

# Using the STIR optimization method to determine the optimal rung drives for resonators in high field head MRI

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## Synopsis

Numerical simulations are used in an attempt to find optimal source profiles for high frequency RF coils. Shielded circular and elliptical birdcage coils operating at 170MHz, 300MHz and 470MHz are studied. The 2D-FDTD optimization is carried out using the calculated EMF fields inside a human head model and sensitivity characteristics of the individual rungs of a resonator. The simulation results demonstrate the strength of the proposed method.

## Introduction

High field technology has brought considerable engineering challenges in the delivery of RF fields. Tissue-RF field interactions lead to significant inhomogeneity in the  $B_1$  field and thus can result in poor MR images under some circumstances [1]. In this report, we investigate the strategy of improving the transmit  $B_1$ -field homogeneity through active control of source profiles [2-4], i.e., to tailor the RF amplitudes and phases applied individually to the rungs of a resonator with the use of an optimization scheme.

## Method

In this study, subspace trust-region interior-reflective (STIR) optimization [5] is employed to determine the rung currents on two 12-element, shielded birdcage coils (see Fig.1) operating at 170MHz, 300MHz and 470MHz. Both circular and elliptical coils [6, 7] are modeled. In the optimization procedure, the first step is to employ FDTD [8] with a cell-size of 3mm to calculate the sensitivity profile of each rung loaded with a 2D axial-sliced head model; the second step is to implement STIR algorithm to search for improved uniformity of RF field inside the sample. During the iterative optimization, superposition of the sensitivity profiles produced by complex current amplitudes for each rung is used to evaluate the  $B_1$  field and hence intensive FDTD calculations are avoided. The manner in which a target function is defined is critical for practical optimization as the phase components of  $B_1$  field need to be taken into account in high-frequency analyses [9]; specifically, as the transmit field is expressed as  $B_1^+ = (B_x + iB_y) / \sqrt{2} = |B_1^+| \exp(i\phi)$ , during the optimization, both the magnitude  $|B_1^+|$  and phase  $\phi$  are weighted differently in the target function for different frequencies/coils. We note that in this investigation, all the rung currents, including the empty case, are determined via the STIR method, instead of using any predefined values [7].

## Simulations

Using the STIR optimization algorithm, the source profiles of the birdcage coils can be determined within two minutes on a 3-GHz PC. Fig.2 shows comparative results in terms of  $B_1$  field distribution before and after the optimization. The results clearly indicate that the optimization is quite capable of improving the uniformity of the RF field. About 85% of the  $B_1$ -inhomogeneity caused by loading effects can be compensated for by optimizing the rung drives.

## Discussions

In this preliminary study, we restrict ourselves to 2D scenarios [10], but the formalism can be easily adapted to other situations including 3D volume resonators and phased array systems. Optimal RF pulse modulation schemes are also being investigated for use with these structures. In addition, the algorithm is being applied to transceiver phased-array coils. It is hoped that these studies will offer insight into coil design and/or useful imaging schemes for high field MRI.

## Acknowledgements

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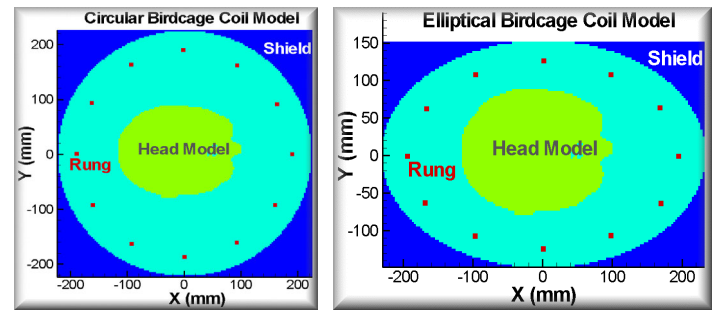


Fig.1. RF coil/tissue interaction model setup in the FDTD calculations.

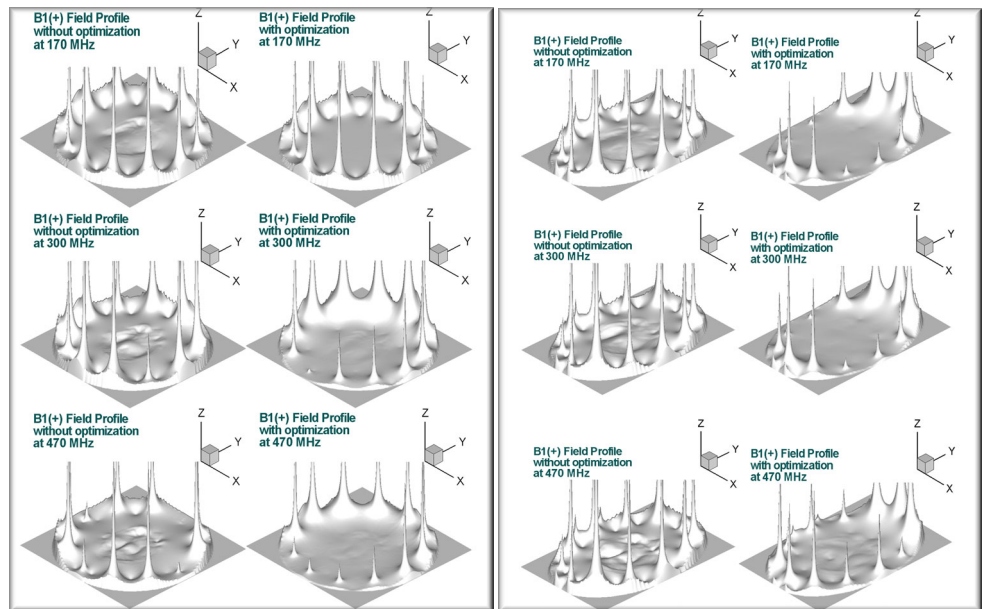


Fig.2. Comparisons of the  $B_1$  field map before and after optimization. (left: circular birdcage coil; right: elliptical birdcage coil)

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