Vertical Loop Decoupling Method for Gapped Phased-Array Coils

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Introduction

In parallel imaging, a gapped phased-array coil provides a lower g-factor than a phased-array coil with overlap decoupling [1,2]. Nearest-neighbor coils in the gapped phased-array coils can be decoupled by using a capacitor network [3,4] and a decoupling interface [5], but the decoupling adjustment of the capacitor network and the decoupling interface becomes complex and difficult as the number of coils increases. We have developed a decoupling method using a vertical loop (VL) in which the value of the capacitor in the VL is changed, thus enabling the easy decoupling of nearest-neighbor coils. We investigated the decoupling ability of the proposed method using numerical simulations, and we also fabricated a two-element coil array with VL and demonstrated its decoupling performance.

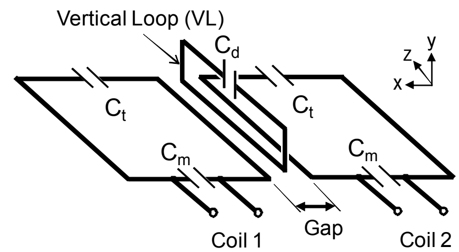

Fig. 1 Two-element coil array with vertical loop

Method

Decoupling method: Figure 1 shows a schematic diagram of a two-element coil array with a VL. The VL consists of a conductive loop and a capacitor (C_d). The resonant frequency of the VL is set to be lower than that of the two coils. The VL acts as inductive loop at the resonant frequency of the coils. When a current flows in coil 1, coil 1 generates magnetic flux, as shown in Fig. 2. The VL also generates magnetic flux because it is coupled to coil 1. The magnetic flux through coil 2 generated by coil 1 (Φ_1) and the VL (Φ_d) are oppositely oriented, because the VL is an inductive loop and is placed between coils 1 and 2 (Fig. 2). Thus, coil 2 is decoupled when the amount of Φ_1 is equal to that of Φ_d. The amount of Φ_d can be adjusted by changing the value of C_d. Therefore, coil 1 can be decoupled to coil 2. *Simulation:* We numerically calculated the impedance characteristics and sensitivity of the coils using our own program, which is based on the method of moments [6]. The two-element coil array was constructed with two 100-mm square loop coils with a gap of 10 mm and a VL that was 10 mm high and 100 mm long. Sensitivity was defined by the strength of the clockwise circularly-polarized magnetic field generated by the coil when a 1-W signal power was applied to it. *Experiment:* A two-element coil array was constructed with two loop coils that were 180 × 100 mm and a VL that was 10 mm high and 180 mm long. The gap between the two coils was 10 mm. The width of the conductor in the coil array was 5mm. The two-element coil array was placed on the outer side of the 290-mm diameter cylinder, and a cylindrical phantom with 252 mm in diameter and 70 mm in length was placed as shown in Fig. 3. The phantom was filled with a 10-mM $NiCl_2$ and 0.4-wt% NaCl solution. The coils were tuned to 127.7 MHz and matched to 50Ω. The S-parameters of the coils were measured with a network analyzer. Phantom images were obtained with a 3T MR scanner using spin-echo sequence (TR/TE = 1000/30 ms, thickness = 5 mm, FOV = 300 mm, and 256 × 256 matrix size).

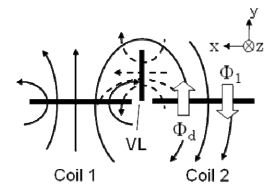

Fig. 2 Magnetic flux generated by coil 1 and VL

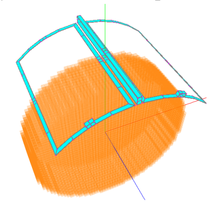

Fig. 3 Position of coil and phantom

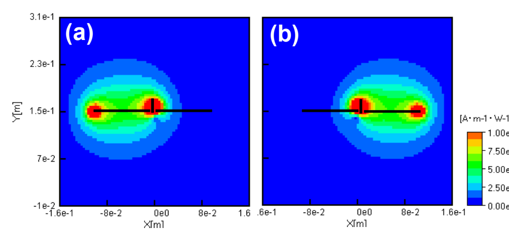

Fig. 4 Calculated axial sensitivity maps of two-element coil array with VL ((a) coil 1, (b) coil 2)

Results and Discussion

The unloaded Q values of coil 1 in the case of coil 1 by itself, coils 1 and 2 with VL, and coils 1 and 2 without VL were 247, 246, and 23, respectively. The Q value of the coil decreases as the coil coupling increases. These results indicate that the VL highly decoupled the two coils. Figure 4 shows the calculated axial sensitivity maps of the two-element coil array with VL. The positions of the coil elements are indicated by solid lines. Coils 1 and 2 showed high sensitivity around the element of coils 1 and 2, as shown in Fig. 4(a) and (b), respectively. This indicates that decoupling by VL improves the isolation of coil sensitivity. In Fig. 4(a) and (b), small regions with low sensitivity were observed near the VL. This is because the magnetic field generated by the VL reduced the sensitivity of the coil locally. This region has little effect on the reduction in the sensitivity of field of view because the region is small and located near the coil element. Figure 5 shows the measured S-parameters of the two-element coil array with VL when they were loaded with the cylindrical phantom. The coupling S_{12} measured between coils 1 and 2 was −28 dB. This means that there is only a 4% signal-power cross talk between coils. Figure 6 shows phantom images of the two-element coil array with VL. Coil 1 and 2 showed high sensitivity near the element of coils 1 and 2, as shown in Fig. 6(a) and (b), respectively. These results indicate that the decoupling method using VL demonstrates a good decoupling performance between two neighboring coils.

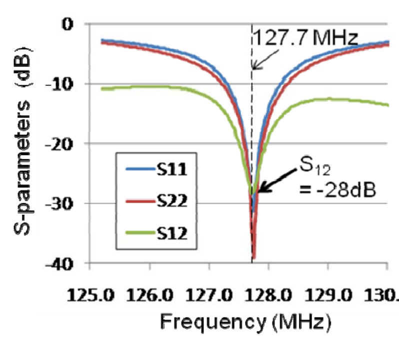

Fig. 5 Measured S-parameters of two-element coil array with VL

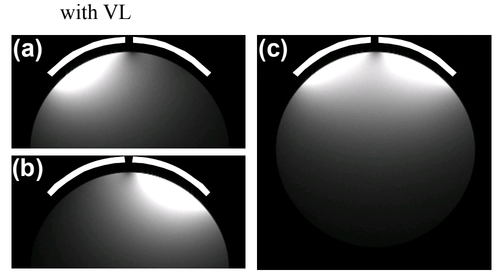

Fig. 6 Phantom images from coil 1 (a), coil 2 (b), and composition of coils 1 and 2 (c). Positions of coil elements are indicated by solid white lines.

Conclusion

We have developed a decoupling method using VL for gapped phased-array coils. Numerical simulations and experiments demonstrated that the proposed method can effectively decouple between nearest-neighbor coils in the gapped phased-array coils.

References [1] M. Weiger, et al., Magn. Reson. Med. 45, 495−504 (2001) [2] J. A.de Zwart, et al., Magn. Reson. Med. 47, 1218−1227 (2002) [3] J. Jevtic, ISMRM 9th Annual Meeting, 17 (2001) [4] C. von Morze, ISMRM 14th Annual Meeting, 3524 (2006) [5] R. F. Lee, et al., Magn. Reson. Med. 48, 203−213 (2002) [6] H. Ochi, et al., SMRM 11th Annual Meeting, 4021 (1992)