B1-dependence of single-voxel MRS sequences: STEAM, PRESS and MEGA-PRESS

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The signal detected by an MRS experiment depends on accurate calibration of transmit B_1 power; it is B_1-dependent. Progress to higher field strengths has brought increasing issues of B_1 inhomogeneity (see Figure 1) and increasing application of exotic RF pulse shapes to deliver increased slice-selection bandwidth. At 7T in particular, B_1 is sufficiently inhomogeneous that the peak B_1 achievable in one region of the brain may be only half the global peak. It is often assumed that the B1-dependence of a 90° pulse goes as $\sin(\pi/2 * B_1/B_{1nom})$, and a 180° pulse as $\sin^2(\pi/2 * B1/B1nom)$, where B_1 and B_{1nom} are the actual and intended B_1 field. However, these expressions are based upon the on-resonance case for rectangular, non-selective pulses, , when shaped slice selective pulses are being used, it is the signal integral across the slice that determines output signal intensity. In this abstract we present simulated and phantom data describing the B_1-dependence of three common MRS experiments: STEAM, PRESS and MEGA-PRESS.

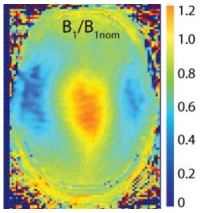

Figure 1: 7T B1 map

Method

Simulations Slice profiles were simulated at a range of B_1/B_{1nom} from 0 to 1 for 'Spredrex', an asymmetric excitation pulse and 'GTST', a high-bandwidth refocusing pulse (see Fig 2). The STEAM sequence localizes with three 90° pulses and PRESS with one 90° pulse and two 180° pulses. The B1-dependence of these sequences is calculated assuming that the three orthogonal slice profiles independently impact signals.

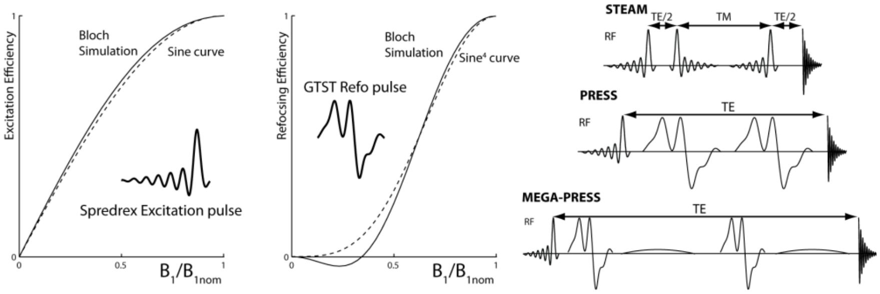

Figure 2: B1-dependence of excitation (left) and refocusing pulse (center). Pulse sequences (right).

Experimental A 10 mM solution of GABA in phosphate-buffered saline was scanned using a Philips Achieva 7T scanner. The B1-sensitivity profiles were measured in a region of maximum B1-field homogeneity. STEAM (TE=14ms) and PRESS (TE=30ms) experiments were performed without water suppression using the the following parameters: TR=3s; (2 cm)^3 volume; 8k datapoints at 5 kHz spectral width (SW); 4 averages; sampling B_1/B_{1nom} factors from 0.1 to 1 in increments of 0.05. MEGA-PRESS experiments were performed with excitation water suppression and the following parameters: TR/TE=3s/70ms; (3 cm)^3 volume; 8k datapoints at 5 kHz SW; 64 averages; sampling B_1/B_{1nom} from 0.65 to 1 in mean increments of 0.025. Water supression pulses were not scaled by B_1/B_{1nom} to maintain good water suppression over all experiments.

Results

Single-pulse Bloch simulations (shown in Figure 2 left) show that the excitation pulse has sine-like behavior, as expected, whereas the refocusing pulse has $\sin^4$ rather than the expected $\sin^2$ behavior. Experimental data shown in Figure 3 are best matched by $\sin^4$ (STEAM), $\sin^{11}$ (PRESS) and $\sin^{15}$ (MEGA-PRESS) functions.

Discussion

Although simple ('naïve') theory expects the B_1 dependence for PRESS to be $\sin^5$, the experimental dependence measured GTST pulses would predict that PRESS will have a $\sin^9$ dependence (based on factors of $\sin^1$ for the spredrex pulse and $\sin^4$ for each GTST pulse). However, the B_1-sensitivity found in the experimental data was even greater than that predicted by simulation - $\sin^4$ for STEAM, and $\sin^{11}$ for PRESS. – the progressively worsening B_1-sensitivity from naïve, to simulated, to experimental is shown above right. The increased experimental sensitivity may be due to B_1 inhomogeneity within the MRS voxel, which was not accounted for, or the interaction of the flip angle variation across the slice profile in the 3 different directions used for localization.

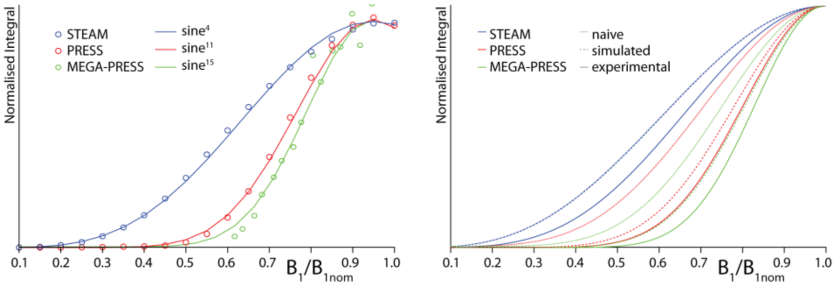

Figure 3: Experimental B1-dependence of sequences (left), comparison of naïve and simulated expectations to experimental curves (right).

Use of lower bandwidth sinc-Gaussian-like refocusing pulses with $\sin^2$ behavior may result in improved signal, especially for MRSI applications, however chemical shift dispersion effects will be greater. The different B_1 sensitivity of PRESS and MEGA-PRESS presents issues for the quantification of MEGA-PRESS, as PRESS measurements of creatine or water are typically used as reference signals. The severity of this issue is underlined in the MEGA-PRESS case, for which a 20% miscalibration of the B1 power will result in over 50% loss in signal. This is especially pertinent at 7T when B_1 field homogeneity is a major challenge. For MRS experiments, careful localized flip angle calibration is critical for optimum SNR, and the use of parallel transmit techniques for improved B_1 field homogeneity will be especially important for MRSI experiments with wider spatial coverage.

This work was supported by NIH funding (NIH P41RR015241).