Self-Consistent Modeling of Thin Conducting Wires and Their Interaction with the Surrounding Electromagnetic Field

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Abstract

Introduction
In Finite Difference Time Domain (FDTD) methods, where a regular structured mesh is used, it is possible to include conducting wires having a radius much smaller than the mesh size into a 3D model [1]. A Telegrapher's equation is employed to solve for the wire current, thus allowing for wave propagation and resonances. Thanks to the regular mesh structure it is possible to describe the two-way interaction with the surrounding electromagnetic field in a fully self-consistent way.

The FDTD scheme has therefore become very popular for modeling of all kinds of situations where thin wires or cables are involved, such as wire antennas and field coupling to and from cables and cable networks. Note that this method allows computation of both the field radiated from a current-carrying wire and the current induced in the cable due to an external time-varying electromagnetic field.

Despite many attempts, no similar technique being of practical use has been presented for finite element methods (FEM). Basically, the reason is the unstructured mesh into which the wire is embedded and the mathematical formulation of FEM. The proposed methods have either required elements almost as small as the wire radius and/or resulted in very complex implementations. A consequence of this is that FEM based solvers are not being considered particularly efficient for solving problems related to ElectroMagnetic Compatibility (EMC) issues and wire antennas.

Use of COMSOL Multiphysics®
Here, we present an approximate method, very easy to implement, that can be used to include wires having a radius smaller than the typical element size into a 3D model. The technique works for both low and high frequencies. In version 4.3 of COMSOL Multiphysics® an implementation of the Telegrapher's equation is introduced in the RF Module. Starting from this and adding the appropriate couplings to the external fields we can build up an approximately self-consistent model of the wire and its surrounding environment. The methodology is explained and illustrated with some examples.

Figure 1 below shows the current induced in a closed resistive loop illuminated by an applied magnetic field. The result from the simulation is compared with an analytical solution. Only some

minor tuning of one single parameter is needed to make the curves fit perfectly. Note that the method allows for a seamless transition from a resistive to an inductively dominated loop.

Reference

[1] Taflove, A. and Hagness, S.C., Computational Electrodynamics: The Finite-Difference Time-Domain Method, 3rd ed., Artech House, 2005.

Figures used in the abstract

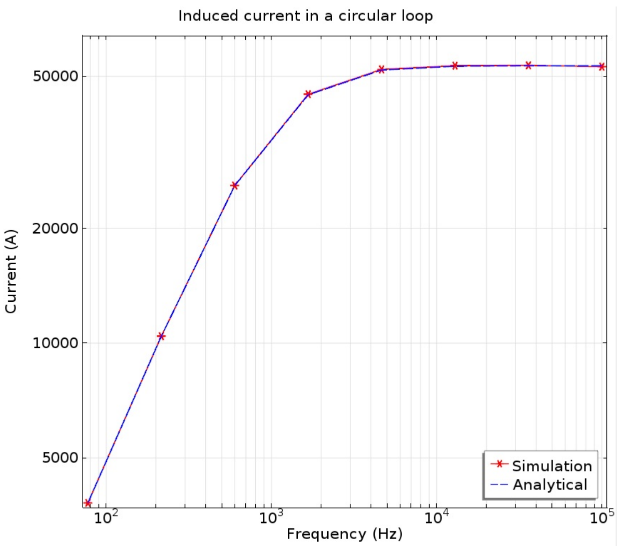

Figure 1: Induced current in a circular loop