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## Structure Adjustment of Surface Dipole Antenna Elements for Body Imaging at 7 Tesla MRI

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### Synopsis

In ultra-high-field magnetic resonance imaging (UHF-MRI), body imaging suffers from B1 inhomogeneity due to relatively short wavelength. A range of new radio frequency (RF) coil designs has been proposed to overcome this problem. As previously reported, dipole antenna had been proposed to address this B1+ inhomogeneity problem for body imaging. In this paper, structural adjustment of dipole antenna has been tried for parallel transmission to improve overall B1+ homogeneity. Surface dipole antennas with several structures are tried and compared with our top-hat dipole antenna array reported previously. Also, static RF shimming was employed to evaluate the B1 uniformity.

### Introduction

Although ultra-high field magnetic resonance imaging has been of interest for many years due to its high SNR and other imaging capabilities, achieving good B1+ homogeneity from the transmit coil is still a big challenge due to the relatively short wavelength of the RF wave. Radiative antenna arrays have been previously proposed to overcome this problem while increasing the total transmission efficiency [1]. In this paper, structural adjustments of dipole antenna with various tilting structures have been tried to improve B1+ homogeneity. Electromagnetic (EM) simulation has been performed, and B1+ field uniformity and SAR are compared for various design parameters. RF shimming was evaluated to achieve better optimization for a given SAR.

### Materials and Methods

Conventional dipole antenna consists of two conductive lines such as microstrips or rods, which are symmetric in both sides (arms), with the source feed at its center. A top-hat dipole antenna is a combination of conventional dipole antenna and pieces of copper [2]. The first structural adjustment refers to the rotation of dipole antenna and the second adjustment is the dipole antenna with curved and rotated shape, like a spiral shape. We will call it a spiral dipole antenna. A surface loop coil of rectangular shape (10 cm W x 50 cm L) is also considered for comparison. Figure 1 shows the top view of these antennas described.

EM simulation analysis based on FDTD method was performed using Sim4Life [3]. For 8-channel configuration, the 8 elements are equally distributed in radial direction (52 cm D) identical to inner diameter of the Achieva 7 T (Philips, The Netherlands) magnet bore. A uniform digital phantom (46 cm D x 52 cm H) with the dielectric properties of oil was used (relative permittivity of 11.74 and the conductivity of 0.764 S/m).

The RF shimming optimization method was previously proposed to improve the B1 uniformity in a selected region of interest (ROI) by optimizing the relative magnitude and phase of RF power delivered to each transmit element [4,5]. To obtain the complex weight of each element, the superposition of linear system was used to solve the optimization equation using the conjugate gradient method [6]. The least square method is implemented in MATLAB as follows:

Solve  $Ax = b$

Or minimize  $\|Ax - b\|$

Or solve  $(A^T A + sI)x = A^T b$

where  $A = B1$  from individual coil,  $s =$  regularization parameter for maximizing uniformity (must be positive),  $x =$  magnitude of power delivered to individual coil,  $A^T =$  transpose of matrix  $A$ ,  $I =$  identity matrix, and  $b =$  desired B1 field from combined coil.

After the optimization for shimming, the power values applied to each element were normalized to produce a rectangular excitation pulse with a duration of 1 msec at the center of the coil and resultant 90° flip angle (B1+ field value of 5.87  $\mu$ T). The RF shimming optimization was evaluated in both 2D and 3D ROI's. The 2D ROI in axial plane is 21 cm and coronal plane is 29 cm in diameter, respectively and 3D ROI is in a cylindrical shape with 21 cm in height and 29 cm in diameter (Fig. 2).

### Results and Discussions

All the dipole antennas were tuned and matched to 298 MHz using Sim4Life matching toolbox. Figure 3 shows B1+ uniformity (%), B1 efficiency, and 10g Average SAR for RF shimming optimization in 2D ROI axial planes, 2D ROI coronal planes, and 3D ROI. And it shows the top-hat dipole antenna has the highest B1 efficiency. However, the spiral dipole antenna (45 degree) shows the best B1 uniformity in the axial plane. From RF shimming optimization in coronal plane, top-hat dipole antenna offers the highest B1 uniformity and lowest SAR. In 3D ROI based RF shimming optimization, top-hat dipole antenna offers the highest B1 efficiency, however, spiral dipole antenna (45 degree) shows the highest B1 uniformity with 10% increase in uniformity. Table 1 shows the total power delivered to 8-channel array to achieve 90° (5.87  $\mu$ T) at the center for 2D ROI shimming (axial), 2D ROI shimming (coronal), and 3D ROI shimming in the uniform digital phantom for the 6 cases.

