Improving pseudo-continuous arterial spin labelling at ultra-high field using parallel transmission

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Introduction: Arterial spin labelling (ASL) is a commonly used non-invasive perfusion imaging technique. Yet its implementation at ultra-high field (UHF) is not trivial. An increase of B_1^+ and B_0 inhomogeneity at UHF leads to poor labelling efficiency, diminishing the perfusion signal [1]. The specific absorption rate (SAR) scales quadratically with B_0, reducing the permitted pseudo-continuous labelling pulse duration and amplitude [1]. Parallel transmission (pTx) provides additional degrees of freedom that allow for constructive and destructive interference of different radio-frequency (RF) waveforms to mitigate B_1^+ inhomogeneity. RF shimming (or “static pTx”) aims to produce homogeneous flip-angles within the region of interest (ROI) by adjusting the complex weight of each available RF channel. In this study, we present an RF shimming strategy for homogenous pseudo-continuous labelling under explicit power constraints.

Methods: Perfusion-weighted images were acquired from two subjects on a Siemens (Erlangen, Germany) Magnetom 7 T scanner equipped with an 8 channel pTx system, and a Nova Medical Inc. (Wilmington MA, USA) 8Tx32Rx head coil. B_1^+ maps were acquired using a 2D “STE first” phase-cycled DREAM sequence [2, 3]. B_0 maps were acquired using a dual-echo gradient-echo sequence. A time-of-flight (TOF) sequence was used to select ROIs around the four principal arteries that feed the brain. The flip-angle optimisation strategy was based on a method proposed by Dupas et al. [4]. A spin dynamics matrix, A, was constructed, including information on B_0 off-resonances, transmit sensitivities, positions, and the gradient and RF waveforms. The RF shimming problem was then presented as the minimisation of $\| |Ab| - \theta \|_2$, subject to explicit power limits [5], where b is the complex weight of each RF channel, and θ is the desired flip-angle. The same algorithm was extended to “phase-only” shimming. The results were compared with those from circular polarised (CP) mode labelling pulses that produced the same amount of sum-of-all-channels power.

Results: The variable-exchange method achieved a good result in 5.4 seconds and the active-set method took 62.5 additional seconds. In simulation, RF shimming achieved a 143% increase in labelling efficiency compared to CP mode, and a 6% increase in labelling efficiency compared to phase-only shimming. *In vivo* experiments showed that RF shimming produced perfusion-weighted images with higher contrast than CP mode.

Discussions and Conclusion: Unlike dynamic pTx, RF shimming does not involve calculation of a full RF waveform, nor optimisation of the gradient trajectory. RF shimming provided significantly improved results in the small ROIs in this study with short calculation time. Overall, we have demonstrated the feasibility of improving ASL using RF shimming on a commercial head coil at 7 T.

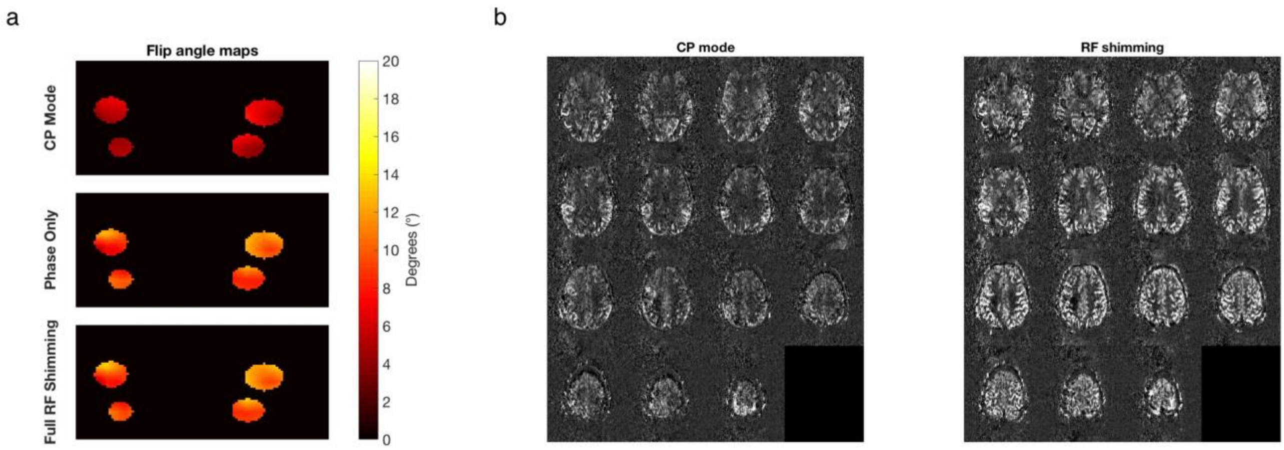

Figure 1 a. Simulated FA maps of the four principal arteries for different RF shims. b. CP mode and RF shimmed perfusion-weighted images of subject 1.

References: 1. Teeuwisse et al. Int J Imaging Syst Technol, 2010. **20**(1): p. 62-70, 2. Nehrke et al. MRM, 2012. **68**(5): p. 1517-26, 3. Tse et al. JMR, 2014. **245**: p. 125-32, 4. Dupas et al. JMR, 2015. **255**: p. 59-67, 5. IEC, 2010.