Analysis of the Effect of an External High Dielectric Sleeve on the Performance of a Head Coil at 128 MHz

Bu S Park[1], Joshua W Guag[1], Leonardo M Angelone[1], and Sunder S Rajan[1]
[1] *CDRH/DP, FDA, Silver Spring, MD, United States*

INTRODUCTION: For high field MRI/NMR, it is apparent that sample power loss can be a significant factor in temperature increase (ΔT), specific absorption rate (SAR), and signal-to-noise ratio (SNR) (1). The conservative electric field (E_c), mainly caused by the scalar electric potential in the coil winding, can be a significant component in the total sample electric field (|E|) (2). Based on previous research (3,4), a simple method is introduced to decrease |E| and related (local and average) SAR using a high dielectric material (HDM) oriented parallel to the axis of the RF coil rod to partially shield the sample from the E_c of the coil. Numerical simulations using a human head model and finite difference time domain (FDTD) method demonstrated the shielding effect. This effect was experimentally verified by direct E-field measurements using a birdcage RF coil, with a distilled water dielectric sleeve.

METHOD: **Numerical simulations**: A High-Pass (HP) birdcage head coil was modeled using 12 rods of 300 mm of length, disposed circularly with an inner diameter (ID) of 290 mm. A 5×5×5 mm^3 isotropic resolution was used. A cylindrical HDM with ID of 340 mm and length of 300 mm was modeled with two different HDM materials, namely Barium Strontium Titanate (5) (relative permittivity (ε_r) equal to 323 and conductivity (σ) equal to 0.2 S/m) and distilled water ($\varepsilon_r = 74$ and $\sigma = 0.0048$ S/m). A human head model with 23 different tissue types and a 5 mm resolution was used (Fig. 1). All simulation work was performed using commercially available software (xFDTD; Remcom, Inc; State College, PA) and analysis of the results was performed in Matlab (The MathWorks, Inc., Natick, MA). All simulation results of electromagnetic fields were normalized so that $|B_1^+| = 4\mu T$ at the coil center.

Experimental measurements: All experiments were performed using in-house built 3T (128 MHz) birdcage head coil (12 rod, ID=290, OD=300, L=240 mm), RF amplifier (EIN Inc., Richardson, TX), electromagnetic-field measuring robot (DASY5, Schmid & Partner Engineering AG, Zurich, Switzerland) and donut-shaped sleeve compartment (ID=305,OD=380, L=350 mm) filled with a HDM made of distilled water (Fig.1). All results of electromagnetic fields were normalized to forward input power $P_{FWD} = 20$ Watts.

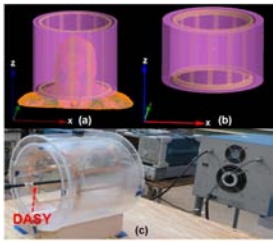

Figure 1 Geometry of 12-rod birdcage coil (yellow), cylindrical high dielectric material (Barium Strontium Titanate (a) or distilled water ((b) violet and (c)) and head model used for simulations ((a) and (b)) and experiment (c).

RESULT: Fig. 2 and 3 show the numerical calculation results of $|B_1^+|$, |E| (Fig.2), and SAR (Fig. 3) over the human head without and with (inside or outside) a cylindrical HDM. The maximum |E| and peak SAR were decreased of about 30%, whereas the mean local and 10g-averaged SAR were decreased of about 15% with the high dielectric material. Fig. 4 shows the experimentally measured results of |E| without and with the HDM made of distilled water. Maximum and mean |E| were decreased of about 21% (i.e., 428 vs. 340 V/m), and 48% (i.e., 273 vs. 143 V/m), respectively, at the end-ring region of the coil (Fig. 4).

