Use of "dark modes" in a loop + dipole array to reduce SAR in 7T C-spine imaging

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Target Audience Ultra-high field neuro (spine) MRI researchers impaired by SAR and B_1^+ homogeneity issues.

Purpose In this study we reduce local SAR by diversifying the field patterns present in a transmit array by adding dipole elements to a conventional transmit spine array of loop elements. The "radiative dipole antenna" was previously introduced as a transmit element [1]. In this work we demonstrate that addition of dipole antennas can reduce the local SAR of loop arrays without changing the B_1^+ distribution significantly.

Methods We simulated the fields of a loop array previously constructed for spine imaging at 7 T [2](Figure 1a) Using the B1+ of the loops alone we found an optimum RF shimming solution that maximizes B1+ homogeneity in the vicinity of the spine.(marked with x's in Figure 2) using particle swarm optimization[3].

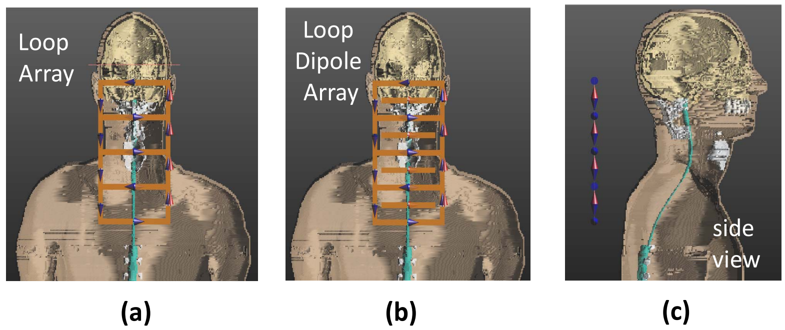

Figure 1 Loop array (panel a) and the proposed loop-dipole array (panel b) for spine imaging. Panel c shows the relative distance of the arrays to the body from side view.

The local SAR distribution due to the loop array is calculated for a mean B1+ field of 1 μT in this spinal cord ROI. We then introduced dipole elements in the middle of each loop element. The dipole elements generate little transverse B1+ field at the location of the spinal cord due to their orientation. However the electric fields generated by the dipoles are comparable in magnitude to the loop elements. By performing an exhaustive search we optimized the currents on the dipole elements to reduce the overall peak local SAR. Since the dipoles do not generate significant B1+ in the region of interest (hence are labeled "dark modes") the B1+ uniformity wasn't changed significantly during the optimization.

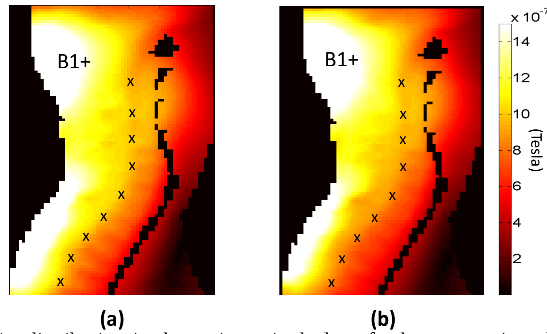

Figure 2 B1+ distribution is shown in sagittal plane for loop array (panel a) and the proposed loop-dipole array (panel b).The addition of the dipole elements do not change the B1+ pattern of the loops significantly.

Results Figure 2 shows the B1+ distribution after B1 shimming due to the loops alone and the nearly identical map of the loop + dipole array after energizing the dipole elements. The excitation by dipoles did not alter the overall B1+ sensitivity or pattern significantly. Figure 3, however, shows that the SAR distribution is reduced when the dipole elements are energized. Figure 3 shows the 10 g local SAR distribution of two arrays in 3 planes chosen so that the axial and sagittal plane always contains the peak local SAR hotspot. The peak local SAR was reduced (45%) by energizing the dipole elements. Global SAR was also reduced (25%).

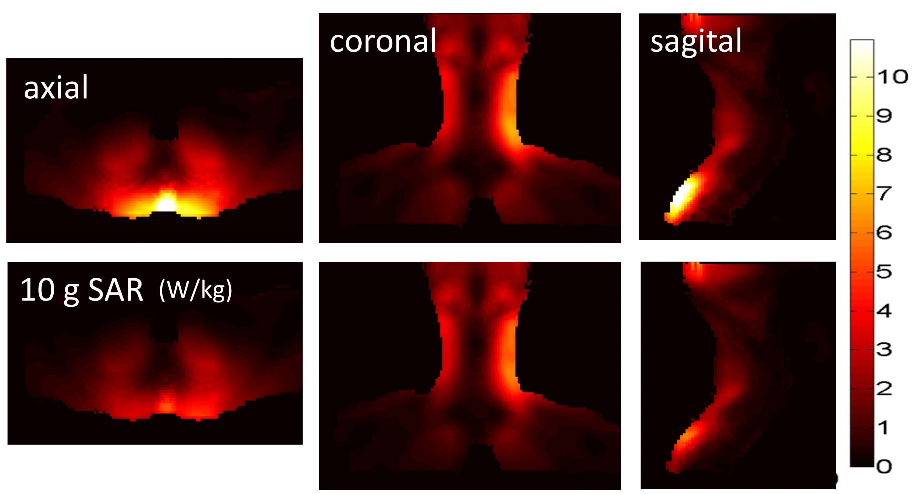

Figure 3 10 g SAR distribution is shown in axial, coronal and sagittal planes for loop array (upper row) and the proposed loop-dipole array (bottom row).The maximum local SAR was reduced due to excitation with loops and dipoles simultaneously.

Discussion For loop arrays the SAR hot spot occurs in the inferior C-spine where the loops are closest to the body. The minimum local SAR utilized higher relative currents on these lower dipole elements. Although the dipoles are "dark" in the sense that they produced little effect on B1+, they can be used to cancel these E fields locally. While showing the principle of "dark mode" SAR reduction, a more systematic optimization scheme is needed.

Conclusion We demonstrate that dipole elements can be used with loop arrays to reduce the local SAR in spine imaging. The local SAR reduction is achieved by energizing "dark" elements which do not change the B1+ profile significantly, but provide additional degrees of freedom to cancel E fields (and thus reduce SAR).

Reference [1]Raaijmakers,A.J.E (2011). MRM 66(5)1488:1497 [2] Zhao ,W. (2012) Proc. Intl. Soc. Mag. Reson. Med. 20 abstract #431 [3] Eryaman,Y. (2009) Proc. Intl. Soc. Mag. Reson. Med. 17 abstract #4777

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