35Cl MRI at 9.4T: Rx Array Decoupling and Matching Strategies for Coupled Coils

Matthias Malzacher[1], Ruomin Hu[1], Jorge Chacon-Caldera[1] and Lothar R. Schad[1]

[1]Computer Assisted Clinical Medicine, Heidelberg University, Mannheim, Baden-Württemberg, Germany

Target audience: RF engineers, researchers at preclinical systems, researchers interested in chlorine MRI

Purpose: Chloride (Cl-) is next to the cations Na+ and K+ the most abundant non-organic anion in the mammals. Assessment of chlorine's (35Cl) concentration in tissue could provide further insights into tissue viability in addition to tissue sodium concentration. Yet, low Signal-to-Noise ratio (SNR), low gyromagnetic ratio, short relaxation times and low-frequency are major challenges. Ultra-high field pre-clinical scanner can overcome these challenges. Yet, the limited space increases coupling between the small and high-Q receiver elements. The effect on SNR by coupled coils despite preamplifier decoupling has been shown before[1]. In this work the effect of coupled coils on SNR is investigated and 2 different approaches to overcome SNR penalties are evaluated.

Methods: Transmit: For transmission a 16 leg low-pass birdcage was built (Figure 1). The shield was realized using a "swiss-roll" configuration. The coil was detuned using PIN diodes in every second leg.

Receive / Decoupling and Matching: A 3 channel Rx array (Figure 2) was built for signal reception. Each coil was made out of double winded silver wire and tuned to the resonance frequency of 39.2 MHz via a split capacitor. The coils were equipped with an active detuning circuit, a cable trap and a low-noise preamplifier. An additional preamp protection diode was added in front of each preamp. The Rx array was wrapped around an FRP tube (diameter 42 mm) resulting in two coils facing each other. While the middle coil can be decoupled from its neighboring coils via overlap, the two facing coils are strongly coupled. Three SNR measurements were performed using different decoupling and matching strategies. For the first measurement the coils were decoupled using transformer decoupling as indicated in Figure 2 (red lines). For the second measurement the coupled coils were both matched to their lower mode. The last measurement was done by decoupling the coupled coils using preamplifier decoupling.

Measurement: Measurements were performed at a 9.4T preclinical MRI scanner (94/20 Biospec, Bruker, Ettlingen, Germany) using a 3D radial density-adapted sequence[2] with parameters: TR/TE = 20/0.54 ms, Flip Angle = 60°, Projections = 3500, Averages = 32, Field-of-View = (36 mm)³, isotropic Resolution = (1.5 mm)³, T_{RO} = 8 ms, TA = 37 min. SNR maps were calculated making a separate noise scan with the same parameters but less projections (350) and without Tx power applied. For the measurements a cylindrical phantom filled with 0.9% saline solution was used. The phantom was placed in 5 mm distance to the Rx array.

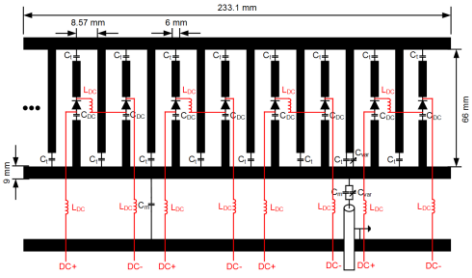

Figure 1: *Circuit diagram of the 16 leg low-pass BC coil. Detuning was realized via PIN diodes which were inserted into every second leg. The coil was balanced using a separate ground ring.*

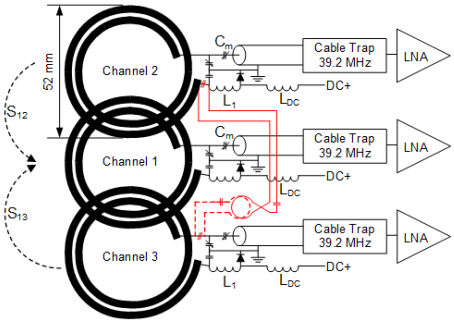

Figure 2: *Circuit diagram of the 3 channel Rx array. Each Rx coil was equipped with an active detuning circuit, Cable Trap and a low noise preamplifier. Additional preamplifier protection diodes were added in front of the preamp. The red circuit represents the decoupling circuit for the transformer decoupled state.*

