A short TR, MFA approach to simultaneous B1+ and T1 mapping

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Introduction: A wide variety of B_1^+ mapping methods have been proposed in the literature, each with advantages and drawbacks. T_1 sensitivity is one factor that usually affects B_1^+ mapping, and the typical way to avoid this problem is to use TR much less than or much greater than T_1. A new simultaneous B_1^+ and T_1 mapping method is proposed here, based on a spoiled multiple flip angle (MFA) experiment with short TR (25-75 ms) that is similar to existing MFA T_1 mapping methods. A series of GRE images are acquired with fixed TR and an increment of the flip angle between measurements. The relevant signal equation is given as $M_0(1-E_1)\sin[\lambda\theta]$ / $(1 - E_1\cos[\lambda\theta])$. The symbol λ represents the position-dependent RF scaling factor, θ the nominal applied flip angle, and E1 is $\exp(-TR/T_1)$. A non-linear fit is applied to the measured data and both T_1 and B_1^+ are determined simultaneously. Computation of both T_1 and B_1^+ in the fitting process will prevent one quantity from influencing the determination of the other. The proposed method (simply termed MFA-B1 throughout) was compared to AFI [1], a well-established B_1^+ mapping technique that also utilizes spoiling and short TR.

Methods: AFI [1] and MFA-B1 scans were acquired on a Siemens 3T TIM Trio with a spherical Siemens water phantom (1.25g NiSO4 · 6H2O). Reception was through an eight channel head coil, and transmission utilized the TIM Trio body coil. T_1 of the phantom is approximately 290 ms. Scan matrix and FOV were identical for the two techniques – 52 x 80 x 96 and 208 x 200 x 240 mm FOV. Hard RF pulses with no slice selection were utilized. AFI utilized a 60 degree flip angle, 25 ms TR_1, TR_2/TR_1 ratio of 5. Spoiling for AFI was implemented as described in Nehrke [2], using values of 129.3 degrees for the RF spoiling increment and 425/2125 mT/m * ms for the gradient spoiler area during TR1 and TR2 respectively.
MFA-B1 utilized a 50 ms TR. A flip angle table of 20 FA's was utilized: 2, 5, 9, 13, 17, 22, 27, 35, 43, 52, 62, 73, 84, 95, 106, 117, 130, 145, 162, and 180. RF spoiling in MFA T_1 mapping has been investigated [3] and optimal RF phase increments for flip angles under 40 degrees have been determined. Another study examined spoiling considering a range of flip angles (10-90 deg) and utilizing randomized gradient and RF tables [4]. In consideration that RF spoiling for higher flip angles in MFA has not been fully investigated yet, a RF spoiling increment of 169.3 degrees and gradient spoiler area of 950 mT/m*ms was utilized. Fitting was performed in IDL with a non-linear least squares routine [5] based on the Levenberg–Marquardt algorithm. Each pixel was averaged over the surrounding 3x3 pixels prior to fitting. The total acquisition time of MFA-B1 is 6.67 times longer than the AFI scan duration.

Results: AFI and MFA-B1 B_1^+ maps are displayed in the upper left and right respectively, given as the RF scaling factor λ. The AFI map is divided by the nominal flip angle of 60 degrees. In the lower left the division of AFI by MFA-B1 is displayed. Over the majority of the phantom, the two techniques are within 1 to 5 percent of one another. In the lower right the T_1 map computed by the fitting is displayed. Measurement of the phantom T_1 with an inversion recovery technique produced a value of 290.5 ms with a standard deviation of 0.926 ms.

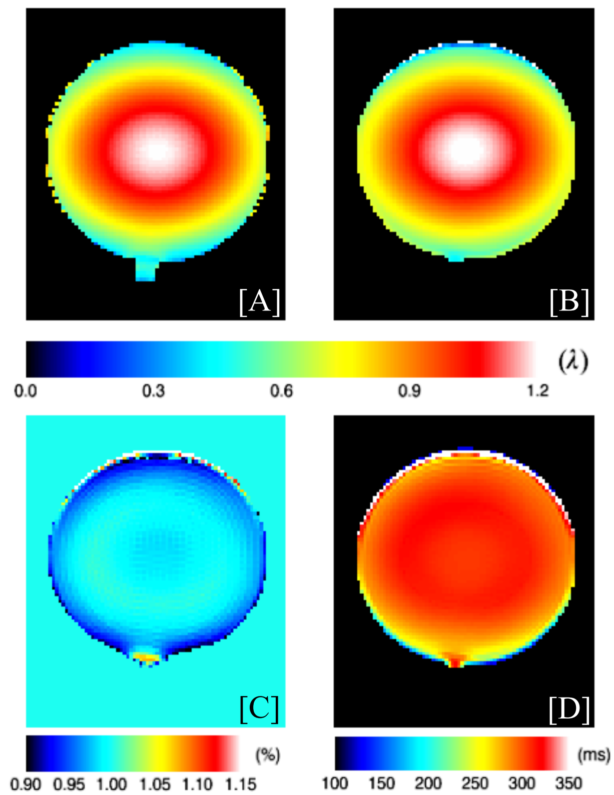

Figure 1: Comparison of MFA-B1 and AFI. [A] AFI flip angle map, displayed as the scale factor λ (Actual Flip Angle / Nominal Flip Angle). [B] MFA-B1 flip angle map, displayed as scale factor λ. [C] The division of [A] by [B]. [D] T_1 map computed by MFA-B1.

Discussion: Figure 1 illustrates that the proposed method produces flip angle maps equivalent to those for AFI in addition to T_1 maps. Several approaches are under investigation to decrease the acquisition time of this technique. Spiral readouts will be integrated to shorten the total acquisition time. Determination of the optimal RF spoiling phase increment for flip angles above 40 degrees is necessary for accurate measurements, and will also allow for smaller gradient spoilers and shorter TR. Further study of flip angle tables should allow for smaller tables than the one utilized in this study (20 FA's), and preliminary work suggests 10-12 should be sufficient. This particular study used a phantom with a T_1 of about 295 ms and a TR of 50 ms, which necessitated acquiring scans with flip angles up to 160 to 180 degrees. Scans with a smaller TR/T_1 ratio will require a smaller range of the flip angle table for mapping. AFI requires that TR_1 and TR_2 are short relative to T_1 to achieve accurate results, but a recent technique (MTM) [6] extends AFI to measure both T_1 and B_1^+. Future work will include a comparison between the proposed technique and MTM, and a comparison to a similar GRE MFA method [7] that utilizes long TR's.

References:

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