A Composite Decoupling Method for RF Transceiver Array Coils in MRI

Y. Duan[1], B. S. Peterson[1], F. Liu[1], and A. Kangarlu[1]
[1]MRI Research, Department of Psychiatry, NYSPI & Columbia University, New York, NY 10032, United States

Introduction

Although widely embraced in clinical applications, array coils [1] still pose tremendous design challenges due to coupling between coil elements [2]. Several strategies have been proposed for eliminating mutual inductance, such as overlapping [1, 3], orthogonal positioning [3], use of low impedance preamplifiers [1], digital post-processing [4], capacitive/inductive networks [5] and shielding design [6]. These strategies, however, have their own shortcomings that include either poor efficiency caused by interactions or implementation only in receiver array coils [7]. In addition, most strategies have been discussed only for decoupling two-channel array coils, assuming that the strategies would be extended easily to higher number of channels. This assumption is untrue in most cases, especially when decoupling cylindrical array coils in which the elements are physically much closer than in planar array coils. In this work, we present a composite scheme for minimizing the mutual inductance of transceiver array coils that have more than two channels, a strategy that combines a novel design for shielding-based decoupling with a method for simplified capacitive decoupling.

Materials and Methods

We decoupled the array coils by minimizing both the crossing field source and the mutual inductances between the coil elements. To test decoupling between both adjacent and non-adjacent elements of cylindrical array coils, we built an array coil having 5 elements mounted on approximately 30% of the surface of a cylindrical acrylic former 250mm in diameter and 300mm in length, modeling 5 channels of a 16-channel cylindrical array coil (fig. 1a). Each element comprised a 200mm long and 40mm wide rectangular copper loop that was connected with a capacitor on each side (fig. 1b).

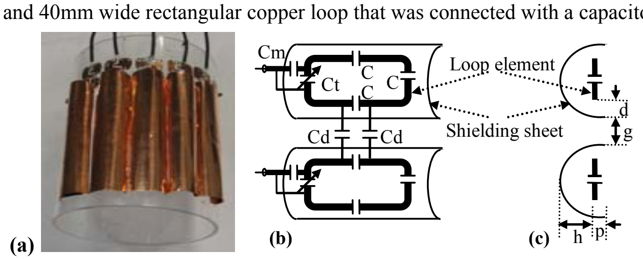

Fig. 1. Decoupling strategy. (a) a photo of the 5-element coil; (b) top view of adjacent elements (c) end view of adjacent elements.

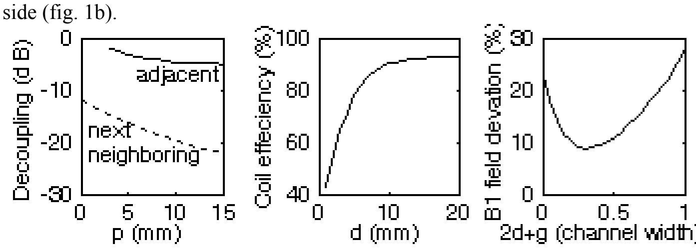

Fig. 2. The effects of parameters of the shielding sheets: (a) decoupling effects vs. penetrating depth; (b) coil efficiency vs. gap; (c) B_1 field deviation vs. gap.

We minimized the crossing field source by shielding the space directly above each coil element and the gaps on either side of the element using an arched cupper sheet of 70um thick, leaving the bottom side of the element open to the subject for transmitting and receiving. We optimized the decoupling effect of each shielding sheet by adjusting four parameters: *d* -- the distance from the copper legs of the coil element to the shielding sheet; *h* -- the distance from the plane of the element to the top of the shielding sheet; *p* -- the depth that the shielding sheet penetrates into the open side of the coil element; and *g* -- the gap between the shielding sheets of adjacent coil elements (fig. 1c). We found that the coupling between non-adjacent elements could be minimized to a desired level by proper shielding. The coupling between adjacent elements, however, remained undesirable. Thus, we connected two capacitors, C_d, between adjacent elements to reduce the mutual inductance between the adjacent elements, thereby minimizing the residual coupling. We obtained all these parameters by simultaneously optimizing the resonance pattern, B_1 homogeneity, and efficiency of the array coil using our in-house FDTD software [8]. Finally we used an Agilent 4395A Analyzer to measure the S-parameters of various elements of the array coil that was constructed using these optimized parameters.

