High-Resolution Modeling of Current and Field Distribution in Planar RF Coils

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<u>Purpose</u>

A software package has been developed to enable accurate and high-resolution characterization of the current on RF coils, matching networks and transmission lines. This package should be useful for modeling coupling and field distributions in RF coil arrays used for microscopy and dynamic imaging.

<u>Introduction</u>

Many investigators are using numerical methods to characterize and understand coil behavior [1-4]. In most cases modes are assumed, and the current distribution on the conductor is ignored. However, recent interest in using arrays for dynamic imaging using techniques such as SMASH [5,6] have caused us to pursue more accurate characterization of the currents on the conductor. In SMASH imaging the receiver sensitivity patterns are used to generate additional phase encode lines. While an estimate of the individual coil sensitivity patterns can be obtained from images, a study of the sensitivity of the technique to coil positioning, geometry and coupling requires an efficient and high resolution method for modeling the sensitivity patterns. We have developed a package which allows the user to sketch one or more coils in a CAD package, determine the current distribution, and in turn the fields with high resolution. This paper describes the package and the method and demonstrates its application to coil structures.

<u>Methods</u>

The program is based on an improved version of a full-wave spectral-domain method-of-moments technique reported earlier [4]. Resolution and speed are obtained by computing all inner-products (which can be interpreted as mutual impedance between small current elements) using FFT's. All inner products are computed simultaneously. The resulting matrix equation is solved iteratively using a conjugate-gradient FFT approach, where each iteration requires simply a "guess" of the current distribution, followed by a 2D-FFT of the current, one matrix multiplication, and an inverse 2D-FFT. Implementing the CG-FFT approach has allowed well over 10,000 unknowns with reasonable execution times on PC platforms.

<u>Results</u>

Figure 1 is a grayscale map of the current density on a coil with an outer dimension of 3.3 cm in each direction. The center conductor has a 25 pF capacitor, and the coil is excited on the center of the right conductor. Each strip has a width of 0.254 cm. This solution used 11,220 unknowns, and required 2.7 hours on a Pentium 200 MMX computer.

Several important features are seen in the plot. Although the coils is excited on the right side, the current in the left loop is larger. The computations indicate that the current in the center conductor is carried essentially only on the left-hand side of the conductor. As expected, current density "rounds" the corners, going to small values in the corners. To verify these results, the current density was measured using MR imaging. The current distribution in the upper right corner of the coil is shown on the left of Figure 2, with the computed current density in this region shown on the right for comparison. The measured current density image demonstrates excellent agreement with the computed results.

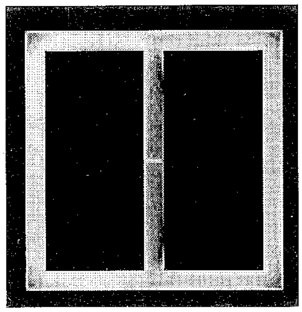

Figure 1. Grayscale depiction of the current density magnitude on an RF coil. Calculations indicate that the current flows predominantly on the left side of the center conductor, and is minimal near corners.

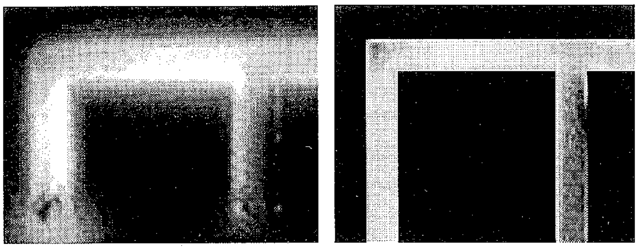

Figure 2. Left: Measured current density in one quadrant on the coil in Fig. 1. Right: Magnification of computed results in Fig 1.

<u>Discussion</u>

The improved resolution of this method provides highly accurate characterization of changes in field sensitivity patterns due to changes in coil geometry and positioning, and even separation from the sample. We are using this program to design array coils for SMASH imaging and to study the sensitivity of the image reconstruction to variations in coil patterns.

<u>References</u>

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