as functions of frequency, soil density, and soil moisture," *Proceedings of IEEE*, vol. 62, pp. 98-103, January 1974.

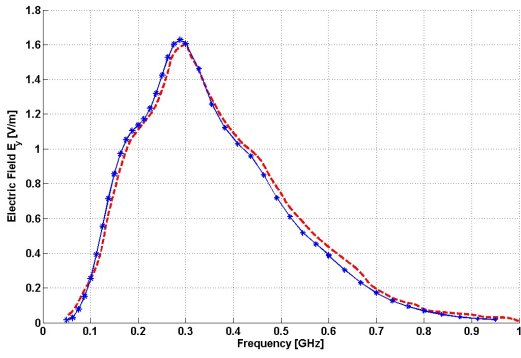
## Figures used in the abstract



**Figure 1:** Statement of the problem.



**Figure 2:** Spectrum of the incident short-pulse field.



**Figure 3:** Comparison of the results obtained by COMSOL (continuous blue line) and those of Vitebskiy et al. [3] (dashed red line), for  $a=15$  cm and  $h=30$  cm.