COMPARISON OF DECOUPLING SCHEMES FOR A THREE CHANNEL ^{31}P ARRAY FOR THE HUMAN CALF MUSCLE AT 7 T USING 3D ELECTROMAGNETIC SIMULATION

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Introduction: Phosphorus-31 NMR spectroscopy benefits from higher sensitivity, increased spectral resolution and shorter relaxation times at 7T. The sensitivity can be further increased by employing an NMR phased array [1], which gives rise to the mutual coupling problem between array elements. Roemer et al proposed overlap decoupling of neighboring elements. Other decoupling techniques include the utilization of a shared conductor and/or capacitive decoupling networks for adjacent coils and next nearest neighbors [2]. The aim of this work is to compare the three different approaches for a three channel ^{31}P calf coil at 7T.

Methods: 3D electromagnetic simulations were performed using XFdtd 7.2.3.4 (Remcom, State College, PA, USA) to optimize and evaluate the performance of three different coil designs (Fig. 1). The coil arrays are bent to a half cylinder shape with a diameter of 14.9 cm. The coil model was loaded with a cylindrical phantom consisting of skin, fat, muscle and bone, since the voxel models of the virtual family have a flattened calf. Overall length and width of the array were kept constant, yielding slightly smaller array elements for the shared conductor design. The element size is 10 x 7 cm^2 for the overlap arrays with an overlap of 9 mm, whereas for the shared conductor array the element size is 10 x 6.4 cm^2. Tuning, matching, and optimal decoupling capacitor values were determined using the circuit co-simulation software ADS (Agilent, Santa Clara, USA). B_1^+ and SAR were evaluated using a fast Matlab (Mathworks, Natwick, USA) based evaluation scheme [3]. To find the optimal phase combination of the three channels, we defined an ROI consisting in the volume of the half cylinder the coil covers. Relative homogeneity (B_1^+ standard deviation/mean B_1^+) and sensitivity (mean $B_1^+/\sqrt{(\text{local } SAR_{10g})}$) were calculated within the ROI for relative phase shifts of 0° to 350° in steps of 10°, yielding 36² different phase combinations per coil array.

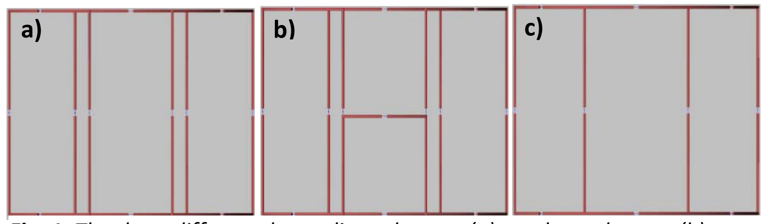

Fig. 1: The three different decoupling schemes: (a) overlapped array, (b) overlapped array with shared capacitor for next nearest neighbor decoupling, (c) shared conductor array.

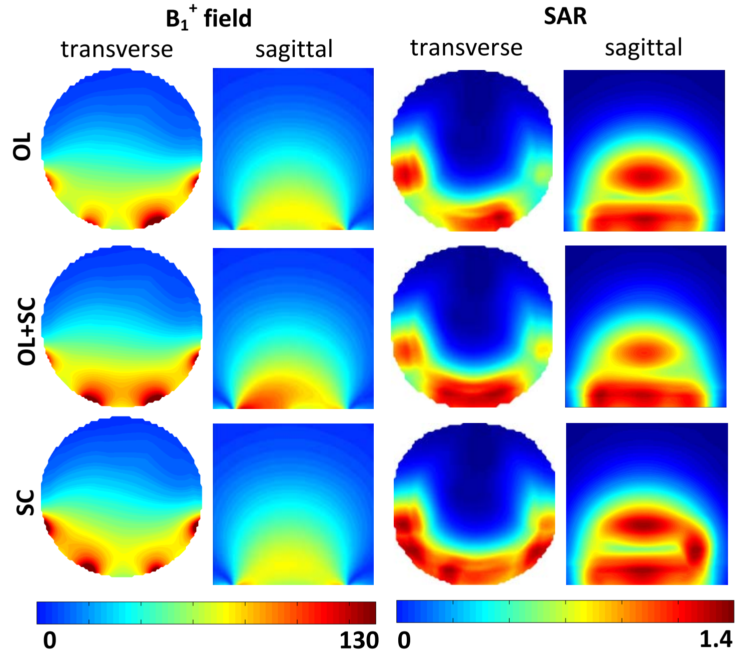

Fig. 2: Simulated B_1^+ fields (left) in transverse and sagittal plane (µT/√kW), maximum intensity projections of local SAR_{10g} /absorbed power in transverse and sagittal plane (1/kg).

Results: Matching better than -28.5 dB was obtained for all coil elements. Transmission coefficients are summarized in Table 1, showing the best isolation for the shared conductor array. There is no significant difference in relative homogeneity and relative sensitivity between the designs. The same holds true for peak local SAR values (Table 1). Figure 2 shows B_1^+ fields and SAR distribution in transverse and sagittal planes.

Design	Transmission coefficients (dB) S_{12}	S_{23}	S_{31}	Peak SAR_{10ccm}	absorbed power (W)	$\overline{B_1^+}/\sqrt{SAR}$	$std(B_1^+)/\overline{B_1^+}$
OV	-9.2	-8.9	-9.5	1.33	0.85	1.617e-6	0.397
OV+SC	-12.8	-13.3	-14.5	1.35	0.92	1.763e-6	0.411
SC	-16.3	-15.8	-19.5	1.37	0.95	1.674e-6	0.417

Tab. 1: Transmission coefficients between the 3 channels, averaged 10 g SAR, absorbed power, relative sensitivity and homogeneity of each design.

Discussion: All three investigated coil designs show comparable field distributions and peak SAR values. Coil isolation is slightly better with shared conductors. Overlapped arrays, on the other hand are easier to build and more robust in terms of load dependence.

Conclusion: The difference in performance between the investigated designs is small. For practical reasons, the construction of an array of overlapping coil elements is suggested.

References: [1] Roemer et al., MRM (1990); [2] Zhang & Webb, JMR (2004); [3] [2] Kuehne et al., Proc. ISMRM #2735 (2012)
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