Ultra High Dielectric Constant (uHDC) Head Insert at 3T for Dramatic Reduction of SAR and B_1^+ inhomogeneity

Christopher Sica[1], Wei Luo[2], Sebastian Rupprecht[1], Michael Lanagan[2], Christopher Collins[3], Raffi Sahul[4], Seongtae Kwon[4], and Qing Yang[1]

[1]Radiology, Penn State College of Medicine, Hershey, Pennsylvania, United States, [2]Engineering Science and Mechanics, Penn State University, Pennsylvania, United States, [3]Radiology, New York University, New York, New York, United States, [4]TRS Technologies, State College, Pennsylvania, United States

Introduction: Dielectric materials have been utilized for improving the RF transmit and receive fields [1-6]. More recently ultra high dielectric materials (uHDC) with E_r = 800 to 1200 have yielded significant gains in transmit efficiency and receive sensitivity, and lower specific absorption rate (SAR) [7-8]. A 96% reduction in required transmission voltage is demonstrated in a phantom enclosed by uHDC ceramic material with a permittivity of ~1200. In this work, we evaluate a similar configuration utilizing ultra high dielectric material (E_r=1200) for brain imaging in terms of calculated SAR, measured SNR, B_1^+ homogeneity, and system estimated SAR reduction.

Methods:

Simulation: Figure 1 shows our configuration consisting of a cylinder of uHDC material with E_r = 1200 surrounding the brain within a volume transmit coil at 3T. The transmit RF fields with and without the dielectric cylinder present were calculated with xFDTD 7.0. Time-averaged SAR maps (10g averaging over the model) were computed with 90 degrees flip angle in the brain. Experiment: Ceramic dielectric blocks [105 mm x 80 mm x 22 mm] were taped to the inside of a Siemens 12 channel head matrix to form a structure similar to the computer model of the uHDC cylinder (See Fig. 1 Right). Several data sets were collected: a 3D slab-selective Bloch-Siegert acquisition [9-10] to measure B_1^+ over the brain (2.45 x 2.45 x 4 mm^3), and a geometrically matched 3D slab-selective GRE acquisition (2.1 x 2.1 x 4 mm^3). The GRE acquisition was acquired with a flip angle of 2 degrees. In this regime the signal is linearly proportional to B_1^+, and it can be divided out of the GRE images to obtain receive weighted images. SNR scaled images were computed as described in [11], utilizing noise scans that were embedded into the GRE acquisition. Transmission power was recorded from the scanner's power measurement unit. All data sets were collected with and without uHDC material present, on a Siemens 3T Magnetom Trio (Erlangen, Germany)

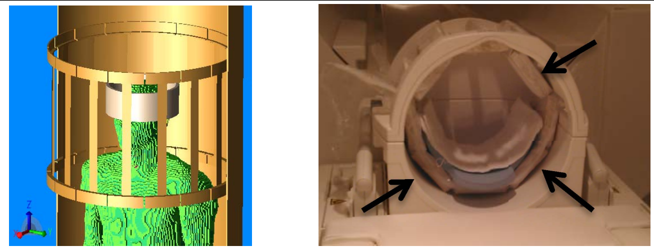

Figure 1 Configuration in simulation (left) and experiment (right). The simulation consists of a human body model in a volume transmit coil, and a cylinder of uHDC dielectric surrounding the brain. Experiment utilized ceramic blocks taped to the inside of a Siemens 12 ch head matrix.

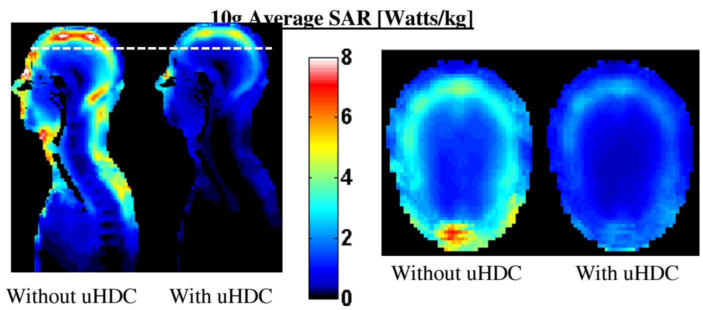

Figure 2 Simulated 10g average SAR with and without dielectric material present. Transverse slices on the right taken along the dotted white line. Both maps are on the same color scale.

