Optimized chemical shift selective suppression for pTx systems at 7T

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Introduction: Parallel RF transmission (pTx) offers flexible control of magnetization generation and has been successfully applied at 7T for spatially tailored excitations and mitigation of in-plane B1+ inhomogeneity for slice-selection [1, 2]. CHESS [3] pulses are known to provide good frequency selective suppression in proton spectroscopy as long as B1+ inhomogeneity is small. In this work we propose an optimized pTx CHESS pulse design for high-field applications where where variation in peak-to-trough excitation field magnitude is large (~3:1).

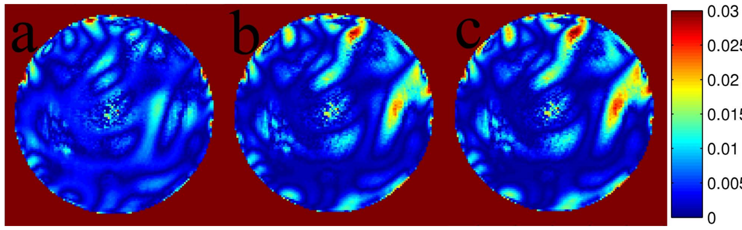

Fig. 1: Simulated absolute longitudinal magnetization for (a) T1=1s, (b) T1=3s, (c)T1=5s

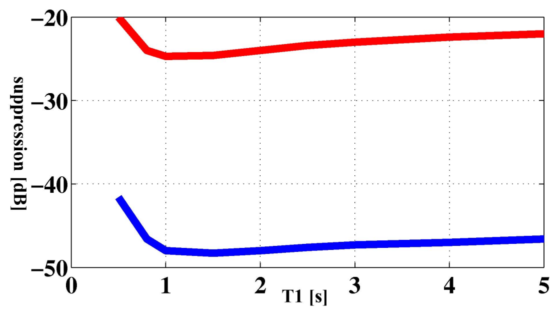

Fig. 2: Simulated mean suppression for pTx CHESS (blue) and conventional CHESS (red)

Methods: The pTx design method relies on a fast high flip-angle optimization over a Bloch simulator [4]. It uses experimentally collected quantitative B1+ maps [5] to optimize pulse amplitude and phase for all transmit channels and all sub-pulses to achieve the best possible water suppression.

The gap between the CHESS sub-pulses was 20ms and they were designed to suppress water in a range of T1 of 1-5s. The performance of the pTx CHESS pulses for water suppression at 7T was demonstrated using B1+ maps from a phantom with 3:1 variation in peak-to-trough excitation field magnitude. These results are compared to conventional CHESS using a birdcage mode excitation.

To accelerate the design and optimization process, all frequency selective pulses are replaced with rectangular pulses that create the same flip-angle. The frequency selection is reintroduced after the pulse optimization is completed without changing the pulse performance.

The availability of 8 transmit channels that drive a loop coil through a Butler matrix makes it possible to create the 3 CHESS sub-pulses in a way that each sub-pulse has spatially different suppression, but the resulting total suppression is very close to uniform. Thus, a low variation in peak-to-trough excitation field magnitude for every sub-pulse is not needed to create uniform water suppression for the three-pulse CHESS combination (Fig. 3).

Results: Numerical simulation of pTx CHESS pulse performance shows large improvement in water suppression compared to conventional CHESS using a birdcage mode excitation (Figs. 1, 2). pTx CHESS pulses achieve a mean water suppression of better than -45dB for the T1 between one and five seconds. Their minimum suppression is always better than -30dB. In contrast, conventional CHESS have a mean water suppression of only around 25dB.

The design method used a graphics processor (NVIDIA, CUDA architecture) for compute intensive parts of the optimization. The pulse design took less than 2 s for an 8 channel transmit array and B1+ maps with a resolution of 128 by 128 (Macbook Pro, 2.2GHz Core 2 Duo and GeForce 8600M GT).

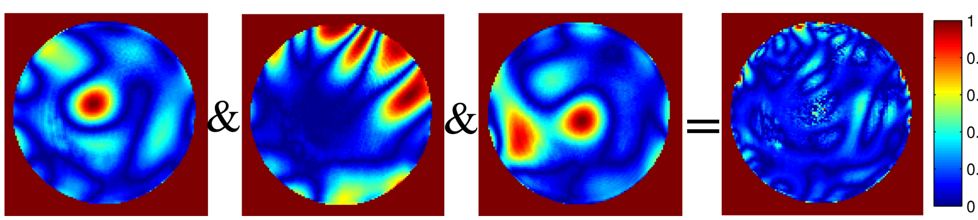

Fig. 3: Three pTx sub-pulses (left) and resulting water suppression for T1=1s (right). Absolute longitudinal magnezitaion is plotted

Discussion and Conclusion: We presented a new method for chemical shift selective suppression for pTx systems in the presence of large B1+ field inhomogeneity. Pulses that achieve a substantially better water suppression compared to conventional CHESS are designed in less than 2 s using a low-end graphics processor. This is achieved without compromising the ability of CHESS pulses to suppress spins over a large range T1.

References: [1] Setsompop et al, MRM 59:908-915 (2008), [2] Setsompop et al, MRM 60(6):1422-32 (2008), [3] Haase et al,Phys. Med. Biol. 30:341 (1985), [4] R. Gumbrecht et al, ISMRM 2010 [5] J. Lee et al, ISMRM 2010

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