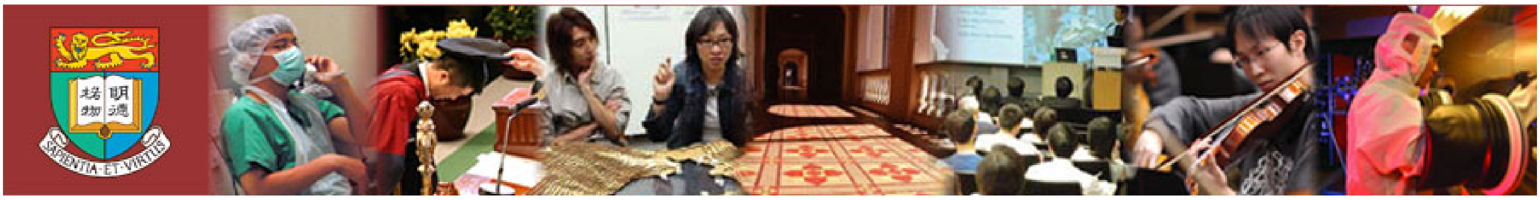

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Inductively Decoupled Microstrip Array at 9.4T

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Introduction

Microstrip arrays [1-3], with independent phase and amplitude control of individual elements, can mitigate sample-induced RF non-uniformities and be used for transmit and receive parallel imaging applications. The main challenge in implementing the microstrip arrays is to find sufficient means to decouple the individual coils when a large number of elements were used. This becomes particularly difficult in transceiver arrays, since preamplifier decoupling is not easily feasible. The method by using interconnected capacitors has been utilized to reduce the mutual coupling between the nearest neighbors [1-4]. However, this method appears inefficient to non-adjacent elements. In addition, the required decoupling capacitance decreases with magnetic fields. For higher frequency (>300MHz), the required decoupling capacitance is usually less than 1pF which is not practical. In this study, we present a new decoupling method by using decoupling inductors. To validate the proposed method, eight-channel microstrip array was fabricated and tested at 9.4T.

Methods

The principle of this decoupling method can be illustrated by using equivalent circuit. For convenience, two strips are assumed of the same geometry and connected by an inductor, as shown in Fig.1. L, M and L_d are the self-inductance of each coil, mutual inductance and decoupling inductance, respectively. C_1 is the tuning capacitor between the ground and the connecting point of L_d. C_2 represents the equivalent tuning capacitor serially placed with C_1. The required L_d in this circuit can be expressed as:

$$L_d = L\cdot\frac{k^2(1-m^2)-2km(1-m)}{m(1+k)^2},\quad \text{for } k > 2m/(1+m) \qquad (1)$$

where $k = C_2/C_1$, and $m = M/L$. Note that in Eq.(1), inductor L_d is only determined by L, m, k and independent of the resonant frequency. Therefore, this method can be used for ultrahigh field. The relationship of L_d and m, k are further illustrated in Fig. 2 by assuming $L = 0.5\mu H$. It can be seen when $m < 0.2$ (this condition is usually satisfied for microstrip arrays), the required L_d can be controlled in a board ranges by varying k.

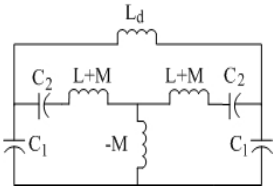


Fig.1 The equivalent circuit of two coupled microstrip coils.

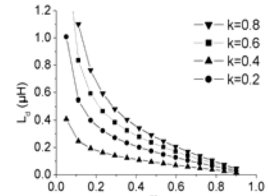
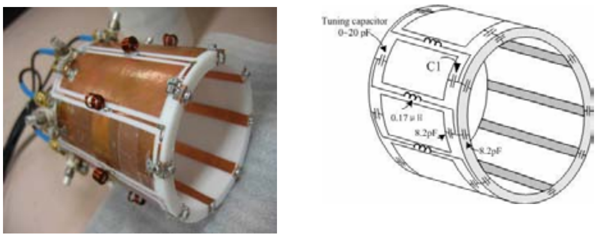


Fig.2 The relationship of *Ld*, *m* and *k*.

A prototype of eight-channel microstrip volume array (Fig.3) was fabricated for 9.4T. A Teflon cylinder with 9.0cm length, 7.6cm outer diameter and 6.4cm inner diameter was selected as the dielectric substrate. The eight coils were built using 6.5mm wide copper strips and 2.5cm wide ground strips. The spacing between two adjacent strips is 2.0cm. The experiment was performed on a 9.4T horizontal bore magnet (Magnex Scientific, UK) interfaced to a Varian INOVA console (Varian Associates, Palo Alto, CA, USA).



