

MRI Enhancement via high dielectric constant ($\epsilon_r = 510$) pad at 3T: brain imaging

Qing Yang^{1,2}, Chris Collins³, Michael Lanagan⁴, Zachary Herse³, Sebastian Rupprecht³, Wei Luo³, Yeun Chul Ryu³, Megha Patel³, and Jeff Vesek³

¹The Penn State College of Medicine, Hershey, Pennsylvania, United States, ²Neurosurgery, The Penn State College of Medicine, Hershey, Pennsylvania, United States,

³The Penn State College of Medicine, ⁴The Penn State University

Introduction:

A recent report showed that water, as a high dielectric constant (HDC) material ($\epsilon_r=78$), could be placed inside a Trans/receive head coil to improve image signal-to-noise ratio (SNR) while lowering SAR in the human cortex at 3T (1). To further develop this approach so it is applicable to general clinical uses, materials with HDC were sought and a new type of HDC material based on a barium titanate (BaTiO_3) has been developed that yields a dielectric constant as high as 515 at a frequency of 128 MHz. Experimental results from the human brain with the HDC pad filled with barium titanate demonstrated that the image SNR can be improved by 28-42% in the brain, while RF power input was reduced by 23.7%.

Methodology:

Barium titanate ceramic is known to have a high dielectric constant value over 1000 with low loss tangent. To make the pads flexible and easily conformable to body parts, its fine powder form was used to mix with water (2). However, the dielectric constant of its fine powder form is drastically reduced (1). Furthermore, the values of dielectric constant of BaTiO_3 mixture with water increases with its volume fraction following a simple mixing rule known as Lichtenegger's logarithmic power law (3). The maximum volume fraction of BaTiO_3 powder with 400 nm in diameter is about $\frac{3}{1}$. In order to increase both the dielectric constant and the volume fraction of BaTiO_3 mixture, 1 mm radius spheres were used, which leads to a volume fraction up to $\frac{4}{1}$ ($V_{\text{spheres}}/V_{\text{D}_2\text{O}}$). With such a mixing volume fraction, the mixture of barium titanate ceramic spheres and deuterium oxide (D_2O) yields a dielectric constant of 515 and conductivity of 0.35 S/M at 123.25 MHz. The HDC pads (190 x 76 x 6 mm) shown in Fig. 1 filled with the material were tested with human brain imaging on a 3T system (Siemens Magnetom Trio) using an 8 channel head receive coil. The Tim Trio body coil was utilized for the RF transmission. Three adult subjects underwent standard clinical T2 Turbo Spin Echo (TSE) sequences (TE 93 ms, TR 6 500 ms) with and without two layers of HDC pads placed around the side of the head above the ears. RF power for 180° flip angle was adjusted through the automated routine. Image SNR was measured using the T2 magnitude images acquired under the two conditions in representative ROIs at multiple locations within the head (Fig. 2).

Results and Discussion:

Fig. 1 shows the HDC pad divided into 50 mm sections to increase its flexibility for better conforming around body parts. Fig. 2 shows T2-weighted brain images without (left) and with (right) two layers of HDC-pads placed over the temporal lobes. Table 1 shows the SNR percentage increases with the HDC pads from 3 ROIs in the brain, indicating that the image SNR increases by 28-42% with the HDC-pads compared to that without HDC pads. RF transmission power reduction was 23.7% with the HDC-pads, which leads to lower SAR for a given scan. With SNR enhancement and SAR reduction, more rapid imaging can be performed with improved image quality. Substitution of deuterium oxide for water removed the strong signal interferences from the pad. With the new material, the HDC pads provided a simple, effective and low-cost method for improving quality and safety of MRI in a variety of applications.

ROI #	ROI Location	SNR with HDC	SNR without HDC	Δ SNR %
1	Right temporal lobe	532.5	376.2	41.5
2	Left temporal lobe	404.8	315.3	28.4
3	Overall slice	700.8	520	34.8

Table 1 Δ SNR percentage on each temporal lobe with and without HDC-pad.



Fig. 1. HDC-pad with 50 mm sections to increase flexibility

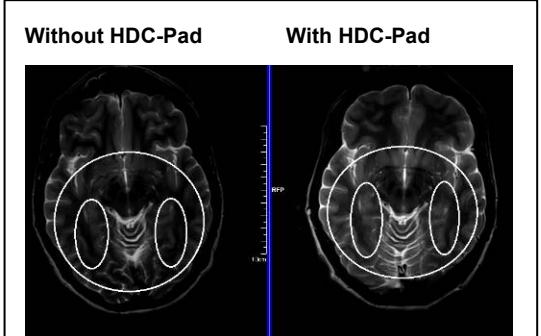


Fig. 2. Axial T2 images acquired without and with HDC-pads placed over the temporal lobe regions. ROIs for SNR measurement are indicated.

Reference:

1. Webb A.G. et al. J Magn Reson 2010; 203; 323-327.
2. McGeary R.K. Journal of the American Ceramic Society 1961; 44 (10): 513-522
3. Haines K. et al. J Magn Reson 2009; 200; 349-353

Acknowledgements:

Funding has been provided in part through NIH R01 EB000454, R01 AG02771 and the Pennsylvania Department of Health