Clinical neuroimaging using high dielectric materials at 7T

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Introduction. It is well-established that volume resonators such as the birdcage and TEM, which produce homogeneous transmit fields at 1.5 T and 3 T, cannot produce the same homogeneous magnetic fields in the human head at 7T [1]. Significant image inhomogeneities and areas of signal loss arise primarily from the dielectric properties of tissue, which result in partial constructive and destructive interactions from RF wave behaviour. Here we show that high dielectric materials [2,3] in deuterated media can significantly improve clinically relevant scans at 7 Tesla with essentially zero background signal.

Methods. Three dielectric pads were prepared and connected together. The central largest bag had dimensions of 33 x 17.5 cm, with two smaller bags 13 x 17.5 cm on either side: these were joined together to form a combined size of 59 x 17.5 cm. A mixture of calcium titanate (Alfa Aesar) in deuterated water (99%) with weight ratio 3:1 was prepared and heat-sealed within a polypropylene pad after taking care to remove as much of the entrapped air as possible. Previous work [2] has shown that this suspension has a high relative dielectric constant of ~110. Three clinically-relevant sequences were run with the following parameters. (i) three dimensional T1-weighted sequence: field-of-view 220 x 224 x 200 mm, spatial resolution 1 x 1 x 1 mm, adiabatic inversion pre-pulse, TR/TE/inversion time/tip angle = 4.3 ms /1.93 ms /1300 ms/7^{o}, SENSE factor 2.9 in right/left direction, total imaging time 5:08 minutes, (ii) three dimensional FLAIR sequence: field-of-veiw 240 x 240 x 180 mm, spatial resolution 1.1 x 1.1 x 1.1 mm, TR/TE/TI 8007/300/2200 ms, SENSE factors 2.4 anterior/posterior and 3 right/left, total imaging time 7:30 minutes, and (iii) two-dimensional multi-slice TSE sequence: field-of-view 240 x 180 mm, 1 mm slice thickness, 24 slices, in-plane spatial resolution 0.6 x 0.6 mm, TR/TE 4080/55 ms, TSE factor 12, total imaging time 3:24 minutes.

Results. Figure 1 compares images without and with the dielectric pads in place. There are clear increases in signal intensity and also image contrast especially in the temporal lobe (b) and cerebellum (a) and (c), as well as the lower neck region which might make this approach also applicable to arterial spin labelling.

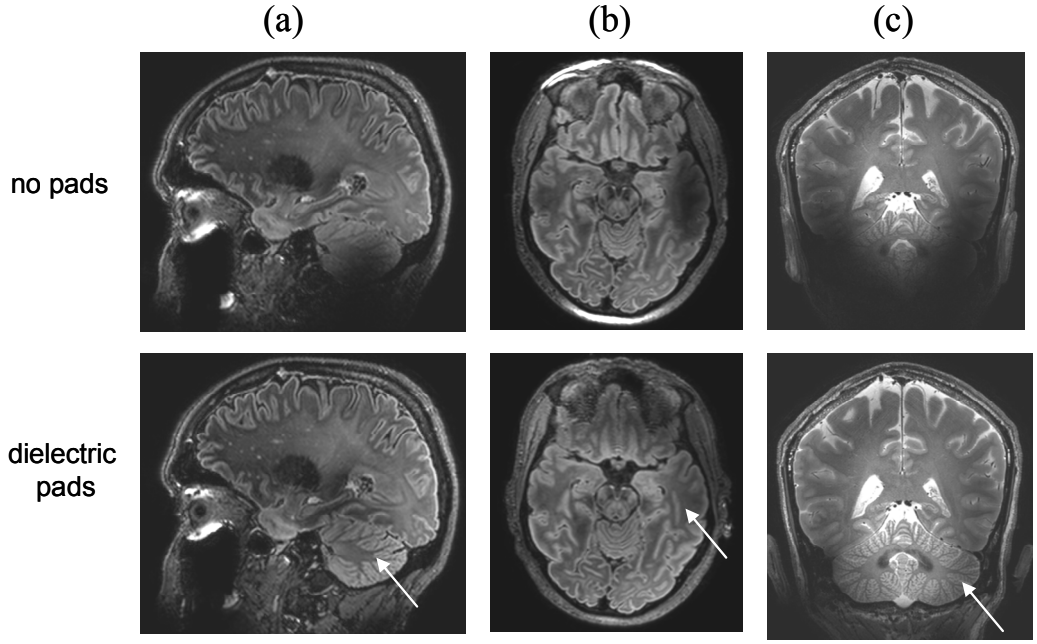

Figure 1. (a) Sagittal FLAIR scans, (b) reformatted axial FLAIR scans, and (c) axial TSE scans, all acquired without (top row) and with (bottom row) the dielectric pads present. Significant increases in signal-to-noise and image constrast produced by the dielectric pads are highlighted by the white arrows in the lower panels.

Discussion. High-dielectric suspensions of metal titanates in deuterated water significantly improve image quality in areas such as temporal lobe and cerebellum associated with low signal intensity. This approach is simple to implement, platform independent, and can be combined with transmit arrays, B1 shimming [4] and specialized RF pulses [5].

References. [1] J.G.Sled and G.B.Pike, IEEE TMI, 17, 653, 1998. [2] K.Haines, N.B.Smith and A.G.Webb, J.Magn.Reson., 203, 323, 2010. [3] J.M.Snaar et al. NMR in Biomedicine, in press, 2010. [4] G.Metzger et al. Magn.Reson.Med. 59, 396, 2008. [5] A.C.Zelinski et al., Magn.Reson.Med. 59, 1355, 2008.