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 $B_1$-dependence of a 90° pulse goes as $\sin(\pi/2*B_1/B_{1\text{nom}})$, and a 180° pulse as $\sin^2(\pi/2*B_1/B_{1\text{nom}})$, where $B_1$ and $B_{1\text{nom}}$ 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 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.

Method
Simulations Slice profiles were simulated at a range of $B_1/B_{1\text{nom}}$ 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 $B_1$-dependence of these sequences is calculated assuming that the three orthogonal slice profiles independently impact signals.

Experimental A 10 mM solution of GABA in phosphate-buffered saline was scanned using a Philips Achieva 7T scanner. The $B_1$-sensitivity profiles were measured in a region of maximum $B_1$-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 $B_1/B_{1\text{nom}}$ 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 $B_1/B_{1\text{nom}}$ from 0.65 to 1 in mean increments of 0.025. Water suppression pulses were not scaled by $B_1/B_{1\text{nom}}$ 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 $\sin^2$, the experimental dependence measured GTST pulses would predict that PRESS will have a $\sin^9$ dependence (based on factors of $\sin^4$ for the spredrex pulse and $\sin^2$ 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. 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 $B_1$ 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.

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