B_1-control Loop Array for Reduction of B_1 Inhomogeneity

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INTRODUCTION

The inhomogeneity of B_1 in a human body increases as the strength of a static magnetic field increases and the RF wavelength becomes shorter. Various methods have recently been developed to reduce the inhomogeneity, such as dielectric pads [1,2], coupling coils [3-6] and RF shimming. However, B_1 inhomogeneity still remains in some cases of abdominal imaging, and a more effective method for reducing B_1 inhomogeneity is required. Our previous study showed that using the 'B_1 rectifying fin' can control the B_1 field locally and reduce B_1 inhomogeneity [7]. In order to combine the B_1 homogenization function of the fin with receive array coils, we're changing the shape of the fin into a loop. In this study, we have proposed a new method of B_1 homogenization: using a 'B_1-control loop array' combined with RF shimming. This method improves B_1 homogeneity more than using RF shimming alone does.

METHOD

Design: The magnetic flux around the conductive fin and loop is illustrated in Figure 1. As shown in Fig. 1(a), the fin can change the magnetic flux because of an electrical counter current flow. The loop, which has sufficiently lower resonance frequency than the transmit RF frequency, exhibits inductive characteristics. The inductive loop changes the flux in the same direction as the fin in Fig. 1(b). The flux density becomes lower around the center of the loop and higher near the edge of the loop. The spatial distribution of the flux density around the loop has a potential to compensate the B_1 inhomogeneity. The loop array is arranged around the abdomen with the some loops used as 'on-mode' and the others used as 'off-mode'. The on-mode means a loop with no capacitor or additional inductor, and the loop works as shown in Fig. 1(b). The off-mode means a loop with some electric cutting point, and the cut-loop can pass the flux. The loop array compensates the B_1 inhomogeneity by selecting the modes, considering the position of larger and smaller B_1 regions in the abdomen. *Simulation:* The effect of the B_1-control loop array was clarified with numerical analysis of the B_1 field, using an electromagnetic simulation tool (xFDTD^{TM}). The simulation model of the loop array is shown in Figure 2. A 2-channnel birdcage coil was used for RF transmission, and the RF frequency was 128 MHz. The phantom size was 350 x 200 mm (*x-y* plane). The conductivity and relative permittivity of the phantom were 0.6 S/m and 80, respectively. Twelve loops were arranged around the phantom, and each loop size was 120 x 250 mm. Six loops were used in on-mode (No. 1, 4, 5, 8, 9 and 12), and the others were used in off-mode, considering the optimal modes based on the previous study [7]. The value of B_1 homogeneity (U_{SD}) was defined as $U_{SD} = \sigma/\overline{B}_1$, where σ is the standard deviation of B_1, and $\overline{B}_1$ is the average of B_1. *Experiment:* Phantom imaging was done with a 3T MR scanner (Varian INOVA). The setup of the B_1-control loop array is shown in Figure 3. Twelve loops are made of copper tape, and each loop size was 120 x 240 mm. The phantom size was 310 x 220 mm. B_1 map was accomplished using the double-angle method. The sequence parameters were as follows: FOV = 450 mm, TR/TE = 1500/8.5 ms, matrix = 64 x 64, thickness = 10 mm and flip angle = 60, 120 degrees.

RESULTS AND DISCUSSION

The simulation results of the B_1 field in the phantom are shown in Figure 4. Case (a) represents the phantom without loop array in quadrature drive (QD) mode, and case (b) represents that in RF shimming mode, case (c) represents the phantom with loop array in QD mode, and case (d) represents that in RF shimming mode. The B_1 values were normalized with the average of B_1 in case (a). The B_1 map was the most homogeneous in case (d), in which both the B_1-control loop array and RF shimming were used. The B_1 homogeneity value (U_{SD}) for (a), (b), (c) and (d) were 0.321, 0.256, 0.277 and 0.222, respectively. U_{SD} decreases in the case (d), comparing U_{SD} in other cases. The experimental results of B_1 map in the phantom are shown in Figure 5. The values of U_{SD} for (a), (b), (c) and (d) were 0.367, 0.297, 0.316 and 0.269, respectively. The B_1-control loop array reduces B_1 inhomogeneity, and the tendency was the same as the simulation results. The averages of B_1 in all cases (a), (b), (c) and (d) were also calculated, and they were almost the same. We found that B_1-control loop array can improve B_1 homogeneity, maintaining the average of B_1.

CONCLUSION

We have proposed a new method of B_1 homogenization: using a B_1-control loop array combined with RF shimming. The results of both FDTD simulation and experiments show that the B_1-control loop array, used with RF shimming, was more effective in reducing B_1 inhomogeneity than RF shimming alone.

REFERENCES

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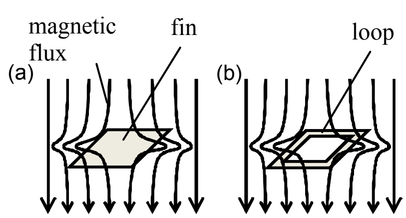

Figure 1 Magnetic flux around (a) conductive fin and (b) loop.

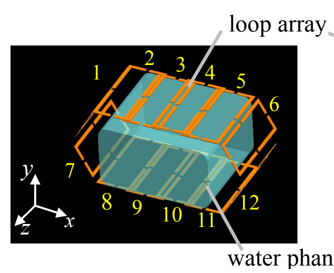

Figure 2 Simulation model of B_1-control loop array.

Figure 3 Experimental setup of B_1-control loop array.

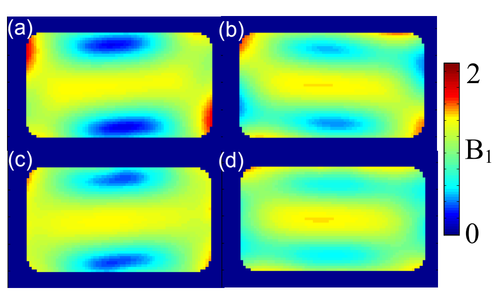

Figure 4 Simulation results with phantom. B_1 map for (a) QD alone, (b) RF shimming alone, (c) QD with loop array, and (d) RF shimming with loop array.

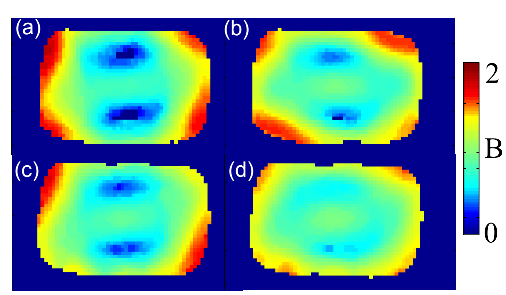

Figure 5 Experimental results with human abdomen. B_1 map for (a) QD alone, (b) RF shimming alone, (c) QD with loop array, and (d) RF shimming with loop array.