1H and 23Na MRI of Rat Head at 4 Tesla with a Simple Double-Tuned RF Surface Coil

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Introduction

MRI is proving to be a very useful tool for sodium (23Na) quantification in animal models of stroke, ischemia, and cancer. To obtain co-registered anatomical (1H) and physiological (23Na) information a dual-frequency RF coil is required, and several designs of surface RF coils were previously reported [1-7].

Aims

We present the practical design of a dual-frequency RF surface coil that provides 1H and 23Na images of the rat head at 4 T. It is comprised of a large loop tuned to the ^{1}H frequency and a smaller co-planar loop tuned to the 23Na frequency. The mutual coupling between the two loops is eliminated by the use of a trap circuit inserted in the smaller coil. We describe in detail the practical aspects of the workbench design and we report also typical congruent 1H and 23Na rat head images.

Methods

In this study we used a whole-body 4T Unity *Inova* scanner (Varian, Palo Alto, CA) equipped with TX/RX 1H and 23Na imaging channels, and a small bore (dia 12 cm) high performance animal insert gradient (MAGNEX SGRAD 205/120/S; 400 mT/m; rise time 170 μs). Figure 1 shows the 4 T dual-frequency surface RF coil prototype and the RF parameters are reported in Table 1. The coil comprises: a large square loop (65mm*65 mm, copper witdth 5 mm), that provides a means of accurate anatomical localisation and B0 shimming; and a small square loop (35mm*35 mm, copper witdth 5 mm) optimised for 23Na signal detection in the adult rat (about 250g) brain. A trap circuit [1], inserted in the smaller coil, allows one to eliminate mutual inductive coupling between the 1H and 23Na coils, see Fig. 1. The trap is made from a small solenoid (36 nH, 3 turns, dia 5 mm) connected in parallel with a 28 pF capacitor and a trimmer capacitor (1-15 pF). The trimmer capacitor allows the fine tuning of the trap circuit to the ^{1}H frequency at 4 T (170.40 MHz), see Fig. 2.

Results and Discussion

As shown in Table 1, without the trap circuit the resonant frequencies of the small and large surface coils were shifted by about 50 kHz and 2.8 MHz, respectively, as compared to the coil when isolated. The presence of the tuned trap allows operation of the two channels effectively. The presence of the trap reduces the efficiency of the 23Na loop coil by about 28%, as compared to the coil without trap, see Table 1. Similar results have been reported for larger size RF coils at 1.5 T [2]. Sodium images of rats head (n=3) were obtained with a 3D GRE pulse sequence. Fig. 3 shows congruent 1H and 23Na axial and coronal images of the rat head. The 23Na images (TR=20ms, TE=2.9ms, non selective square pulse, length=200 μs, bandwidth=6.4kHz, NEX=200, total acquisition time=35min) were collected with a FOV=40×40×80mm3 and acquisition matrix of 32×32×16. The rat head 23Na density-weighted images presented in Fig 3 show a good SNR (average brain: SNR=7, ventricular cerebrospinal fluid space: SNR=11) and a good spatial resolution (image pixel volume=8 μl).

Conclusions

We have reported the design and testing of a simple dual-frequency surface coil providing proton and sodium images of rat brain at 4 Tesla. The *in vivo* SNR values obtained with this coil design are comparable to, if not better than, other contemporary designs in the literature [7]. This simple and cheap dual-frequency surface coil should be a useful tool for 23Na quantification in animal models at high field (≥4 T) MRI.

References

[1] Fitzsimmons et al MRM, 10:302 (1989). [2] Tropp J and Sugiura S, MRM 11:405 (1989). [3] Schnall M, NMR Basic Principles and Progress, vol. 26:33 (1992). [4] Vaughan et al, Proc. ISMRM, pg. 722 (1998). [5] Thulborn KR, et al, MRM 41:351 (1999). [6] Lin SP, et al, Stroke 32:925 (2001). [7] Bartha R, et al, MRI 22:983 (2004).

TABLE 1	f0 (MHz)	S11 (dB)	Q	90° FLIP ANGLE (μs) @ 37dB
23Na coil alone	45.06	- 36	80	188
1H coil alone	170.40	- 21	76	450
23Na &1H without trap	45.01	-42	79	200
	173.20	-20	76	1050
23Na &1H with trap	45.03	-41	65	240
	170.40	-36	81	475

Fig. 1. Dual-frequency (1H/23Na) RF 4 T surface coil (trap circuit is on the left side of the small loop coil).

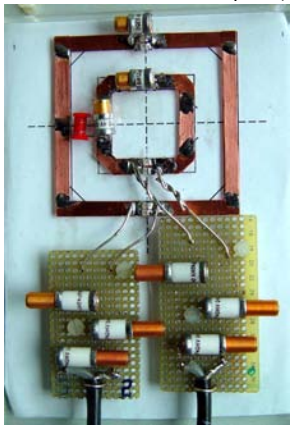

Fig. 2. The S11 response as measured from the 1H (top) and 23Na (bottom) channel.

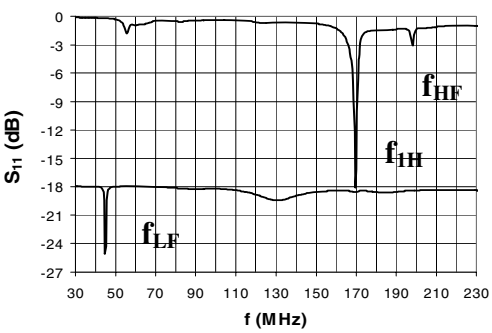

Fig. 3. Congruent 3D GRE 1H (top) and 23Na (bottom) rat head images in the axial (A) and coronal (B) orientation.