B_1 Homogenization and Local SAR Reduction Using B_1-control Receive Array Coil at 3T

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TARGET AUDIENCE RF engineers or scientists with an interest in B_1 and local SAR

INTRODUCTION

B_1 inhomogeneity in the human body increases as the strength of a static magnetic field increases. Various methods to reduce B_1 inhomogeneity such as dielectric pads [1,2], coupling coils [3-9], and RF shimming [10,11], have recently been developed. However, B_1 inhomogeneity still remains in some cases of abdominal imaging; for example, it remains around the periphery of the abdomen in a large body. A more effective method for reducing B_1 inhomogeneity is required. Our previous study showed that a "B_1-control receive array coil (BRAC)" can control the B_1 field locally; the BRAC improved B_1 inhomogeneity in a phantom experiment [12]. However the effect of BRAC on the human body has not been shown, and it is therefore important to investigate how BRAC affects local SAR in the body. In this study, the BRAC around a human model was designed in an FDTD simulator, and the B_1 field and local SAR field were calculated. It was confirmed that the BRAC can reduce B_1 inhomogeneity and maximum local SAR in the human body.

METHOD

Principle: The magnetic flux around a conductive loop is shown schematically in Figure 1. The loop, whose resonance frequency is sufficiently lower than the transmit RF frequency, exhibits inductive characteristics (inductive mode). The flux density decreases around the center of the loop and increases near the edge of the loop. The spatial distribution of the flux density around the loop can compensate the B_1 inhomogeneity. A circuit schematic of a receive coil with a BRAC is shown in Figure 2. Compared to a traditional receive array coil, additional PIN diodes (D_I) are connected in parallel to the capacitors of the BRAC. The traditional coil only has a detuning mode during the RF transmit period. On the contrary, the BRAC has both detuning and inductive modes, and the two modes can be switched. A schematic of the 12-channel BRAC is shown in Figure 3. Six loops were used in the inductive mode (No. 1,4,5,8,9,and 12), and the others were used in the detuning mode. This combination was optimized in a previous study [12,13]. *Simulation*: The effect of the BRAC was clarified through numerical analysis of the B_1 and local SAR field using an electromagnetic simulation tool (CST Microwave Studio™). The simulation model is shown in Fig. 3. A 2-channnel birdcage coil was used for RF transmission, and the RF frequency was 127.8 MHz. The diameter of the birdcage coil was 700 mm, and the length of the rungs was 520 mm. Hugo (height: 180 cm, weight: 90.3 kg) was used as a human model. The arms of Hugo were repositioned from the side of the body to above the head, as in Fig. 3. The landmark position was set at the pelvis in the z-direction. Each loop was made of a copper sheet, and the loop size was 240 x 120 mm. 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 in an axial slice at z = 0 mm. The maximum local SAR was defined as the maximum value of 10g SAR in the body. RF transmission mode was quadrature (QD) drive or 2ch RF shimming, and U_{SD} or the maximum local SAR was minimized in RF shimming.

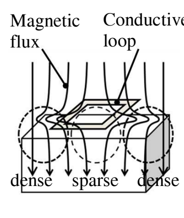

Fig.1: Magnetic flux around a conductive loop.

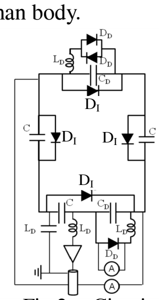

Fig.2: Circuit of BRAC.

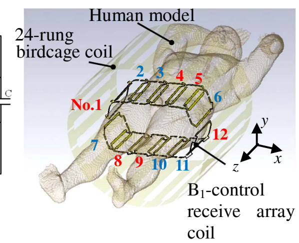

Fig.3: Schematic of 12-channel BRAC.

