# Radiofrequency Variations in Spectroscopic Imaging at High Field: Differences in Coupled and Uncoupled Spin Systems

J. Snyder[1], R. B. Thompson[1], J. M. Wild[2], A. H. Wilman[1]

[1]Biomedical Engineering, University of Alberta, Edmonton, Alberta, Canada, [2]Academic Radiology, University of Sheffield, Sheffield, Yorkshire, United Kingdom

**Introduction**

At increasing magnetic field, spectroscopic imaging yields significant advantages in signal-to-noise ratio (SNR) and spectral resolution. However, one problem more prevalent at higher field is the superposition of standing waves (field focusing effect), which affects the radiofrequency (RF) distribution in the human head. This problem is due to the comparable dimensions of the human head and the RF radiation wavelength at 4.7 T (~20 cm), resulting in superposition effects. Therefore, flip angles can decrease dramatically near the edge of the brain from the intended flip angle near the center when using standard clinical imaging sequences that employ soft pulses for excitation and refocusing. At 4.7 T, the RF magnitude received by areas near the edge of the brain can vary up to 40% of the intended flip angle [1]. Consequently, spectroscopic voxels displaced from the center of the head will experience less than optimal excitation and refocusing because of the decreased flip angle. Furthermore, it is possible that coupled and uncoupled spins may differ in response to varying flip angles, resulting in quantification errors. Coupled spins may experience large signal variations and lineshape changes making quantification difficult. It is expected that singlet resonances will have a simple response to the decreased flip angle, with varying peak amplitudes corresponding to the deviation in flip angle. This work analyzes the effects of the RF field focusing effect on coupled spins from a theoretical and experimental point of view. Singlet resonances choline (cho) and N-acetyl aspartate (NAA) and coupled systems glutamate (glu) and glutamine (gln) are investigated using the standard PRESS sequence ($\alpha$ - 2$\alpha$ - 2$\alpha$) for single voxel (SV) techniques and spectroscopic imaging (MRSI).

**Methods**

Experiments were performed on a cylindrical, pH – balanced phantom containing cho, glu and gln in physiological ratios (48 mM glu, 16 mM gln, 6 mM cho) at 4.7 T using a quadrature birdcage coil for transmission and reception. For each spin system, theoretical calculations were performed to simulate the PRESS sequence under varying flip angles using an in-house software package for each metabolite, and previous RF field map calculations [2]. Glu and gln (collectively termed glx) were modeled individually and the resultant spectra were added together in a physiological ratio of 3:1 to better reflect the in vivo environment. Peak areas were calculated at each flip angle for cho, and the PQ multiplet of glx. For simulation and experiment, optimized timings of $TE_1$ = 20 ms and $TE_2$ = 100 ms were chosen to maximize the signal yield and simplify the glx lineshape to ease area calculations. MRSI experiments were performed on healthy volunteers under the same conditions as the phantom experiments without flip angle variation. A strip was excited (2 cm x 10 cm x 2 cm) in the left-right direction which was phase encoded into 16 individual voxels. Area calculations were performed for each voxel for NAA and glx PQ to produce spectroscopic images.

**Results**

Figure 1 shows the spectra for cho (a) and glx PQ (b) at flip angles of 90° (dotted line), 80° (dashed) and 65° (solid) for the SV phantom areas. Notice the large reduction in the glx signal at reduced flip angles in comparison to the 90° case. At 65°, the glx PQ peak area is reduced to 23% of its maximum value at 90°, whereas the cho peak area is only reduced to 56%. This shows that a global correction factor applied to all spin systems in the sample to compensate for this effect will produce quantification errors. Figure 2 is a summary of the SV study, showing phantom and simulation peak areas for varying flip angles. Note the good agreement between simulation and experiment. The rapid decrease in the glx PQ area is readily apparent.

