Detailed Experimental and Computational Analyses of the RF Field at 7T: Effects of the Load Content on Achieving 90° Tip Without SAR/Power Violations

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Introduction

In ultra high field (UHF) human experiment, the dimensions of the coil/load can be on the order of multiple wavelengths [1, 2]. Thus the geometry and the properties of the subject/load have a significant influence on the performance of the coils and/or transmit/receive arrays. In this study, we provide computational (using the finite difference time domain, FDTD, method) [3] and experimental (using a 7 tesla whole body MRI scanner) analyses that examine the required RF power and transmit field in two different loads in order to achieve a 90° tip angle without local/global specific absorption rate (SAR) violations at 7 tesla.

Methods

Simulations using an FDTD algorithm were carried out for a transverse electromagnetic (TEM) coil [4] operating at 7 tesla. We calculated the B_1 map/electric field inside two spherical/head-sized phantoms at the TEM coil's linear mode of operation. The conductivity of the phantoms were set to 0.46 S/m (phantom1) and 1.15 S/m (phantom2), which approximately resemble the conductive properties of the brain and CSF/cerebellum at 300 MHz, respectively. Using the B_1 map (transmit and receive) calculated with the FDTD method, we generated the GRE images at different input voltages. We validated the simulation results by comparing the calculated GRE images to experiment results obtained using a Siemens 7 tesla whole-body Tim Trio scanner. After the validation, we used the FDTD calculated B_1 map and electric field maps to analyze the global and local SAR of the two phantoms.

Results and Discussion

For validation purposes, Fig 1 shows the calculated and experimentally acquired (at 7 tesla) GRE images for both phantoms. In the experiment, 90° flip angle was achievable for phantom1; however, the maximum flip angle for phantom2 was obtained around 38° (max. allowed voltage was reached on the scanner without increasing TR beyond 2000 [ms]). Fig 2 depicts the local SAR and the $|B_1^+|$/Flip angle distributions within both phantoms when the FDA local SAR limit (8W/kg per 1gm) [5] was reached. Fig. 2 also provides the global SAR, at which the local SAR limit was reached. At local FDA SAR limit, the maximum intensity of the $|B_1^+|$ field and the flip angle (assuming a 2 ms width hard pulse) for Phantom1/Phantom2 were found to be 6.43/5.34uT and 197°/164°, respectively. At the local FDA SAR limit, the average flip angle across the volume of both phantoms was found to be 65°/54°, respectively. Note that the ratio of the power absorption to total real power (radiated and absorbed) entering the coil was found to be 88.44%/86.53% for both phantoms. The difference between 100% and these values will be the console's overestimates when determining SAR violation for this coil.

We also observed that the pixel in which the maximum intensity of the $|B_1^+|$ field occurs is not the same pixel in which the maximum local SAR occurs. Their locations are distanced by 3.4/1.7cm for the two phantoms. The abovementioned results also demonstrate that in order to reach local FDA SAR limit, more power absorption is required in the higher conductivity phantom (Phantom1) than in the lower conductivity phantom (Phantom 2). However at a desired average and/or maximum flip angle, the higher conductivity phantom would reach the SAR limit (both the local and the global) faster than the lower conductivity phantom.

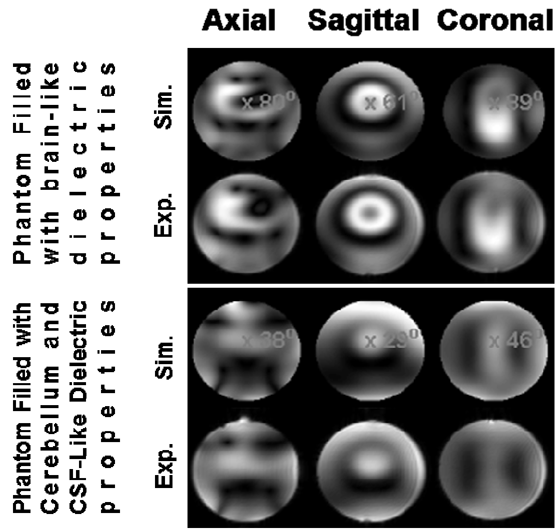

Fig. 1, (Sim.) Simulation results obtained using $Img=sin(\alpha|B_1^+|)\cdot|B_1^-|$, where $|B_1^+|/|B_1^-|$ are the coil's normalized transmit/receive fields; α is the flip angle. (Exp.) Experiments were conducted using GRE sequence with TR=2000 (> $16XT_1$) [ms] and TE=3 [ms]. The flip angles (displayed on the simulation images) are in excellent agreement with experimental results.

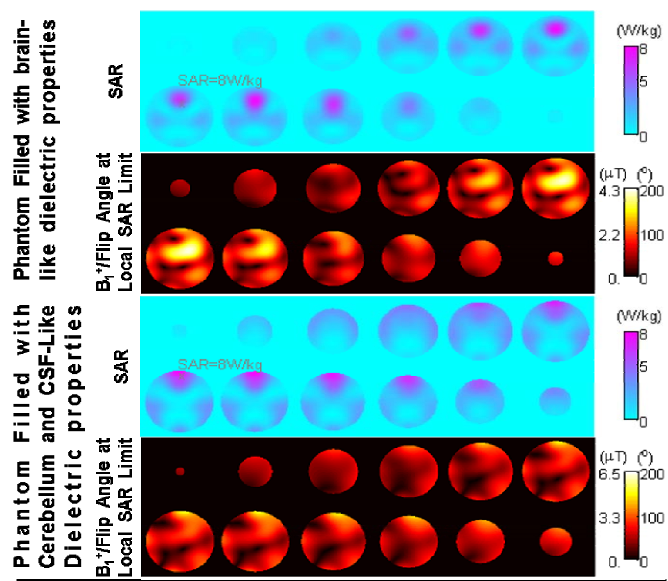

Fig. 2, Local SAR and B_1^+/flip angle maps (assuming a hard pulse with 2 ms width) at the local FDA SAR limit. The local SAR limit occurred at 1.97 W/Kg average SAR (5.2W total power absorption) for Phantom1 and 2.48 W/Kg average SAR (6.52W total power absorption) for Phantom2.

Reference:

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