A Novel Method of Flip Angle Mapping and Calibration

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Introduction and Purpose

The Double-Angle Method [1] is often used to obtain flip angle maps for the purpose of either calibration or intensity correction. In the case of in-vivo calibration, the number of images per TR maybe limited by SAR leading to scan time increase. In this work, we present a method for mapping the flip-angle using arbitrary set of flip angle (θ-$\alpha\theta$) rather than θ-2θ pair, where $\alpha<2$ and $\theta \leq 100°$.

Theory and Methods

Provided TR >> T1 and assuming there are no diffusion or flow effects, signal from a gradient-echo pulse sequence is proportional to $\sin(\theta)$ where θ is the flip angle of the excitation RF pulse. Let S_1 and S_2 be the images acquired with flip-angles θ and 2θ, respectively. In this case there is closed form expression $\theta = a\cos(S_2/2S_1)$ to calculate the flip-angle map as proposed by Strollberger at al [1]. In some cases, doubling the θ value may require an inconveniently large range of RF peak power. For an arbitrary flip-angle ratio $R = \sin(\alpha\theta)/\sin(\theta)$, another approach is to expand R using Taylor series (accurate to within about 2.5% for $\theta \leq 100°$) such as:

$$R=\frac{\sin(\alpha\theta_i)}{\sin(\theta_i)}\approx\alpha+\left(\frac{\alpha-\alpha^3}{6}\right)\theta_i^2+\left(\frac{3\alpha^5+7\alpha-10\alpha^3}{360}\right)\theta_i^4$$

. Solving this equation for θ, results in the expression:

$$\theta=\sqrt{\left[6\cdot\frac{\left(5\cdot\alpha^3-5\cdot\alpha-\sqrt{-5\cdot\alpha^6+50\cdot\alpha^4-45\cdot\alpha^2+30\cdot\alpha^5\cdot R+70\cdot\alpha\cdot R-100\cdot\alpha^3\cdot R}\right)}{\left[\alpha\cdot\left(3\cdot\alpha^4+7-10\cdot\alpha^2\right)\right]}\right]}.$$

Using this expression we used double-angle-method with compensation pulse[1], and this novel method to compare the results on a phantom and a volunteer. The results were shown to be similar with negligible error. All images were acquired on a GE Healthcare 1.5T Excite 3 system using parameters: FGRE, TR=150ms, TE=2.2ms, 128x128 matrix, 40cm FOV, 10mm slice thickness, body coil T/R, 27cm diameter 14mM NiCl phantom.

Results

The AFA (arbitrary flip angle) method was tested at both 1.5T and 3.0T with various flip angles. Figure 1 shows two cases comparing the double-angle method with the AFA method. The first set of images was acquired using 30 and 60, whereas the second set was acquired with 30 and 50. In the first set (upper), both methods yield the same result with a maximum error of 0.02 degree. However in the second set (lower), only AFA yields the correct result.

Conclusion

We proposed a method to calculate flip-angle maps using arbitrary flip angles, as opposed to traditional double-angle method. The results show that it is possible to obtain in-vivo flip-angle maps within a short time with reasonable accuracy. This technique can be used for either as an intensity calibration scan by minimizing the power deposition in the tissue or in correction methods to reduce the dielectric effect.

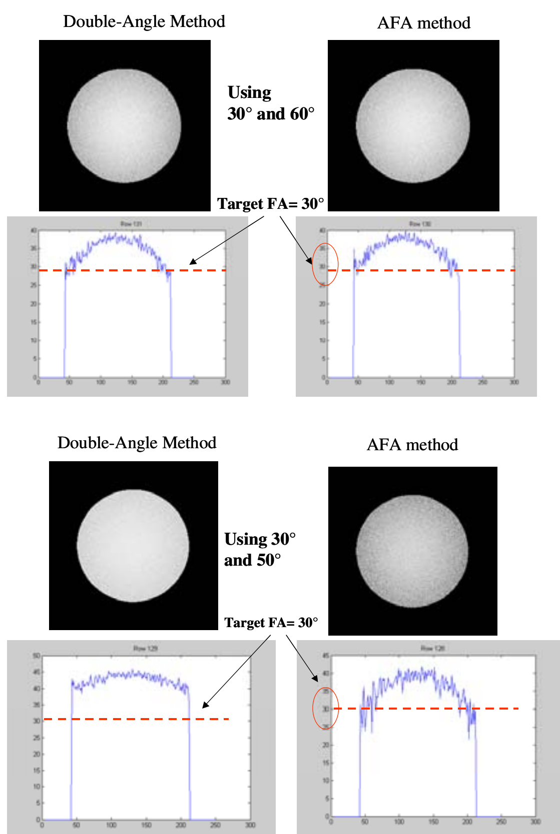

Figure 1: 30/60 degrees (upper), and 50/30 degrees (lower).
The max error for the 30/60 case was 0.02 degree in an ROI of 3228 pixels.

References:

1. Strollberger R and Wach P. MRM 35:246-251 (1996).