An MTL coil array with a broad frequency tuning range for ultra-high field human MR applications from 3T to 7T

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Introduction: Technical challenges in high frequency RF coil designs have been an obstacle in *in vivo* MRI/MRS applications at high and ultra-high magnetic fields (>4T). These technical challenges include increased radiation losses, increased coil-cable/subject interaction, difficulty in frequency tuning even for surface coil designs. Microstrip transmission line (MTL) has been proven to be a good candidate for high frequency RF coil designs *in vivo* (1-4). In this study, we use MTL to design an RF coil array characterized with an extremely broad frequency tuning range from 115 MHz to 310 MHz at loaded condition. This coil array could be used for the proton nucleus applications at different field strengths covering from 3T to 7T and/or it can also be used to study both ^{1}H and ^{31}P nuclei at the same field strength of 7T. In general, the coil array can be useful for parallel imaging applications. By changing the angle between the two coil loops to 90^0 under the decoupling condition, this coil becomes a high-frequency quadrature coil with enhanced NMR sensitivity. The flexibility for varying the angle makes this array design suitable for different organs (e.g. brain and skeletal muscle).

Methods: At current stage, this coil array consisted of two MTL loops (MTL resonators). The two loops were identical and in square shape with dimensions of 8.4-cm by 8.4-cm. The MTL was built on Teflon substrate. The strip conductor (3-mm wide) and ground (6-mm wide) of the MTL were made from 36-μm adhesive-backed copper tape (3M, St Paul, MN). The MTL resonators were capacitively terminated with tunable capacitors (1-30pF) on both ends of the lines. In the middle of the MTL strip conductor, a capacitor with 24-pF capacitance was connected serially. Another tunable capacitor was serially connected to one end of each MTL resonator to perform impedance match. The overlap adjustment of two MTL loops, in order to meet the decoupling condition, was monitored by Agilent's 8712ES network analyzer. Mineral oil phantom and human MRI/MRS experiments using the prototype array coil were conducted on a 4T and a 7T magnets (Magnex Scientific, UK) interfaced to the Varian INOVA console (Varian Associates, Palo Alto, California). Before each experiment, the coil was tuned and matched correctly.

Results: The prototype array coil achieved an extremely broad range of frequency tuning from 115 MHz to 310 MHz by varying the tunable terminative capacitors from 1pF to 30 pF. Such a broad frequency range covered the ^{1}H frequencies from 3T (128 MHz) to 7T (300MHz) or ^{31}P (121 MHz) and ^{1}H (300MHz) frequencies at 7T. An excellent decoupling of greater than -20 dB between two loops was observed over all the frequency-tuning range from transmission coefficient measurement on the network analyzer. At each desired frequency, the coil was well-matched to 50 Ω with the single matching capacitor. As expected, the coil's Q factor varied with the resonant frequency. In the frequency range of 120MHz to 300MHz, the ratios of unloaded to loaded Q changed from 135/360 to 90/300. At 7T, the coil was first tuned to 296 MHz for ^{1}H MR imaging. Oil phantom images were collected from each loop independently and also from the two-loop combination. Figure 1 shows the oil phantom image from the two-loop combination at 7T. The images from each loop were reconstructed using SENSE (6) at different total reduction factor (R) as shown in Fig 2. After the proton experiment at 7T, the coil was tuned to 119.6MHz for human muscle ^{31}P MRS and chemical shift imaging (CSI) study. Figure 3 demonstrates a global ^{31}P spectrum and CSI acquired using the MTL array coil (two-loop combination) from the human leg muscle at 7T. To further validate the performance of this MTL coil array, we tuned the resonant frequency of the coil to 169 MHz and acquired oil phantom image at 4T as shown in Fig 4.

Conclusions: An MTL coil array with a extremely broad frequency-tuning range was successfully designed, constructed and validated. The broad tuning range makes the array suitable for the same spin nucleus MR applications with a wide range of B_o or different spin nuclei at the same B_o. The array is also flexible for MR applications in different human organs. Therefore, it is a truly multiple-purpose coil array with high Q factor and superior decoupling between the array coils. This makes high/ultra-high field MR experiments more robust. Finally, the same design concept can be applied to a coil array with more loops.

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References: 1)Zhang X, *et al. Magn Reson Med*, 46: 443-450 (2001); 2)Adriany G, *et al*, 11th annual meeting of ISMRM, 2002, p474; 3) Zhang X, *et al. J Magn Reson*, 161: 242-251 (2003); 4)Zhang X, *et al*, 9th annual meeting of ISMRM, 2001, p699; 5)Zhang X, *et al*, 10th annual meeting of ISMRM, 2002, p159; 6)Pruessmann, K, et al, *Magn Reson Med*, 42: 952-962 (1999).

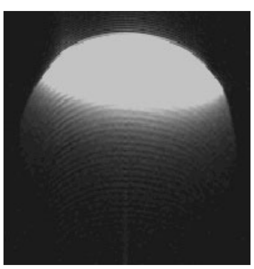

Fig 1. The mineral oil phantom image acquired using the MTL coil array (two-loop combination) at 7T.

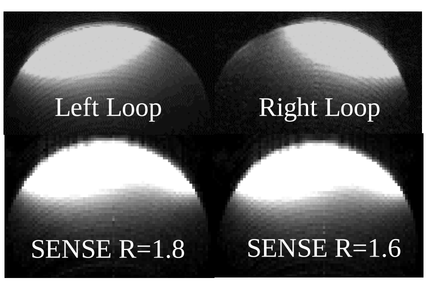

Fig 2. The mineral oil phantom images acquired from each loop independently (upper insert) and the SENSE images with different total reduction factors (lower insert), the center calibration line = 16 (lower left) and 32 (lower right), outer reduction factor = 2. Matrix = 128 × 128.

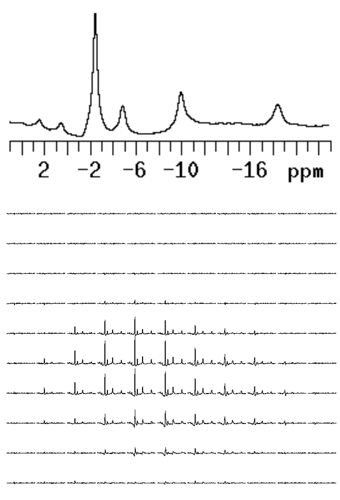

Fig 3. The global ^{31}P spectrum (upper insert) and CSI acquired from the human leg using the MTL coil array at 7T.

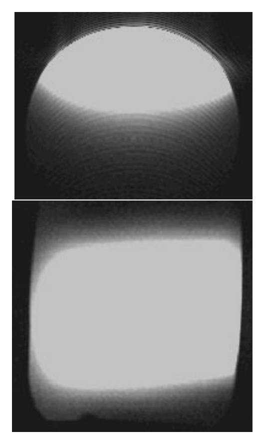

Fig 4. The GRE images in transverse (upper insert) and coronal (lower insert) orientations acquired from the mineral oil phantom at 4T.