Parallel Transmission in Liver MRI at 7T: Initial Results

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Introduction: The feasibility of torso imaging at 7T has been demonstrated in several targets (heart, prostate, kidneys, hips, etc.) [1-5]. However, to consider successful clinical applications in those organs, fast, robust and practical methods must be developed to address the severe transmit B_1 (B_1^+) inhomogeneity present at such high magnetic field. B1 shimming proves to be a successful approach to address this issue, especially in organs of a limited size such as the prostate [1]. However, obtaining a uniform B_1^+ field at 7T using B1 shimming over the longest dimension of large organs such as the liver is extremely challenging [6], if not impossible, and such B1 shim solutions typically come at the cost of very low RF efficiency (high level of destructive interferences [7]) yielding SAR values beyond acceptable limits. Parallel transmission (pTX) [8,9] has much larger degrees of freedom to address B_1^+ inhomogeneity and has been shown to be able to produce spatially homogeneous excitation in the human head [10]. This technique, however, has not yet been demonstrated in body imaging at 7T, where mapping B_1^+ on multiple channels in the presence of respiratory motion is an additional challenge. Here, we report the first liver images obtained using 3D slice selective pTX RF pulses for flip angle homogenization at 7T.

Methods: Healthy volunteers who signed an IRB approved consent form were imaged on a whole body 7T MR scanner with an eight-channel prototype pTX system (Siemens, Erlangen, Germany). An eight-channel transceiver stripline array [11] was used, consisting of two (anterior and posterior) plates of 4 elements each, each channel being powered with a 1kW RF amplifier (CPC, USA). 3D slice selective pTX RF pulses were designed in Matlab with spoke trajectories to create uniform excitations of the liver within an axial view positioned at the largest transverse section of the organ. RF sub pulses were Gaussian shaped with a time-bandwidth-product of 2. Slice-selective gradients were designed for a slice thickness of 5 mm. Magnitude and phase modulations of individual spokes and individual RF channels were calculated based on a magnitude least squares optimization [10]. RF pulses were designed with different numbers of spokes and the resulting images were compared. In vivo complex B_1^+ maps (Fig. 1) for the 8 channels were obtained using an ultra fast multi-channel B_1^+ estimation technique [12] based on a calibration scan acquired within a single breath hold (20s). B_0 maps, derived from images at two TE's, were incorporated into RF pulse design to minimize off-resonance effects. Excitation patterns were imaged using a modified 3D gradient echo (GRE) pulse sequence for which relevant imaging parameters were: FOV=450×253×32mm^3, matrix size=256×205×32, TR/TE=11/1.66 ms, GRAPPA=2 and partial Fourier=6/8. Acquisition time was ~20 seconds, allowing for single breath hold imaging.

Results: Fig. 2 displays the middle slice of the 3D GRE images acquired using different RF pulses, along with the corresponding simulation results. As can be seen, pTX with multi-spoke pulse design significantly improved the flip angle homogenization within the liver as compared to static B1 shim (1-spoke pulse design in this case). The two evident dark bands (indicated by arrows) present in the image obtained with static B1 shim were effectively removed by applying multi-spoke pTX pulses. In addition, our Bloch simulations of transverse magnetization distributions using different RF pulses provided good predictions for the overall characteristics of the corresponding experimental images, as can be seen in Fig.2 despite the fact that the experimental images are still modulated by the receive profile of the coils, responsible for a brighter signal in the periphery than in the center of the torso.

Discussion and Conclusion: We have shown the feasibility of liver imaging at 7T for which advanced pTX RF pulse design is needed. Critical in this study is the ultra fast B_1^+ estimation which consistently provides robust B_1^+ maps in the body. Our preliminary data show that 3D spoke pTX pulses can be used to obtain images with uniform RF excitations over an entire section of the liver, which holds promising potential for future clinical applications.

