Feasibility of Rapid B1 Mapping with RF Prepulse Tagging

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Introduction

Measurement of the B1 transmit distribution is important for tasks such as RF coil development, SAR analysis, multiple-transmit coil applications, and general analysis of image quality or artifacts [1]. On high-field human MR, the B1 field patterns depend greatly upon the sample, not just upon coil design. Therefore, it is ideal to measure the B1 field per subject. For these reasons, we desire a B1 mapping technique which is fast and tolerant of patient motion. In this work, we propose an accurate and efficient method of 2-D B1 mapping with RF prepulse tagging.

B1 Mapping Technique

The SPAMM prepulse is well known for cardiac tagging applications, but it can also be used to measure transmit B1 fields [2]. A SPAMM sequence with two RF pulses spatially modulates the z component of the magnetization [3]: $M_z(r)= -M_0[\sin\theta_1\sin\theta_2\cos\phi(r) -\cos\theta_1\cos\theta_2]$. Here θ_1 and θ_2 are flip angles of the first and the second RF pulses, M_0 is the initial equilibrium magnetization, $\phi(r)$ is the spatially dependent phase introduced by the tagging gradient between the two RF pulses, and r is the spatial variable along the gradient direction. The cosine modulation of the z component of the magnetization leads to periodic intensity variations in the r direction. Setting $\theta_1=\theta_2=\theta$, then $M_z(r)=M_0[\cos^2\theta-\sin^2\theta\cos\phi(r)]$. M_z has a minimum of $M_{z,min}(r)=M_0\cos2\theta$ when $\cos[\phi(r)]=1$, and a maximum $M_{z,max}(r)=M_0$ when $\cos[\phi(r)]= -1$. For $\theta<45°$, we define a tagging factor $\tau= M_{z,min}(r)/M_{z,max}(r)= \cos2\theta$. Measuring the local minimum and maximum pixel intensity in the tagged image, τ is calculated and θ is then determined. The approximate B1 distribution is estimated from corresponding θ.

Since minimum and maximum intensities come from different pixels, the B1 calculated by this method represents the local neighborhood of consecutive minimum and maximum pixels, not an independent B1 measurement at each acquired image pixel. The designer has a choice of the spatial period between maxima of the sinusoidal pixel modulation; the maxima cannot be so far apart that the local neighborhood is too large and the B1 map is not precise, yet not too small so the measurement of peak and trough amplitudes is unreliable and sensitive to underlying pixel variations from native image contrast. In our simulations using a matrix = 250×250, we chose a period size of 6 pixels to balance these effects.

Simulations Results and Discussion

Simulations were performed to validate the method. First, a normalized artificial B1 field distribution $B1_{scale}(n_x)=(n_x-125)^2/250^2+0.75$ is superimposed onto a uniform 250×250 image (Figure 1a), where n_x is the pixel number along the x direction. The non-uniform image is then tagged with a prepulse with RF pulses of flip angle $\theta = B1_{scale}*45°$ (Figure 1b). The B1 field distribution is then estimated with the method described above. Figure 1c shows the assumed B1 field distribution and the calculated B1 field distribution along one pixel row in the x direction, located at the line in Figure 1b. Figure 1d shows a calculated 2D map of the B1 field over the whole image. The black areas inside the brain represent pixels where the signal intensity has a large fluctuation and the B1 value cannot be estimated. It can be seen that the resulting B1 map agrees well with the assumed distribution, despite pixel variations due to anatomy.

A second Monte Carlo simulation was performed to study the precision of the algorithm in the presence of noise. Estimated B1 with additive random pixel noise give least absolute error and least relative error for RF flip angles near 50° (Figure 2). For $\theta < 45°$, it is practical to simply detect extrema, as described above. Larger flip angles in combination with magnitude image reconstruction generate more complicated tagging patterns, and require a more sophisticated fitting to extract the tip angle, including convolution of the tagging profile with the pixel point spread spatial distribution. One intended application of this technique, when the proposed prepulse and analysis methods are combined with true single-shot imaging, is detection of changes in B1 fields from patient physiological motion.

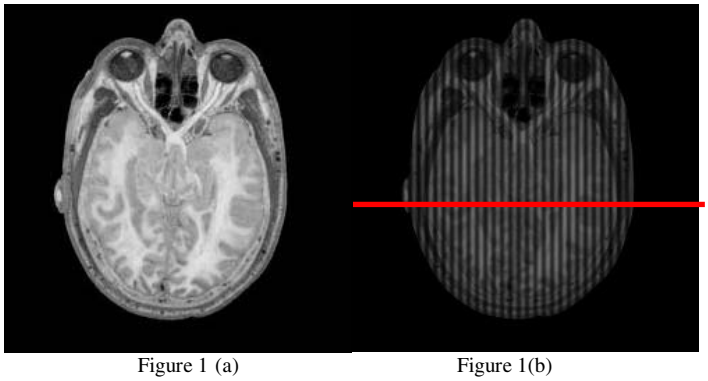

Figure 1 (a)

Figure 1(b)

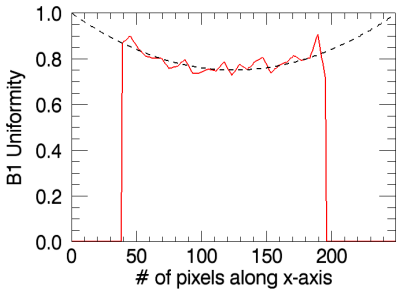

Figure 1 (c)

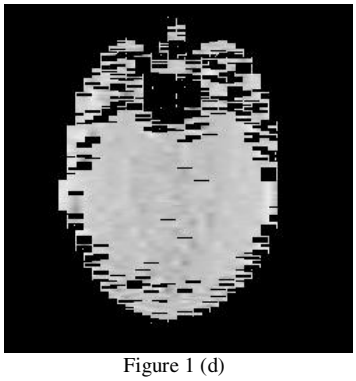

Figure 1 (d)

Figure 1(a) the original image
Figure 1(b) the tagged non-uniform image, red line shows location of data for Fig1(c)
Figure 1(c) calculated (red) and assumed B1 distribution (black)
Figure 1(d) simulated 2D B1 map over the whole image

Figure 2: The absolute errors and the relative errors for different tagging flip angles from this technique. Monte Carlo simulations used noise with a standard deviation equal to 1% of the untagged signal.

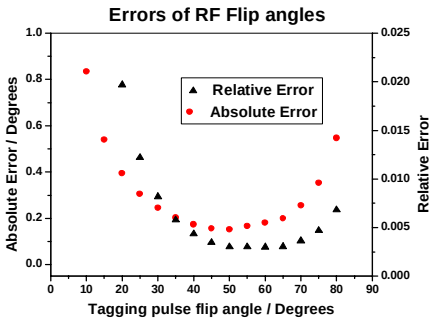

Figure 2

References:

[1] Jiru F and Klose U, MRM vol 56: 1375-1379 (2006) [2] Axel L, Dougherty L, Radiology 1989, vol 171:841-845. [3] Bernstein MA, King KF and Zhou XJ, Handbook of MRI Pulse Sequences, Elsevier Academic Press, 2004