(a) (b)

Fig.3 Photo (a) and schematic (b) of 8-channel microstrip array at 9.4T.

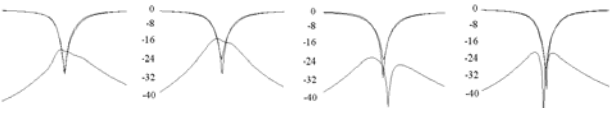
Results

When one microstrip resonator was tuned to 400MHz with other seven strips open-circuit, the unloaded *Q* was measured as 130 and loaded *Q* was 85 after loaded with saturated NaCl-solution phantom (cylinder with 9cm length and 5.5cm diameter). After mounting the decoupling inductors, the unloaded *Q* of all elements in the array were around 120~130 and the loaded *Q* were around 72~82, no significant loss was observed.

Without the decoupling inductors, the strong coupling between the nearest and the 2nd neighbors caused the resonant peaks split. After mounting the inductors, the mutual couplings were reduced not only between adjacent elements, but also between non-adjacent elements. It is more obvious for the 3rd and 4th neighbors (Fig.4). The decoupling inductors can bring additional 3dB~14dB isolations for non-adjacent elements.

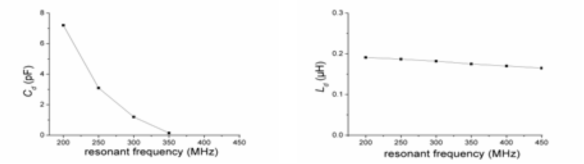
The inductively decoupling method is compared with the method by using capacitors. Two microstrip resonators in the prototype were tuned to the frequencies ranged from 200 MHz to 450 MHz by varying the tuning capacitors on the strips. The tuning capacitors on the strips were kept with the same values so that k is approximate a constant. Fig.5 shows that the required decoupling capacitor decreases with the resonate frequency. When the frequency is higher than 350MHz, the required capacitor is less than 0.5pF which is difficult to control in practice (Fig.5a) while the required inductor is in the narrow range of 0.17~0.19μH (5-7 turns copper wire with 7mm diameter) as shown in Fig.5b.

The sensitivity profiles obtained from each channel show good isolations between elements (Fig.6a). Fig.6b shows a combined image from the individual images in Fig.6a. The signal intensity of this image was distributed strongly in peripheral area and weakly in the center. Such a pattern of the signal distribution was mainly caused by the phantom used. The NaCl-solution was too concentrated and reduced B1 penetration.



(a) (b) (c) (d)

Fig.4. The S parameters of the nearest neighbors (a), the second neighbors (b), the third neighbors (c) and the forth neighbors (d) after loading with phantom. The span is 50MHz and the central frequency is 400.0MHz



(a) (b)

Fig.5. (a): Two strips are decoupled with an interconnected capacitor. (b): Two strips are decoupled with an inductor.

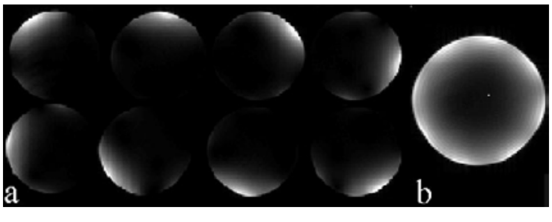


Fig.6 Sensitivity profiles obtained from each channel (a) and the combined image (b). Image parameters: FOV: 10cm×10cm, matrix size: 128 ×128. flip angle: less than 20°.

Conclusion

In this study, an inductive decoupling technique for microstrip array at ultra high fields has been discussed. The decoupling inductance is nearly independent of resonant frequency. Thus microstrip arrays can be tuned and work well at the magnetic fields higher than 7T. For the prototype of volume microstrip array, the introduced inductors can reduce the mutual coupling not only between the adjacent elements, but also among the non-adjacent elements.

Acknowledgements

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Reference [1]Adriany G, et al., MRM53:434-445 (2005). [2]Adriany G, et al., Proc of ISMRM13 673 (2005). [3]Snyder C.J et al,. Proc of ISMRM13 674 (2005). [4] Lee RF MRM 51:172-183 (2004)