Hadamard Encoded 3D MRSI of Human Brain at 7T

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Introduction: At 7T in the human brain reduced RF amplitude and increased spectral dispersion result in chemical shift dispersion (CSD) artifacts that can distort metabolite ratios. For 2D encoding within the plane of a slice, CSD artifacts can be eliminated by replacing in-plane gradient based slab selective refocusing with RF shimming based outer volume suppression. However, for 3D acquisitions CSD artifacts during slab selection corrupts the most superior and inferior slices manifesting as artifactually large and small NAA/Cr ratios. Hadamard encoding in the slab direction minimizes this error by providing multiple thin slices with minimal CSD effects, increasing spatial overlap of the Cr and NAA volumes, thereby increasing the overlap of NAA and CR volumes from <40% (conventional 3D CSI) to 92.5%.

Methods: All data were acquired on a human 7T system using an 8 element transceiver array. The pulse sequence (1a) uses two RF spatial distributions: a homogeneous distribution (1b) for slice selective excitation, refocusing and water suppression and a "ring" distribution (1c) for outer volume suppression. The Hadamard excitation encoding provides 8 slices of 5mm thickness. 16x16 2D encoding was used with a FOV of 192mmx192mm and TR=1.2S, resulting in a 41 min. acquisition. The TE for the cascaded slices ranged from 12 to 36.5ms. To maximize homogeneity over the entire ROI, automated 1^{st}-4^{th} order shimming using a higher order shim insert was used. For comparison purposes a TE=15 ms 3D MRSI using a 4cm thick slab selective excitation pulse was acquired using 16x16x8 encodes.

Fig 1a

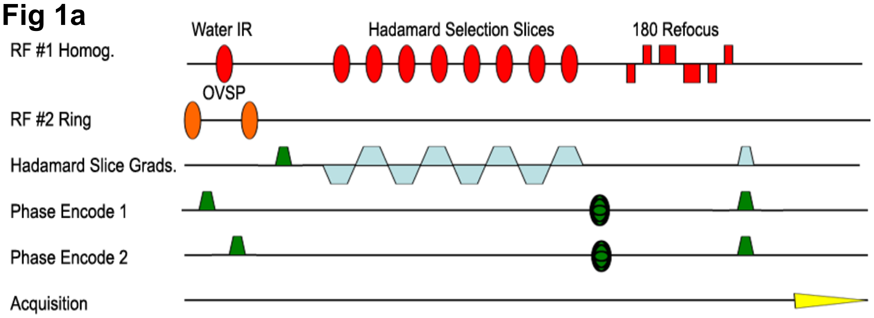
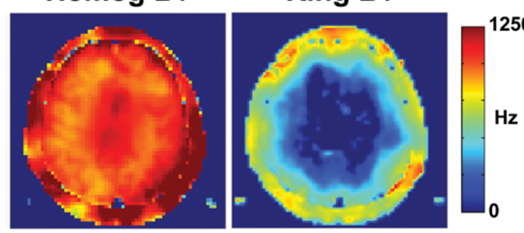


Fig 1B **Homog B1** **Fig 1C** **Ring B1**



Results: Representative spectra from each of the 8 slices from a 16x16x8 conventional 3D data set are shown in Fig. 2. CSD artifacts associated with slab selection in the conventional encoding set manifest as artificially low NAA/Cr ratios in slice 1, artificially large NAA/Cr ratios in slice 7 and strongly reduced signal in slice 8 (slice 4 is the center of the encoding). Displayed in Fig 2 are representative spectra, from slices 1-8 for the Hadamard encoding and scout and NAA images. The CSD artifacts seen in Fig.2 are not present in the Hadamard encoded data (Fig 3.) due to the high gradient strengths and narrow slice widths (5mm) used. The standard deviation of the B_0 field with 1^{st}-4^{th} order shims was 13.7Hz, (compared to 30.1Hz for 1st^{t}-2^{nd} order shims), enabling good spectral resolution over the entire slice.

Fig 2 Conventional 3D encoding in slab direction

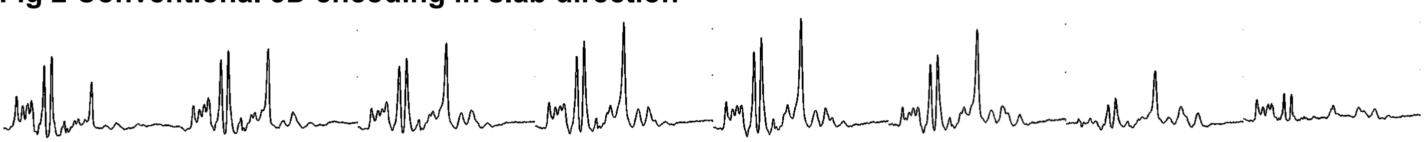
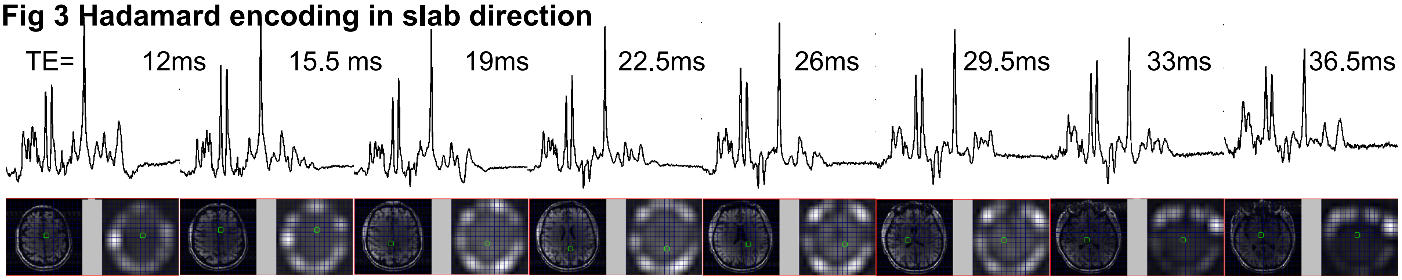


Fig 3 Hadamard encoding in slab direction



Conclusions: Hadamard encoding and in-plane OVSP minimizes CSD artifacts for 3D MRSI acquisitions, enabling all 8 slices to be interpreted without the need for large corrections to the measured metabolite ratios. By cascading the 90° pulses overall power deposition can be constrained to <2W/kG, below current FDA guidelines. The use of 1^{st}-4^{th} order shimming reduces the overall B_0 inhomogeneity by 54%, dramatically improving spectral quality across the ROI.