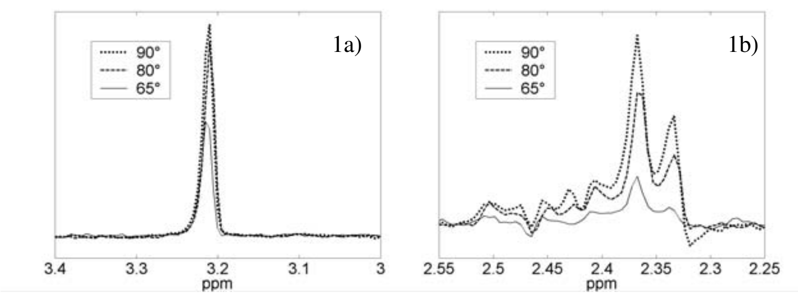



*Figure 1: SV experimental spectra for a) cho and b) glx PQ at varying flip angles.*

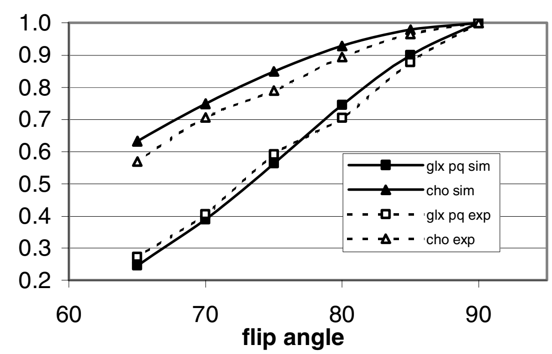
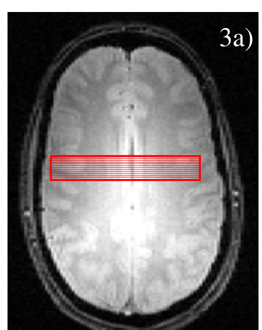



*Figure 2: Normalized areas for simulation (solid lines) and experiment (dashed) versus flip angle for glx PQ (squares) and cho (triangles) in the SV study.*

Figure 3 shows the results from the spectroscopic imaging experiment. The overlaid rectangle on the reference image corresponds to the spectroscopic strip used. The spectroscopic images for NAA and glx PQ are shown in Figures 3b) and 3c), respectively. The RF variations in this experiment show agreement with the SV studies, as the glx PQ area of the left most voxel is 32% of the maximum located near the center, compared to 63% for NAA. Both NAA and glx PQ experience the same trend of decreasing intensity when the voxel is located further from the center of the brain. A global correction factor cannot be used to alleviate the RF effects because of the differing variations in the glx PQ and NAA intensities.



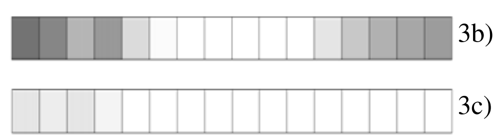




*Figure 3: a) Reference volunteer image with MRSI localization (2 cm x 2 cm x 10 cm) overlaid, b) spectroscopic image for glx PQ, and c) spectroscopic image for NAA. The MRSI images are oriented in the left-right direction. Individual voxels measured 2 cm x 0.625 cm x 2 cm. Dark areas denote lower area intensities.*

**Discussion**

This study illustrates how variations in RF amplitude due to the field-focusing effect can affect the coupled spin systems glu and gln differently than the singlet systems of cho and NAA. This effect has been demonstrated in simulations as well as single voxel studies by varying the flip angle (thus producing RF variations) which give similar results to RF effects in spectroscopic imaging. In the MRSI experiment, glx PQ area was reduced to 32% at the side of the brain compared to 63% for NAA. It is important in metabolite quantification in spectroscopic imaging to be aware of differences in yield for coupled and uncoupled spins caused by RF variation. Future work may incorporate techniques that are insensitive to RF field inhomogeneities, *i.e.* sequences using adiabatic pulses (*e.g.* LASER, [3])

**References**

[1] Thomas *et al.*, MRM 51:1254-64 (2004). [2] Collins CM, Smith MB, MRM 45:684-91 (2001). [3] Garwood M, Delabarre L, JMR 10:1-7 (1999).