RF Field Optimization of 4T Double-Tuned Surface TEM Resonators for 1H/23Na MRI

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INTRODUCTION. Sodium MRI/MRS benefits of improved SNR obtainable at high fields (3-12 T). Surface TEM resonators are especially designed for high-field applications [1-3]. In recent works [4-6] a novel double-tuned (DT) surface TEM resonator, made by three microstrip elements and suitable for sodium and proton MRI at 4T was described.

Here, we report workbench and 4T MRI data showing the optimization of the RF field distribution of the 23Na channel by a proper selection of the relative distance between the external microstrips, while maintaining the 1H field distribution.

METHODS. To study the dependence of the RF field distribution from the mutual distance of the two 23Na microstrip elements, we built and tested two DT surface TEM prototypes (Fig. 1) made by: 1) a central copper microstrip (10mmx190mm) for the 1H channel, connected to the ground plane by two end capacitors (A: 8.2 pF; B: 11 pF); and 2) two lateral microstrip (5mmx190mm) for the 23Na channel, each connected to the ground plane by two end capacitors (68 pF). The centre-to-centre separation between the sodium strips was adjusted as equal to S=35mm (Fig 1 (A)) or S=25mm (Fig 1 (B)). The ground plane, made by adhesive copper foil (105mmx190mm), is separated by the strip plane by an 16 mm thick PVC slab, then by an air gap of 29 mm and finally by a 16 mm thick PVC slab. Non-magnetic trimmer capacitors, connected in a balanced fashion, were used for fine-tuning and matching. The TEM resonators were tested on the workbench and in a 4 T MRI scanner in the presence of a cylindrical phantom (dia=150 mm; H=78mm) filled with 1 litre of a solution containing water, 1.25g of $NiSO_4$-$6H_2O$ and 5g of NaCl. The TEM resonators were tested in TX/RX mode using 3D gradient-echo sequences.

RESULTS. Figure 2 shows the three resonant modes for each TEM prototype. Mode 1 is the useful MRI mode for the 23Na channel (f0=44.5 MHz) and it gives an RF field distribution with a pattern enclosing the two external strips. Mode 3 is tuned at the 1H frequency (f0=168.3 MHz) and the useful RF field distribution extends around the central strip. Decreasing the relative 23Na separation results in an increased frequency sweep between the 23Na modes due to a stronger inductive coupling. Table 1 reports the Q-factors of the two TEM prototypes when loaded with the sample. The matching was always better than -20 dB. It can be noted an increased Q factor for both channels as the mutual distance of the external microstrips decreases (11% and 24% respectively).

The MR images were acquired with a 3D gradient-echo with resolution of 2.2 mm/pixel for the S=35mm coil and 1.5 mm/pixel for the S=25 mm coil. Figure 3 shows the MRI comparison of the two TEM prototypes at 23 mm from the microstrip plane. The lower SNR measured with the S=25mm TEM prototype is due to the increased image resolution. In Fig. 4, the normalized 23Na signal profiles along the left/right direction for different positions from the plane are reported for both prototypes. The S=25mm TEM presents a more homogeneous RF profile for the 23Na channel. The RF distribution of the 1H channel showed a narrower profile at d=13mm, while it was practically unaffected at $d \geq 23$mm.

CONCLUSIONS. We have compared two DT TEM surface resonators and demonstrated that approaching the external elements to the central one improves the RF field homogeneity of the 23Na channel in the direction transverse to the microstrip length. With S=25mm the axial RF homogeneity is about 150 mm and the transverse RF homogeneity is about 50 mm, these values should be useful for many in vivo applications.

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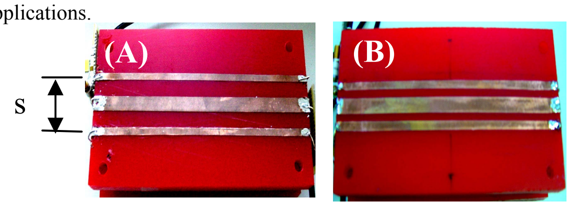

Fig 1 TEM prototypes with: (A) s=35mm. (B) s=25mm.

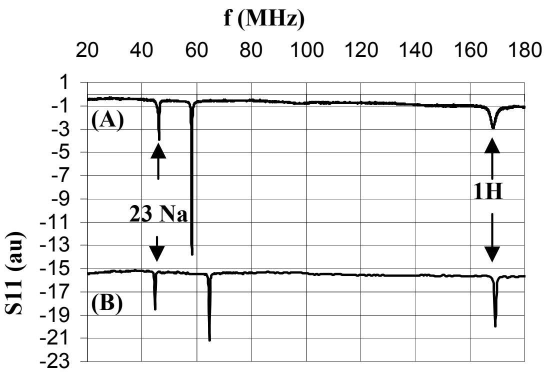

Fig 2 S11 of the TEM prototypes with: (A) S=35mm. (B) S=25mm.

Table 1: Q of the TEM prototypes when loaded with saline.		
S (mm)	Q_L @23Na	Q_L @1H
35	80	50
25	89	62

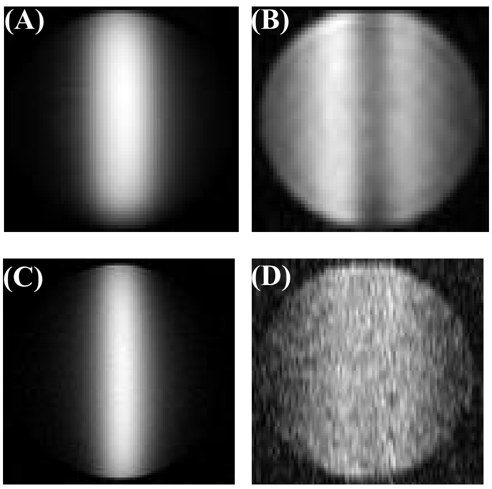

Fig. 3. S=35mm: (A) 1H image (TR=50ms, TE=3.7ms, NEX=1) and (B) 23Na image (TR=21ms, TE=2.1ms, NEX=24). S=25mm: (C) 1H image (TR=3.2 ms, TE=1.40 ms, NEX=1) and (D) 23Na image (TR=15 ms, TE=2.8 ms NEX=24).

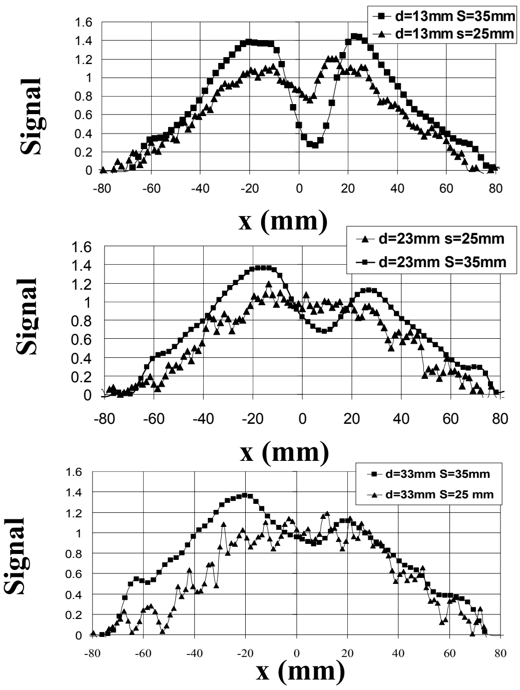

Fig. 4. Comparison of MRI signal profiles for the TEM prototypes obtained at (top) d=13mm, (middle) d=23mm, (bottom) d=33mm from the microstrip