Dual-frequency coil design using common mode and differential mode (CMDM) technique for 1H/13C MRSI at 7T

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Introduction

Hyperpolarized ^{13}C with high field MR spectroscopy and spectroscopic imaging techniques is proven to be promising for metabolism studies in vivo. To facilitate the further development of hyperpolarized ^{13}C MR at ultrahigh fields, a dual tuned carbon-proton transmit-receive probe using common-mode/differential-mode (CMDM) technique was developed for in vivo ^{13}C spectroscopy and ^{1}H imaging applications. The EM fields of the common and differential modes in a coupled transmission line are orthogonal to each other and their resonant frequency can be tuned independently. This makes common-mode and differential mode technique a promising candidate for double-tuned coil designs. Preliminary results on proton imaging and ^{13}C MRSI from a corn oil phantom were demonstrated using the proposed CMDM coil at 7T.

Methods

In this work, the common mode and differential mode was realized by microstrip transmission lines. The coil was built on a 0.64-cm thick acrylic board. The strip conductors were made from back-adhesive copper foils and measured 0.64-cm wide and 9-cm long. The two microstrips were separated by 1.9-cm. The strip conductors were directly connected on one end and connected via a capacitor on another end. In this structure, the two parallel microstrips form the common-mode current while the microstrip loop forms the differential mode current. In the common mode circuit, which was tuned for proton, each of its two resonant elements was a $\lambda/2$ microstrip resonator with capacitive termination on both ends. The differential mode circuit was tuned to 7T carbon Larmor frequency. In this design, the common mode was driven capacitively while the differential mode was driven inductively. The structure of the proposed common-mode and differential-mode (CMDM) microstrip resonator circuitry is sketched in Fig 1. Based on the theoretical analysis of microstrip coil (1), the resonance frequency could be adjusted independently not only because the isolation of currents of each mode but also because of the orthogonality of their magnetic field. Bench tests on coil resonant modes and isolation between two channels were implemented on a network analyzer (Agilent E5070B). The termination capacitance measurement was conducted on a RCL meter (Fluke PM6303A). The proposed dual-tuned coil was also analyzed numerically in terms of the resonance frequency, field distribution and isolation between the two modes by using FDTD algorithm. The proton MR imaging and ^{13}C spectroscopy experiments were performed on a GE 7T whole body MR system (GE Healthcare, Waukesha, WI). A corn oil phantom was used to acquire both proton and carbon MR signals in this preliminary study. A set of spin echo images in axial images was collected with TR=2sec, FOV=9cm, no average. A 16x8 2D ^{13}C FIDCSI was also performed with TR= 2sec, 9mm in plane and 20mm thick, number of excitation (NEX) =1.

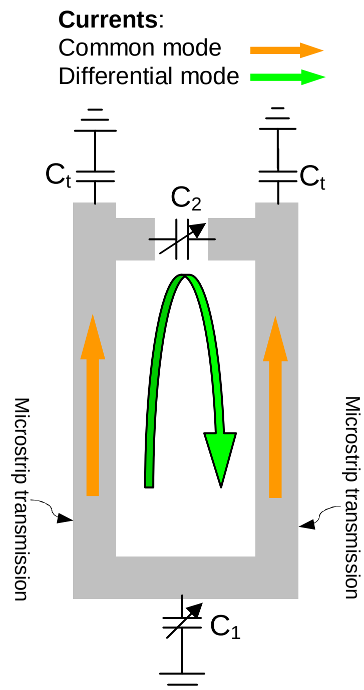

Fig 1. A Sketch of the proposed CMDM MTL resonator for double-tuned coil designs at high fields.

Results and Conclusions

The dual-tuned transceiver coil was tuned to 298.14 MHz (for 1H) and 75MHz (for 13C) on the two driven ports respectively. Each port was matched to system 50 Ohm by a series capacitor. Well-matched resonance peak for ^{1}H channel and ^{13}C channel are clearly identified on the network analyzer. The isolation between driving ports was greater than 30dB between ^{1}H channel and ^{13}C channel in both loaded and unloaded cases. FDTD analysis showed a -46 dB or better decoupling or isolation between the two channels. Proton spin echo image and ^{13}C spectroscopic imaging are shown in Fig 2. One of the advantages of the proposed CMDM technique is that the two magnetic fields have a similar distribution which helps B_0 shimming for low gamma nuclei. This was verified by FDTD simulation results and real MR imaging. Based on the preliminary results on simulation, bench test and MR experiments, the dual-tuned microstrip coil with common and differential modes is feasible. The proposed design may provide a simple and efficient approach to dual-tuned surface coil design for in vivo multinuclear MR at ultrahigh fields. The dual-tuned CMDM resonators can also be used as resonant elements of parallel imaging arrays for multi-nuclear MR applications.

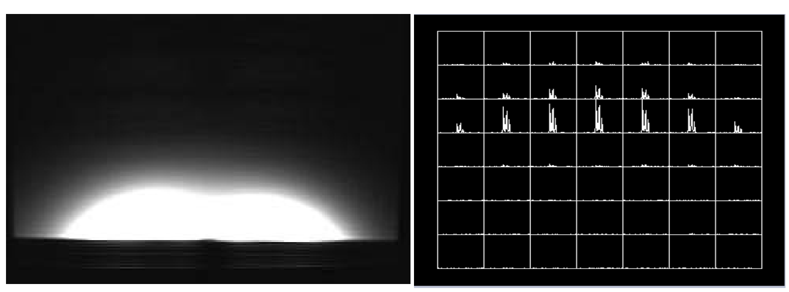

Fig.2 preliminary results: 7T proton image (left) and ^{13}C Chemical shift imaging (right) of a corn oil phantom acquired using the prototype CMDM transceiver coil at 7T. The B_1 fields of 1H channel (common mode) and ^{13}C channel (differential mode) have a similar distribution, which potentially helps B_0 shimming for low-gamma nuclear MRSI.

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Reference (1)Zhang X, et al, IEEE Trans BME 52:495-503