A novel dual-frequency volume coil using common mode/differential mode (CMDM) resonators at 7T

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Introduction

Double resonant operation recently is more concerned, because it can obtain information from two different nuclei simultaneously, especially as the hyperpolarization technology was extensively applied for metabolism studies. One of the challenges of designing such dual-tuned coils is the electrical and magnetic interferences between high-frequency resonant elements and low-frequency resonant elements in the coils. Although it is possible to use trap circuits to block one resonance (1, 2), the dual resonant operations could not be obtained simultaneously and the trap circuit may degrade the NMR efficiency. In this work, we applied common mode and differential mode concepts we developed recently to design dual frequency volume coil designs. Common mode and differential mode (CMDM) exist within two coupled parallel transmission lines, yielding two current distributions and magnetic radiation fields. Fig.1 shows that at the common mode, the two currents on a resonator are identical. At the differential mode, the currents are opposite to form a current loop on the resonator. Both currents and magnetic fields in a CMDM resonator are isolated between two modes. Therefore, these modes could be designed independently at two resonant frequencies without any interference. Based on CMDM technique, we presents a dual tuned carbon-proton volume coil working on 7T MR system. The volume coil had 8 CMDM elements with the 75MHz and 298.14MHz operating frequencies for in vivo $^{13}C/^{1}H$ MRI/S studies at 7T. Preliminary results from a corn oil phantom were acquired using the proposed coil at 7T.

Methods

The quadrature CMDM dual-tuned volume coil was built on an acrylic cylinder with dimensions of 4” O.D, 3.75” I.D and 4” in length. The acrylic cylinder served as both dielectric material and mechanical support. Fig.2 shows a diagram of the prototype coil. The CMDM resonator elements had 0.0625” gaps between two of them. In the proton channel, each of its 8 resonant elements was common mode resonators with capacitive termination on both ends. Two quadrature proton ports were driven electrically. The carbon channel also comprised of 8 resonant elements. In order to operate at the relatively low frequency of 75 MHz, the resonators worked at differential mode to form loop currents. The one end was capacitive terminated and the other was shorted to ground. Two quadrature proton ports were driven inductively. Bench tests on coil resonant modes and isolation between two quadrature ports were implemented on a network analyzer (Agilent E5070B). The termination capacitance measurement was conducted on a RCL meter (Fluke PM6303A). The proton MR imaging and ^{13}C spectroscopy experiments were performed on a GE 7T magnet (GE Healthcare, Waukesha, WI). A cylindrical corn oil phantom was used in this preliminary study. A set of fast spin echo images in sagittal orientations and axial images were acquired. An 8x8 2D ^{13}C FIDCSI was also performed with TR= 2sec, 12mm in plane and 20mm thick, 4 NEX.

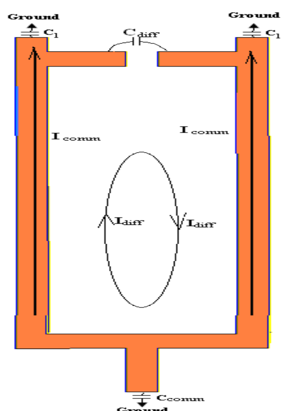

Fig.1 A CMDM resonator with two isolated current distributions at two resonant frequencies.

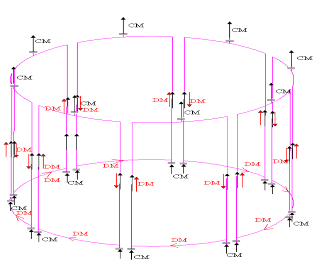

Fig.2 A diagram of a volume coil with 8 CMDM elements and their current distributions.

Results and Conclusions

The proton channel and carbon channel were tuned to 298.14 MHz and 75MHz on the two quadrature ports respectively. Each port was matched to system 50 Ohm by a series capacitor. Well-defined five resonance peaks for ^{1}H channel and five peaks for ^{13}C channel are clearly identified on the network analyzer. On the bench test, the isolation between driving ports was greater than 20dB for both ^{1}H channel and ^{13}C channel. These results indicate that the two channels of ^{1}H and ^{13}C are decoupled sufficiently. Proton GRE image and ^{13}C CSI are shown in Fig 3. Based on the preliminary results on bench test and MR scans, dual-tuned microstrip volume coil with CMDM resonant elements is feasible. The proposed design may provide a simple and efficient approach to dual-tuned volume coil design for in vivo multinuclear MR at ultrahigh fields.

Reference (1) Gary Shen, et al, MRM 38:717-725 (1997); (2) Schnall MD, et al, JMR 65:122-129 (1985)

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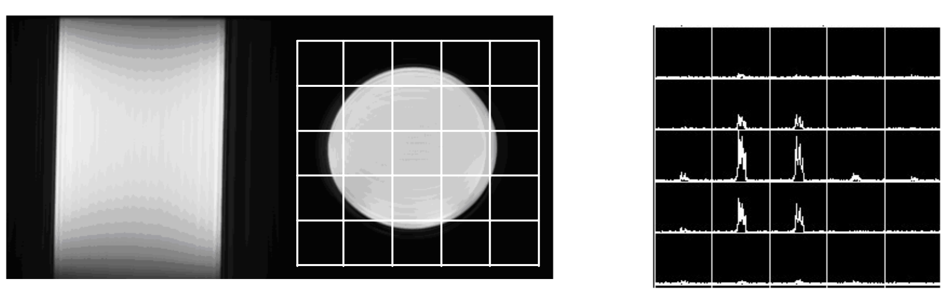

Fig.3 Preliminary results: 7T proton images (left) and ^{13}C chemical shift imaging (right) of a corn oil phantom acquired using the prototype at 7T.