### Conclusion

The B1 uniformity can be improved by structural adjustment of dipole antenna. The top-hat dipole antenna array offers the highest B1 efficiency while spiral dipole antenna shows the maximum uniformity. Application of RF shimming showed B1 uniformity enhancement and they have proved to be very effective in SAR reduction. In future work, these antennas array will be verified experimentally in both phantom and in-vivo studies.

## Acknowledgements

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## Figures

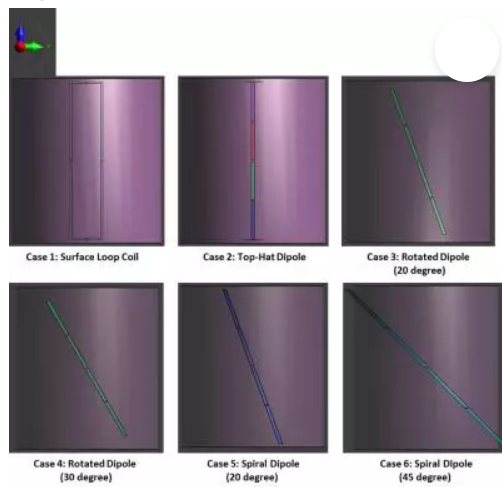


Figure 1. Shape and design of 8-channel array.

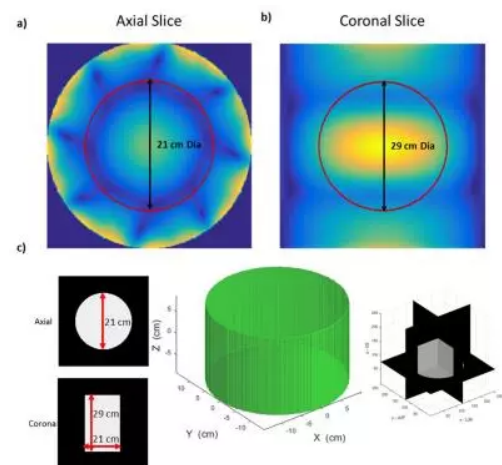


Figure 2. Description of a) the axial 2D ROI, b) the coronal 2D ROI, and c) description of the 3D ROI.

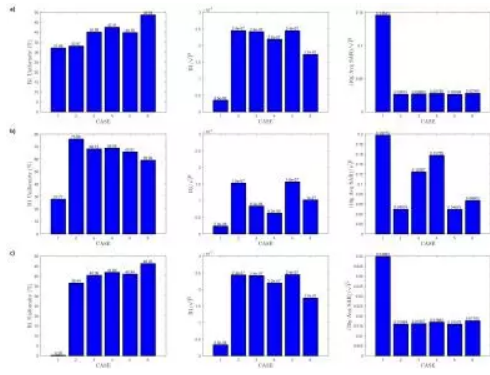


Figure 3. B1+ uniformity (%), B1 efficiency, 10g Average SAR for a) 2D ROI axial plane, b) 2D ROI coronal plane, and c) 3D ROI based RF shimming optimization.

	2D Shimming (Axial) (Watt)	2D Shimming (Coronal) (Watt)	3D Shimming (Watt)
Case 1	28591.882	66026.2258	32272.5882
Case 2	577.9046	1486.6310	582.6465
Case 3	592.3564	4949.1050	593.3938
Case 4	722.3007	9075.3757	722.3999
Case 5	577.7296	1417.4529	577.7390
Case 6	1156.7357	3319.1733	1144.8359

Table 1. Total power for 90° Flip angle for 2D ROI shimming (axial), 2D ROI shimming (coronal), and 3D ROI shimming for 6 cases.

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