Improved uniformity of RF-distribution in clinical whole body-imaging at 3T by means of dielectric pads

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Introduction:

The use of high field whole body MR-scanners operating at 3T predict a gain in SNR compared to conventional clinical 1.5 T systems. In clinical routine imaging this gain can be used to reduce scan time, to improve spatial resolution, or to improve the overall image quality for diagnostic benefits. However, in many high field applications the image quality is compromised by physical phenomena, such as stronger susceptibility gradients, increased SAR, and a rather inhomogeneous RF-distribution in the sample. The inhomogeneous RF-distribution is caused by a variety of conductive and dielectric effects in the tissue under investigation. Theoretical simulations, however, have shown that the use of pads filled with a medium of high electric permittivity can significantly homogenize the B_1-distribution in tissue with high conductivity [1]. Here, we investigated the applicability of dielectric pads filled with water or doped ultrasound gel to address the problem of B_1-inhomogeneities in clinical whole body imaging procedures at 3T.

Material and Methods:

8 healthy volunteers were scanned on a clinical 3T system (Magnetom Trio, Siemens, Erlangen, Germany) using the product receive body array coil. Abdominal imaging was performed during breath holding by using T_2-weighted HASTE (TR/TE/α/BW/turbofactor=2000ms/88ms/150°/558Hz perPixel/192), TSE (TR/TE/α/BW/turbofactor=4000ms/103ms/150°/337Hz per Pixel/29) sequences, respectively. Moreover, a T_1w 2d FLASH sequence (TR/TE/α/BW=100ms/2.65ms/70°/320Hz per Pixel) was used to investigate the influence of the pads on short-TE scans. All images were acquired in transversal orientation. We investigated the effect of two different dielectric pads for their influence on the RF-uniformity. Pad #1 was filled with water (ε≈80) doped with $MnCl_2$ (0.15g/l Mn++). Pad #2 was filled with an ultrasound gel (ε≈60) doped with Gd DTPA (1.1g/l Gd++). Doping of the dielectric pads showed to be necessary to reduce T_2 relaxation times in order to attain MR-invisibility of the pillows. Pad #1 had a dimension of approximately 40cm x 45cm x 2cm thickness (weight ≈4.0kg), and pad # 2 had a dimension of 25cm x 35cm x 3cm thickness (weight ≈3.5kg), respectively. For comparison of the image quality with and without the dielectric pads, T_2 and T_1 weighted imaging protocols were repeated three times: a) without pads, b) with water filled pad, and c) with the ultrasound gel pad placed on the subjects abdomen.

Results and Discussion:

The signal loss in the abdomen was only visible in slim volunteers, while volunteers with more abdominal fat didn't show the effect. We suspect that abdominal fat has a similar effect as the dielectric pads. Figure 1a) demonstrates a typical abdominal T_2-weighted HASTE-image of a slim volunteer without any pads. Figures 1b) and 1c) show corresponding images with the doped water pad and the ultrasound gel, respectively. Different positions of the abdomen during breath holding of the volunteers led to slightly different slice position in this comparison. Images acquired without dielectric pads usually exhibit significant signal loss in the anterior regions of the abdomen. With pads the signal is clearly recovered and makes the images useful for clinical diagnosis. Differences in image quality in experiments with the water and ultrasound gel pads appear to be negligible. Chemical doping of the pad leads to a fast signal decay. Consequently, T_2-weighted images of the abdomen are not contaminated by signals from these dielectric pads. However, in T_1-weighted images (c.f. Fig. 1d) with short echo times TE pads still produce bright signal intensities. With the choice of a sufficient large field-of-view (FoV) these signals, however, do not result in additional image artifacts. Introducing light-weighted dielectric padding with chemical shifts is potentially capable to further reduce shortages in image quality and the additional weight on the patients body during the examination.

Recently, other approaches have suggested optimized hardware and software, such as special coils [2,3] and RF-pulse design [4] to address the problem of RF-distribution at high magnetic fields. In contrast to the method proposed herein they are usually expensive and not capable to address the problem to that extent and for such a wide range of applications.

Conclusion:

In this investigation we have shown that dielectric padding with high dielectric constants (ε≈80) is an inexpensive and effective way to significantly reduce signal loss from eddy currents and dielectric resonances in abdominal MR images at 3T. Differences between the used padding materials demonstrated to be negligible. Therefore, ongoing investigations focus on the use of light-weighted fillings and MR-invisible characteristics for whole body imaging with short echo-times.

References:

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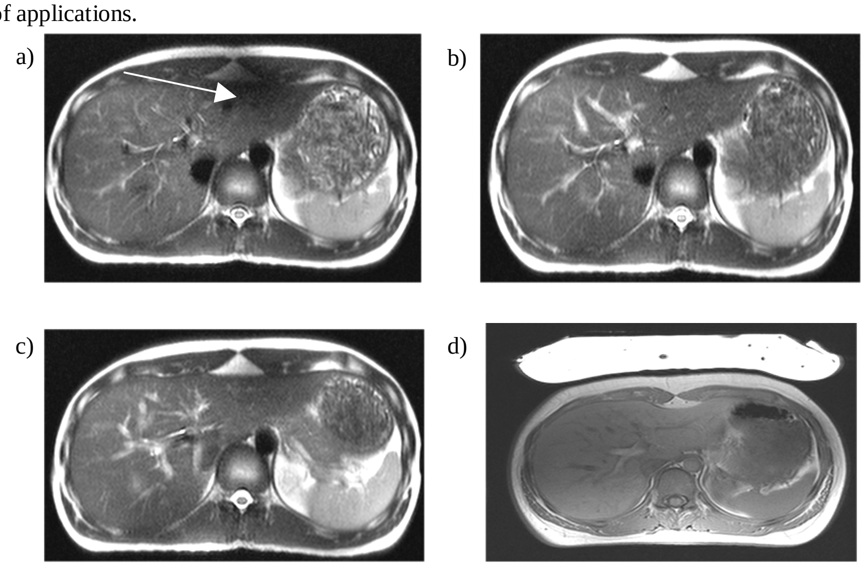

Figure 1: Images acquired with the HASTE sequence, a) without any pad, b) with pad #1 and c) with pad #2. Figure 1d shows an image acquired with the 2d FLASH sequence with pad #2. The figure depicts the typical bright signal of the pillow.