B_1-control Receive Array Coil for Abdominal Imaging

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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. A more effective method for reducing B_1 inhomogeneity is thus required. Our previous study showed that a B_1-rectifying fin and a B_1-control loop array can control the B_1 field locally [12,13]. However, additional space around the abdomen is needed to install both a receive array coil and the B_1-control loop array. To solve that problem, in this study, the B_1-control loop (BCL) was combined with the receive array coil by using PIN diodes for generating the B_1-control loop during the RF transmit period. We fabricated a 12-channel "B_1-control receive array coil" and confirmed both its receive sensitivity and its effect of B_1 homogenization experimentally.

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 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 can compensate the B_1 inhomogeneity. A circuit schematic of a receive coil with a BCL 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 coil with the BCL. The traditional coil only has detuning mode during the RF transmit period; on the contrary, the coil with BCL has both detuning mode and inductive mode. The two modes can be switched according to current source A or B (Fig. 2). A cross-sectional diagram of the 12-channel receive coil with BCL is shown in Figure 3. Six loops were used in inductive mode (No. 1, 4, 5, 8, 9, and 12), and the others were used in detuning mode. This combination was optimized by FDTD simulation in a previous study [12,13]. *Coil*: The setup of the 12-channel receive coil with BCL is shown in Figure 4. Each loop is made of copper tape and has a size of 220×115 mm. The coil has a partially overlapped loop arrangement and low-input impedance preamps for decoupling coils. The upper and lower 6-channel coils were housed in an acrylic structure with inner size of 450×240 mm (*x*-*y* plane). *Experiment:* Q values of coils were measured with a network analyzer. Phantom imaging was done with a 3T (f_0=127.8 MHz) MR scanner (Varian INOVA) for measuring SNR (Signal to Noise Ratio). In consideration of abdominal imaging, the phantom size was set to 350×180 mm (*x*-*y* plane). The gradient-echo sequence parameters were as follows: FOV = 500 mm, TR/TE = 1000/7 ms, matrix = 128 x 128, thickness = 5 mm, and flip angle = 30 degrees. SNR was calculated using the signal from the region of interest (ROI: 90% area of the phantom) and the noise outside the ROI. A B_1 map was measured by using the double-angle method. The gradient-echo sequence parameters were as follows: FOV = 500 mm, TR/TE = 1500/7 ms, matrix = 64 x 64, thickness = 10 mm, and flip angle = 60 and 120 degrees. The value of B_1 homogeneity (U_{SD}) was defined as $U_{SD} = \sigma/\bar{B}_1$, where σ is the standard deviation of B_1, and $\bar{B}_1$ is the average of B_1. A two-channel birdcage coil was used for RF transmission by quadrature (QD) drive and 2ch RF shimming.

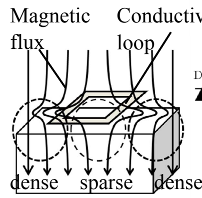

Fig.1: Magnetic flux around a conductive loop.

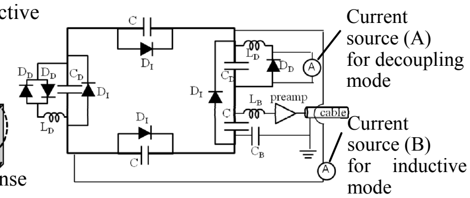

Fig.2: Circuit of a receive coil with BCL.

