An accurate electromagnetic field model for optimization and selection of intravascular multimode coil geometry
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Target Audience: Interventional radiologists and cardiologists, MRI coil designers.

Purpose: To develop a simulation methodology to accurately model intravascular coils under actual scanning conditions and to compare their performance through simulation.

Methods: The multi-mode coil consists of a series-tuned imaging coil and tracking coil in series [1] and is designed to couple inductively to the transmit coil during transmit phase. The signal profile of the coil can therefore be optimized for the specific functionality by adjusting the B₁ field profile [2]. The functional requirements for tracking and imaging coils are divergent, with the latter requiring broader radial and axial coverage and the former requiring a highly sensitive and localized signal, such that it yields a dominant sharp peak for accurate tip-tracking. The tracking and imaging coil geometry can be optimized for improved multimode coil performance. Numerical simulation is a good option to perform this optimization and requires an accurate estimate of the current induced in the multi-mode coil by a circular polarized B₁ field. In this work, we have developed a simulation model to accurately estimate current induced in a multi-mode coil, validated it experimentally and investigated four different multi-mode coil configurations.

An FEM technique was used to simulate the fields produced during actual scanning conditions by modeling the excitation source as an idealized birdcage coil under quadrature excitation in order to calculate the induced current in the device. A simulation model of a multi-mode coil (20-turn tracking solenoid, 3-turn imaging loop, 36 AWG wire, 3cm length, 2mm width) was developed (Figure 1c). With the device placed in the circularly polarized B₁ field, the net field profile in the vicinity of the device was calculated as a superposition of the transmit B₁ field, the scattered field and the field due to induced current in the coil. For model validation, the Bloch-Siegert B₁ mapping sequence [3] (FOV = 92mm×92mm, acquisition matrix = 256x256, slice thickness = 1.5mm, excitation flip angle = 30°, 8-ms Fermi-shaped off-resonance pulse at Δ = 4000Hz and flip = 400°) was used to estimate field profile of a multi-mode coil whose specifications matched the simulation model. The multi-mode coil was precisely positioned in a phantom with 0.9% NaCl solution. The body coil was used to generate circularly polarized B₁ fields. After verification of the simulation methodology, the technique was extended to three other multi-mode coil geometries.

Results: Figure 2 shows experimental and simulated B₁ field maps for an oblique slice in plane with the multi-mode coil. A field mismatch of 0.4μT at the measured and simulated values indicates good model validity. Table 1 shows the simulations for the four multi-mode coil geometries considered in the study and a comparative performance analysis.

Discussion and Conclusion: Results show that the Helmholtz pair tracking and rectangular loop imaging multi-mode coil configuration has the largest induced current and best couples with the external coil to magnify the local B₁ field for imaging, while also providing a single tracking peak. The proposed simulation methodology can be used to quickly and accurately optimize geometry to meet application specific requirements and can be extended to study unintended tissue heating caused by guide-wires and implantable devices like stents and pacemakers.


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