14T Dual-tuned RF Probes for 13C/1H MRI Using Common-Mode Differential-Mode (CMDM) Method

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Introduction:

Double-tuned radiofrequency (RF) coils are critical for multinuclear MR applications, in which they improve: 1) image co-registration of ^{1}H anatomic images and multinuclear metabolic images, and 2) provide B0 shimming using the ^{1}H channel for heteronuclei excitations with low natural abundance, such as carbon. One of the major challenges for making double-tuned RF coils is to achieve electromagnetic isolation between the two channels. The Common-Mode Differential-Mode (CMDM) method has been proposed for designing double-tuned RF coils with better decoupling between channels and was demonstrated to provide excellent performance and easy implementation at 7T [1]. In this work, the CMDM method is investigated for 14T. A double-tuned CMDM surface coil was built and tested by bench tests and phantom imaging to demonstrate the performance of the CMDM method in designing double-tuned coils for heteronuclear MR applications at 14T.

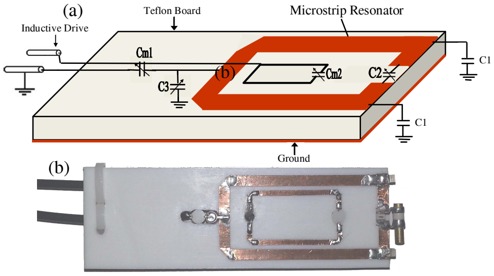

Fig 1. Diagram of the double-tuned CMDM microstrip surface coil operated at 14T (a), and the corresponding photo of the coil (b).

Material and method:

Based on the CMDM method[1], a surface coil was built with a microstrip resonator as shown in Fig 1. The resonator is 56 mm in length and 20 mm in width, with 3.2-mm-wide copper tape used as a strip conductor. A 3.2 mm thick Teflon board was used as the substrate with permittivity of about 2.1. One end of the coil was terminated by two symmetric fixed capacitors C1 of 5.6 pF to drop the resonance frequency for both CM and DM. The other end was terminated by a variable capacitor C3 ranging from 0.5 to 12.5 pF for tuning CM. A variable capacitor C2 ranging from 0.5 to 12.5 pF and a fixed capacitor of 9.1 pF were connected in parallel between two ends of the strip conductor for tuning DM.

In order to improve decoupling of the two channels, the CM and DM were driven capacitively and inductively, respectively, with variable capacitors connected in series for impedance matching: Cm1 for matching CM and CM2 for matching DM. The resonant frequency of CM and DM can be estimated by using the method described in reference [1] which helps to design the parameters described above.

Bench testing was conducted in terms of the resonant frequencies, the reflection coefficient S11, Q-value and the transmission coefficient S21. Phantom experiments were performed, including ^{1}H and ^{13}C imaging by CM and DM respectively, in a 14T MR system. The imaging sample was an approximately 2.6-cm-diameter spherical phantom containing ^{13}C-labelled lactate and urea solution. Images of the phantom in the axial and coronal planes were acquired using gradient echo sequences. The acquisition parameters for ^{1}H imaging were TE = 2.28 ms, TR = 5000 ms, matrix size = 128 × 128, FOV = 30 mm, flip angle = 90 deg, number of average = 2. The acquisition parameters for ^{13}C imaging were TE = 1.67 ms, TR = 5000 ms, matrix size = 64 × 64, FOV = 64 mm, flip angle = 30 deg, number of average = 4.

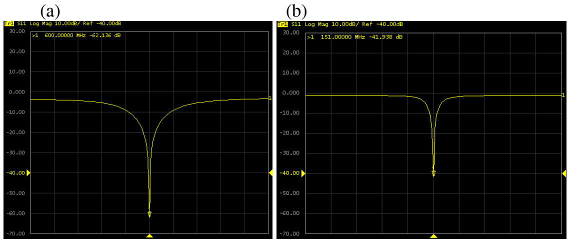

Fig 2. S11 measurement in bench tests. Resonance at Larmor frequency for ^{1}H (599.8 MHz)(a), and resonance at Larmor frequency for ^{13}C (150.9 MHz) (b) at 14T.

Table 1 Bench test results

channel	Resonance frequency (MHz)	S11(dB)	Q value	S21 (dB)
^{1}H	599.8	-62.1	204.5	-48.3
^{13}C	150.9	-41.9	208.7	-54

Results:

In Fig 2 bench tests showed that CM and DM were tuned to 151 and 600 MHz, respectively. The findings from bench tests in the unloaded case are shown in Table 1. The S21 was about -50 dB, demonstrating excellent decoupling between the two channels. The S11 was lower than -40 dB, demonstrating a good impedance match.

The ^{1}H coronal image (Fig 3b) and ^{13}C axial image (Fig 3a) have SNR of 53.7 and 34.5 respectively. The ^{1}H image demonstrated relative homogeneous B1 field distribution at 600 MHz.

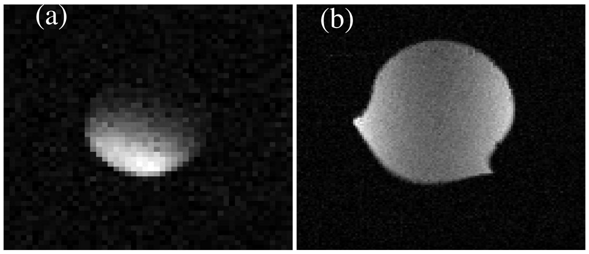

Fig 3. MR image derived with this double-tuned CMDM surface coil. ^{13}C image (a) and ^{1}H image (b).

Discussion and Conclusion:

A double-tuned RF coil at 14T based on the CMDM method was built by simple microstrip resonator, and validated by bench test and imaging. The CMDM coil has an intrinsic advantage of decoupling between the two channels, demonstrated by low S21 value in bench tests, which is important for the detection of small heteronuclear signal intensity. The capability of tuning each channel independently can simplify the implementation for multinuclear applications. The next step is to build a CMDM volume coil for 14T for more homogeneous, larger field of view imaging.

References:

1. Pang Y, et al, IEEE Trans Med Imag 2011;30: 1965–1973.