Fast B1+ mapping with Validation for parallel transmit system in 7T

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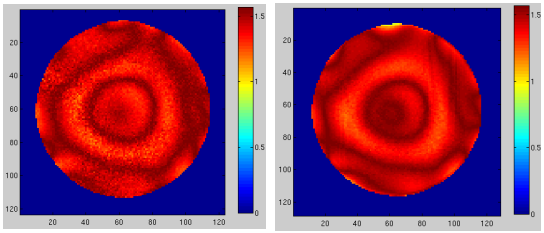
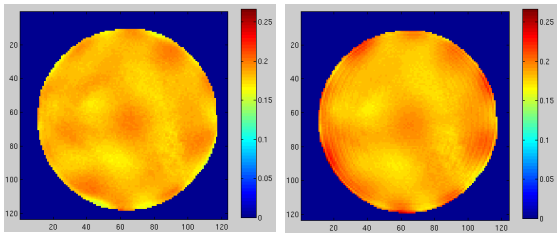
Introduction

Inhomogeneity of RF excitation Field (B1+) is severe at high field (7T), which leads to inhomogeneous flip-angle distribution. Parallel transmission (pTx) can be used to mitigate these field variations and achieve spatially uniform flip angle. Integral to the design of pTx RF pulses is the rapid and reliable mapping of B1+ for transmit arrays. A two-phase method measures the B1+ of the eight modes transformed by the Burtler matrix [2]. For the birdcage mode, images are collected with several excitation flip angles. The excitation profile of the birdcage mode and the receive profile (B1-) are then estimated. For the other seven modes, a single image with a low flip angle for each mode is collected. By dividing out the receive profile, the B1+ of the other seven modes can subsequently be estimated. We propose a modification of this approach for the birdcage mode mapping by collecting several images with saturation and excitation pulses [3]. In this method, the excitation flip angle is kept constant, but a saturation flip angle is varied. For the other seven modes, we collect one image per each mode with the same excitation flip angle but without the saturation pulse. Because we use very low excitation flip angle, T1 relaxation effect can be ignored even with the short TR. Thus, the B1+ mapping scan is rapid. For demonstration of the utility of this method, we acquired multi-slice B0 and B1+ maps and designed a low-flip-angle spoke pTx RF and a high-flip-angle composite pulse for pTx at 7T.



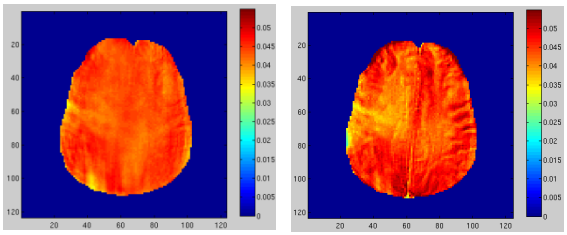
(a) Bloch Simulation (b) Measured

Fig. 1. Flip angle (radian) of Composite pulse for Water Phantom, iso-center slice



(a) Bloch Simulation (b) Measured

Fig. 2. Flip angle (radian) of two spokes in Water Phantom, off-center slice (F10mm)



(a) Bloch Simulation (b) Measured

Fig. 3. Flip angle (radian) of two spokes for in-vivo, iso-center slice

Methods – B1+ mapping

For the Birdcage mode, which is the most uniform mode for the Butler array, we acquired several images using a turbo-flash readout. The excitation flip angles is kept constant, but the saturation angles vary. A sinc pulse is used for saturation and excitation pulse. For each pixel, the images are fitted to a cosine function of the saturation flip angle. To reduce the effect of the nonlinearity of the high flip angle excitation of the sinc pulse, we iterated the fitting process to select and use the images where the estimated saturation angle less than 70º. By this fitting method, we can estimate the actual saturation angle, $\theta_{s,act}(x,y)$, and the multiplication of the density of the subject, the receive profile (B1-), and the sine of the excitation flip angle, $\rho(x,y)RX(x,y)\sin(\theta(x,y))$, can be estimated. By dividing out the sine of the actual excitation angle, we can estimate the multiplication of the density of the subject and the receive profile, $\rho(x,y)RX(x,y)$. This profile is used in estimating B1+ of the other modes, where only one image without the saturation pulse is acquired. We use the same excitation pulse and the image is acquired by the turbo-flash readout. The actual excitation flip angle is estimated by dividing the image by the product of the density of the subject and the receive profile (B1-). This mapping procedure was implemented as a multi-slice acquisition.

Methods –Validation with low-flip angle spoke pTx pulse and high-flip angle pTx composite pulse

The low-flip-angle pulse, two-spoke pTx mitigation, was played as an excitation pulse in a gradient-echo sequence for all eight modes. By diving out the receive profile, the excitation angle can be estimated. The high-flip-angle pulse, a pTx composite pulse [4], was played as a saturation pulse preceding a turbo-flash readout with the low flip angle slice-selective sinc excitation pulse played only on the birdcage mode. By diving out the low-flip angle image without the saturation pulse, the actual saturation angle of the pTx composite pulse can be determined. We compared the flip angles measured by the scan to the flip angle estimated by the Bloch simulation using the measured B0 and B1+ map.

Results

The scans were performed on water phantom (T1 of 175ms) with a 3:1 variation in magnitude of B1+ and *in-vivo* subjects using the eight-channel parallel transmit prototype system on a 7T Siemens scanner. An eight-channel pTx array coil was used with a Burtler matrix [2]. For a single slice acquisition with 128 PE lines, the turbo-flash scan takes 20 seconds (TR=1s) for water phantom and 200 seconds for in-vivo scan (TR=10s). For five slices with 128 PE lines, the scan takes one minute for water phantom and 200 seconds for the in-vivo scan. For the water phantom, we designed and play all of spoke, and composite. However, for in-vivo, we play only the low flip angle pulse due to local SAR constraints. The flip angles of the Bloch Simulation and the measured flip angles are shown for composite pulse on the water phantom in Fig.1, two spokes on the water phantom in Fig. 2, and two spokes on a human subject in Fig. 3. The phantom data show excellent agreement between Bloch simulation and experiments, and the human data agree to within 8% although some residual anatomical contrast is evident.

Conclusion: We developed a fast B1+ mapping method for pTx at 7T and validated its performance phantoms and a human subject. The measured flip angle maps show excellent agreement with predictions by a Bloch simulation.

References: [1] Setsompop, MRM 2008, [2] Alagappan, MRM 2007, [3] HP Fautz, p1247, ISMRM 2008, [4]R. Gumbrecht et al, submitted, ISMRM 2010.

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Disclaimer: The concepts and information presented in this paper are based on research and are not commercially available.