RF Field Enhancement at 0.5T to 1.5T with Ultra High Dielectric Constant Material (uHDC)

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Introduction: Recent experiments at 3T utilizing pads with ultra high dielectric constant (termed uHDC) (εr = 1200) have yielded 2-3 fold improvements in both transmission (B_1^+) and reception (B_1^-) fields [1], suggesting that such improvement may be achieved at lower field strength with higher dielectric constant materials. In this investigation, we demonstrated that the same level of enhancement of RF field can be achieved at 1.5T with ε_r = 3300. Our computer simulation results further indicated such drastic enhancement can be obtained even at 0.5T using even greater ε_r values.

Methods:

<u>Experiment:</u> The phantom consisted of an uHDC block placed in a square container of water (ε_r = 79) as shown in Fig. 1. Experimental data were acquired on a Siemens 1.5T Avanto system (Erlangen, Germany) with a 12 channel Siemens head matrix coil and a monolithic dielectric block (101 mm x 77 mm x 14 mm) with ε_r = 3300, and a Siemens 3T Tim Trio system with an 8 channel InVivo head coil and a block with ε_r = 800. A slice-selective Bloch-Siegert scan was utilized to acquire B_1^+ maps [2-3]. A slice-selective GRE scan with a 2° flip angle was acquired to calculate receive weighted images. In the small tip regime the signal is linearly proportional to B_1^+, thus the transmit factor can be divided out of the image to obtain an image weighted by the receive field.

<u>Simulation</u>: To further investigate the applicability of uHDC pads to lower fields, computer simulation of the phantom experiment with identical configuration were carried out with xFDTD 7.0 software with ε_r = 800 at 3T, ε_r = 3300 at 1.5T, ε_r = 10000 at 1.0T, and ε_r = 28000 at 0.5 T, respectively.

Results:

The experimental results in Fig. 2 shows that uHDC block with ε_r = 3300 yielded the same high level of B1+ and B1- enhancements at 1.5 T as in 3T. Both the transmit field and receive field are enhanced by 2 to 3 in the region surrounding the block. The matching experimental and simulation results at 1.5T and 3T show good agreement. Simulation results indicated that these enhancements can be achieved at 1T and even 0.5T using materials with εr = 10000 and 28000, respectively.

Discussion: The experimental results demonstrated that the drastic enhancements in transmit and reception field with uHDC pads shown at 3T can be achieved at 1.5T using higher permittivity materials. The computer simulation accurately reproduced the experimental results. Subsequently, we further explored the potential application of uHDC material to even lower fields. Note that the enhancements demonstrated at these permittivity aren't necessarily at the optimal. Our results suggested that the B1 field enhancement could be obtained at even lower field at 1.0T and 0.5T using uHDC materials. Low field systems possess advantages over higher field systems – lower cost, reduced issues in siting, and reduced susceptibility effects among others. While B_1^+ homogeneity and SAR are typically not a major concern at 0.5T – 1.5T, the large increase in receive field sensitivity and associated increase in SNR is of great value because it would allow for image quality equivalent to those acquired in 3T at 1.5T or at 0.5T. Thus, the prospect of using uHDC materials for low field application could have great clinical and financial impacts on MRI technology.

At the present, there are no suitable uHDC materials available for 1T and 0.5 T applications. Future developments of uHDC material could potentially provide low-loss material at optimal permittivity for enhancement across a variety of field strengths.

Fig. 1: Phantom setup for simulation and experiment. A single dielectric block is placed parallel to the z axis centered within the container.

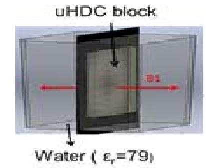
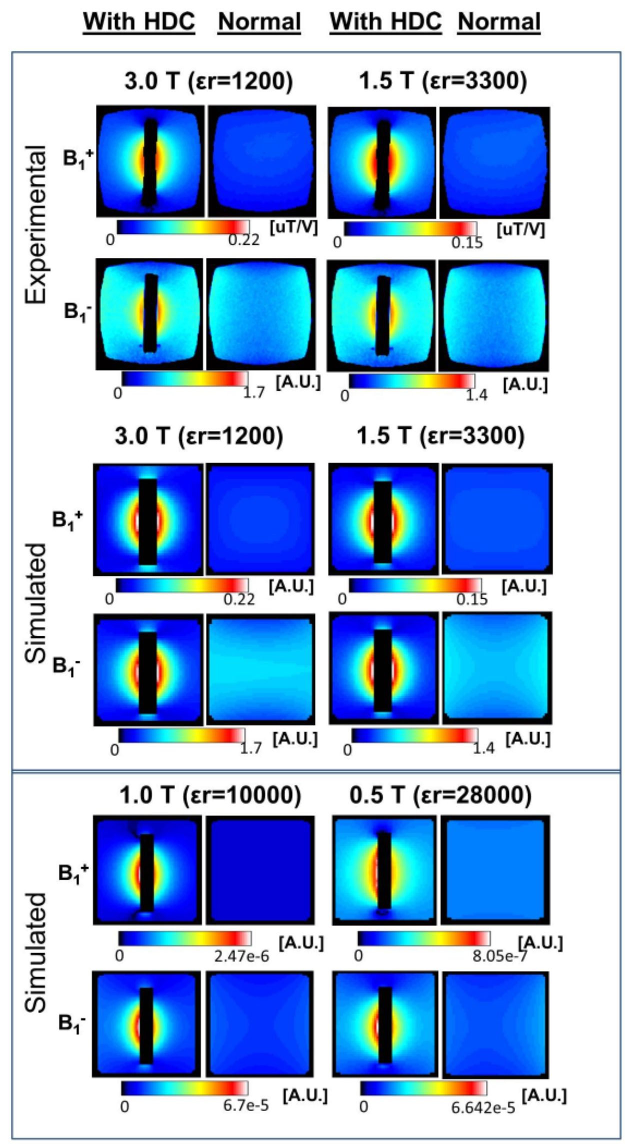


Fig. 2: Experimental and simulated RF field patterns for various field strengths and dielectric values. The black bar in the below maps is the region occupied by the dielectric block



<u>References:</u> [1] Rupprecht et al, ISMRM 2013 [2] Sacolick et al., MRM 2010. [3] Jankiewicz et al., ISMRM 2012