Reduction of B_1 Inhomogeneity Using B_1 Rectifying Fin at High Fields

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Introduction

B_1 inhomogeneity in a human body increases as the strength of static magnetic field increases and the RF wavelength becomes smaller. Recently, various RF control methods have been developed to reduce B_1 inhomogeneity. For example, some methods involve devices such as dielectric pads [1,2] or coupling coils [3,4], or techniques such as B_1 shimming [5,6]. However, B_1 inhomogeneity still remains in some cases of abdominal imaging, and a more effective method for reducing B_1 inhomogeneity is required. In this paper, we have proposed a new method to reduce B_1 inhomogeneity using a "B_1 rectifying fin" combined with B_1 shimming. This method can reduce B_1 inhomogeneity less than 2-port B_1 shimming used in some commercial MRI, and moreover, the fin has a simple structure with no capacitor or inductor. The effect of the fin on B_1 inhomogeneity was analyzed using both finite-difference time-domain (FDTD) simulation and experiments.

Method

Design: The fin consists of a thin sheet with conductive property. In an electromagnetic field, the fin can change the magnetic flux around it, that is, it can create high or low density of the flux. This is because an electrical current flows in a direction which counters the magnetic flux across the fin. The spatial distribution of the B_1 field can be controlled by using this phenomenon in an appropriate manner. Figure 1 illustrates an example of the B_1 rectifying fin arranged to reduce B_1 inhomogeneity. The fins around the body are arranged like a windmill, taking into consideration the phenomena of RF propagation from the RF transmit coil to the abdomen, and the position of larger and smaller B_1 regions in the abdomen. Specifically, the fins are positioned near the abdomen where the B_1 value is larger, and the edges of the fins are positioned near the region of the smaller B_1. There is no need, in principle, to use a capacitor or inductor with this method.

Simulation: The effect of the B_1 rectifying fin was confirmed through numerical analysis of the electromagnetic field. The spatial distribution of the B_1 field in the phantom was calculated using an electromagnetic simulation tool (xFDTD®). A 2-port birdcage coil was used for RF transmission, and the RF frequency was 128 MHz. The phantom size (xy plane) was 350 x 200 mm. The conductivity and relative permittivity of the phantom were 0.55 S/m and 50, respectively. Four fins were set around the phantom. In this case, the fins covered 50 % of the surface of the phantom, and the gap between the fin and the surface was 20 mm. A B_1 homogeneity value (U_{SD}) was used to evaluate B_1 inhomogeneity, and U_{SD} = standard deviation of B_1 / average of B_1.

Experiment: A human abdominal imaging experiment was conducted, using a 3T MR scanner (Varian INOVA). The B_1 rectifying fins were set around the abdomen, and the placement of the fins (coverage percentage and gap) was the same as that in the simulation case. Copper mesh sheets (0.1 mm thick) were used as the material for the B_1 rectifying fins for this experiment, and their weight was very small (~ 0.1 kg). The mesh sheets were put on a synthetic rubber sheet (20 mm thick), and the rubber sheet was set around the lower abdomen, like a torso coil. B_1 mapping was accomplished using the double-angle method in order to evaluate the effect of the fins. The sequence parameters were FOV = 450 mm, TR/TE = 5000/6.7 ms, matrix = 128 x 64, thickness = 10 mm, flip angle = 60, 120 degrees.

Results and Discussion

Figure 2 shows the simulation results of the spatial distribution of the B_1 field in the phantom. The B_1 map in case (b), with B_1 shimming alone, is more homogeneous than that in case (a), with a quadrature drive (QD). The B_1 map is the most homogeneous in case (c), in which both the B_1 rectifying fin and B_1 shimming were used. Figure 2 (d) represents the B_1 homogeneity value (U_{SD}) and the average of B_1. The B_1 average values were normalized with the value in case (a). The values of U_{SD} for (a)(b)(c) are 0.224, 0.164, and 0.126, respectively, and U_{SD} decreases when both the B_1 rectifying fin and B_1 shimming are used. The average values of B_1 for (a)(b)(c) are 1, 0.97, and 0.95, respectively, and the average of B_1 remains static. The B_1 rectifying fin doesn't reduce the average of B_1, which means that the fin has the effects of both enhancing and diminishing the magnetic flux. It was confirmed that the B_1 rectifying fin can reduce B_1 inhomogeneity, while maintaining the average value of B_1. Figure 3 shows the experimental results of the spatial distribution of B_1 in a human abdomen. The values of U_{SD} for (a)(b)(c) are 0.222, 0.168, and 0.112, and the average of B_1 for (a)(b)(c) are 1, 1.00, and 0.99, respectively. The B_1 rectifying fin can contribute to reducing B_1 inhomogeneity as shown in the simulation results. It is suggested that the B_1 rectifying fin can be useful for reducing B_1 inhomogeneity at higher magnetic field, more than 3 T.