DISCUSSION: As shown in Fig. 2, the |E| with HDM becomes smaller over the whole head and between head and RF coil because of the partially shielding effect, which is well consistent with experimental results in Fig. 4, resulting in decreased local and 10g-averaged SAR (Fig. 3). It is expected that this improvement should also correspond to slightly higher SNR and reduced temperature increase (ΔT) (6). The shielding effect is more obvious at near the surface of the model having strong |E|, local and 10g-averaged SAR (Fig. 2-4). Compared to previous research using HDMs located between the RF coil and sample (Fig. 2 Inside) (3), our method locating the HDM outside of the coil (Fig. 2 Outside) generates lower |E| between the coil and HDMs, and thereby allowing more space for the sample inside the coil, and more flexibility of HDM thickness optimization. Results of ongoing calculations using different geometry of the HDM (Fig. 1 (b)) will guide construction of an optimized HDM in the near future. The methods and results presented here can provide useful information for high field RF coils design having big challenges of increased absorbed power and temperature change.

REFERENCES

1. Minard and Wind, CMR 2001;13(3)190-210
2. Park *et al.* JMR 199 (2009) 233–237.
3. Yang *et al.*, JMRI 2006; 24:197-202
4. Wang and Zhang, ISMRM 2009; p3054
5. Neuberger *et al.*, CMR 33B(2) 109–114 (2008)
6. Park *et al.* JMR 202 (2010) 72–77.

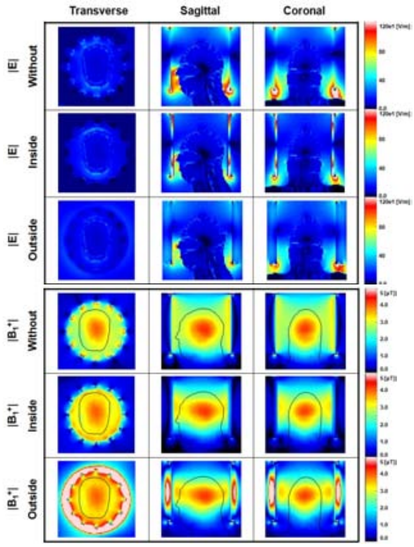

Figure 2 Comparison of |E| and $|B_1^+|$ after normalization on the central transverse (first column), sagittal (second column) and coronal (third column) slices of the head model a) without HDM, b) with HDM placed inside the coil, and c) HDM placed outside the coil. The HDM was located between the coil and sample (inside) or outside of the head coil.

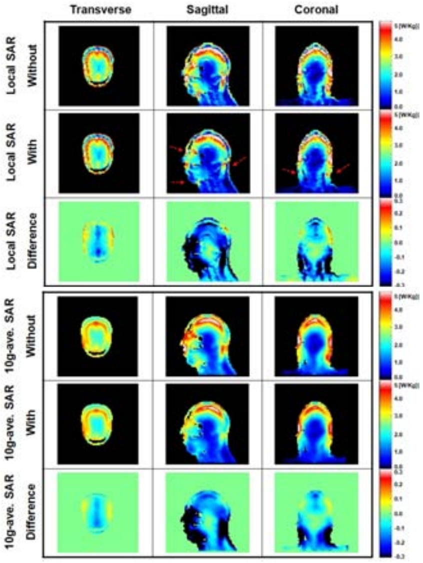

Figure 3 Numerical calculation results of local- and 10g-avg. SAR without and with the HDM located outside of the head coil showing over 30% reduction of SAR at near the surface of the model.

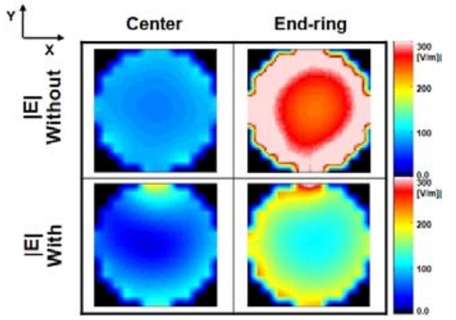

Figure 4 Experimentally measured |E| without and with the HDM at the center (first column) and edge (close to the end-ring of the RF coil, second column) region.