References: **1.** Metzger et al., MRM 59:396-409(2008). **2.** Vaughan et al., MRM 61:244-248(2009). **3.** Snyder et al., MRM 61:517-524(2009). **4.** Ellermann et al., ISMRM 2010 p849. **5**. Metzger et al., ISMRM 2010 p403. **6.** Snyder et al., ISMRM 2007 p729. **7.** Van de Moortele et al., MRM 54:1503-1518(2005). **8.** Katscher et al., MRM 49:144-50(2003). **9.** Zhu, MRM 51:775-84(2004). **10.** Setsompop et al., MRM 60:1422-1432(2008). **11.** Snyder et al., ISMRM 2007 p164. **12.** Van de Moortele et al., ISMRM 2009 p367. **Acknowledgments:** KECK Foundation, EB006835, PAR-02-010, EB007327, P41 RR008079, P30 NS057091 and S10 RR026783.

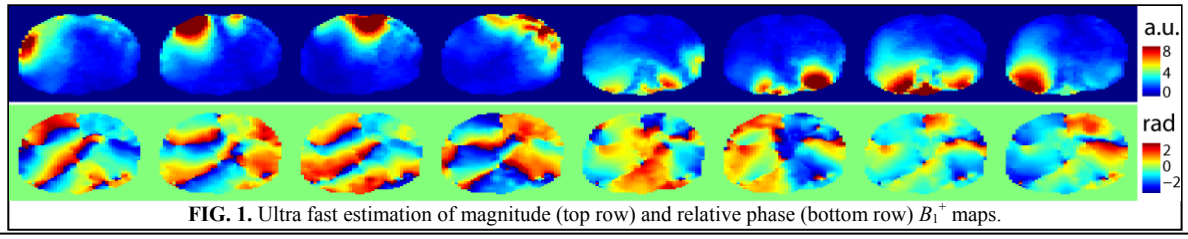

FIG. 1. Ultra fast estimation of magnitude (top row) and relative phase (bottom row) B_1^+ maps.

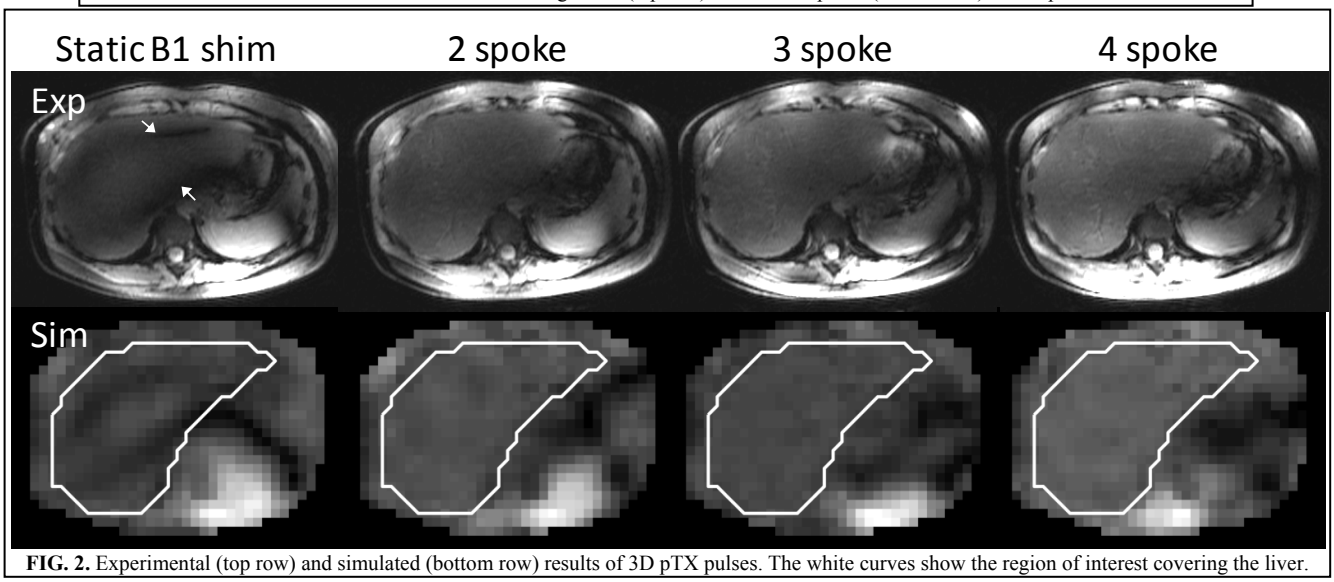

FIG. 2. Experimental (top row) and simulated (bottom row) results of 3D pTX pulses. The white curves show the region of interest covering the liver.