Novel Automated 3D MRSI Acquisition with Whole Brain Slice Selection and Outer-Volume Suppression

E. Ozhinsky[1,2], A. B. Kerr[3], and S. J. Nelson[1,4]

[1]Surbeck Laboratory of Advanced Imaging, Department of Radiology and Biomedical Imaging, University of California, San Francisco, San Francisco, CA, United States, [2]UCSF/UCB Joint Graduate Group in Bioengineering, University of California, San Francisco, [3]Department of Electrical Engineering, Stanford University, CA, United States, [4]Department of Bioengineering and Therapeutic Sciences, University of California, San Francisco

Introduction: Automated prescription of 3D Magnetic Resonance Spectroscopic Imaging (MRSI) [1,2] can improve brain coverage and reproducibility compared to manual prescription [3]. Outer-Volume Suppression (OVS) and slice selection have been used previously instead of PRESS in 2D MRSI [4,5]. For 3D MRSI, this approach could allow for a non-cuboidal volume of interest, better approximating the shape of the brain, but would require a large number of OVS sat bands. Cosine-modulated (CM) VSS pulses have been used previously to simultaneously suppress two parallel bands [6] but doubled the required peak RF amplitude. While lower peak-power dualband VSS pulses can be designed with root flipping [7,8] as in [9], this approach required the complex RF design to be performed at scan time. The present work has combined a new automatic prescription algorithm with an MRSI protocol that uses slice selection in place of PRESS. The VSS pulse design was modified to allow for simpler pulse sequence implementation.

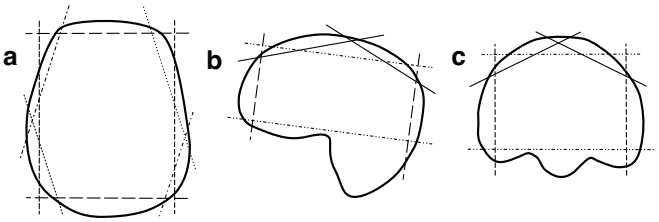

Fig. 1: Automatically prescribed OVS band configuration

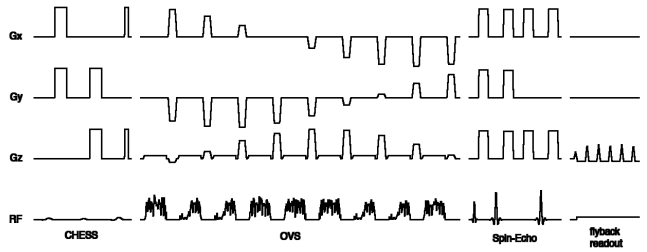

Fig. 2: MRSI pulse sequence (sections scaled differently)

Methods: *Automated Prescription:* The technique was based on the one described in [1] and included acquisition of T1-weighted anatomical images, segmentation to obtain brain and lipid surfaces, landmark-based definition of the inferior oblique plane, optimization of the excited slice and optimization of OVS sat band placement. The OVS prescription (fig. 1) included 5 pairs of parallel bands, implemented with dualband pulses (dashed lines) and 4 tilted sat bands in a pyramid configuration (solid lines). Total optimization time was around 30 seconds.

Pulse Sequence: To achieve slice selection, the PRESS MRSI pulse sequence (fig. 2) was modified to make the X and Y refocusing pulses non-selective. The slice selection and OVS band parameters were defined by files generated by the automatic prescription software. Stimulated echoes from the OVS pulse train were minimized by using crusher gradients in X, Y and Z following offset cosine patterns, similar to the method in [5].

RF Pulse Design: The $B_s(z)$ polynomial of an SLR [10] pulse for exciting a single band was designed as in [9] with a ratio of passband to transition width of 15 and profile ripples (δ_1, δ_2, δ_3) of (.007, .141, .003) as shown in Fig. 3a. The ripples (δ_1, δ_2) were chosen to give M_z in-slice ripple of 0.02 and out-of-slice ripple of 0.02, while the small δ_3 was required to prevent in-slice interference when a dualband pulse was formed. A search of root flipping zeros in the passband of $B_s(z)$ was made to find which resultant RF pulse $B_{1,s}(n)$ yielded the lowest peak amplitude in the worst-case dualband envelope $|B_{1,d}(n)|_{max} = |B_{1,s}(n)| + |B_{1,s}(N\text{-}n+1)|$. The dualband RF pulse (fig. 3d) was formed at scantime by independently modulating the RF pulses $B_{1,s}(n)$ and $B_{1,s}(N\text{-}n+1)$ with complex exponentials and summation.

