Analysis of a Prototype MRI Hybrid Birdcage RF Coil with Uncertainty Quantification (*)

J. T. Fong[1]

[1]National Institute of Standards & Technology, Gaithersbug, MD, USA

Abstract

1. INTRODUCTION. In a magnetic resonance imaging (MRI) system (see Fig. 1), it is necessary to excite the nuclei of a patient into coherent precession for imaging. This requires coupling between the nuclei and a source of radio frequency (RF) power (the transmitter). To receive a meaningful signal, one also needs to couple the nuclei to an external circuitry (the receiver). These two devices are called RF coils or resonators, and are key components in an MRI system (see Fig. 2, after Ref. [1]).

2. USE OF COMSOL MULTIPHYSICS® SOFTWARE. In this paper, we present the finite-element-method-based solutions at infinite degrees of freedom, with uncertainty quantification, of the first resonance of a prototype MRI hybrid 16-legged and 2-port birdcage coil (see Fig. 3) using the RF Module in COMSOL Multiphysics® software. To quantify the uncertainty due to element type, we used two types of 3D mesh operations in COMSOL software, namely, (a) the free tetrahedra, and (b) the swept type involving layers of prism or hexahedral elements. To quantify the uncertainty due to mesh density, we applied a nonlinear least squares 4-parameter logistic function fit technique (see Ref. [2]) to five candidate solutions of increasing degrees of freedom such that a solution at infinite degrees of freedom can be estimated.

3. RESULTS. In designing the hybrid birdcage for the finite element method-based analysis, we introduced free parameters not only for the 16 capacitances in the upper and lower rungs, but also capacitances in the 16 legs of the coil. We also introduce a parameter for refining the mesh density. The results of the analysis, when expressed in the absolute value of S11, the power parameter for the reflected wave of the active port of the birdcage coil, are shown in Fig. 4 for the two types of elements we used, namely, the all tetrahedron-runs and the swept type (mixed prism-hexahedrons). The extrapolated results of the two element types, 3.82 dB for the all tetrahedron type, vs. 4.39 dB for the swept type, differ by about 13 %.

4. CONCLUSION. We show in this paper that element type and mesh density play a significant role in determining the accuracy and uncertainty of a finite-element-method-based solution of a typical problem in electromagnetics.

Reference

[1] J. Jin, Electromagnetic Analysis and Design in Magnetic Resonance Imaging. New York: CRC Press, Taylor and Francis Group (1999).

[2] J.T. Fong, J.J. Filliben, N.A. Heckert, P.V. Marcal, R. Rainsberger, L. Ma, "Uncertainty Quantification of Stresses in a Cracked Pipe Elbow Weldment using a Logistic Function Fit, a Nonlinear Least Squares Algorithm, and a Super-Parametric Method," in Proc. 14th International Conf. on Pressure Vessel Technology (ICPVT-14), Sep. 23-26, 2015, Shanghai, China. Also in Procedia Engineering, 130 (2015) 135-149, www.sciencedirect.com, 2015.

