

# A triple-resonant RF coil setup for $^1\text{H}$ , $^{23}\text{Na}$ and $^{39}\text{K}$ MR imaging of the rat brain at 9.4T

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## Introduction

The maintenance of a gradient of potassium and sodium ions across the cell membranes is essential for the physiological function of the mammal organism. The measurement of the spatial distribution of pathologically changing ion concentrations of  $^{23}\text{Na}$  and  $^{39}\text{K}$  offers a very promising approach in clinical diagnostics. For MR imaging of both elements and the acquisition of anatomical proton images in the same experiment without moving the subject or the RF coil we developed a triple-resonant RF coil setup for the rat head at 9.4T. A lot of imaging and spectroscopy studies of  $^{23}\text{Na}$  exist already, as well as several spectroscopy studies and one post mortem imaging study for  $^{39}\text{K}$  (1-4). But, so far, no imaging study of  $^1\text{H}$ ,  $^{23}\text{Na}$  and  $^{39}\text{K}$  with one single setup has been performed.

## Methods

The RF coil for  $^{39}\text{K}$  imaging at 18.7MHz was built with 0.8mm copper wire. Two Teflon carriers each with four windings with 1mm spacing formed a Helmholtz pair with 40mm distance and 35mm diameter. Perpendicular to the axis of that coil a saddle coil with the same proportions made of two single loops of 3mm silver wire was added that was tuned to the resonance frequency of  $^{23}\text{Na}$  (106MHz). The tune and match elements of these coils were soldered on printed circuit boards which were then glued together with epoxy glue to form a cube with holes that allow access to the animal for stereotactic positioning. For the proton resonance frequency of 400MHz we introduced a 32mmx32mm flat double-D structure coil made of copper plated circuit board perpendicular to the  $B_1$  field of the  $^{39}\text{K}$  coil 10mm above the center of the circuit board cube. Fig.1 shows the whole setup with a rat head placed inside and the corresponding circuit layouts. Imaging experiments were done on a Bruker Biospec 94/20USR small animal system equipped with a 740mT/m gradient. A glass vial filled with 12ml of a solution containing 150mM NaCl and 150mM KCl was imaged using a 2D-FLASH sequence (TR/TE=20ms/1.317ms, 1ms gauss pulse, RO-bandwidth 3kHz, FOV 32mmx32mm, matrix 32x32, 1mm slice, 1000 averages, 10min 40sec acquisition time, SNR=12) for  $^{23}\text{Na}$  and a 3D-FLASH sequence (TR/TE=100ms/1.6ms, 1ms gauss pulse, RO-bandwidth 5kHz, FOV 96mmx96mmx48mm, matrix 32x32x8, 64 averages, 27min acquisition time, SNR=4.6) for  $^{39}\text{K}$ .

## Results

All three coils were easily tuned to the corresponding resonance frequencies and matched to coaxial 50 Ohm lines. The frequency shift was negligible when we introduced the coil setup into the magnet. The Q-factor was 82 for the  $^1\text{H}$  coil, 137 for the  $^{23}\text{Na}$  coil and 117 for the  $^{39}\text{K}$  coil. No coupling between the coils was observed.  $^1\text{H}$ ,  $^{23}\text{Na}$  and  $^{39}\text{K}$  images were acquired without changing the setup. The  $^1\text{H}$  coil showed sufficient coverage for shimming and anatomical images of a rat head (Fig.2a). The  $^{23}\text{Na}$  and  $^{39}\text{K}$  coil delivered a good homogeneity over the sample volume (Fig.2b and 2c).

## Discussion

We demonstrated the possibility to image physiological sodium and potassium concentrations with good homogeneity over the sample volume as well as protons with sufficient coverage in one RF coil setup. This coil setup combined with imaging sequence optimization allows the detailed examination of the Na/K interplay in various pathological states which can lead to new diagnostic applications.

## References

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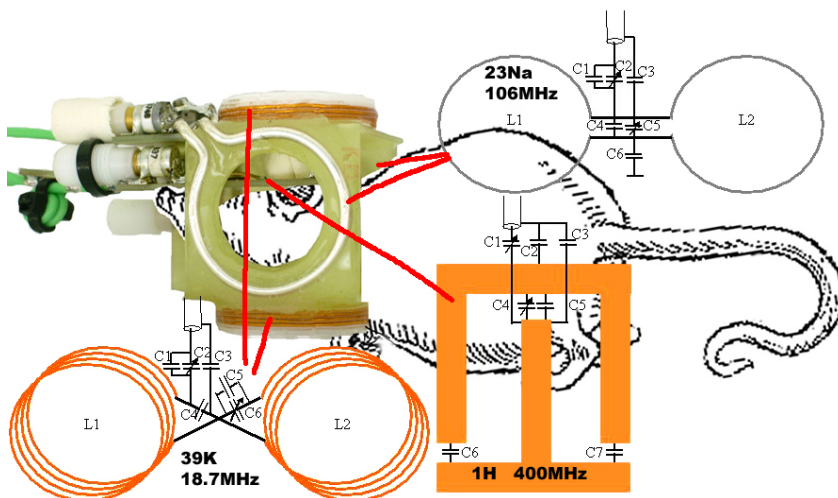


Fig.1: Triple-resonant RF coil setup for  $^1\text{H}$ ,  $^{23}\text{Na}$  and  $^{39}\text{K}$  imaging

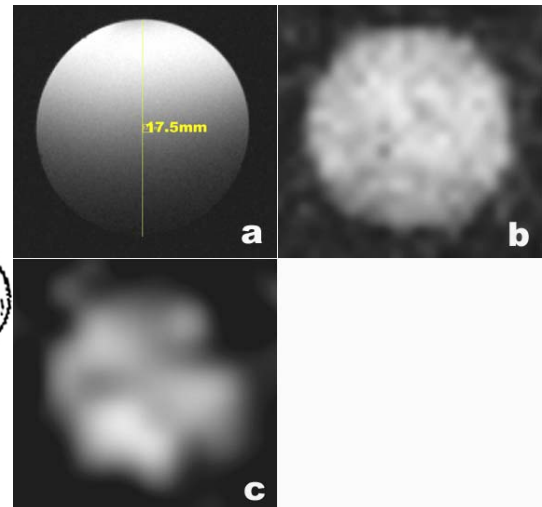


Fig.2:  $^1\text{H}$  (a),  $^{23}\text{Na}$  (b) and  $^{39}\text{K}$  (c) images