Combined loop + dipole arrays for 7 T brain imaging

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Target Audience MRI researchers working on the RF safety, B1+ mitigation, specific absorption rate (SAR) constrained pulse design, transmit coil design.

Purpose In this study we improve the local SAR and image fidelity performance by diversifying the field patterns present in a transmit array designed for brain imaging at 7 T. We demonstrate this principle using a head transmit array that consists of loop and dipole antennas. The "radiative dipole antenna" was previously introduced as a transmit element [1]. It was shown to have a higher peak local SAR at 7T compared to a loop element producing identical B_1^+ in the middle of the head. Despite the higher SAR, we hypothesize the orthogonality of the field patterns can be exploited to reduce peak local SAR. We demonstrate that a transmit array comprising both loop and dipole antennas outperforms an array of loops-only in terms of local SAR performance and image homogeneity.

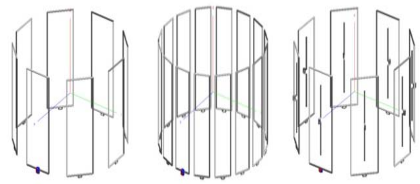

Figure1: 8 Channel Loop Array(left), 16 Channel Loop Array(middle), 16 Channel Loop-Dipole array(right)

Methods We evaluated the trade-off between 10 g peak local SAR and excitation fidelity using electromagnetic simulations of the 8 and 16 channel loop arrays, and the 16 channel loop-dipole array (similar to that previously used in receive [2]) shown in Figure 1. All simulations are performed with visible human head model by using the FEKO EM solver (EMSS-SA). SAR matrices are compressed to a smaller set of VOP (Virtual Observation Points)[3] to enable fast evaluation of peak 10 g local SAR during pulse optimization. For each array, the optimum least square RF shimming and the 2-spokes pulse design solutions are calculated using an optimization approach which explicitly constrains both global and local SAR[4]. Calculating the pulse several times with different local SAR constraints results in a L-curve that shows the tradeoff between flip angle target fidelity and local SAR. The target pattern was a uniform 10^o flip angle excitation. The maximum peak and average power is also explicitly constrained (to 1 kW and 100 W respectively.) The head average SAR is constrained to < 3.2 W/kg in all solutions.

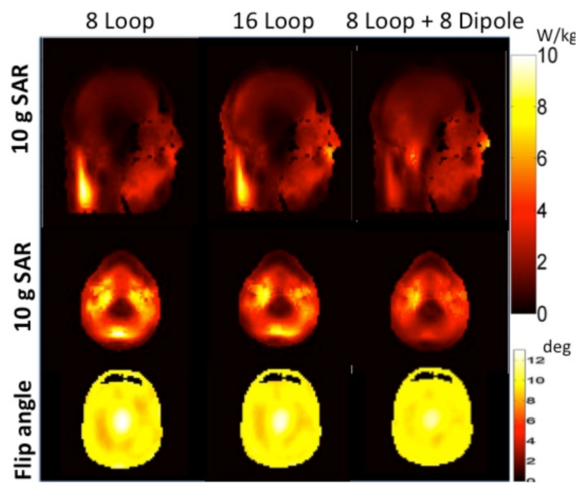

Figure 2 10 g SAR distribution is shown in sagittal (first row) and axial planes (middle row). Flip angle distribution is shown in an axial plane (bottom row)

Results Figure 2 shows the 10 g local SAR and the flip angle distribution in axial and sagital planes for a 2-spoke design with a peak local SAR of 10W/kg. The axial images show the plane with the highest local SAR. The RMSE excitation fidelity was 8.8%, 7.6%, and 5.3% for the 8 loop, 16 loop and 8 loop+8 dipole array respectively. Thus adding the dipoles was able to improve the excitation fidelity at given local SAR constraint. Figure 3 shows the L curve trade-off between excitation fidelity and local SAR for RF shimming and 2 spokes pulse design. The loop + dipole array reduced the peak local SAR significantly (40%) compared to 8 loop array with 2 spokes pulse design at a given RMSE fidelity (10%).

Discussion For both RF shimming and 2 spokes pulse design; the 16 element loop + dipole array outperformed 8 element loop array for its local SAR and excitation fidelity performance. Similar statement can also be said for the comparison of 16 element loop dipole array with a 16 element loop array, which shows that the performance improvement was not due to increase in number of elements alone, but benefited from the differing field patterns of the radiative dipoles. The local SAR benefit of adding dipoles was more noticeable with the 2 spokes pulse design. In both shimming and 2 spokes excitations the loop + dipole arrays gave a better excitation fidelity within the maximum SAR constraints.

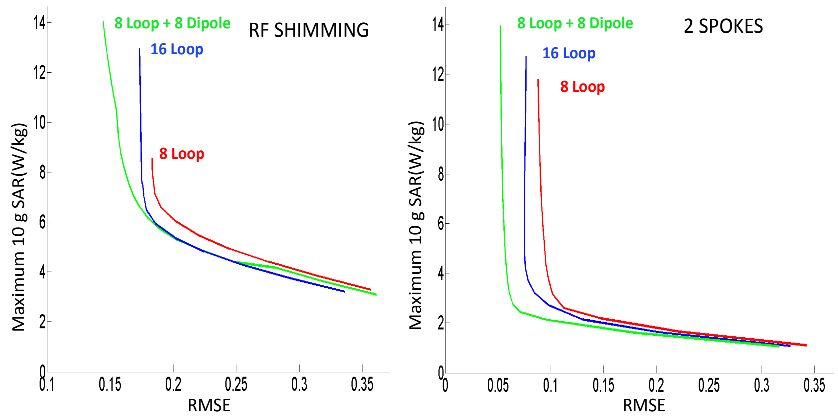

Figure 3: L Curves show the trade-off between maximum 10 g SAR and image fidelity(RMSE) for RF shimming and 2 spokes pulse design.

Conclusion The trade-off between 10 g peak local SAR and excitation fidelity is evaluated for three transmit arrays that can be used for head imaging at 7T. Simulation results show that an array composed of both loop and dipole elements have better local SAR excitation fidelity trade-off compared to an array that is composed of loops only.

Reference [1]Raaijmakers,A.J.E (2011). MRM 66(5)1488:1497 [2]Wiggins G.C.(2012) Proc. Intl. Soc. Mag. Reson. Med. 20 #2783 (2012) [3]Gebhardt, M. (2011). MRM **66**(5): 1468-1476[4]Guerin B (2012)Proc.Intl.Soc.Mag.Reson.Med 20 #2215 Acknowledgements: R01EB006847, R01EB007942,This project is also supported by the Comunidad de Madrid and the Madrid MIT M+Vision Consortium.