A novel decoupling technique for non-overlapped microstrip array coil at 7T MR imaging

Z. Xie[1], and X. Zhang[1,2]

[1]Department of Radiology, UC San Francisco, San Francisco, CA, United States, [2]UC Berkeley Joint Graduate Group in Bioengineering, San Francisco & Berkeley, CA, United States

Introduction Parallel magnetic imaging, a fast imaging technique developed recently, requires multi-channel RF coil arrays for signal detection and encoding. One of the challenges of designing such coil arrays is to obtain sufficient decoupling among closely placed resonant elements in coil arrays. For loop-type coil, decoupling can be achieved by overlapping. Due to the increased g-factor in the overlapping area of an overlapped coil array, non-overlapped array design is desired for parallel imaging technique in order to have a higher SNR of images. Some decoupling methods for non-overlapping design have been proposed, such as the method using lumped L/C decoupling circuits (1,2). In some circumstances, the decoupling method using lumped L/C elements shows its limitations due to the required values of L/C becoming impractically small, in particular, at ultrahigh magnetic fields. In this work, a new decoupling method for designing non-overlapped coil arrays is introduced by using magnetic wall that generated by a circuit, such as a microstrip line placed between two adjacent resonant elements. There is no physical connection between the decoupling microstrip line and coil elements. Theoretically this method is not frequency-sensitive, therefore the decoupling performance can be maintained in a broad frequency range, particularly useful to decouple elements that operate at two or more frequencies (i.e. dual-tuned or multiple tuned elements). Bench test and preliminary imaging results are shown using the proposed coil array at 7T.

Methods The shielded surface coil array decoupled using the proposed decoupling technique was built on a plastic board with a thickness of 0.375". Fig.1 shows the schematic of the prototype coil array with only two elements for concept demonstration. The two identical shielded surface coil loops have a size of 4.25" by 3.5". The decoupling microstrip line measures 8.25" long and is capacitively terminated on its two ends. The width of all the strips used for surface coils and the strip conductor of the decoupling microstrip line is 0.25". Both the shielded surface coils are tuned to 298.144 MHz, the Larmor frequency of proton at 7T. The frequency of the decoupling microstrip line (~190MHz) is far off the proton Larmor frequency. Based on the Kirchhoff's voltage law (KVL), in circuit model shown in Fig.2, the currents satisfy $\begin{bmatrix} X_{L1} & -X_{Mcc} & X_{Mdc} \\ -X_{Mcc} & X_{L1} & X_{Mdc} \\ X_{Mdc} & X_{Mdc} & X_d \end{bmatrix}\begin{bmatrix} I_1 \\ I_2 \\ I_3 \end{bmatrix} = 0$, [1] where *X's* are the impedances. X_d in the impedance matrix is the impedance of the decoupling microstrip line, and $X_d = j\omega L_d + \frac{1}{j\omega C_d}$ where ω is the frequency and Ld and C_d are the equivalent inductance and capacitance of the decoupling microstrip line. The impedance matrix has two eigenvalues at the same resonant frequency $\omega_0 = \frac{1}{\sqrt{(L_1 + M_{cc})C_1}}$, if and only if $X_d = \frac{X_{Mdc}^2}{X_{Mcc}}$ [2] where X_{Mdc} and X_{Mcc} are the mutual impedance of coil-to-decoupling-element and impedance of coil-to-coil respectively. The eigenvectors for the same eigenvalue are orthogonal, in other words, decoupled to each other. Bench test on the resonant modes and isolation between two loop coils were implemented on a network analyzer (Agilent E5070B). The termination capacitance measurement was conducted on a RCL meter (Fluke PM6303A). The MR imaging experiments were performed on a GE 7T/90cm magnet (GE Healthcare, Waukesha, WI). A bottle of pure water was used as a phantom in this preliminary study. A set of gradient echo images in axial orientation were acquired using the coil array. Acquisition parameters were –TR = 150ms, TE = 6.8ms, thickness = 5mm, flip angle = ~20^0, FOV = 20cm, no average.

Results and Conclusions Each coil element was matched to system 50 Ohm by a series capacitor. The decoupling between the two elements was greater than 25dB. No resonant peak split is observed for both elements. These results indicate that the two channels are decoupled sufficiently. Fig 2 shows the MR images from each resonant element, in which no signal is observed from other coil, indicating the effectiveness of the proposed decoupling technique at ultrahigh field of 7T. The proposed design provides a robust approach to design of parallel imaging arrays at ultrahigh fields. The future work will be focused on investigation of the proposed decoupling technique with more resonant elements and evaluation of the g-factor of the design.

Reference (1) Wu B, et al, Thirteenth Annual Meeting of ISMRM: 949 (2005); (2) Wu B, et al, J Magn Reson 182:126–132 (2006).

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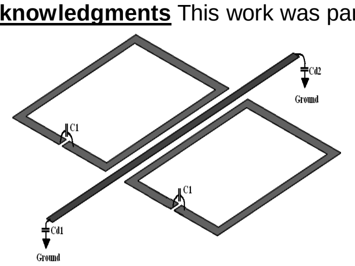

Fig.1 The 7T microstrip coil array with 2 decoupled loop coils and one decoupling element.

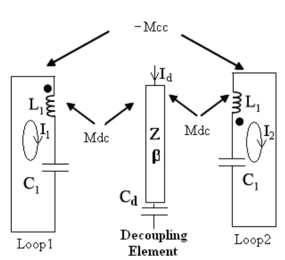

Fig.2 Diagrams of equivalent circuit model for the coil array.

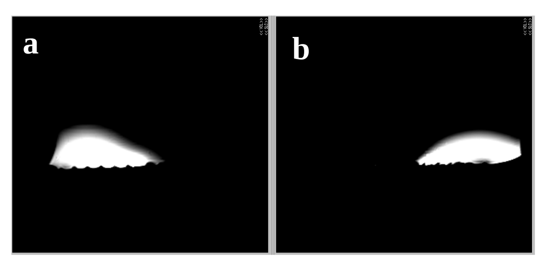

Fig.3 7T MR imaging results of a water phantom: (a) right coil and (b) left coil.