Sensitivity Simulation of 16ch Spine/Torso Array Coil at 3T

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Introduction

The design of receive array coils are optimized to maximize the signal-to-noise ratio of the region of interest (ex. head, torso [1], and spine [2]). Thus, the receive array coil corresponding to an imaging region must be used for every scan. If a receive coil is commonly used for more than one imaging region, the frequency of coil exchange can be decreased, and the efficiency of scans is improved. Since the region of the posterior torso coil overlaps that of the cervical-thoracic-lumber (CTL) spine coil, the integration of these coils is feasible. We have designed a 16ch spine/torso array coil, and evaluated its sensitivity at 3T using numerical simulations. We also compared the sensitivity of the designed coil with that of the traditional spine array, and evaluated the sensitivity of a 32ch torso coil consisted of two designed coil.

Method

Coil Design: A schematic diagram of the designed coil is shown in Fig. 1(a). This coil was constructed with 16 (4 × 4) loop coils each having dimensions of 155 × 140 mm. The loop coils in the leftmost and rightmost columns were flexible. For spine imaging, the designed coil was placed on the patient table as shown in Fig. 1(b). The region of CTL spine can be covered by arranging the two designed coils in the head-foot (H-F) direction. For torso imaging, the two designed coils were wrapped around a torso as shown in Fig. 1(c). Nearest neighbor loop-coils partially overlapped for coil decoupling [3]. Diagonal pairs of the loop coils were decoupled by using a cancel coil [4]. A preamplifier with input impedance of 2 Ω was connected to the feed of each loop coil in order to provide preamplifier decoupling [3].

Simulations: We numerically simulated characteristics of coils using our own program which was based on the method of moments (MoM) and the impedance method [5]. Since MoM can calculate the characteristics of conductors with arbitrary shape, a loop coil with a curved surface can be calculated. This program can also calculate the sensitivity distributions of the coils with a load. The calculated results of the sensitivity distribution in the load were in good agreement with experimental results [6]. A torso phantom was used for the load as shown in Fig. 2. The conductivity and relative permittivity of the phantom were 0.66 S/m and 50, respectively. By changing the values of the capacitors, the loop coil was tuned to 127.8 MHz (3.0 T) and matched to 50 Ω. The conductivity of the coil conductor was set to 5.8×10^{6} S/m in view of degradation due to soldering and oxidation. The Q value of capacitors was set to 1000. The coil sensitivity was defined by the strength of the clockwise, circularly polarized B_1 field generated by the coil when a signal with a power of 1 watt was fed to the coil.

Evaluation: To confirm the effect of decoupling methods applied to the designed coil, coupling between the loop-coils were evaluated. The amount of coupling between the two coils was calculated from the ratio of the current in the non-fed coil to that in the fed coil when one coil is fed. The sensitivity of an array coil was calculated for a sum-of-squares combination with noise correlation. The noise correlation matrix was calculated from the sum of electric fields in the load [3]. The sensitivities of the traditional spine array as shown in Fig. 3 and the traditional 16ch torso array were also calculated for comparison. The loop coil of the spine array had the same dimensions as that of the designed coil.

Results and Discussion

The unloaded Q values of the loop-coils in the designed coil ranged from 280 to 300, and the loaded Q values ranged from 18 to 20. The maximum coupling of the designed coil was 6 %. This suggests that the loop-coils in the designed coil were decoupled very well. Figure 4 shows the calculated sensitivity maps of the designed coil and the spine array in the axial plane of the center of the torso phantom, respectively. Both maps had asymmetrical sensitivity in the left-right (L-R) direction. This phenomenon is caused by the inhomogeneity of the B_1 field in the dielectric and conductive materials. The sensitivity distribution of the designed coil is similar to that of the spine array. Figure 5(a) shows the sensitivity profiles in the L-R direction passing through the center of the phantom. The sensitivity of the designed coil was higher than that of the spine array. The averaged sensitivities of the designed coil and the spine array in the lower half of the phantom were 0.77 and 0.69 $A/m/W^{0.5}$, respectively. Figure 5(b) shows the sensitivity profiles in the anterior-posterior (A-P) direction. The sensitivity profile of the spine array was very similar to that of the designed coil, and the difference between the both profiles was at most 7%. These results suggest that the designed coil substitutes for the traditional spine array. Figure 6(a) shows the calculated axial sensitivity map of the designed coil wrapped around the torso phantom. The sensitivity of the region near the left and right side of the phantom was increased. The averaged sensitivity of the coil in the lower half of the phantom was 0.84 $A/m/W^{0.5}$. These results suggest that the designed coil wrapped around a body improved the sensitivity in the region of interest of the spine image. Figure 6(b) shows the calculated axial sensitivity map of a 32ch torso coil constructed with two designed coil. The maximum coil coupling of the 32ch torso coil was 5 %. Figure 7 shows the sensitivity profiles of the 32ch and the traditional 16ch torso coil. The 32ch torso coil exhibited higher sensitivity and a wider field of view than the traditional 16ch torso array. The averaged sensitivities of the designed coil and the spine array in the lower half region of the phantom were 0.67 and 0.58 $A/m/W^{0.5}$, respectively. These results show that the designed coil can be used as a torso coil.

