B0 and B1 correction using the inherent degrees of freedom of a multi-channel transmit array

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Introduction

Recent advancements in parallel transmission have focused on the development of tailored, multi-dimensional pulses (1) with potential undersampling (2,3) for correction of B0 and B1 homogeneity and reduction of SAR (4), particularly. We present a method which exploits the intrinsic frequency, phase, and amplitude degrees of freedom of a parallel transmitter to correct for B0 variation and non-uniform B1 profiles for the improvement of fat saturation preparation and removal of off-resonant effects in TrueFISP imaging, potentially with elimination of banding. Experiments were performed at 1.5T using a 4-channel current mode class D amplifier (6-7) configuration to demonstrate the potential of parallel transmission using these methods in the clinical arena.

Theory

Fat saturation techniques like CHESS (5) suffer diminished efficacy from off-resonance when some tissues lie outside the bandwidth of the spectrally selective pulse, and can also introduce unwanted water saturation. By tuning the frequency of each element in a multi-channel transmission array to its local, average Larmor frequency fat saturation can be improved in the vicinity of the coil, while overall saturation is improved through the sum of all coils. We call this Parallel excitAtion for B-field insensitive fat Saturation preparaTion (PABST). Similarly, adjusting the phase of the many channels can create a spatially-varying axis of rotation, tailored to be perpendicular to the off-resonance angle map in TrueFISP, $\beta = 2\pi\gamma\Delta B T_R$, such that no spins lie parallel to the B1 field (which leads to banding). In a two-pulse scheme, spins at the end of TR are returned to z and then re-excited into the transverse plane, pre-phased to account for off-resonance. Slight adjustment of the amplitude of the two (nominally $\alpha/2$) pulses can accommodate decay to reduce and even eliminate the effects of off-resonance, including banding.

Materials and Methods

Two-dimensoinal Bloch simulations were carried to verify the performance of the two proposed techniques. For PABST, a 10ms CHESS pulse was simulated on a uniform volume coil and 8 channel transmit array, both in the presence of an 8ppm liner off-resonance gradient. The frequency of each array channel was centered at the density and sensitivity weighted average frequency as would be collected from an FID. The amplitude was increased slightly to restore a 90° tip angle in the center of the array by numerically calculating the effects of off-resonant excitation on absolute tip angle. Imaging experiments were carried out using a four channel, CMCD (6,7) based array and a Siemens 1.5T Espree (Siemens AG, Erlangen, Germany), with a misadjusted x-shim to introduce roughly 8ppm off resonance across the sample. Simulations of the off-resonant correction in TrueFISP were performed (TR=10ms, $\beta=\pm 3\pi/2$ across FOV) for a traditional, alternating phase excitation using a volume coil and again with two-pulse correction method that matches rotation axis to off-resonance angle. A two-tissue phantom was used simulating blood (T1=1250ms, T2=125ms) and muscle (T1=900, T2=50), to observe potential change in contrast.

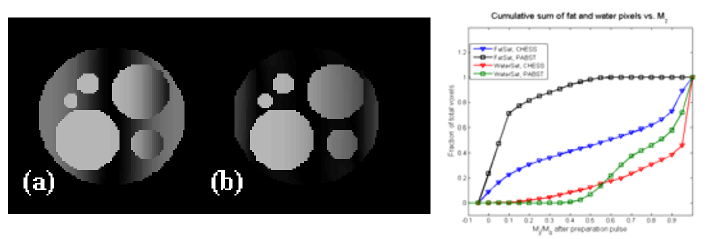

Figure 1: Simulations of (a) Traditional, single-channel CHESS fat sat (FS) and improvement with PABST (b). (c) Pixel statistics of fat and water saturation levels.

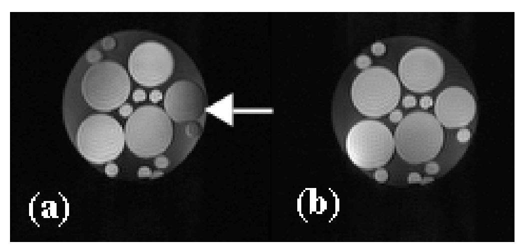

Figure 2: Phantom images of (a) Traditional CHESS and (b) PABST with a four channel CMCD array. PABST exhibits superior fat saturation (left and right sides) with reduced water saturation (indicated by arrow).

Results and Conclusions

Simulation (fig 1) and phantom imaging experiments (fig 2) both demonstrate the increased efficacy of fat saturation with the PABST method over traditional CHESS. In PABST, 71% of fat is excited to $|M_z| < 0.1\ M_0$ and no fat has $|M_z| > 0.5\ M_0$, compared to 22% with CHESS (max $|M_z| = 0.7M_0$). Imaging experiments confirm that fat saturation is improved over traditional CHESS, with more uniform fat saturation and reduced water saturation (fig 2). TrueFISP simulation for the standard volume coil (fig. 3a,b), and the new method (figure 3c). Off resonance effects are corrected, to within 5% of signal power for an image with no off resonace. Both situations present novel avenue of research in the application of a multi-channel transmitters to the clinical routine at 1.5T.

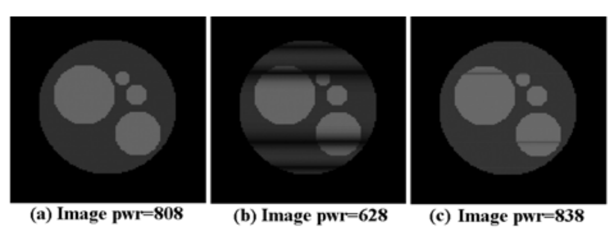

Figure 3: Simulation of TrueFISP magnetization with off-resonance correction. (a) No off-resonance, (b) with off-res, (c) two pulse correction Scheme. Note only small fissured remain from bands and no change in contrast.

References

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