Excerpt from the Proceedings of the COMSOL Conference 2009 Boston

Designing B-field Coils from the Inside-Out

Christopher B. Crawford[*1], Yunchang Shin[1], and Greg Porter[1]
[1]University of Kentucky
*Corresponding author: Department of Physics and Astronomy, 177 Chem.-Phys. Bldg., Lexington, KY 40506-0055, crawford@pa.uky.edu

Introduction

Traditionally the design cycle for magnetic fields involves guessing at a reasonable conductor / magnetic material configuration, using FEA software to calculate the resulting field, modifying the configuration, and iterating to produce the desired field.

In this paper, we take the opposite approach of specifying the desired magnetic field, imposing it as a boundary condition on the region of interest, and then solving the Laplace equation to determine the field elsewhere in free space. The exact conductor configuration along the boundaries is extracted from the solution in the post-processor.

This method is being applied to design magnetic field coils and RF waveguides for low energy neutron experiments, such as the nEDM [1] (Fig. 1), and n-^{3}He experiments [2].

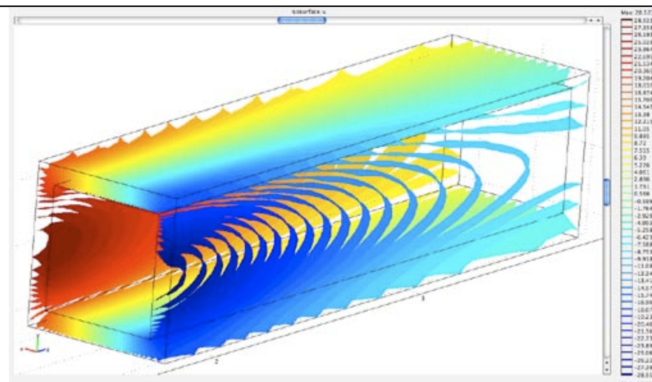

Figure 1: Schematic of conductors in a sample field coil designed for a low energy nuclear experiment to measure the electric dipole moment of the neutron. The conductors are wound around the perimeter of each equipotential ribbon (shown in color). The field is uniform and horizontal in the interior region, tapering from 5 G in the front left to 100 mG on the back right. The B-field flux returns from the front right (blue) to back left (red) through the intermediate region occupied by the ribbons (around the top and bottom). The boundary conditions prescribe exactly zero fields outside the coil. Not shown is a current sheet on the inside along the top, bottom, and ends.

Use of COMSOL Multiphysics

Unlike standard electromagnetic solvers, COMSOL gives the flexibility to solve any PDE using finite element analysis, and this offered the flexibility to implement this new approach. Our method involved solving the classical Laplace equation on regions with imposed boundary conditions, which was implemented straightforwardly in COMSOL.

Expected Results

The final FEA design solution of two coils (one DC and one RF) will be presented along with detailed comparisons with the field calculated with a traditional three-dimensional Biot-Savart code.

Conclusion

As shown by the above examples, use of the magnetic scalar potential is a powerful technique to design coils ab-initio based on the field requirements. The resulting magnetic field convergences to the design specification by adding more (finer-grained) coils. This example showcases the flexibility of using COMSOL to implement unique problem-solving techniques, versus canned software packages, which implement only traditional solutions.

Reference

1. http://p25ext.lanl.gov/edm/edm.html
2. http://www.pa.uky.edu/~crawford/pub/n3he_proposal_sns.pdf