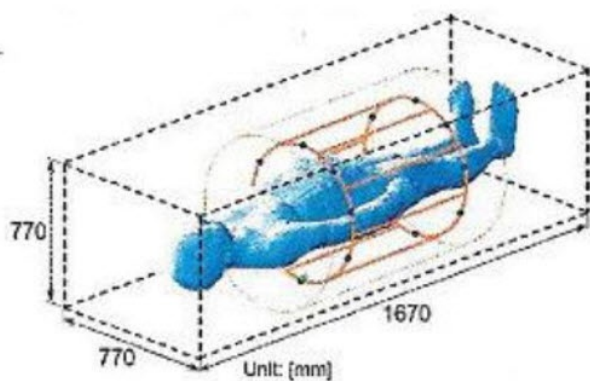# Figures used in the abstract

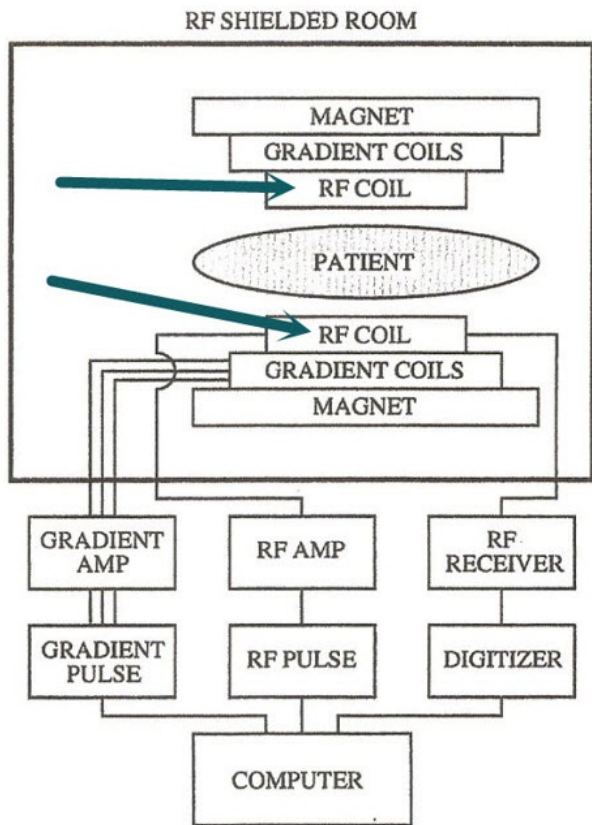**Figure 1**: A magnetic resonance imaging (MRI) system with a patient.

Figure 2: A schematic of an MRI system.

Highpass birdcage coil   Lowpass birdcage coil
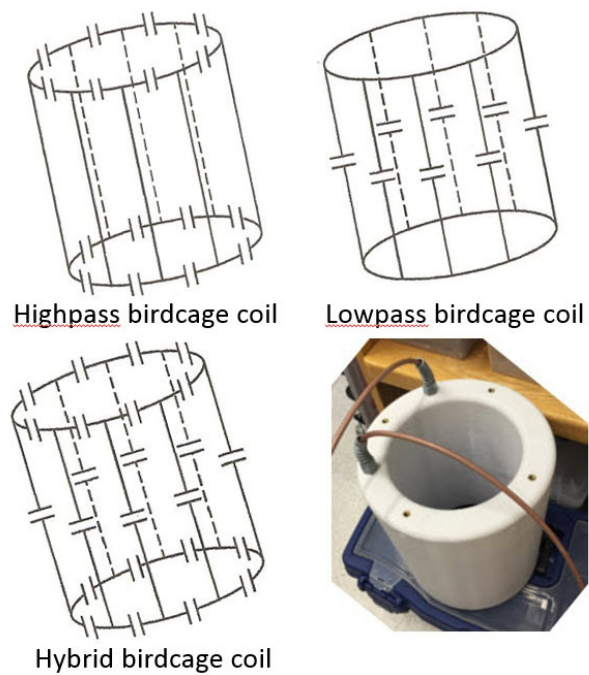
Hybrid birdcage coil

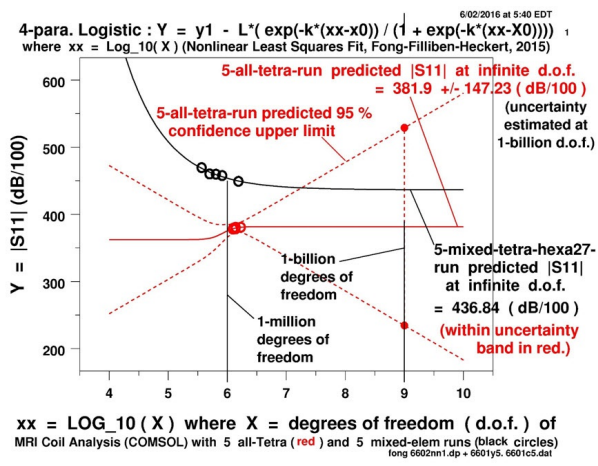**Figure 3**: Three different kinds of birdcage coils and a prototype.

Figure 4: Typical results of a plot of abs(S11) vs. degrees of freedom.