Simulation and Comparison of B1+ Mapping Methods at 3T

C. T. Sica[1], Z. Cao[1], S. Oh[1], and C. M. Collins[1]
[1]Penn State College of Medicine, Hershey, PA, United States

Introduction: Inhomogeneity of the applied RF field is a significant factor that affects the quality of MR imaging and parametric mapping at field strengths of 3T and higher. Compensation methods for RF inhomogeneity typically require accurate B1+ maps for optimum performance. Recent work at 7T [1] indicates significant deviations between 3 mapping methods selectively studied: the AFI method [2], double angle method, and a GRE series method [3] utilizing multiple flip angles. A potential limitation of this approach is the need to assume one of the experimental methods is the gold standard, with no knowledge of the true $B1^+$ field distribution. The goal of this study is to accurately simulate the AFI method and GRE series method at 3T, utilizing an MRI simulator [4] and electromagnetic field simulations. The simulation maps are compared to the input $B1^+$ field distribution and to experimental results acquired under similar conditions.

Methods: Simulation: Electromagnetic field simulations were performed with xFDTD (Remcom, Inc), utilizing realistic models of the 3T Siemens Trio body coil and Siemens bottle phantom. The fields from xFDTD served as the input complex $B1^+$ fields to a MRI simulator. B0 maps, T1, and T2 of the Siemens bottle phantom were measured experimentally and provided as inputs to the MRI simulator. The AFI mapping method and GRE series method were implemented within the Siemens programming environment and exported to the MRI simulator. All MRI simulations were performed upon a single 2D coronal plane of the bottle phantom, permitting usage of non-selective RF pulses. AFI was simulated with TR1/TR2 = 12/60 ms, 256x256 mm FOV, 64x64 matrix, 60° flip angle, and adjustable spoiling of the transverse magnetization at the end of each TR. The GRE series method consisted of GRE scans with TR 400 ms, TE 2 ms, 256x256 mm FOV, 64x64 matrix, and flip angles of 10,20,40,60,80,100,120,140,160,180 degrees. A least squares fitting routine was utilized on a pixel by pixel basis to fit $\beta\sin(\lambda\alpha)$ to the flip angle intensity curve. Experiment: B1+ mapping scans were performed with a 3T Siemens Trio and a Siemens bottle phantom. Transmission and reception utilized the Trio body coil. The 3D AFI sequence was utilized (TR1/TR2 = 12/60 ms, 256x256x256 mm FOV, 64x64x64 matrix, non-selective excitation, 60° flip angle, gradient and RF spoiling as described in [5]). The GRE series method consisted of 2D coronal scans with acquisition parameters and flip angle series equivalent to the simulated version, with the non-selective excitation replaced with a slice-selective sinc pulse.

Results and Conclusions: Figure 1a shows the ratio of the simulated AFI flip angle map (normalized to nominal value) to the input $B1^+$ field distribution. Deviation between the two maps is within 5% over most of the map, with greater deviation at the edge of the phantom where B_0 inhomogeneity is significant (200-300 Hz). The transverse magnetization was completely spoiled at the end of each TR in the AFI simulation. Figure 1B shows the ratio of the simulated GRE series $B1^+$ field distribution to the input $B1^+$ field distribution. Deviation is within 5% except at the phantom edges, where B_0 inhomogeneity is significant. Figure 1C displays the ratio of the simulated AFI flip angle map (normalized to nominal value) divided by the GRE series $B1^+$ field distribution. Excluding regions of B_0 inhomogeneity at the edges, the two maps are within 8% of one another over most of the phantom. Figure 1D displays the experimental, normalized AFI flip angle map divided by the experimental GRE $B1^+$ field distribution. The deviation between the two experimental maps is significant, with the AFI map overestimating the GRE series method up to 25% in some regions.

Additional attempts were made in simulation to reproduce the large experimental deviation between AFI and the GRE series method, through adjustment of the AFI spoiling. These attempts were unable to reproduce the large deviation between AFI and the GRE series method seen in experiment. Simulated AFI images with poor spoiling reveal a ripple like pattern throughout the phantom, which is also seen in experimental AFI images when the advanced spoiling method [5] is not utilized. This suggests in practice that experimental spoiling works very well.

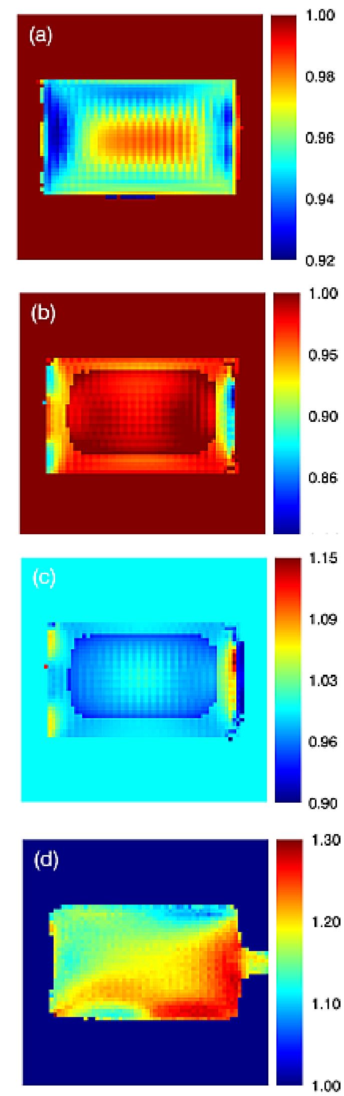

Figure 1: **(a)** Simulated AFI map divided by input $B1^+$ map **(b)** Simulated GRE series map divided by input $B1^+$ map **(c)** Simulated AFI map divided by simulated GRE series map **(d)** Experimental AFI map divided by experimental GRE series map

Simulation of AFI and the GRE series method reveals deviations of ~5% from the input $B1^+$ field distribution, excluding edge regions influenced by B_0 inhomogeneity. The accuracy of the AFI map is partially affected by the short T1 (100 ms) of the phantom relative to TR1/TR2 of 12/60 ms, but this error is expected to be on the order of 1-2%. Simulations indicate that operating on 'ideal' hardware, both mapping methods should perform well. The ratio map in Figure 1D reveals a significant deviation in experiment which is not predicted by simulation. As suggested in Moore et al. [1], a significant systematic error in real systems may be present that was not accounted for in these simulations.

Acknowledgements: Support from NIH through R01 EB000454 and R01 EB006563

References: [1] Moore et al. P.ISMRM 2009, p.373. [2] Yarnykh V. Magn Reson Med 2007; 57:192-200 [3] Hornak JP et al. Magn Reson Med 1988; 6:158-163 [4] Cao et al., ISMRM 2009 Parallel Imaging Workshop [5] Nehrke K. Magn Reson Med 2009; 61:84-92