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 B1 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 B1 field strengths in vivo for the refocusing pulses, achieving sufficient spatial homogeneity of B1, and avoiding saturation effects due to the longer T1 relaxation times while maintaining an acceptable scan duration. Calculating the dependence of the available magnetization given the T1 relaxation times, repetition time, and B1 nonuniformity provides better insight into actual signal behavior. These saturation factors may also be used to improve quantitation, given accurate knowledge of T1 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 B1 and T1. B1 variation is described by a dimensionless scaling function which can be derived from a B1 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:

\[ \mathbf{M} = R_3 F_3 (R_2 F_2 (R_1 F_1 \mathbf{M}^{1000} + \mathbf{M}_1) + \mathbf{M}_2) + \mathbf{M}_3 \]

Iterating this expression 100 times safely produces steady state. One can then calculate the signal as the (2) component of the M vector:

\[ S = R_3 F_3 (R_2 F_2 (R_1 F_1 \mathbf{M}^{1000} + \mathbf{M}_1) + \mathbf{M}_2) \]

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

RESULTS: Figures 1a-c show the available signal for a singlet calculated as above for T1 relaxation times between 500 ms and 2.5 s, for repetition times of 15 s, 5 s, and 2 s, for a range of B1 scale factors from 0.8 to 1.9 (similar to that seen in phantoms at 7T). For longer T1’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 B1 variation (2a - B1 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 T1’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 T1, 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.