Results/Discussion: In Figure 3 axial SNR maps of the single channels of the Rx array are shown. The channel 1 coil shows almost the same pattern for the three measurements whereas the coupled coils show very different behavior. In the decoupled case the channel 2 and 3 coils have a distinct coil profile but lower SNR than the channel 1 coil. This lower SNR might arise from the additional losses of the transformer decoupling circuit. In contrary the mode matched coils show an almost similar coil profile which is expected. But the SNR is lower compared to the first measurement. Since the coils are strongly coupled in the mode matched case these coupling losses might reduce SNR performance. In the preamp decoupled case the coils show distinct coil profiles but very low SNR. This result is in good accordance to earlier works concerning this topic. Single channel und combined SNR ratio maps are plot in Figure 4. The single channel SNR ratio maps show that the channel 1 coil remains the same concerning its SNR performance but the channel 2 and 3 coil show SNR increase partially up to factor 3 compared to the preamp decoupled coils. The combined SNR maps show different SNR gains compared to the reference scan acquired with the BC coil only. Mean SNR is up to 18% higher compared to the preamp decoupled configuration.

Conclusion: Preamp decoupling is pushed to its limits for strongly coupled, low loaded coils. Severe SNR penalties might be overcome by decoupling these elements additionally with different decoupling strategies or different matching strategies.

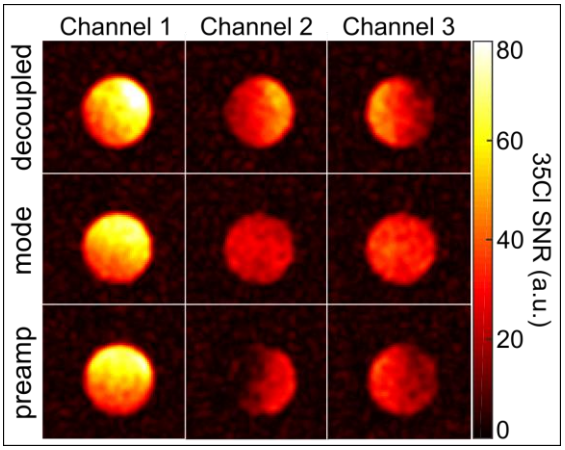

Figure 3: *Axial 35Cl SNR maps of the 3 single channels for the 3 different decoupling and matching setups.*

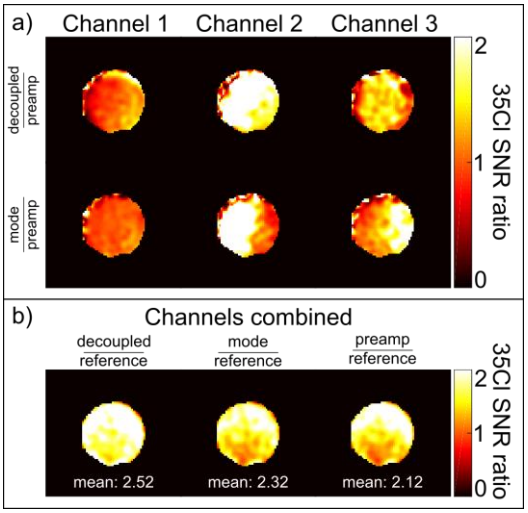

Figure 4:

a) *35Cl SNR ratio maps of the single channel SNR maps. The ratio maps were generated referred to the preamp decoupled state, since it is the basic decoupling method of next nearest neighbor coils.*

b) *35Cl SNR ratio maps of the combined SNR maps. The SNR ratio maps were generated to a reference image acquired with the BC coil only without the Rx array inserted.*

The SNR ratio maps were cut out with a mask.

References: [1] Malzacher et al., ISMRM 2016, p.2157 [2] Hu et al., ISMRM 2017, 2949