Initial Experience of 7T MRSI with 2-channel Multi-transmit

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Target Audience: Investigators interested in improving 7T human imaging or spectroscopy methods with multi-transmit capabilities

Purpose: Magnetic Resonance Spectroscopic Imaging (MRSI) should benefit from higher spectral resolution when translated from 3T to 7T [1,2]. This advantage should improve MRSI measurements of glutamate/glutamine (Glx) and myo-inositol (mI) resonances that reside in a crowded spectral region between 3.6ppm to 3.8ppm[3]. We recently developed a 7T MRSI method consisting of one pair of adiabatic full passage (AFP) pulses [4] with dual band water and lipid suppression [5]. Two AFP refocusing pulses resulted in an echo time of 28ms that achieves a balance between retaining signals of Glx and mI and attenuating macromolecule signals. The dual band suppression approach allows SENSE [6] acceleration so high spatial resolution is achieved with whole-slice coverage. However, earlier implementations suffered from B1 inhomogeneity effects associated with conventional quadrature RF transmission at 7T. Here, we report recently improved implementations of this MRSI method using 2-channel independent RF shimming.

Methods: All *in vivo* scans were performed on a 7T whole body scanner with a 32 channel phased array head receiver coil (Achieva, Philips Healthcare, Best, the Netherlands) and two orthogonal channel transmitter coil. 4 healthy subjects volunteered for this study with informed consent. B1 and B0 maps were acquired prior to all MRSI scans. RF shim and B0 shim parameters were optimized numerically for the prescribed slice location (Fig.a&b). Specifically for B1 shimming, independent RF amplitudes and phases were calculated and sent to the coil by two RF amplifiers. Non-suppressed water MRSI and dual band MRSI scans were acquired twice, with quadrature RF transmit and the optimized RF shimming. The parameters of both MRSI scans were: slice=10mm, FOV=220mm×190mm, resolution=$(6mm)^2$, matrix= 32×36 (LR×AP), TE=28ms. For water MRSI, TR=2.2s, SENSE=3×3, scan time=3:51, SAR=75%. For suppressed MRSI, TR=3s, SENSE=2×2, scan time=11:24, SAR=76%. In addition, a T1-weighted image and co-registered B1 maps were acquired post B1 and B0 shimming. For post-processing, per pixel frequency and phase corrections were performed on the water and the suppressed MRSI. Water signals and residual water signals were integrated to provide quantitative evaluation of the two RF methods.

Results: Figure 1 (a&b) shows slice location. Figure 1 (e through j) also shows comparisons of B1 maps, water MRSI maps and residual water maps of suppressed MRSI. The middle column was acquired with quadrature RF transmit and the right column was acquired with RF shimming. Both B1 maps and water MRSI maps show a small improvement in the low B1 region (18%±9 increase for water MRSI) with RF shimming. That is evident in the profile comparison in Fig.1c. However this small improvement in B1 resulted in a considerable reduction (57%±20) in residual water in the suppressed MRSI (Fig.1i&j). This is also evident in Figure 2 where two small MRSI grids (location marked in Fig.1d) show that, with RF shimming, spectral baselines are significantly improved in the region containing peaks of Glx and mI. (Both percentages were based on values in the low B1 region.)

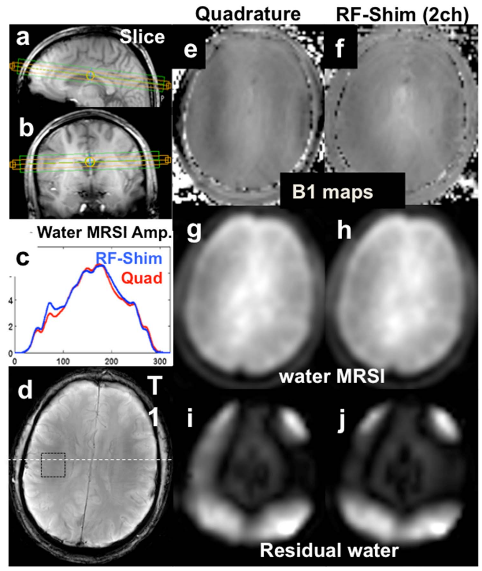

Figure 1. 7T MRSI with quadrature transmit and 2-channel independent RF-shimming. (a&b) Slice location; (c) 1D profiles of water MRSI acquired with quadrature (red) and RF-shim (blue); (d) Profile location in 'c' and grid location in Fig.2; (e&f) B1 maps; (g&h) water MRSI maps; (i&j) *Residual water maps showing improved water suppression at a well known low B1 region at 7T.*

Discussion: An immediate advantage of the independent RF transmit system is that two RF amplifiers now drive the transmit coil. More power allowed TR to be reduced from 4.5sec to 3sec so a higher spatial resolution was prescribed ($6mm^2$ vs. $7mm^2$). With a slice of 10mm, current voxel size is less than half of our commonly used value at 3T that is appropriate with increased field strength. More importantly, RF-shimming based on B1 mapping reliably addressed the "B1 hole" often seen in a human brain at 7T. While the direct increase in acquired signal is small, the benefit of B1 shimming lies with improved performance of water suppression. This should not be surprising as modern suppression methods [7] depend on multiple RF pulses with numerically optimized flip angles. For Glx and mI signals that are close to water peak, successful water suppression leads to flat baselines and more accurate measurements.

Conclusion: RF shimming with 2 independent channels based on B1-mapping achieved expected B1 compensation for 7T MRSI. Acquisitions of Glx and mI were significantly improved in a well known low B1 region in the brain. This RF shimming approach may be implemented with more transmit channels to provide better MRSI measurements, but 2 channels improve performance over a single channel.

References: [1] Avdievich et al MRM 62: 17-25 (2009) [2] Boer et al MRM 68: 662-70 (2012) [3] Tkac et al MRM 46:451-456 (2001) [4] Garwood et al JMR 153:155-177 (2001) [5] Zhu et al MRM 69: 1217-25 (2013) [6] Dydak et al MRM 46: 713-722 (2001) [7] Ogg et al JMRB 104:1-10 (1994)

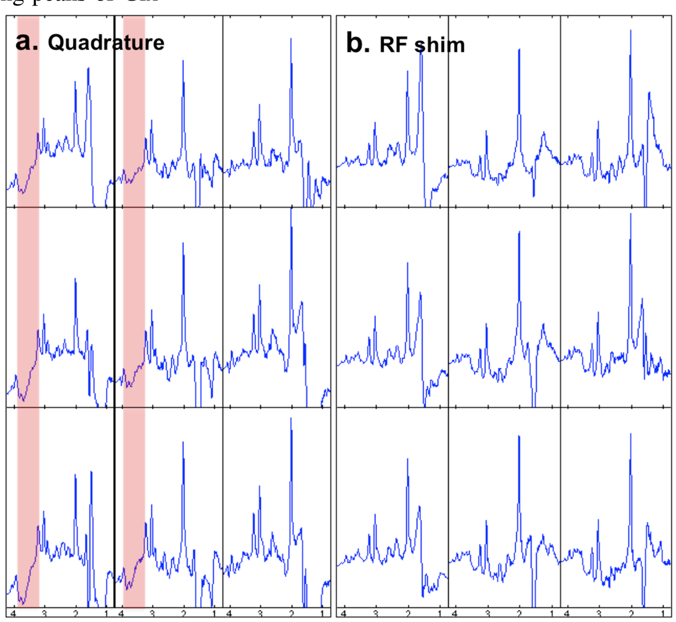

Figure 2. Comparison of grid spectra acquired with quadrature (a) and RF shim (b).