Three Dimensional Multi-voxel Proton Hadamard Spectroscopic Imaging in the Human Brain at 3T

Ouri Cohen[1,2], Assaf Tal[1], and Oded Gonen[1]

[1]*Center for Biomedical Imaging, NYU, New York, NY, United States,* [2]*Biomedical Engineering, Columbia University, New York, NY, United States*

Introduction: Transverse Hadamard spectroscopic imaging (T-HSI) [1] can overcome the limitations of chemical shift imaging via its approaching-ideal point spread function. However, since it uses RF pulses that are superpositions of *N* single slice pulses, the resulting amplitude is magnified ×*N*. As the $\mathbf{B_1}$ available decreases with magnetic field strength [2], the pulses' bandwidths must be reduced and selective gradients weakened leading to degraded slice profiles and increased voxel bleed and chemical shift displacement. Here we present a new sequence that overcomes these limitations by cascading the pulses in time, allowing an *N*-fold increase in bandwidth.

Methods: Encoding in the first two dimensions is achieved with a cascade of frequency-shifted selective pulses played under alternating gradients (Figure 1). The magnetization is refocused and returned to the longitudinal direction. Outer volume suppression (OVS) is provided by a SLR 90°, exciting regions to the left and right of the VOI. Crushers then dephase all transverse magnetization from outside the VOI. Finally, a pulse cascade subdivides the VOI in the 3rd direction and tips the magnetization back to the transverse plane where it is refocused by a selective SLR 180° pulse and the echo sampled. Suppression of extraneous magnetization excited by the 3rd pulse is accomplished by a 4-step phase cycle that alternates the phase (0°,180°) of the 3 pulse cascades between four measurements.

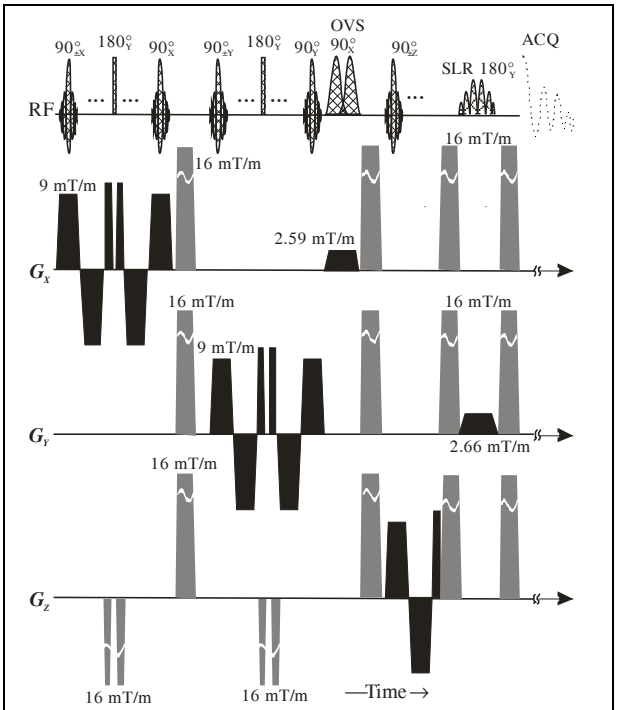

Figure 1: Three pulse cascades define the VOI. Note that the strong selective gradients mitigate the chemical shift displacement.

Results: The approach is demonstrated on the brain of a healthy male at 3T in a Tim Trio (Siemens AG, Erlangen Germany) with its standard TEM head coil. A VOI of 8×8×4 cm^3 (left-right (LR)×anterior-posterior (AP)×inferior-superior (IS)) was partitioned into 8×8×4 voxels by 8 SINC, 1.28 ms pulses in the LR×AP directions and 4 pulses in the IS direction. At TR=1.2s the 8×8×4×4=1024 encoding steps took under 21 minutes and the results are shown in Figure 2, along with the image of the brain for anatomical reference.

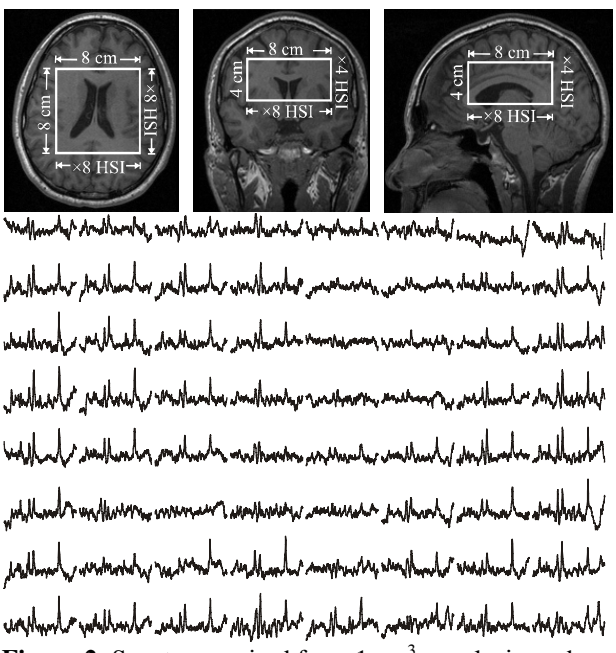

Figure 2: Spectra acquired from 1 cm^3 voxels, in under 21 minutes from an axial slice

Discussion and Conclusions: A novel sequence is shown that maintains the benefits of Hadamard encoding while reducing the chemical shift displacement despite the higher field with only a short echo time. *In vivo* results show good localization and high SNR making it suitable for short T_2 or *J*-coupled metabolites.

References:

[1] Cohen et al., Magnetic Resonance in Medicine 2012 , [2] Vaughan et al., Magnetic Resonance in Medicine 2001