RF Engineering - Coils: RF modelling

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Target audience: Physicists/Engineers interested in simulating RF electromagnetic fields.

Objectives: You will learn about:

- Methods for EM simulations.
- Modelling of coils and human anatomy.
- Post-processing of simulation results to obtain fields relevant for MR research.
- Verification of simulation results.
- Current use of RF modelling in MRI research.

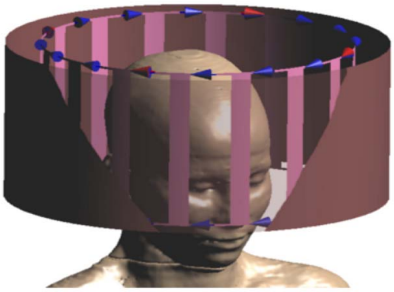

Figure 1: 3D model of a birdcage head coil and a human anatomy used for EM simulations.

Purpose: Coil geometry, patient anatomy and RF frequency strongly affect the behaviour of RF electromagnetic (EM) fields. RF modelling is used to predict EM fields.

Methods: EM simulations require a 3D model of the RF coil and the object of interest, e.g. human anatomy (see figure 1). Relevant electric properties are assigned to the model, for example, to define lumped elements and biological tissues with various electric properties. Several techniques are available to simulate the EM fields. The EM fields are typically post-processed to obtain fields which are relevant for MR research. Those are, for instance, the B_1^+ and B_1^- field, which are related to the transmit efficiency and receive sensitivity. Furthermore, SAR (specific absorption rate, related to tissue heating) and noise correlation can be derived from the E-field. Verification of the simulations can be performed by direct comparison with the B_1^+ field (measured with MRI), or the E-field (measured with E-field probes).

Results: Phased arrays, RF pulse design and novel coil designs are increasingly used to improve transmit field homogeneity at high static magnetic field strengths. EM simulations are used to compare costs (SAR, safety) and benefits (transmit field homogeneity) as a function of phase/amplitude settings, RF pulse design, RF frequency, anatomy etc. To improve the receive efficiency (e.g. by increasing SNR or the use of accelerated imaging), noise correlation and receive sensitivity are investigated with RF modelling.

Conclusion: RF modelling is a versatile tool to gain insight into EM fields generated and received by RF coils.

Recommended reading:

Hoult, D. I. (2000), The principle of reciprocity in signal strength calculations—A mathematical guide. *Concepts Magn. Reson.*, 12: 173–187.

Jin, J.M. *Electromagnetic Analysis and Design in Magnetic Resonance Imaging*, Biomedical Engineering Series, Crc Press; 1999

Roemer, P. B., Edelstein, W. A., Hayes, C. E., Souza, S. P. and Mueller, O. M. (1990), The NMR phased array. *Magn Reson Med*, 16: 192–225