Results and Discussion

The FDTD simulation showed that the parameters of shielding sheets, *p, d, h,* and *g*, were critical for the decoupling and efficiency of the array coil and for improving the homogeneity of the B_1 field. First, within a realistic range from 3mm to 15mm, the penetrating depth of the shielding sheet, *p*, was found to be proportional to the isolation between both adjacent and non-adjacent elements (fig. 2a). Second, the efficiencies of the shielded coil elements depended mainly on the distance from the shielding sheet to the coil loop, *d*, and slightly on the distance from the top of the shielding sheet to the plane of the loop element, *h,* when *h* was greater than 15mm (fig. 2b). Third, the minimum deviation of the B_1 map occurred for a gap between adjacent coil elements, (2*d*+*g*), that ranged from 0.2 to 0.45 times the width of the element (fig. 2c). More importantly, we found that adjusting the shielding sheet of one element only changed the resonance frequency of the element and minimally affected the resonance pattern of other elements. Based on these findings, we selected *p, d, h, and g* to be 10mm, 7mm, 20mm, and 2mm respectively. Using these parameters for shielding, we obtained decoupling of better than -21dB between non-adjacent elements at 128MHz, which would have split the resonant peaks without shielding. However, the decoupling between adjacent elements was as low as -6.2dB. This poor isolation between adjacent elements was then improved to better than -22dB while maintaining the good isolation between non-adjacent elements by combining use of these shielding parameters with capacitive decoupling in which adjacent elements were connected with two capacitors of 8.2 pF each (fig. 3).

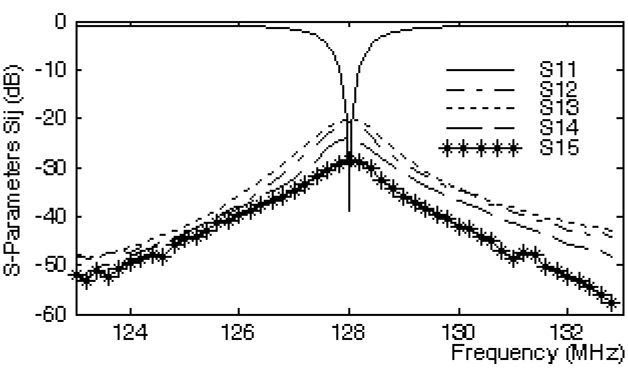

Fig. 3. Measured S-parameters of the constructed 5-element array coil

Conclusions

In combination with simplified capacitive decoupling, shielding sheet decoupling with optimized parameters can provide excellent isolation between both adjacent and non-adjacent elements of array coils together with good efficiency and B_1 homogeneity of the coils. The significant advantage of this composite strategy is that the adjustments of decoupling parameters for each coil element minimally affect other elements. This characteristic of the new strategy largely minimizes the interactions between the decoupling mechanisms for different elements and thereby simplifying the complexity of the scheme for decoupling transceiver array coils.

References

[1] Romer PB, et al., *MRM* 16(20):192-225 (1990). [2] Lee RF,et al., *MRM* 48:203-213 (2004). [3] Wright SM, et al. *NMR Biomed*.10:394–410 (1997). [4] Song XY, et al., *Proc. Nat. Sci* 13(9): 683–689 (2003). [5] Jevtic J, *Proc. ISMRM* 9: 17 (2001). [6] Qu P, et al. *Proc. ISMRM* 11:1605 (2004). [7] Ohliger MA, et al. *NMR Biomed* 19: 300–315 (2006). [8] Duan Y, et al., *JMRI* 29:13-22, (2009)