Correction Accuracy in B1 measurement for high field Image Intensity Correction

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[Introduction]

MR imaging with phased array receive coils became available at 3T and higher field strengths. In lower field strength systems, uniformity correction methods using body coil image as homogeneous reference image are widely used, but this correction method does not perform well at high field because of dielectric effect. To correct for image non-uniformity caused by dielectric effect, in-vivo B1 mapping-based image correction methods were recently presented [1-2]. The B1 field or flip angle (FA) field map may be perturbed due to various reasons including susceptibility artifact, tissue relaxation parameters, etc.. To reduce the sensitivity to these measurement errors, a simulation analysis was performed to characterize noise variation in the B1 map. Then a novel B1 field estimation and filtering method was proposed based on the simulation results.

[Materials and Methods]

To measure the B1 field spatial distribution, calibration images with two different FAs (using FGRE) were acquired with body coil[3-4] and surface coil reference scan with same FA was acquired to measure coil receive sensitivity. When the FA of α degree and $\alpha/2$ degree were used in the calibration scan, one can estimate FA spatial distribution from the following simple equation:

$$\theta(x,y) = 2\cos^{-1}\left(\frac{I_\alpha(x,y)}{2I_{\alpha/2}(x,y)}\right)$$

where θ(x,y) is the measured FA at each location (x,y). Surface coil image inhomogeneity can be corrected by using the following formula:

$$I_{corrected}(x,y) = I_{acquired}(x,y) \times f(x,y) / s(x,y)$$

where f(x,y) is the function to correct transmit field uniformity and s(x,y) is the coil sensitivity spatial distribution function estimated from surface coil reference and body coil reference image. Transmit field correction function f(x,y) can be calculated from the estimated flip angle map to correct image intensity of spin echo or gradient echo images [1,3].

$$f(x,y) = \frac{\alpha}{\theta(x,y)\sin^3\left(\dfrac{\pi}{2}\dfrac{\theta(x,y)}{\alpha}\right)} \qquad f(x,y) = \frac{\alpha\sin(\beta)}{\theta(x,y)\sin\left(\beta\dfrac{\theta(x,y)}{\alpha}\right)}$$

Here β is the FA of the acquired image to be corrected by this method. The noise in calibration image may distort the correction function. The variance of the transmit field correction function can be evaluated by the following equation:

$$\sigma_f^2 = \left(\frac{\partial f(x,y)}{\partial I_\alpha}\right)^2 \sigma_{I_\alpha}^2 + \left(\frac{\partial f(x,y)}{\partial I_{\alpha/2}}\right)^2 \sigma_{I_{\alpha/2}}^2$$

By using this equation, one can estimate the expected signal standard deviation of the transmit field correction function from image noise standard deviation. To improve the robustness of the intensity correction method, an appropriate threshold was set to avoid the noise sensitive area in the B1 map, where the correction function f(x,y) has large standard deviation, σ_f. Then the signal less than the threshold in B1 map was cut and the transmit correction map was extrapolated with 2nd order polynomial fit to fill the area cut-out. To verify the correction accuracy improvement, volunteer experiments were performed on a 3T MRI scanner (SIGNA EXCITE, GE Healthcare) with 8-ch phased array head coil. Reference slice location was prescribed to cover the whole imaging region.

[Results and Discussion]

Figure1 shows the standard deviation of the transmit field correction function for spin echo acquisition as a function of the estimated flip angle. Figure.1(a) shows the dependency of the correction function on the calibration scan SNR at the 60 degree calibration scan flip angle. σ_f value at SNR of 200, 400 and 800 were simulated. As SNR increased, the standard deviation σ_f decreased significantly when measured flip angle is far from calibration scan flip angle. Signal error could reach to factor of two if flip angle drop is 20 degrees by dielectric effect. Figure1(b) shows the dependency of the correction function on calibration scan flip angles of 50, 60 and 70 degrees, respectively. Reliable flip angle range increases when the flip angle of calibration scan increases. These results suggest that reliable flip angle measurement can be achieved when the measured flip angle is around the prescribed flip angle of calibration scan with high SNR calibration scan. Figure 2 shows the correction result of a T1-weighted image acquired with 8ch phased array coil at 3T. The high intensity bright signal spot appeared at the location where B1 value was not measured properly due to susceptibility artifact in calibration scan. After applying the proposed method to this image, we could successfully remove the unreliable flip angle measurement and could get the accurate correction function. The proposed method reduced the hot spot like artifact effectively, and we could get a homogeneous image.

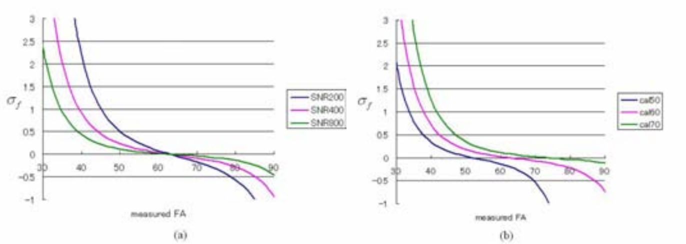

Figure.1 Signal characteristics in the transmit field correction function. (a) the correction function dependency to calibration scan SNR, calib. Scan FA=60degree (b) the correction function dependency to calibration scan flip angle at SNR=500.

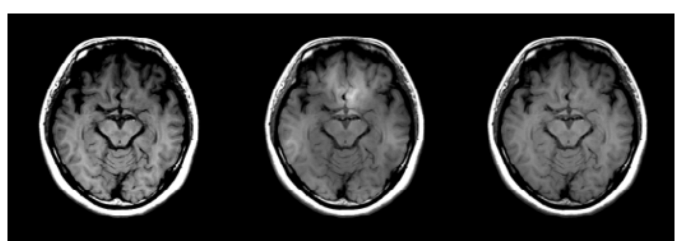

Figure 2 image correction result. Left : original image. Middle: transmit field correction without filtering. Right:corrected image by proposed method.

[Conclusion]

In this study we investigated the correction reliability in flip angle distribution measurement using double flip angle method. The proposed method effectively suppressed hot spot artifact caused by B1 measurement inaccuracy. The results also suggest that reliable flip angle measurement can be achieved when the measured flip angle is around the prescribed flip angle of calibration scan with high SNR calibration scan

[Reference]

[1] Guclu et al, ISMRM 2005, abs#846 [2] Wang et al, MRM 53:408-417 (2005) [3] H.Mihara et.al, MAGMA 7, 115-120 [4] Stollberger et al. MRM 35:246-251 (1996)