SAR Analysis of Parallel Transmission in Cardiac Imaging at 7T

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Introduction: Recently, there has been an increasing interest in body imaging at 7T [1-3]. One critical issue to be addressed in those applications is the severe transmit B_1 (B_1^+) inhomogeneity present at such high magnetic field. Parallel transmission (pTX) [4-6] shown to be able to reduce B_1^+ inhomogeneity [7] holds great potential for body imaging. However, pTX at 7T involves complicated behavior of specific absorption rate (SAR) as was shown in the human brain [8,9]. Here, we investigated SAR behavior of pTX when using 3D spoke RF pulses for homogenizing B_1^+ in cardiac imaging at 7T.

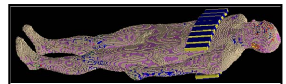

FIG. 1. EM modeling

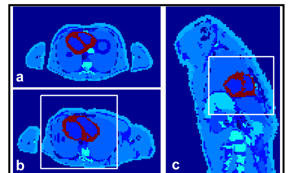

FIG. 2. Axial (a), four chamber (b) and short axis (c) views.

Methods: A tight 16Ch transceiver array similar to that in Ref. [10] was considered, consisting of two (anterior and posterior) plates of 8 elements each. Electromagnetic fields within a body model were simulated using the XFDTD software (Remcom Inc.) (Fig. 1). 3D slice selective spoke pTX RF pulses [7] were designed to achieve uniform excitations in a region of interest (ROI) covering the heart for two cases: one short axis view and one four chamber view (Fig. 2). In order to characterize SAR behavior, different RF design scenarios were considered and respective SAR values were calculated and compared. RF pulses were designed with different numbers of spokes (Ns = 2, 3, 4, 5 and 6), different numbers of coil elements (Nc = 4, 8, 12 and 16) and different excitation errors (defined as $\||Ab|-m\|/\|m\|$ using the same notations as in Ref. [7]). To evaluate RF performance, transverse magnetization (Mxy) patterns were simulated. In addition, homogeneity coefficients defined as the standard deviation of Mxy over the mean were calculated within the ROI. Note that the Nc channels chosen for each view were those having the greatest average B_1^+ amplitudes within the ROI since a separate analysis (not shown here) showed they were the most efficient for SAR reduction.

Results and Discussion: As seen in Fig. 3, global and maximum 1g SAR values for the short axis view first decreased drastically from 4 to 8 channels and then changed slightly from 8 to 16 channels, whereas SAR values for the four chamber view constantly decreased with increasing number of channels (except for the 3 spoke pulse design where the global SAR was not monotonic). Those results show that in general more channels are desired to minimize local SAR, especially for the four chamber view. Fig. 4 shows SAR versus excitation fidelity for different numbers of spokes when using 16Ch transmit. The Mxy patterns (see white box Fig. 2) are shown for 3-spoke pulse design with dashed ellipses indicating the ROI. It can be seen that, as excitation error increased, global and local SAR of both short axis and four chamber views initially decreased rapidly as long as errors were small (< 2%), then slowly for intermediate (2-4%) and large (> 4%) errors . The L shape of those curves suggests that an acceptable compromise between excitation fidelity and SAR could be found.

Conclusion: We have characterized SAR behavior for 3D pTX pulses when used for B_1^+ homogenization in cardiac imaging at 7T. Our simulation results show that SAR strongly depends on pulse design specifications (including target size and location with respect to RF coil elements) and that in general more RF channels are desired to reduce local SAR.

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.** Katscher et al., MRM 49:144-50(2003). **5.** Zhu, MRM 51:775-84(2004). **6.** Ullman et al., MRM 54:994-1001(2005). **7.** Setsompop et al., MRM 59:908-915(2008). **8.** Wu et al., ISMRM 2007 p3350. **9.** Zelinski et al., JMRI 28:1005-1018(2008). **10.** Snyder et al., ISMRM 2007 p164.

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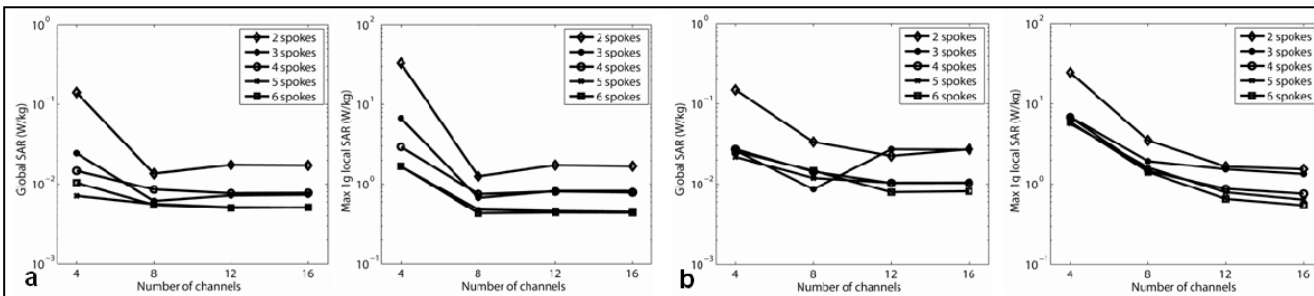

FIG. 3. SAR vs number of channels for different numbers of spokes for short axis (a) and four chamber (b) views. Nominal flip angle=10º.

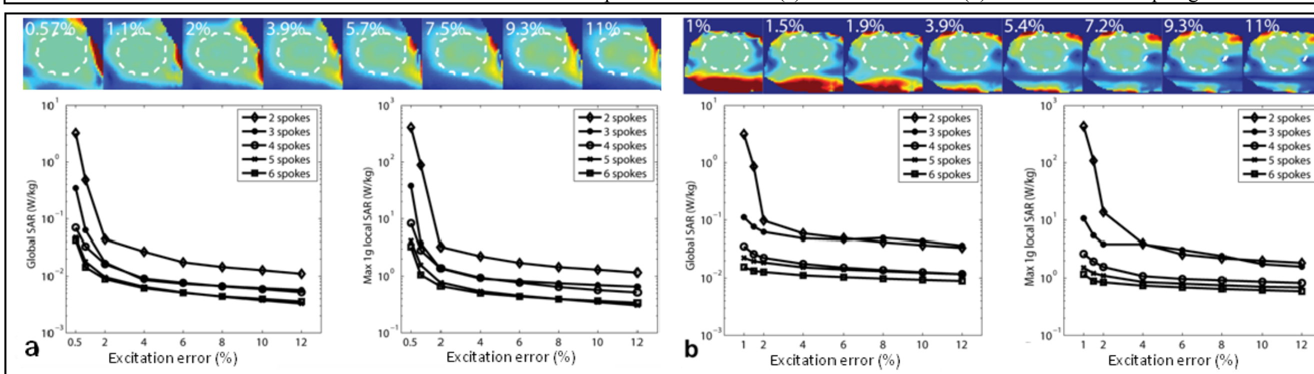

FIG. 4. SAR vs excitation error for short axis (a) and four chamber (b) views. Top row shows Mxy patterns with homogeneity coefficients.