A Dual-tuned Microstrip Volume Coil Array for Human Head Parallel ^{1}H/^{31}P MRI/MRS at 7T

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INTRODUCTION: Human brain ^{31}P MR spectroscopic imaging (MRSI) at high/ultrahigh fields has proven to be promising due to increased SNR and spectral dispersion (1). Combining with a fast imaging technique, such as parallel imaging with SENSE reconstruction algorithm, and RF coil array technique, it is possible to significantly increase both temporal and spatial resolutions for *in vivo* ^{31}P MRSI. This would be essential for studying high-energy phosphate metabolism and bioenergetics in the human brain at high fields; however, the unavailability of the required double-tuned volume coil array has obstructed the development of this technique. In this work, we present an 8-channel by 8-channel double-tuned (^{1}H/^{31}P) volume coil array design using the microstrip transmission line (MTL) method (2,3) for human head parallel ^{1}H MRI/^{31}P MRSI applications at 7T.

METHOD: An 8-channel by 8-channel MTL coil array operating at 120 MHz and 300 MHz ranges was designed and constructed for the human head ^{1}H/^{31}P study at 7T. Each element was a 17.5-cm long MTL resonator with a strip conductor width of ~1.2 cm and a substrate thickness of ~0.6 cm. The strip conductor and ground plane of each MTL element was made from the 3M copper tapes with a thickness of 36-µm. All the microstrip resonators were terminated with capacitors on both ends to bring the resonant frequency down to the desired values. Substantial E-fields on both ends of the microstrip elements were stored in the termination capacitors, thus reducing the possible tissue heating during the MR experiments. Eight identical ^{1}H elements and eight identical ^{31}P elements were built interleavedly on a Teflon cylinder with dimensions of 26.8-cm ID and 28-cm OD, as shown in Fig 1. The resonant frequency of those terminated MTL elements were determined by the following equation, which was solved numerically using a Matlab code,

$$f_r = \frac{(2\pi Z_0 f_r)^2 C_t C_{t1} - 1}{2\pi Z_0 (C_t + C_{t1})} \tan\left(\frac{2\pi l\sqrt{\varepsilon_{eff}}}{c} f_r\right)$$

where ε_{eff} is effective permittivity; c is light speed in free space; Z_0 is characteristic impedance of the line; C_t and C_{t1} are the capacitance of the terminating capacitors connected at the two ends of the microstrip resonator and l is the length of the MTL resonator. This equation was presented previously in (4) in which the equation was typed incorrectly. The decoupling among the elements was evaluated using transmission coefficient S21 measurements taken on a network analyzer (Agilent 8712ES). A mineral oil phantom with a diameter of 15-cm was used for proton imaging so that the decoupling among the elements can be clearly and correctly presented. At this stage, the ^{31}P spectra were acquired from a ^{31}P phantom (15-cm in diameter). All MR experiments were performed on a 7T/90cm magnet (Magnex Scientific, UK) interfaced with the Varian INOVA console (Varian Associates, Polo Alto, California).

RESULTS: All 8 ^{1}H elements and 8 ^{31}P elements were tuned to 300 MHz and 120 MHz ranges, respectively. The frequency equation derived above is accurate, yielding an agreement within 2% between the calculated and measured values. The transmission coefficient measured between the two adjacent ^{1}H (or ^{31}P) elements was better than -15 dB in the loaded case. The decoupling between the two adjacent ^{1}H element and ^{31}P element was better than -25 dB. Figure 2 shows the mineral oil phantom images acquired from 8 ^{1}H channels. The well-defined image profiles indicate that sufficient decoupling among all elements was achieved. By adding all the 8 images together, a complete transverse image of the mineral oil phantom was formed, as shown in Fig 3. The signal intensity of this image was distributed strongly in peripheral area and weakly in center area. Such a pattern of the signal distribution is desired for achieving a more uniform image of the human head in which a prominent dielectric-resonance effect exists at 7T. Fig 4 shows a set of ^{31}P spectra with different excitation RF power collected using the ^{31}P channel of the double-tuned MTL volume coil array at 7T.

CONCLUSIONS: A double-tuned volume coil array using MTL method was successfully designed for the human head ^{1}H/^{31}P parallel MRI/MRS applications at 7T. With this coil array, high spatial and temporal resolution ^{31}P MR could be achieved for human brain MR studies at ultrahigh magnetic fields.

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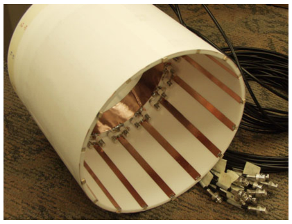

Fig.1 The double-tuned MTL coil array for in vivo ^{1}H/^{31}P parallel MRI/MRS at 7T.

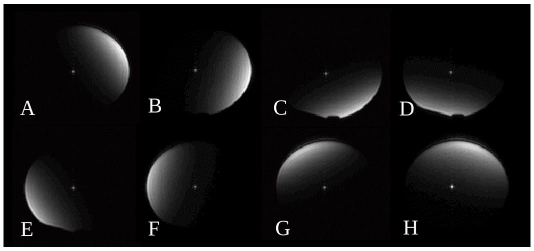

Fig. 2 Sensitivity profiles (A-H) obtained from each ^{1}H channel. Each profile has a well-defined shape, showing an excellent decoupling among the MTL elements. Image parameters: FOV: 30cm × 30cm, matrix size: 128 × 128, flip angle: less than 22^0.

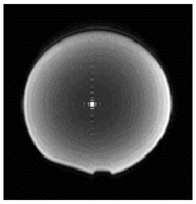

Fig. 3 Combined mineral oil image obtained from the 8 individual images shown in Fig 2.

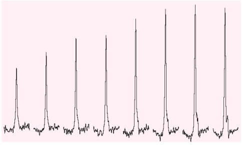

Fig. 4 ^{31}P spectroscopy acquired using the double-tuned MTL coil array at 7T