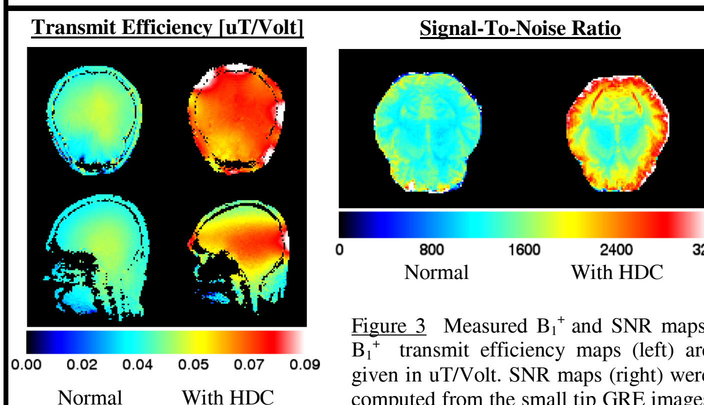

Figure 3 Measured B_1^+ and SNR maps. B_1^+ transmit efficiency maps (left) are given in uT/Volt. SNR maps (right) were computed from the small tip GRE images with the transmit factor removed.

Figure 4	Normal	With HDC	Ratio
Whole Body 10g Average	1.273 W/kg	0.251 W/kg	0.197
Whole Brain 10g Average	2.881 W/kg	1.159 W/kg	0.402

Results: Figure 2 displays the calculated SAR maps. There is a significant reduction in both whole body and whole brain SAR with uHDC material. No hotspot is present in these SAR maps. The measured B_1^+ transmit efficiency in transverse and sagittal planes in Fig. 3 demonstrates a greater uniformity with reduced central brightening. Visible within the sagittal slice, the addition of uHDC leads to a band of high B_1^+. The length of the uHDC blocks dictates the length of this band along z. Representative SNR maps of one slice from the volume acquisition are also displayed in Figure 3. The SNR gain varied from 50% in the periphery to several percent in the center. Figure 4 lists SAR statistics from the simulations. The 10g-average SAR is reduced by 80.3% and 59.8% with uHDC for whole body and whole brain, respectively. Experimentally, the system transmit power was reduced by 70%, within the range of calculated SAR reduction for the body and head. Across 16 slices from the B_1^+ volume, the coefficient of variation in the brain was reduced on average by 30%, with the reduction on a single slice varying between 20% and 39%.

Discussion: The HDC configuration presented here dramatically reduces both whole body and whole brain 10g-SAR while simultaneously improving the homogeneity of B_1^+ over the brain. This is an important issue because there is concern about the potential local SAR increase along with enhanced B_1^+ in the uHDC-enclosed regions, such that the elevated local SAR could exceed the limit imposed by the power monitor without detection. The calculated SAR reduction in the head (59.8%) and the SAR reduction estimated by the Siemens online monitor (57%) indicate that this is unlikely because the power monitor correctly assessed the SAR in the head in the presence of uHDC material. This suggests that a dielectric insert may allow for safe reduction of the TR when a given protocol is at the IEC limits. Thus, the SAR reduction with uHDC insert can be used to accelerate image acquisition for SAR-limited techniques such as the multiband technique, which requires high transmission power because of simultaneous slice excitation within a given TR. The simulation and experiment utilized an uHDC material currently available to us, it is possible to improve on these results with optimized geometry, permittivity, and reduced loss of the uHDC insert.

References: [1] Yang et al., JMRI 2006. [2] Yang et al., MRM 2010. [3] Teeuwisse et al., MRM 2011. [4] Teeuwisse et al., MRM 2012. [5] Luo et al., MRM 2013. [6] Yang et al, JMRI 2013 [7] Sica et al, ISMRM 2013 [8] Rupprecht et al, ISMRM 2013 [9] Sacolick et al., MRM 2010. [10] Jankiewicz al., ISMRM 2012 [11] Kellman et al, MRM 2005