A novel double-tuned head coil with 16 double-tuned elements for 7T MRI/S

C. Wang[1], B. Wu[1], D. Xu[1], and X. Zhang[1]

[1]Radiology, University of California San Francisco, San Francisco, California, United States

Introduction:

MR imaging and spectroscopy at ultra high filed have advantages of high SNR and better spectral resolution. Double-tuned radiofrequency (RF) coils are very useful for multinuclear magnetic resonance applications, because they facilitate accurate localization without changing coils between imaging and multinuclear spectroscopic examinations. In this work, a novel 16-element head-sized double-tuned volume coil was designed and tested at 7T.

Methods:

A head-sized double-tuned volume coil with and without RF shield are shown in Fig 1. The coil comprised of 16 double-tuned elements (Length: 5", Width: 2"). The circuit diagram is shown in Fig. 2. The inductor (L1, L2) was made from 1/4" wide adhesive-backed copper tape. C1 and C2 are trimmer capacitors (Johanson, Boonton, NJ). Resonant condition for the circuit in Fig.2 is shown in Eq. (1), where ω are the possible resonant frequencies.

$$\omega^4 L_1C_1L_2C_2 - \omega^2 (L_1C_1 + L_2C_2 + L_1C_2) + 1 = 0 \qquad (1)$$

$$\omega_{1,2} = \left\{ \frac{(L_1C_1 + L_2C_2 + L_1C_2) \pm ((L_1C_1 + L_2C_2 + L_1C_2)^2 - 4L_1C_1L_2C_2)^{1/2}}{2L_1C_1L_2C_2} \right\}^{1/2} \qquad (2)$$

There are two solutions for Eq. (1), which indicates high and low resonant frequencies of each element (see Eq. (2)). 16 elements were positioned at a diameter of 10" between two end rings with equally distributed distance and inductively coupled each other (Wen et al. [1] used the similar structure to build a single resonant frequency head coil with free elements). RF shield was wrapped around all elements. The coil was driven in quadrature for both ^{1}H and ^{13}C. All four driven ports were inductively matched to 50 ohm. Baluns were used to reduce RF current leakage on the coax cable shield. A head-shaped and head-sized corn oil phantom was used. Resonant modes of the coil were measured with a network analyzer (Agilent E5070B). Proton MR imaging and ^{13}C spectroscopy experiments were performed on a GE 7T MRI system (GE Healthcare, Waukesha, WI). Proton image obtained using a gradient echo sequence with TE=6.8ms, TR=500ms, Flip angle=30°, FOV=20cmx20cm, slice thickness=3mm, matrix size=256x256, NEX=1. ^{13}C spectrum of corn oil was acquired with average=16 and TR = 2 sec, spectral width of 5 kHz and 2048 points.

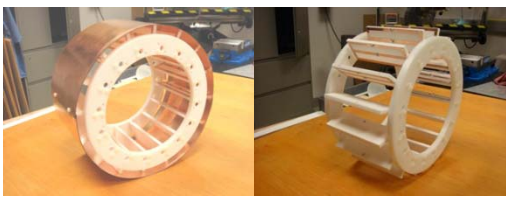

Fig.1 16-element double-tuned volume coil with shield (left) and without shield (right)

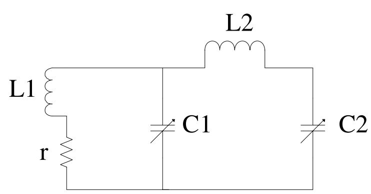

Fig.2 Circuit diagram of each double-tuned element

Results and Discussion:

The measured frequency responses (S11) of the coil are illustrated in Fig. 3. Well-defined peaks of different modes are apparent at both low frequency (for ^{13}C spectroscopy) and high frequency (for ^{1}H imaging). The useful mode (mode 1) for ^{13}C MRS and ^{1}H MRI were tuned to 75MHz and 298MHz respectively. Generally, it is difficult to set up a strong coupling at high resonant frequency for double-tuned coils in which high frequency resonant elements and low frequency resonant elements are placed alternatively[2], possibly caused by residual coupling between high frequency (^{1}H) elements and low frequency (^{13}C) elements. In our design, the frequency separation between mode 0 and mode1 is greater than 10MHz, and the frequency separation between mode 1 and mode 2 is even greater than 15MHz in Fig.3 (b) at high frequency. It indicates there is strong coupling between each element for high resonant frequency. For better quality factor, the RF shield was used to reduce radiation loss (unloaded Q for ^{13}C and ^{1}H are ~250 and ~220 respectively). It also can enhance inductive coupling between each element. On the other hand, this type of design can generate relatively identical B1 field distribution for both ^{13}C MRI and ^{1}H MRI because symmetry of the elements for ^{13}C and ^{1}H are exactly the same. This characteristic may yield better shimming for both nuclei. Another advantage of this design is that the 16-elment coil has 16 elements for both ^{1}H and ^{13}C. Proton image of corn oil phantom acquired using the prototype coil is shown in Fig.4 (left). It demonstrates the relatively homogeneous intrinsic B1 pattern generated by the prototype coil. Fig.4 (b) illustrated good SNR for ^{13}C spectroscopy.

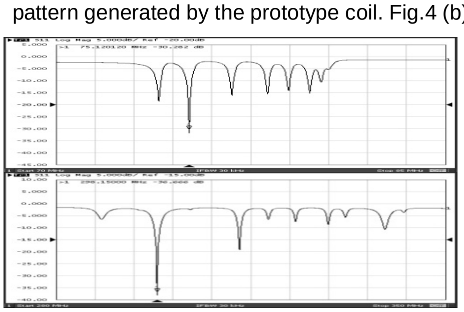

Fig.3 Measured frequency response of the double-tuned prototype volume coil for (top) ^{13}C with frequency span of 15MHz and (bottom) ^{1}H with frequency span of 70MHz

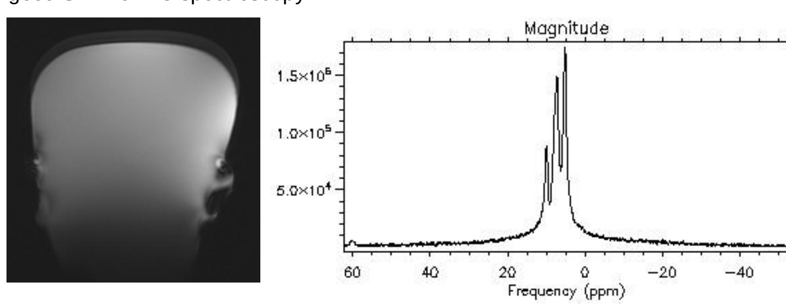

Fig.4 Proton image (left) and ^{13}C spectra (right) of a head-size and head-shaped corn oil phantom acquired using the double-tuned prototype volume coil.

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References: [1]Han Wen, et al, Magn. Reson, Med. (1994) 32:492-498 [2] N.I. Avdievich, et al. ISMRM (2007) p239