MRI Birdcage RF Coil Resonance with Uncertainty and Relative Error Convergence Rates

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Abstract

In a magnetic resonance imaging (MRI) system, it is necessary to excite the nuclei of a patient into coherent precession for imaging. This requires a coupling between the nuclei and a source of radio frequency (RF) power using a transmitter. To receive a meaningful signal, we also need a coupling between the nuclei and an external circuitry known as the receiver. Both the transmitter and the receiver are called RF coils or resonators, and are key components in any MRI system. In this paper, we use COMSOL 5.2a to model a NIST prototype birdcage RF coil using two low-pass coil mesh design types: Mesh-1, a series of 15 all-tetra-10-element designs with degrees of freedom (d.o.f.) ranging from 169,906 (very coarse) to 3,640,696 (very fine), and Mesh-2, a series of 15 mixed-hexa-27-and-tetra-10-element designs with d.o.f. ranging from 188,812 (very coarse) to 2,615,980 (very fine). For each of the 30 meshes, we compute its first resonance frequency, fres , and its time average reflection coefficient given by S11 in dB unit. After getting 15 pairs of the two parameters, (fres , S11), for Mesh-1 and Mesh-2, we use a 4-parameter logistic function nonlinear least squares fit algorithm to obtain an estimate of the two parameters at infinite degrees of freedom as well as their uncertainty at one-billion-d.o.f. and relative error convergence (REC) rates. It is interesting to see that the COMSOL analysis results of the two mesh types differ significantly from each other as shown below:

freq (MHz) S11 (dB) Uncertainty (S11) REC Rate (S11)

Mesh-1 (all-tetra) 19.271 - 3.843 3.27 % - 1.43.

Mesh-2 (mixed) 19.365 - 4.237 10.76 % - 0.54.

Based on the classical theory of error estimates for finite element method and the general theory of statistical estimation, we conclude that Mesh-1 (all-tetra-10) type solution is the better of the two.

Figures used in the abstract

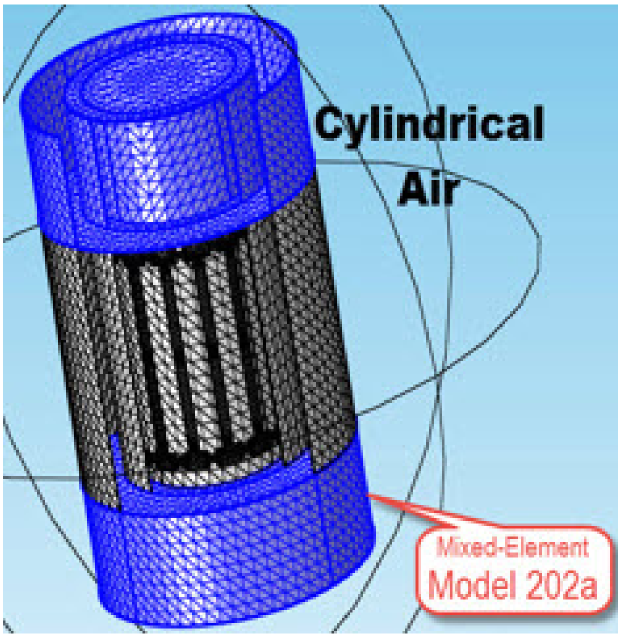

Figure 1: Mesh-2 (Mixed-Type-Element)