Local SAR Estimation for Human Brain Imaging Using Multi-channel Transceiver Coil at 7T

Xiaotong Zhang[1], Sebastian Schmitter[2], Jiaen Liu[1], Pierre-Francois Van de Moortele[2], and Bin He[1,3]

[1]Department of Biomedical Engineering, University of Minnesota, Minneapolis, MN, United States, [2]Center for Magnetic Resonance Research, University of Minnesota, Minneapolis, MN, United States, [3]Institute for Engineering in Medicine, University of Minnesota, Minneapolis, MN, United States

Introduction: Parallel transmission technique has been recognized as a potential powerful tool for B1 inhomogeneities compensation at UHF; however, elevated SAR associated with increased main magnetic field strength remains as a major safety concern in its application. As an alternative to the conventionally used numerical model-based electromagnetic simulation method, a B1-based subject-specific local SAR estimation approach for single channel transmission is presented in this study. A series of imaging methods [1-2], which were developed to deal with biological tissues with complex anatomical structures, have been adapted for human brain imaging. The feasibility of present approach was demonstrated in a human subject experiment at 7T using a 16-channel transceiver head coil.

Methods: A healthy volunteer who signed an IRB approved consent form was imaged in a 7T scanner (Siemens) equipped with an elliptical 16-channel head transceiver coil [3]. A volume of interest containing 12 contiguous transverse slices was chosen for the study at a spatial resolution of 1.5×1.5×5mm^3. A series of 16 small flip angle GRE images were acquired with each individual channel transmitting at a time while receiving all together; a long TR, short TE, GRE image was obtained in order to produce a map of proton density (PD) biased $\tilde{B}_{1,j}^-$, after normalization by the sinus of the excitation flip angle to remove the $\tilde{B}_1^+$ component; a 3D map of the excitation flip angle was obtained with the AFI technique [4]. Based on these data, $|\tilde{B}_{1,k}^+|$, PD biased $|\tilde{B}_{1,j}^-|$ and corresponding relative phase maps were calculated [5-6]. The 2D GRE images (small flip angle) were obtained in 29 mins with ten averages, while the long TR GRE images in 21 mins with one average, and the 3D AFI map in 18 mins with two averages.

Based on the empirical observation of approximately symmetric nature of the magnitude of transmit and receive B1 fields [7], the relative PD distribution was extracted first, and $|\tilde{B}_{1,j}^-|$ can be estimated as discussed in [2]. Then utilizing measured relative phase information, by applying Gauss Law for magnetism and ignoring $\tilde{B}_z$ component, the absolute phase of $\tilde{B}_{1,k}^+$ and $\tilde{B}_{1,j}^-$ can be retrieved voxel-wisely as in [2]. By employing the modified Dual-excitation algorithm over the retrieved complex B1, the EPs can be reconstructed as in [1,8]. Finally, the voxel-wise (unaveraged) local SAR can be estimated using complex B1 and reconstructed EPs as described in [9], under the assumption of a dominant $|\tilde{E}_z|$ compared to other components of electric field. Note that, in experimental conditions, since weak MRI signals observed in bone tissue is expected to deteriorate B1-mapping results and subsequent EPs reconstructions within and close to scalp and skull regions, the present study was confined within soft brain tissues, e.g. cerebrospinal fluid, gray matter, white matter, etc.; local SAR estimation was performed and depicted only within brain region. SEMCAD (Speag, Switzerland) was used to provide simulation result as a reference. The Ella model (2×2×2mm^3) from Virtual Family, was loaded in the reproduced same RF coil, with the head and neck portion placed supinely in the coil center. Simulated voxel-wise (unaveraged) SAR results from axial slices exhibiting the largest anatomical similarities were chosen for comparison.