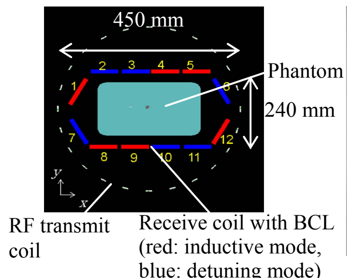

Fig.3: Mode of each coil during transmit period

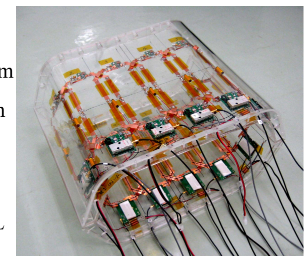

Fig.4: 12-channel B_1-control receive array coil

RESULTS AND DISCUSSION

The unloaded and loaded Q values (Q_{UNLOAD}/Q_{LOAD}) of the 12-channel receive coil without D_Is (traditional coil) were 79.3/14.2, and those of the coil with BCL were 76.3/13.9. The Q values of the coil with BCL are slightly decreased by adding PIN diodes, but this addition has little effect on the receive sensitivity because the loss of the load is dominant. Phantom images from the traditional coil and the coil with BCL are shown in Figure 5. The images from the individual channel are shown in Fig. 5(a), and the composite images from all channels of the traditional coil or the coil with BCL are shown in Figs. 5 (b) and (c). SNR in the case of the traditional coil was 267, and that in the case of the coil with BCL was 264. These results show that the receive sensitivity of the traditional coil and the coil with BCL are almost the same. The B_1 maps in the phantom are shown in Figure 6. Image (a) shows the B_1 map obtained without BCL in QD drive; image (b) shows that obtained without BCL in RF shimming; image (c) shows that obtained with BCL in QD drive; and image (d) shows that obtained with BCL in RF shimming. The B_1 values were normalized with the average of B_1 in (a). The B_1 map is the most homogeneous in image (d), in which both RF shimming and the coil with BCL were used. The B_1 homogeneity value (U_{SD}) for images (a), (b), (c), and (d) are 0.302, 0.228, 0.210, and 0.173, respectively. Comparing U_{SD} in the other cases, U_{SD} decreases in image (d). The receive array coil with BCL reduces B_1 inhomogeneity, and the U_{SD} tendency is the same as the previous simulation results [13]. These results show that the coil with BCL can improve B_1 homogeneity, while maintaining receive sensitivity. Note that the experiment was conducted using 3T MR scanner; however, the B_1-control receive array coil can be applied to a higher magnetic field, for example 7T.

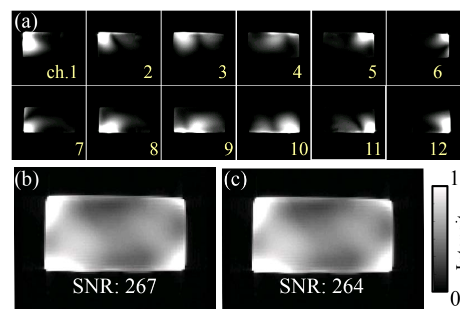

Fig.5: Phantom images: (a) Images from each channel of the coil with BCL, (b) composite image from traditional receive coil, and (c) composite image from the coil with BCL.

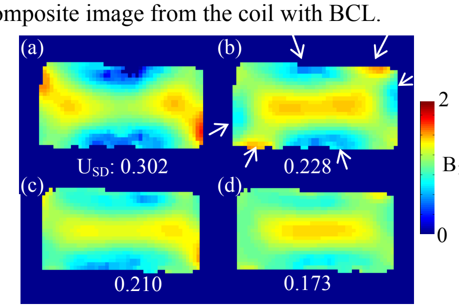

Fig.6: B_1 maps in phantom. (a) QD drive alone, (b) RF shimming alone, (c) QD drive combined with BCL, and (d) RF shimming combined with BCL.

CONCLUSION

A B_1-control receive array coil using PIN diodes for generating an inductive loop was developed. The results of phantom imaging show that a B_1-control receive-array coil can improve B_1 inhomogeneity, while maintaining receive sensitivity. Moreover, using the coil with RF shimming was more effective in reducing B_1 inhomogeneity than using RF shimming alone.

REFERENCES

[1] Schmitt M et al. ISMRM 2004; 11: 197. [2] Kendra MF et al. J Magn Reson Imaging 2008; 27: 1443-1447. [3] Schmitt M et al. ISMRM 2005; 13: 331. [4] Wang S et al. ISMRM 2007; 15: 3275. [5] Wiggins GC et al. ISMRM 2007; 15: 1054. [6] Wang S et al. IEEE Trans Med Imag 2010; 28: 551. [7] Sacolick L et al. ISMRM 2010; 18: 3809. [8] Hancu I et al. ISMRM 2010; 18: 2470. [9] Merkle H et al. MRM 2011; 66: 901. [10] Nistler J et al. ISMRM 2007; 15: 1063. [11] Hajnal JV et al. ISMRM 2008; 16: 496. [12] Kaneko Y et al. ISMRM 2010; 18: 3810. [13] Kaneko Y.et al. ISMRM 2011; 19: 3837.