Study for using high dielectric materials to increase the B1+ homogeneity in abdominal imaging at 3T.

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Introduction

The appearance of significant image artifacts in abdominal imaging at 3 Tesla has been noted by many groups. Some report that severely obese patients present the worst situation, others that this also occurs for very thin patients (1). Signal loss is often attributed to “dielectric resonance”. In addition to recent advances in dual channel transmit systems (2), the use of a dielectric pad placed on the abdomen has been reported to improve the image quality in many cases (3,4). In this simulation study the aim is to optimize the geometry, size, and permittivity of these pads placed around the body in terms of producing as uniform B1+ field as possible. In particular, recently developed materials with very high permittivity (5) are investigated since these can potentially reduce the size and weight of such pads, increasing patient comfort.

Method

To simulate the various configurations, a finite difference time domain method is used (xFDTD, Remcom, PA). The RF coil is a 16 rung high pass birdcage coil with a diameter of 61 cm, length 56 cm, driven by 32 ideal current sources impedance matched to 50 Ω. A male torso (Duke) from the virtual family (6) was placed in the centre of the coil. To determine the optimal pad permittivity a grid search was used in which the relative permittivity values of different numbers of pads were varied from 1 to 600. For comparison a commercially available water pad (3,4) was included in the simulations. Normalization was to 1 Watt dissipated power in the tissue. The mean value divided by the standard deviation across the simulated B1+ map was chosen as the figure-of-merit, and evaluated in MATLAB (Mathworks, Natick, MA). To confirm the results acquired by doing the simulations In Vivo MRI scans of a test person have been performed. This was done with a 3T Philips Achieva MRI scanner. On the body two barium titanate pads (permittivity ~300) where placed on the anterior and posterior side. To get the B1+ map a double TR method has been used.

Results

Figures 1a and 2a shows the simulated B1+ map with no pads in place. Central slices in the transverse and coronal planes are shown. The characteristic asymmetric pattern arising from a cylindrical geometry (7) is quite apparent with areas of low efficiency close to the anterior and posterior areas of the body. Figure 1b shows the results from the most commonly used commercial pad which is 3 cm thick, 36 x 26 cm, and is typically placed on the front of the liver. Figure 1c shows the results from the optimized setup determined in this work. Two pads with a relative permittivity of respectively 400 and 500, 1 cm thick, 36 cm x 26 cm are positioned both at the back and front of the subject. The figure-of-merit was improved slightly by the addition of the commercial pad, but the optimized setup 1c improved it by a factor-of-two.

The results of the In Vivo MRI scan is shown in figure 3. There where 5 transversal slices taken at the location of the liver. The upper slices are without the pads and the lower slices with the pads. The inhomogeneity in the images without the pads can be clearly seen and resembles the simulation result. When the pads are placed the figure of merit almost doubles again which was also seen in the simulations.

Discussion and Conclusion

The simulation results show that significant increases in B1+ homogeneity can be achieved using high permittivity materials placed around the body. The optimum permittivity value of ~400 cannot be produced in practice yet. But by suspensions of barium titanate in either protonated or deuterated water pad of an permittivity of ~300 can be produced in practice. The 1 cm thickness (as opposed to 3 cm for commercial pads) should result in significantly increased patient comfort. The practical results show strong correlation with the results gained by the simulations.

References