# A Double Resonant Solenoid Coil for 35Cl/ 23Na Imaging of the Rat Brain at a Whole Body 7 Tesla MRI

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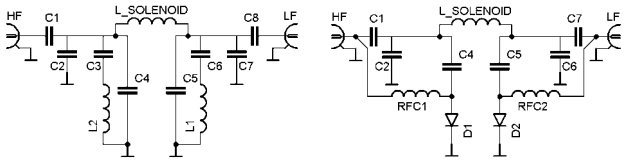
## INTRODUCTION

Sodium and Chlorine ions are central in the physiology of living organisms. Quasi-simultaneously detection in a rat brain would improve the understanding of (patho-) physiological processes. Combined chlorine ($^{35}$Cl) and sodium ($^{23}$Na) imaging in rat brain was presented by Kirsch et al. on a dedicated small animal 9.4T MRI system [1].

The aim of the study was to design and characterize double resonant coils for imaging $^{35}$Cl and $^{23}$Na in the rat brain. For all measurements a 7Tesla whole body MR system was used to simplify the translation of small animal experiments to human applications.

## MATERIAL and METHODS

For comparison and characterization of double resonance performance, four segmented solenoid coils (l=35mm, d=50mm, 2 turns) were built. Two solenoids were single resonant tuned to 29.1MHz and 78.6MHz, which are the Larmor frequencies of $^{35}$Cl and $^{23}$Na at 7T. For the double resonant setups, each end of the solenoid was equipped with a matching network. The other end was shorted to ground respectively with a frequency depended switch realized by passive elements or active pin diodes (Fig.1) [2].




(a) design with traps (b) design with pin diodes

Fig.1: Networks of the double resonant circuits

**SNR Comparison:** After performing a global flip angle calibration, a cylindrical phantom (l = 50 mm, d = 45 mm, 0.3% NaCl solution) was imaged with a density adapted 3D radial sequence DA-3DPR [3] (TR($^{35}$Cl)=165ms, TR($^{23}$Na)=275ms , TE=0.3ms, $\alpha_E$=90°, avg.=1, nominal resolution=(3mm)$^2$, TA($^{35}$Cl)=11:00min, TA($^{23}$Na)=18:20min). Experiments were conducted using a whole body 7T MRI (Siemens Healthcare AG, Erlangen, Germany). The SNR was determined according to the National Electrical Manufacturers Association definition [4], using the magnitude signal of noise-only images.

**Imaging of Rat Brain:** In vivo imaging of an anesthetized RNU rat was performed with the better double resonant setup and a DA-3DPR sequence (TR($^{35}$Cl)=20ms, TR($^{23}$Na)=40ms , TE=0.3ms, $\alpha_E$=75°, avg.($^{35}$Cl)=22, avg.($^{23}$Na)=10, nominal resolution($^{35}$Cl)=(3mm)$^2$, nominal resolution($^{23}$Na)=(2mm)$^2$, TA($^{35}$Cl)=29:20min, TA($^{23}$Na)=26:40min, Hamming filtered). A reference phantom (l=35mm, d=15mm, 0.3%NaCl solution) was placed on top of the rat's head.

## RESULTS

The SNR of both double resonant setups was reduced compared to the single resonant designs (Table 1). Furthermore, the SNR of the setup with pin diodes was lower than the SNR of the one with traps. In the measured images the sodium SNR was 5.2 to 11.3 times higher than the chlorine SNR.

| Coil configuration | SNR $^{35}$Cl | SNR $^{23}$Na |
|---|---|---|
| $^{35}$Cl only | 8.8 | - |
| $^{23}$Na only | - | 63 |
| $^{35}$Cl/$^{23}$Na with traps | 6.9 | 50 |
| $^{35}$Cl/$^{23}$Na with pin diodes | 2.2 | 25 |

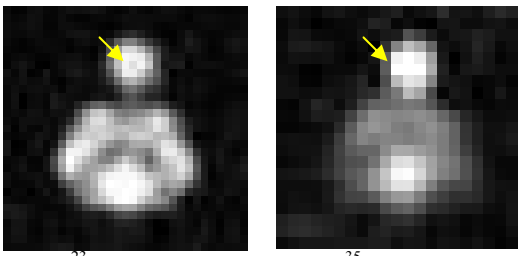
Table 1: SNR comparison

Fig. 2 shows the acquired in vivo sodium and chlorine images of a rat brain. The reference phantom was marked by a yellow arrow. The SNR normalized to the voxel volume in the sodium image is 2.6 and in the chlorine image 0.5.

## DISSCUSSION

Caused by the non balanced setup and the additional components necessary to doubletune the coil it was expected that the SNR of the double tuned setups is lower than the SNR of the single resonant ones. The SNR loss of the setup with the pin diodes might be due to the series resistance of the pin diodes or coupling to the DC channel. Assuming a linear noise model the signal of chlorine is expected to be approximately 9.6 times lower than the sodium signal [1]. The comparably lower sensitivity of chlorine can be verified by the measurements. Nevertheless, the ratio does not yield the analytical prediction coming from neglects of additional parameters such as coil properties.

The SNR values of the in vivo images cannot be compared to each other directly because of relaxation effects and different total acquisition times.



$^{23}$Na image $^{35}$Cl image

Fig. 2: In vivo Image of Rat Brain
(Yellow arrow highlights a reference phantom)

## CONCLUSIONS

With the SNR optimized setup from the comparison above in vivo chlorine and sodium images of a rat brain were acquired with a reasonably high resolution and in an acceptable total acquisition time. Anatomical details of the brain can be distinguished; hence the setup can be investigated for further $^{35}$Cl/ $^{23}$Na in vivo studies.

## REFERENCES

[1] Kirsch et al., NMR Biomed. 2010;23(6):592-600.
[2] J. Mispelter et al., Imperial Collage Press, 2006
[3] A. Nagel et al., Magn Reson Med. 2009;62(6):1565-73.
[4] NEMA Standards Publications MS 1-2001