Estimating Saturation Factors for PRESS with Inhomogeneous B1 at 7T

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INTRODUCTION:PRESS [1] is commonly used for localization in single voxel and spectroscopic imaging applications [2], but is quite demanding of peak B_1 field strength to produce the refocusing pulses with sufficient bandwidth to overcome chemical shift misregistration effects. At field strengths of 7 Tesla and above, difficulties emerge with achieving sufficiently high B_1 field strengths in vivo for the refocusing pulses, achieving sufficient spatial homogeneity of B_1, and avoiding saturation effects due to the longer T_1 relaxation times while maintaining an acceptable scan duration. Calculating the dependence of the available magnetization given the T_1 relaxation times, repetition time, and B_1 nonuniformity provides better insight into actual signal behavior. These saturation factors may also be used to improve quantitation, given accurate knowledge of T_1 relaxation times. Fortunately, the three most commonly imaged metabolites -- N-acetyl aspartate, choline, and creatine -- are singlets, and full quantum mechanical calculations are not required.

METHODS: We wish to calculate the resulting signal from a singlet spin such as N-acetyl aspartate in a double spin echo experiment in steady state as a function of B_1 and T_1. B_1 variation is described by a dimensionless scaling function which can be derived from a B_1 mapping experiment; the flip angle for each pulse is simply the nominal flip angle multiplied by this scaling factor. One can then construct matrix representations of the nutation and relaxation operators for each of the time intervals.

The effect of one TR interval is $M^k = R_3F_3(R_2F_2(R_1F_1M^{k-1}+M_1)+M_2)+M_3$

Iterating this expression 100 times safely produces steady state. One can then calculate the signal as the (2) component of the M vector $M = R_3^*F_3(R_2F_2(R_1F_1M^{100}+M_1)+M_2)$

This function was evaluated at decreasing values of repetition time from 15 s to 1s. Reducing the repetition time clearly reduces the signal level, but also reduces the variation in available signal with B1.

Spectroscopic imaging data was collected from a 17 cm diameter spherical phantom containing water, gadolinium, and metabolites [3]. Data were acquired on a GE Signa 7T Human MR Research System (GE Healthcare, Waukesha, WI), an investigational device, with a 2 channel Nova (North Andover, MA) transmitter with an 8 channel receiver array, with TE of 90 ms, TR of 2000 ms, 8x8x8 acquisition (21 min acquisition time), with 0.5 ml voxels. Data were transferred offline for processing using in-house software [4] for Fourier transformation, apodization, baseline estimation, peak extraction, and receiver combination [2] to yield arrays of spectra. By aligning the CSI acquisition to resampled B_1 field maps constructed from the double angle method [5] with a 2 s repetition time, estimates of the local B_1 were used along with the estimated T_1 of NAA in the phantom to extract saturation factors and renormalize the spectra. Finally the adjusted NAA peak area was rendered as an image.

RESULTS: Figures 1 a-c show the available signal for a singlet calculated as above for T_1 relaxation times between 500 ms and 2.5s, for repetition times of 15s, 5s, and 2s, for a range of B1 scale factors from 0.8 to 1.9 (similar to that seen in phantoms at 7T). For longer T_1's, saturation effects become apparent at shorter repetition times, as the signal variation with B1 is substantially reduced. Figure 2 shows results in a phantom with high permittivity showing significant B_1 variation (2a -- B_1 map, PRESS box, and CSI grid; 2b: uncorrected spectra showing NAA, Cr, and Cho with significant signal variation over the selected volume; 2c, spectra renormalized by the calculated saturation factors; 2d, uncorrected NAA peak image; 2e -- corrected NAA image). A single correction factor was used for each voxel; different metabolites have different T_1's and so will need different correction factors. While variation remains, the NAA image is substantially more uniform. The accuracy of this correction is strongly dependent on the estimate of the peak T_1, which is problematic at 7T due to the difficulty of achieving a uniform inversion or saturation across the phantom. *This work was supported by a UC Discovery academic-industry partnership grant Itl-bio-04-10108 with GE Healthcare.*

REFERENCES: [1] Bottomley, PA *Ann NY Acad of Sci* **508**, 1987. pp 333-48. [2] Xu, D et al. Magn Res Im **26**, 2008 pp 1201-6. [3] Schirmer, T and Auer D. *NMR in Biomedicine* **13** 2000 pp 28-36. [4] Nelson SJ MRM 46 228-39. 2001. [5] Stollberger R and Wach P MRM **35** 246-51. 1996

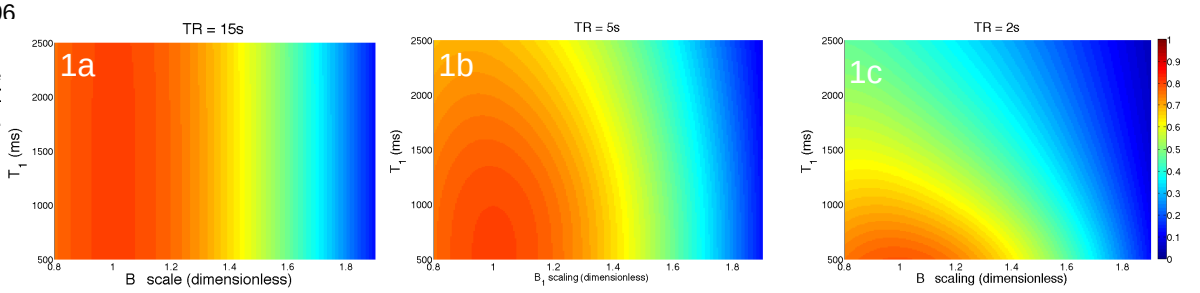

Figure 1 a-c: Singlet signal for TR = 15s, 5s and 2s calculated vs T1 and relative B1 scaling

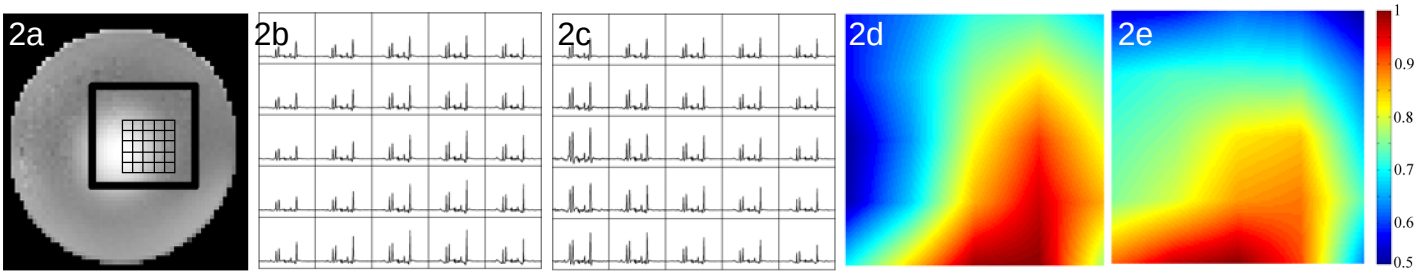

Figure 2 PRESS phantom data a: B1 map and volxel location, b: spectra, c: adjusted spectra, d: NAA map, e: adjusted NAA map