Optimization of a four channel phased array coil for rat lung imaging at 7 T

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INTRODUCTION

Small-animal lung imaging with magnetic resonance has become an important tool in biomedical research. ^1H lung MRI is usually limited by very short T2* and low ^1H density [1]. With the advent of ultra short echo time (UTE) sequences visualization of lung tissue became feasible for the first time. UTE combined with highly sensitive MR coils will improve further signal gain from the lungs. In order to optimize SNR, filling factor optimized coil arrays [2] are needed. The usual approach in human thorax applications is a split design with anterior and posterior coil elements. However, when doing rat lung with only four available Rx channels, such elements become large, and covering as much of the circumference as possible results in a close proximity and hence strong mutual coupling of anterior and posterior coil elements. We here show that optimizing the filling factor by an anatomically shaped housing, including well-chosen coil decoupling mechanisms, leads to a sensitive array design.

Fig.1: second phased array

MATERIALS & METHODS

A first coil array has a cylindrical shape (inner diameter: 48 mm) and is detachable into an anterior and posterior part for better access during animal handling and preparation. The array consists of two pairs of coil elements, both decoupled by shared conductors. However, there is no decoupling mechanism from upper to bottom elements (Fig. 2) but preamplifier decoupling. All four elements have equal sizes (50 x 36 mm^2). The second array (Fig. 1) is built with a very close fitting to the rat body in order to achieve the highest possible filling factor and SNR. Therefore, the inner silhouette of the new four channel array has an elliptical form (long axis 66 mm, short axis 47 mm) which is very close to the anatomical shape of the rat body in supine position. An additional bulge for the spinal column at the bottom of the array supports an exact positioning of the rat along z-direction. The two top elements are slightly larger (60 x 65 mm^2) in order to yield overlap decoupling to the bottom elements (60 x 50 mm^2). All neighboring coil elements are decoupled by overlap (Fig. 2) which is made possible by electric connections between the two housing parts. The next-neighbor elements are decoupled by capacitive networks. The first array is smaller and suitable for rats up to a weight of 350 g, whereas the second array has an enlarged housing size and can handle rats up to a weight of 500 g. Both arrays offer preamplifier decoupling and an interface box containing low noise preamplifiers (0.5 dB noise gain). Furthermore the second array contains a heating bed. The experiments of both arrays were performed on a 7 T MR system (Bruker Biospec 70/30, Ettlingen, Germany). All SNR evaluation was performed on a cylindrical phantom (diameter 45 mm, length 74 mm) filled with $CuSO_4$ (1g/l) + H_2O (aqua bidest).

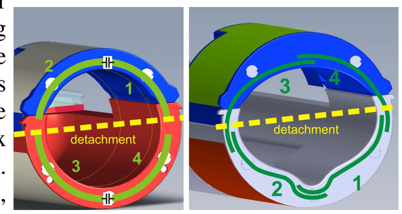

Fig.2: element alignment of the two array coils. left: first version, right second version

RESULTS AND DISCUSSION

The workbench coil measurements are shown in Table 1. The second array shows far better isolations (S21) and, especially, a better noise correlation (Table 2). This originates from the additional decoupling mechanism introduced from upper to lower elements. This improvement can also be seen in the SNR maps (Fig. 3, scaled to 100%) on the phantom. In the center of the phantom (ROI) the SNR of the second, improved array is raised approximately by a factor of 2. Because of the elliptical shape of the second array, the rat lies close to its natural attitude and, hence, the coil elements get closer to the rat lung. This results in a better filling factor which is of interest especially for the SNR in the outer regions. The center is expected to remain nearly unaffected by the better filling factor due to the sample noise domination of the design where volumetric arrays do not offer better SNR in the center than corresponding volume resonators. Fig. 4 shows MR-images (axial/coronal) of the second, improved array with a 420 g rat, acquired with FLASH- and UTE-sequences. There is no detrimental effect from the relatively large coil elements to be observed (induced by using overlap instead of shared inductor for decoupling) [3].

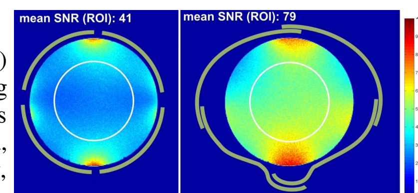

Fig.3: SNR-map (SOS) left: fist version, right: second version (ROI is marked by white circle)

CONCLUSION

It was shown that for the application on the rat lung a fully decoupled coil array scheme yields better results in terms of SNR than a split array, if the mutual coupling between upper and bottom coil elements gets too strong. For an optimum gain, it still makes sense to optimize the filling factor by an anatomically shaped housing, especially in the outer regions or in order to reduce sample noise. Due to the anatomic shape of the second coil housing, measurements with a non-deformed rat lung are possible, but will improve abdominal imaging as well.

	Q_U / Q_L	S21- neighbor	S21- next neighbor
first array	3,6	-16 dB -8 dB (top to down)	-10 dB
second array	3,3	-19 dB (all elements)	-16 dB

Table 1: Q-measurements (Q_unload /Q_load), decoupling

first	CH1	CH2	CH3	CH4
CH1	100	5	7	62
CH2	5	100	70	12
CH3	7	70	100	19
CH4	62	12	19	100
second	**CH1**	**CH2**	**CH3**	**CH4**
CH1	100	8	16	8
CH2	8	100	13	7
CH3	16	13	100	12
CH4	8	7	12	100

Table 2: Noise Correlation [in %] for the first (top) and second (bottom) array version

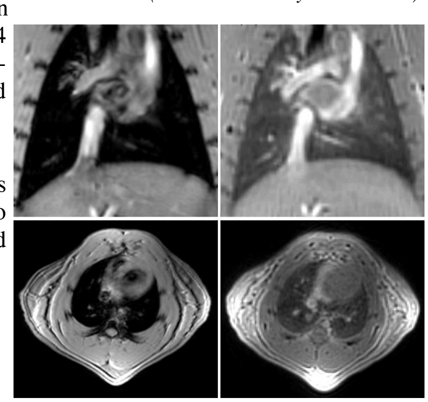
Fig.4: MR-Images of a rat lung acquired with the elliptical/second coil array. (axial/coronal). Left: FLASH (FOV 60 mm, matrix 256x256, sl 1 mm, FA 30°, TE 2ms, TR 135 ms). Right: UTE (FOV 60 mm, matrix 128x128, sl 0.5 mm, FA 5°, TE 20 µs, TR 3 ms)

REFERENCES: [1] Nackos J.S. et al.: ISMRM 2012, #3966,
[2] Roemer PB, et al.: MRM 1990, 16:192, [3] Wichmann T. et al.: ISMRM 2007, #1032