A Hybrid Design for Dual-tuned Quadrature 13C/1H Volume Coil at High Field

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Introduction:

It is technically challenging to design double-tuned volume coils with quadrature excite/receive for high field ^{13}C/^{1}H MR applications, due to the interaction between the two nuclear channels, large separation of the two resonance frequencies, and issues caused by high frequency required for proton. Microstrip RF coils show unique high-frequency capabilities, providing an efficient, compact means for MR signal excitation and reception for *in vivo* MRI studies (1,2). However, the microstrip design that was originally developed for high frequency applications may not be a good choice for low frequency operation, such as ^{13}C imaging at 3T (32MHz), especially for small animal applications. Compared with transmission line-type or distributed circuit-type volume coils, birdcage coils (3) usually have high inductance which is advantageous for low frequency coil designs. In this work, we propose a hybrid design (4) for double-tuned volume coils which combines a microstrip design for high frequency and birdcage design for low frequency. The prototype ^{13}C/^{1}H coil was designed, constructed and tested at 3T.

Method:

The proposed hybrid double tuned volume coil was built on a Teflon tube with 6.6cm OD, 5.0cm ID and 10cm in length. The microstrip design was applied for ^{1}H channel with a target frequency of 128MHz. 8 microstrip elements were chosen for required B1 homogeneity. 1/8" wide back-adhesive copper tape (3M, St Paul, MN) was used as strip conductors. Each microstrip resonant element was a capacitive terminated resonator which resonates at a frequency slightly higher that the required 128 MHz. The two ports with 90^0 apart were used to feed this ^{1}H channel in quadrature to gain sensitivity and reduce excitation power. The ^{13}C channel was realized by using a low-pass birdcage coil design. Its long current path and large inductance of the birdcage coil help to reduce the resonance frequency to 32 MHz—the Larmor frequency of ^{13}C at 3T. The ^{13}C birdcage coil was also driven in quadrature. Accessible trimmer capacitors with 1-20pF tuning range (Voltronics Corp) attached to each feeding port provide fine tuning of the resonance frequency and impedance match. There were no trap circuits used in this double-tuned volume coil design. A network analyzer model E5062A (Agilent Technologies, Santa Clara, CA) was used for measurement of S-parameters and evaluation of other behaviors of the prototype coil on bench. MR imaging and spectroscopy experiment with this coil was performed on a GE 3T whole body MR system with phantoms and rats.

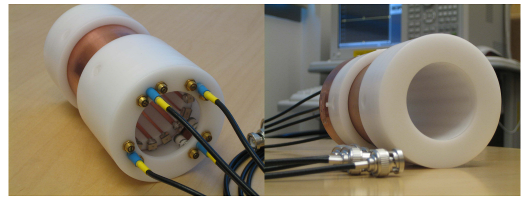

Fig.1. The photograph of the proposed hybrid double-tuned volume coil with quadrature feature for ^{13}C/^{1}H MR applications at 3T.

Results and Conclusions:

Fig.1. shows the prototype of the proposed hybrid double tuned volume coil for *in vivo* ^{13}C/^{1}H MRI and MRSI applications at 3T. Both ^{1}H and ^{13}C channels were tuned to the desired frequencies (i.e. 128 MHz and 32MHz) and matched to system 50 Ohm. The 5 resonance modes of microstrip coil and 4 resonance modes of the birdcage coil based on the S11 measurements taken on the network analyzer demonstrated a right behavior of this 8-element by 8-element double tuned volume coil, as shown in Fig.2(a,b). The separation of the resonance modes is sufficient for high quality acquisitions in vivo. S21 measurement between the ^{1}H channel and the ^{13}C channel with better than -25 dB at 128MHz and -40 dB at 32MHz shown in Fig.2(c) demonstrated an excellent decoupling performance for the two nuclear channels, which is essential for double nuclear MR studies. Aside from bench testing, this hybrid coil was also validated by with both phantom and living rat 3T MRI. Fig.3. shows the 3T ^{1}H imaging acquired using the quadrature ^{1}H channel of the prototype hybrid coil from the rat head and ^{13}C MRSI using the quadrature ^{13}C channel from an unlabeled corn oil phantom. We also tested the quadrature performance of the hybrid double-tuned coil. For ^{13}C MR, when the quadrature phase was not correctly connected to the quadrature hybrid, a significant signal reduction can be observed, indicating the excellent quadrature performance of ^{13}C channel. Similarly, the ^{1}H channel formed by the microstrip design, when the phase was correct, a uniform, high SNR ^{1}H image can be acquired. If it's anti-phase, the signal was nearly cancelled completely as shown in Fig.4.

Fig.2. Well-defined resonance modes of (a) ^{1}H channel (microstrip) and (b) ^{13}C channel (birdcage) of the proposed hybrid double-tuned volume coil at 3T. Insert (c) shows S21 measurement between the ^{1}H channel and ^{13}C channel, demonstrating excellent isolation between the two nuclear channels.

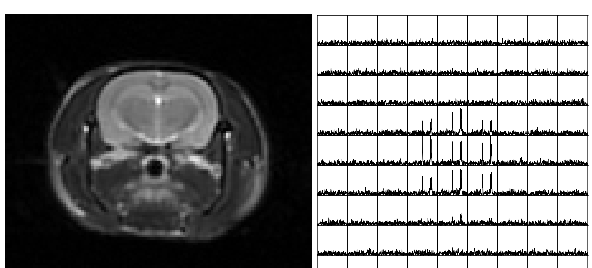

Fig. 3 ^{1}H image and ^{13}C MRSI (natural abundance) acquired from the rat head and corn oil phantom using the new hybrid coil at 3T.

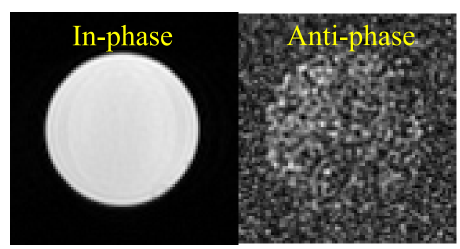

Fig.4. ^{1}H images acquired from a phantom using the 1H channel of the proposed hybrid double-tuned volume coil in right quadrature phase (left) and anti-phase (right), showing excellent quadrature behavior of the coil.

References:

1) R Lee, et al, MRM 2001, 45: 673-683; 2) X Zhang, et al, MRM 2001, 46: 443-450; 3) C Hayes, et al, JMR 1985, 63:622-628; 4) N. Avdievich, et al, ISMRM 2007, p239