MRSI Acquisition: Long echo (TE = 144 ms) and short echo (TE = 35 ms) MRSI data were acquired on a 3T GE scanner with an echo-planar flyback sequence (18x18x16, 1cc isotropic voxels, T_{acq} = 6.5 min). Raw data were reconstructed and processed offline using methods, described previously [11].

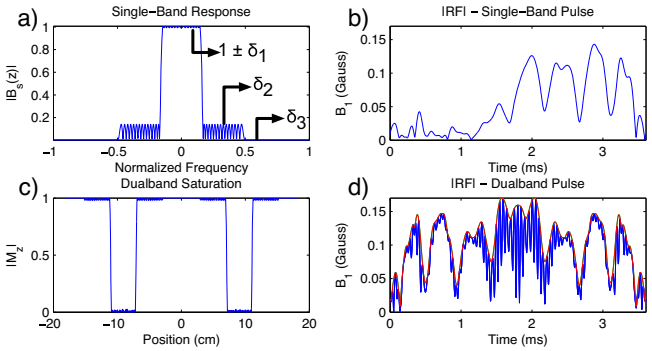

Fig. 3: (a) $B_s(z)$ polynomial describing single-band excitation evaluated on unit circle; (b) Magnitude of single-band RF pulse; (c) Simulated saturation M_Z profile for a dualband pulse (d, blue) and the worst-case dualband envelope (d, red).

Results and Discussion: To assess the behavior of the dualband pulses, phantom images were acquired with the same excitation and OVS as in the MRSI acquisition. The dualband pulses exhibited a much sharper transition band than CM pulses, with a slight increase in out-of-slice ripple. The dualband pulse duration was 3.6 ms compared to 6 ms for the CM VSS pulses. The OVS scheme consisted of 5 dualband and 4 single-band pulses, resulting in an OVS duration of only 51 ms.

Long echo and short echo MRSI data were acquired from 2 healthy volunteers and 2 patients with brain tumors. For long echo MRSI (fig. 4 a,b), the technique achieved good spectral quality, with Cho, Cre and NAA peaks clearly visible. The metabolite map shows that data was acquired from almost the whole volume of the supratentorial brain, a much larger volume than that shown in earlier approaches [3]. In short-echo data (fig. 4c), the lipid peak was more prominent due to its short T2, but did not overlap with the NAA peak in most voxels. Additional peaks, such as mI and Glx, could be resolved.

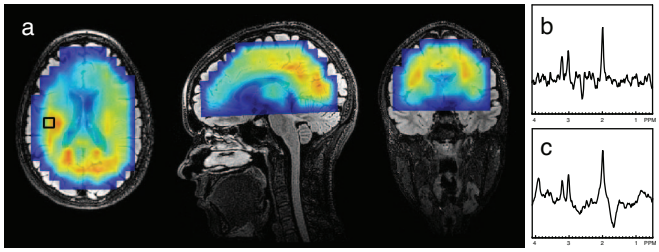

Fig. 4: Healthy volunteer MRSI acquisition: (a) NAA metabolite maps; (b) sample voxel TE=144 ms (c) TE=35 ms

The use of slice selection instead of PRESS will allow a single spin-echo sequence to be implemented to achieve even shorter echo times and reduce RF power deposition. In conclusion, the combination of slice-selective excitation and effective outer-volume suppression using dualband VSS pulses allowed high-quality 3D MRSI data from supratentorial brain to be acquired in only 6.5 min. Automated prescription allows this technique to be implemented without the need of significant operator training.

References and Acknowledgements: [1] Ozhinsky et al., Proc 17th ISMRM, 2009: 2376. [2] Martinez-Ramon et al., MRM 63(3):592-600, 2010. [3] Ozhinsky et al., Proc 18th ISMRM, 2010: 963. [4] Henning et al., MRM 59(1):40-51, 2008. [5] Henning et al., NMR Biomed 22:683-96, 2009. [6] Osorio et al., MRM 61(3):533-40, 2009. [7] Shinnar et al., MRM 32:658-60, 1994. [8] Pickup et al., 33:648-55, 1995. [9] Kerr et al, Proc 17th ISMRM, 2009: 2577. [10] Pauly et al., IEEE TMI 10(1):53-65, 1991. [11] Nelson, MRM 46(2):228-239, 2001. This research was funded by NIH R01 CA127612-01A1 and UC Discovery Grant ITL-BIO04-10148 in conjunction with GE Healthcare