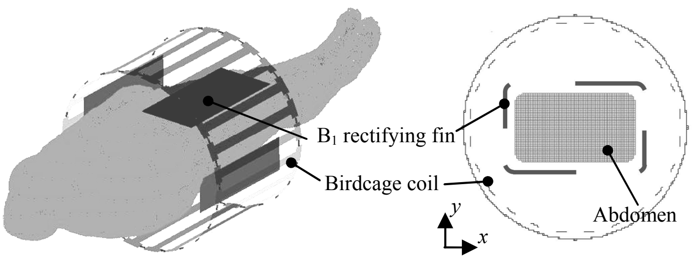

Figure 1 Schematic of B_1 rectifying fin.

Conclusion

We have proposed a new method using a B_1 rectifying fin combined with B_1 shimming. Both FDTD simulation and experiments were conducted, and we confirmed that the B_1 rectifying fin, used with B_1 shimming, was more effective in reducing B_1 inhomogeneity than B_1 shimming alone.

Reference

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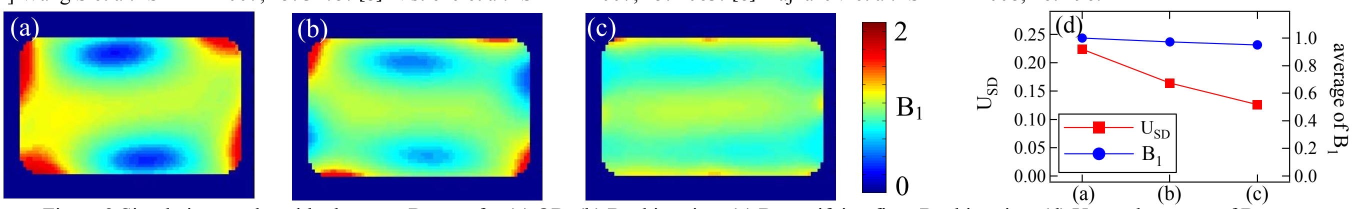

Figure 2 Simulation results with phantom. B_1 map for (a) QD, (b) B_1 shimming, (c) B_1 rectifying fin + B_1 shimming. (d) U_{SD} and average of B_1.

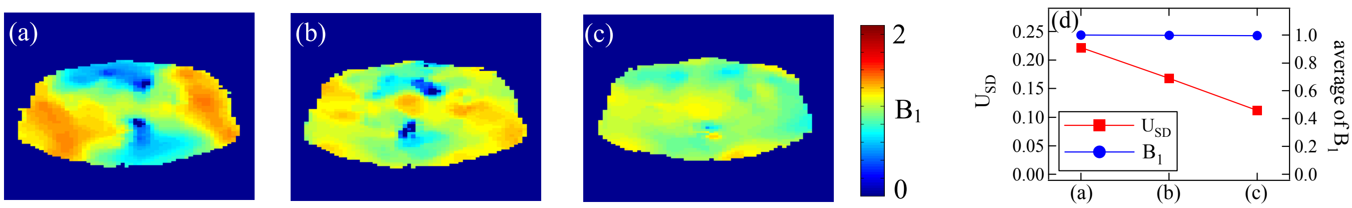

Figure 3 Experimental results with human abdomen. B_1 map for (a) QD, (b) B_1 shimming, (c) B_1 rectifying fin + B_1 shimming. (d) U_{SD} and average of B_1.