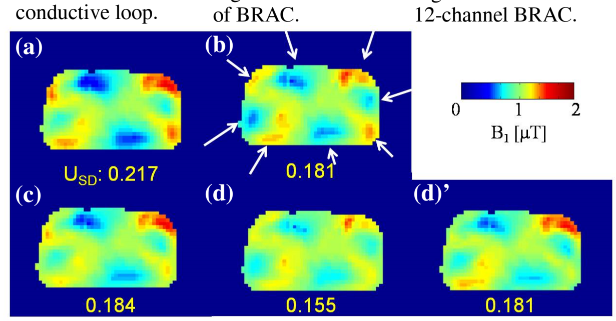

Fig.4: B_1 maps in the human model: (a) B_1 map obtained without BRAC in QD drive (b) B_1 map obtained without BRAC in RF shimming (minimization of U_{SD}) (c) B_1 map obtained with BRAC in QD drive (d) B_1 map obtained with BRAC in RF shimming (minimization of U_{SD}) (d)' B_1 map obtained with BRAC in RF shimming (minimization of maximum local SAR, maintaining U_{SD} in case (b)).

RESULTS AND DISCUSSION

The B_1 maps and the values of U_{SD} in the human model are shown in Figure 4. Case (a) represents the B_1 map obtained without BRAC in QD drive; case (b) represents that obtained without BRAC in RF shimming (minimization of U_{SD}); case (c) represents that obtained with BRAC in QD drive; case (d) represents that obtained with BRAC in RF shimming (minimization of U_{SD}); and (d)' represents that obtained with BRAC in RF shimming (minimization of maximum local SAR, maintaining U_{SD} in case (b)). The $\overline{B}_1$ was normalized to 1 μT. B_1 inhomogeneity remains around the periphery of the pelvis in case (b), in which RF shimming alone was used. The B_1 map is the most homogeneous in case (d), in which both RF shimming and the BRAC were used. The U_{SD} tendency is the same as in the previous phantom results [12]. The local SAR maps are shown in Figure 5. Each map shows an axial slice that includes the maximum local SAR position. The values of the maximum local SAR in cases (a), (b), (c), and (d) are almost the same, and it is shown that the maximum local SAR does not increase when the BRAC is used. The maximum local SAR is the smallest in case (d)', in which both RF shimming and the BRAC were used. The relationship between U_{SD} and maximum local SAR is shown in Figure 6. The data points shown in the figure were obtained by varying the differences of the amplitude/phase between channels 1 and 2 in steps of 1dB/10deg. The points representing the case when the BRAC was used are shifted to the left side, which means that the BRAC reduces the U_{SD} around the various parameters. The BRAC can reduce B_1 inhomogeneity by 15 %, maintaining the maximum local SAR in the case of RF shimming alone. The BRAC can reduce the maximum local SAR by 20 %, maintaining B_1 inhomogeneity in the case of RF shimming alone. The technique of the local SAR management in MR scanner has been studied [14], and it was found that reduction of the local SAR in actual human body imaging can be achieved by applying the technique combined with the BRAC. Note that the simulation was conducted at 127.8 MHz (3T); however, the BRAC can be applied to a higher magnetic field, for example 7T.

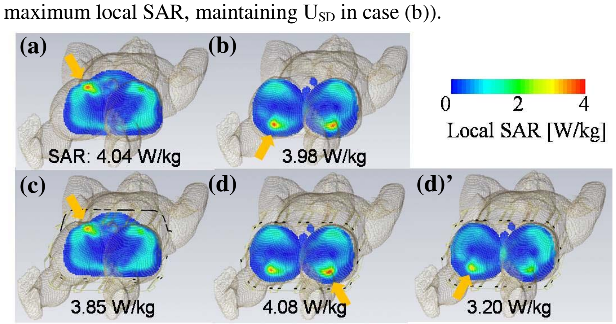

Fig.5: local SAR maps in the human model.

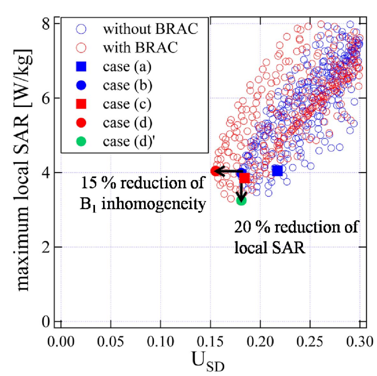

Fig.6: The relationship between U_{SD} and maximum local SAR.

CONCLUSION

It is shown that a B_1-control receive array coil (BRAC), which has an inductive mode during RF transmission, can reduce B_1 inhomogeneity and local SAR in a human body. Using the BRAC with RF shimming is more effective in reducing B_1 inhomogeneity and local SAR than using RF shimming alone.

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