Comparison of Local and Remote Transmit Arrays for Body Imaging at 7T under Power and Local SAR Constraints

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Target audience: RF engineers and MR physicists.

Purpose: So far, predominantly local coil arrays that are placed directly on or close to the subject are used for body imaging at 7T. Placing the coil array under the bore liner would simplify the workflow and increase subject comfort. To assess the imaging performance of such remote arrays in comparison to local arrays under power and local SAR constraints, simulations were performed for various array configurations and channel counts.

Methods: The five parallel transmit (pTx) arrays shown in Fig. 1 were studied. The first two arrays are a local tight-fitting 8-channel body array[1] and a local 16-channel array[2], where the anterior coil elements are arranged in a semi-circle inside the bore liner. The three remaining arrays are remote body coils placed under the bore liner. All arrays were loaded with the Duke body model[3] and simulated with CST Studio Suite (CST, Darmstadt, Germany). The Tx channels were ideally decoupled[4,5]. Subsequently, B_1^+ maps were extracted for the individual channels and SAR matrices based on the VOP algorithm[6] were computed. RF shims and 2-spoke pulses were designed by formulating the quadratically constrained (local SAR and maximal power per channel) least square problem as a second order cone program. This was solved with SeDuMi[7] in combination with the variable exchange algorithm. The target magnetization was set to 6.5 µT, which corresponds to a flip angle of 60° for a 0.8 ms rectangular pulse. For coronal slices, a ROI with length of 30 cm along the longitudinal axis was used.

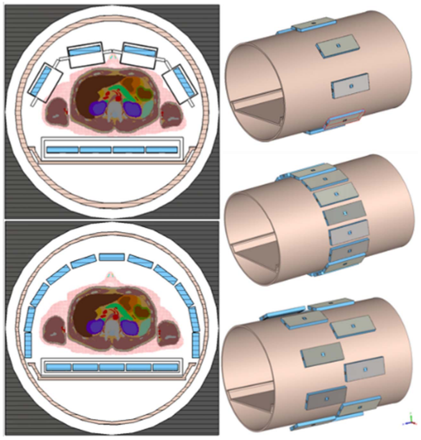

Fig. 1: The five pTx arrays studied.

Results/Discussion: Results are represented as L-curves. In Fig. 2 a,c,e,g the max. peak power in the Tx channels required to achieve a given flip angle (FA) error at a constant maximal local SAR of 200 W/kg is plotted. In Fig. 2 b,d,f,h the max. local SAR for a given flip angle (FA) error at a max. peak power per channel of 500 W is shown. For the SAR, the duty cycle was not taken into account. Duty cycles for typical sequences range from under 1% (long TR) to 10% (short TE and TR). For the axial slice in the array center (Fig. 2 a,b) and reasonable local SAR below 400 W/kg, the tight 1x8 channel array achieves lower FA errors than the remote 1x8 channel array. For tight constraints (peak power < 70 W), the local 1x16 array reaches lower FA errors than the remote 1x16 channel array. These findings hold also for off-center slices (not shown). However, for coronal (Fig. 2 c,d) and sagittal (not shown) slices the remote arrays outperform the tight arrays. On the one hand, the closer the coil elements are to the body, the stronger they couple to the body and the more power efficient the array. On the other hand, the B_1^+ field of a remote coil decays more slowly in the longitudinal direction, which is advantageous in coronal and sagittal slices with large FOV. When comparing both 16 channel remote arrays, it turns out that the 1x16 configuration reaches lower FA errors than the 2x8 configuration for the axial slice. In contrast, for coronal (Fig. 2c,d) and sagittal slices, the 2x8 channel remote coil achieves a better homogeneity, but only if power and SAR constraints are lax (SAR > 400 W/kg). This is different from the situation at 3T[8] where it is beneficial to add additional coils in the z-direction for arrays with more than 8 elements even for tight constraints. In general, utilization of 2-spoke pulses yields a significantly improved overall homogeneity versus an RF shim (7 % vs. 17 % minimal FA error). In axial slices, the tight 1x8 array still outperforms the remote array (Fig. 2 e,f). If power is the limiting factor, the local 1x16 array is superior to the remote 1x16 array. If local SAR is the limiting factor, it is the other way round. Also for spokes pulses, remote arrays perform better than tight ones in sagittal and coronal slices. In the example studied here, using 2 spokes results in longer pulse durations and, thus, the power constraints are less critical. Consequently, the range where the 2x8 array performs better than the 1x16 array is larger.

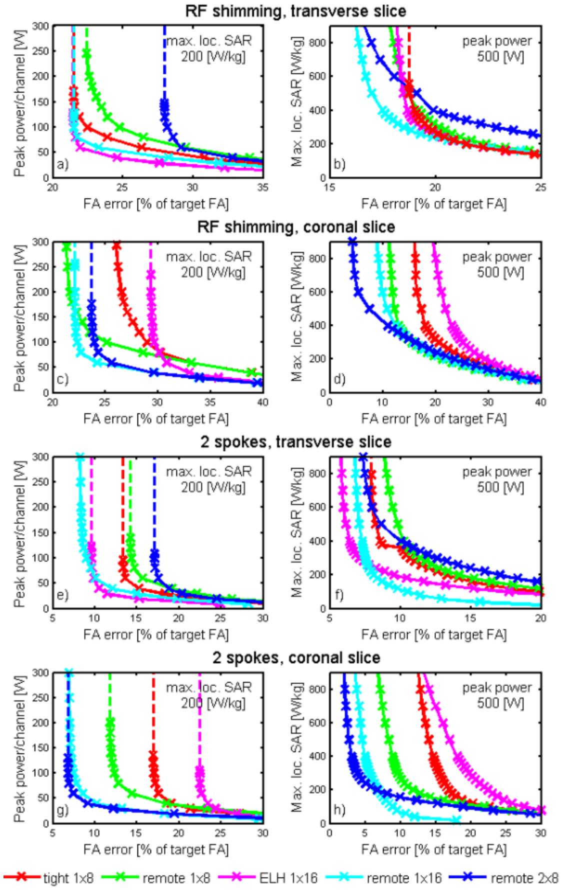

Fig. 2: L-curves for RF shimming and 2-spoke pulses in transversal and coronal slices at either constant maximal SAR or constant maximal power. SAR values have to be reduced by the duty cycle.

Conclusion: While tight-fitting coil arrays have better performance in axial slices, remote coil arrays achieve better homogeneity in coronal and sagittal slices. Arranging the coil elements in multiple rings offers more degrees of freedom for shimming in the longitudinal direction. However, in contrast to the situation at 3T[8], this often does not result in better homogeneity because of power and SAR constraints.

References: [1] Orzada et al. (2009). Proc. ISMRM 17:2999. [2] Orzada et al. (2010). Proc. ISMRM 18:333. [3] Christ et al. (2010). Phys. Med. Biol. 55(2):N23-38 [4] Mahmood et al. (2013). Proc. ISMRM 21:2722. [5] Mahmood et al. (2014). Proc. ISMRM 22:584. [6] Eichfelder, Gebhardt (2011). MRM 66:1468. [7] Sturm (1999). Optim. Methods Softw. 11:625. [8] Guérin et al. (2014) MRM.

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