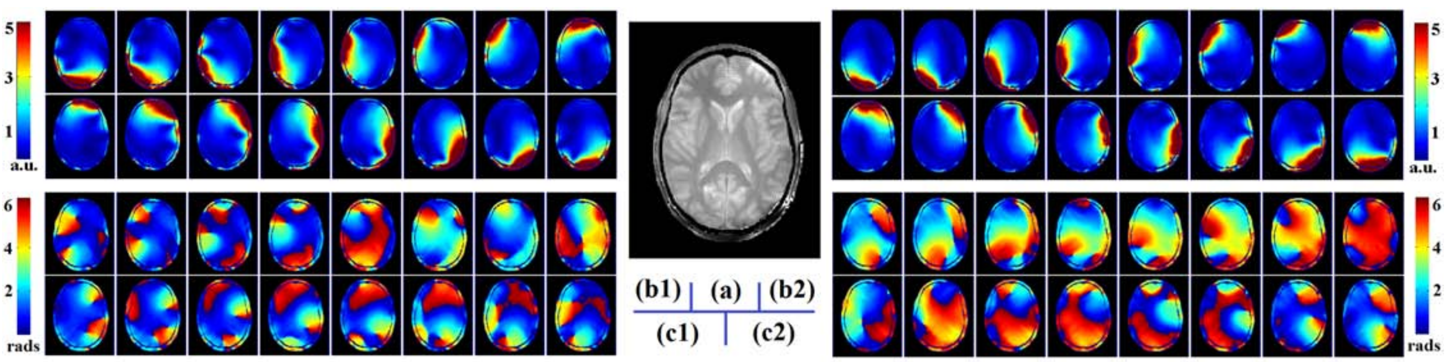

Fig. 1: (a) Extracted relative PD, (b1) measured $|\tilde{B}_{1,k}^+|$ and (b2) estimated $|\tilde{B}_{1,j}^-|$ distributions. (c1)(c2) Retrieved absolute phases of $\tilde{B}_{1,k}^+$ and $\tilde{B}_{1,j}^-$, respectively.

Results: Fig. 1 shows, on the slice of interest, extracted proton density map, measured/estimated B1 magnitude distributions, and retrieved absolute phase images. Fig. 2 shows, on two slices of interest, estimated (in experiment) and the corresponding simulated SAR for selected channels. Reasonable overall similarity is observed. Note that at UHF, B1 distribution is more sensitive to individual's head structure, head position within the coil, as well as actual current distribution along coil conductors. Noticeable differences can be observed in Fig. 2, which may result from such factors in numerical modeling.

Discussion and Conclusion: The present study has demonstrated the capability of estimating subject-specific local SAR for single transmit element, which holds strong promises for explicit constraint in B1 shimming calculation and multi transmit RF pulse design. Future work shall involve SAR estimation in real metric.

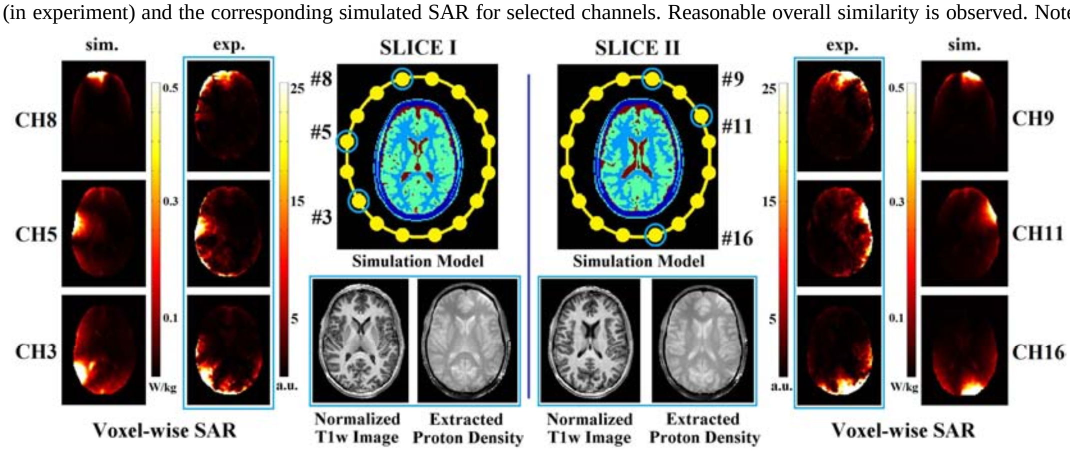

Fig. 2: On two axial slices, normalized T1w images [10], extracted proton density, and estimated voxel-wise local SAR for selected channels. Simulation results on similar slices shown as references. (Experiment results encircled by blue rectangles)

References: [1] Zhang et al., IEEE TMI 2010, 29(2): 474-481. [2] Zhang et al. MRM 2012 (Online). [3] Adriany et al., MRM 2008, 59: 590-597. [4] Yarnykh, MRM 2007, 57:192-200. [5] Van de Moortele et al., MRM 2005, 54: 1503-1518. [6] Van de Moortele et al., ISMRM 2007, 1676. [7] Van de Moortele et al., ISMRM 2009, 367. [8] Liu et al., ISMRM 2012, 3486. [9] Zhang et al., ISMRM 2012, 2669. [10] Van de Moortele et al., NeuroImage 2009, 432-446. **Acknowledgment:** NIH R01 EB006433, R01 EB007920, R21 EB014353, T32 EB008389, P41 EB015894, S10 RR26783 and WM KECK Foundation.