Conclusion

We have designed a 16ch spine/torso array coil and demonstrated its sensitivity with a torso phantom using numerical simulations. The simulation results suggest that the designed coil can be commonly used as a spine coil and a torso coil.

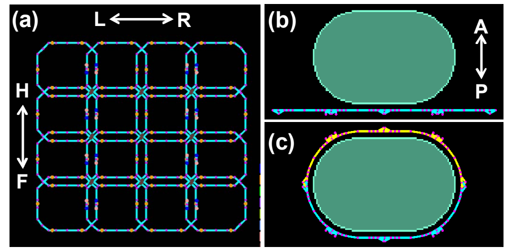

Fig. 1 16ch spine/torso array coil ((a) Simulation model, (b) Setup for spine imaging, (c) Setup for torso imaging)

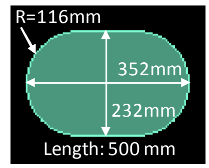

Fig. 2 Torso Phantom

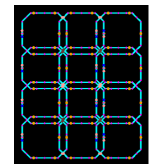

Fig. 3 Traditional spine array

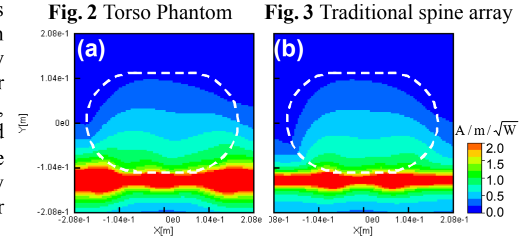

Fig. 4 Calculated axial sensitivity maps ((a) Spine/torso array, (b) Traditional spine array)

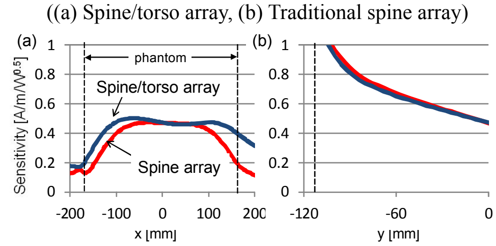

Fig. 5 Calculated sensitivity profiles ((a) L-R, (b) A-P)

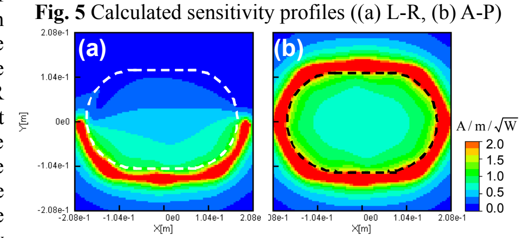

Fig. 6 Axial sensitivity maps of the spine/torso array wrapped around a phantom (a) and combined with an anterior torso coil (b)

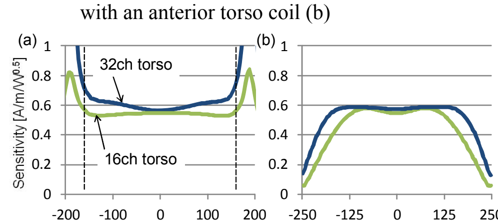

Fig. 7 Sensitivity profiles of torso coils ((a) L-R, (b) H-F)

References [1] C. J. Hardy, et al., Magn. Reson. Med. 52, 878−884 (2004) [2] L. Feng, ISMRM 11th Annual Meeting, 2634 (2004)
[3] P. B. Roemer, et al., Magn. Reson. Med. 16, 192−225 (2000) [4] T. Nabeshima, et al., U.S. patent 5,489,847 (1996)
[5] H. Ochi, et al., SMRM 11th Annual Meeting, 4021 (1992) [6] Y. Soutome, ISMRM 16th Annual Meeting, 1115 (2008)