# *Small Animal MR Imaging using a 3.0 Tesla Whole Body Scanner: Rapid $B_1^+$ Field Mapping for Quantitative MRI*

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***Introduction***: *In vivo* MRI for small animal models is an important technique in biology because MRI parameters ($T_1$, $T_2$, proton density, ADC etc.) can act as markers of biological activities. To minimize errors in the quantitative assessment of these MRI parameters, the homogeneity of the $B_1^+$ field is critical. We perform small animal MRI using a combination of a 3.0 Tesla whole body scanner and a small solenoid coil, because this MRI system is advantageous for translational research. Previous studies have demonstrated the usefulness of a whole body scanner for small animal imaging [1]; however, *in vivo* $B_1^+$ mapping in small animal organs has never been performed. This is partly due to the long acquisition time when the conventional double angle method (DAM) is used [2, 3] (approximately 7 hours for the mouse brain with a $T_1$ of 1.5 s at 3 T).

In this study, we evaluated rapid $B_1^+$ field mapping using a 3D-spoiled gradient echo (SPGR) sequence reported by Dowell et al. [4] with minor modifications to investigate the homogeneity of $B_1^+$ in the mouse brain.

***Materials and Methods***: All images were acquired with a 3.0 Tesla whole body scanner (Signa HDx, GE Healthcare, Milwaukee, WI) equipped with a receiver coil dedicated for the small animal use (3-turn solenoid type; 35 mm in diameter) or an 8-channel brain coil for humans. To investigate $B_1^+$ inhomogeneity, a spherical phantom filled with 98 % water (16 cm in diameter, $T_1 \fallingdotseq 350$ ms (MRS SPHERE, GE Healthcare, Milwaukee, WI)), a bottle phantom filled with 14 mM nickel chloride ($NiCl_2$) solution (23 mm in diameter, $T_1 \fallingdotseq 120$ ms), and seven male ddY mice were used. Using a previously reported 3D-SPGR sequence (TR/TE = 35/10 ms; 128 x 128 matrix; FOV/THK = 240/7 mm, 80/2 mm and 50/2 mm in the water, $NiCl_2$ phantoms and the mouse brain, respectively; and 28 slices), five sets of image data were obtained using flip angles (FAs) of 140°, 160°, 180°, 200°, and 220° (in this range of FA, the signal intensity and FA show a quasi-linear relationship in SPGR sequences [4]). Since slice profile effects induce errors in estimating $B_1^+$, no slab select gradient was applied. The total acquisition time was 9 min 15 s, 6 min 15 s and 12 min 15 s in the water, $NiCl_2$ phantoms and the mouse brain, respectively.

Using the data set, the FA that provided a null signal ($FA_{null}$) was calculated on the pixel-by-pixel basis using in-house built software as follows: 1. Signal intensities were plotted as a function of FA; 2. A v-shape line was drawn using the least square method; 3. $FA_{null}$ was determined as the FA that provides the minimum value on the v-shape line (Fig.1); Finally, FA scale factors were calculated by dividing 180° by $FA_{null}$ [4].

FA scale factor maps from the phantom were compared with $B_1^+$ maps obtained by the conventional DAM using a 3D-gradient echo (GRE) sequence (FA = 30/60°; TR/TE = 1750/10 ms and 600/10 ms in the water and the $NiCl_2$ phantoms, respectively; and the total acquisition times were 41 min 06 s and 179 min 28 s, respectively) to confirm that both maps were comparable. After good correspondence was demonstrated, FA scale factor maps for the mouse brain were obtained using the 3D-SPGR sequence mentioned above.

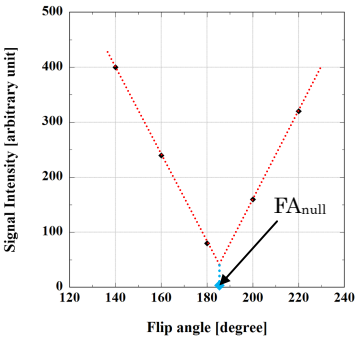


Fig.1 explains how to determine $FA_{null}$ in this study. $FA_{null}$ is the FA value that gives the minimum on the v-shape line (arrow). In this case, $FA_{null}$ is equal to 185°.

***Results and Discussion***: $B_1^+$ maps acquired by DAM and FA scale factor maps were comparable in the 14 mM $NiCl_2$ solution phantom and 98 % water phantom (Fig.2); in other words, FA scale factor maps accurately depict $B_1^+$ distribution. The FA scale factors were 1.005 ± 0.008 and 1.020 ± 0.090 (mean ± 1SD) in the $NiCl_2$ phantom and the mouse brain, respectively. The coefficient of variance (100 x 1SD / mean) of the FA scale factors were 1.83 ± 0.37 and 3.33 ± 1.11, respectively. These data indicated a homogeneous $B_1^+$ field in our MRI system for animals. This was probably due to our use of animals with a smaller size than the RF wavelength (26 cm in water at 3 T) and the fact that we performed the RF transmission using a larger body coil than the target object. The high SNR of our solenoid coil permitted accurate v-shape line fitting without critical errors even in the relatively low signal range around an FA of 180° [4].

***Conclusions***: We demonstrated the production of a homogeneous $B_1^+$ field in the mouse brain using a combination of a 3.0 T whole body scanner and a small solenoid coil using rapid $B_1^+$ field mapping. We believe that the homogeneous $B_1^+$ field observed in our small animal MRI would allow sufficiently accurate measurement for quantitative MRI.

***References***: [1] MRM; 49; 551-557, [2] MRM; 53; 408-417, [3] JMR; Series A 103; 82-85, [4] MRM; 58; 622-630

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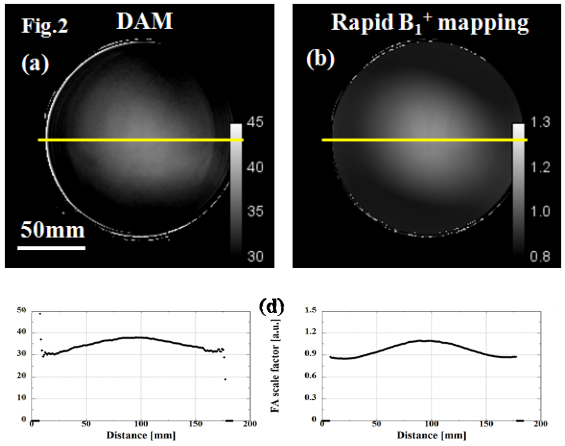


Fig.2 (a) and (b) show a $B_1^+$ map acquired by DAM and an FA scale factor map of a 98 % water phantom, respectively. Fig.2 (c) and (d) show that the profiles of these two maps along the yellow lines have comparable $B_1^+$ distributions.

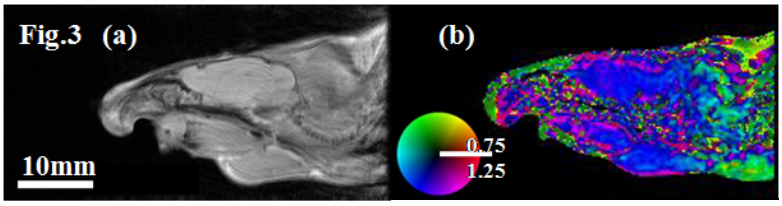


Fig.3 (a) and (b) show a 2D-SE image (TR/TE = 3000/11 ms) and an FA scale factor map of the mouse brain, respectively. On the FA scale factor map, the $B_1^+$ distribution in the mouse brain is homogeneous. In this case, the FA scale factor is approximately 1.1 (colored purple).