B_1-Homogenization in abdominal imaging at 3T by means of coupling coils

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Introduction:

During the last years a strong trend towards higher magnetic fields for research and clinical routine has evolved. The main motivation is the expected gain in SNR which is often traded for higher spatial or temporal resolution. Body imaging, however, is one of the few remaining applications at 3T, that is still hampered by reduced image quality due to reduced B_1-homogeneity. Several approaches have been proposed, for example special RF pulse designs [1] or coil designs [2,3] to overcome this challenge. Last year dielectric pads were introduced, but these ultrasound filled pads are heavy and get visible in sequences with very short echo times TE [4]. The effect of the dielectric pads was shown in MRI experiments as well as in simulations [5]. Simulations also indicate that local coils, in which a reactive current flow is induced during the excitation phase, may influence the B_1 distribution in the body. Moreover, these simulations also have shown that the additional local coil should have a higher resonant frequency than the frequency of the main magnetic field (ω_0 =123,2 MHz) to compensate for the RF eddy currents induced in the body [6]. The aim of this study was to test possible coil designs in phantom and volunteer measurements at 3T.

Material and Methods:

To find the optimal coil dimension and resonant frequency of the coil, phantom and volunteer measurements were performed on a clinical 3T system (Magnetom Trio, Siemens, Erlangen, Germany) using the product receive body array coil. To emphasize B_1 distribution effects, a special Spin Echo-based sequence (TR/TE/α/BW/=300ms/17ms/720°/558Hz per Pixel) was used. This sequence consists of a nonselective 720° pulse and a slice selective 180° refocusing pulse to visualize B_1 differences in the MR images. Moreover, a T_2-weighted HASTE sequence (TR/TE/α/BW/turbofactor=2000ms /88ms/150°/558Hz per Pixel/192) was used, which is very sensitive to B_1 inhomogeneities due to the rather large number of RF pulses. The coils were tuned to 129 MHz and 139 MHz, respectively. We used two different coil dimensions for both frequencies. The first coil (coil A) had a dimension similar to that of the body array coil (width: 18cm, length: 30cm) and the second one (coil B) had a width of 32cm, to increase the volume expansion of the B_1 homogenizing effect. To have a reference for the homogenization effect of the coils all measurements were performed (1) without any pad or coil, (2) with the dielectric pad filled with ultrasound gel and (3) with one of the coupling coils. Similar to the dielectric pads, the coils were positioned directly on the phantom and the body of the volunteer, respectively.

Results and Discussion:

First phantom results indicated that the induced currents give rise to high local SAR when using coils having a resonant frequency of ω_0 = 129 MHz. Therefore, these coils were not used in volunteer experiments. The coils with a resonant frequency of 139 MHz were both tested in phantom and volunteer experiments. The results of the volunteer experiments are shown in Fig.1a-c. The larger coil did not result in a better volume expansion of the B_1 homogenization effect. Moreover, compared to the larger coil, the smaller coil demonstrated the best signal enhancement of the dark regions in the abdomen. This result was also confirmed by simulations, which predict a field strength reduction by a factor of approximately $\sqrt{2}$, when the size of the coil is doubled at a constant coil current. Comparing the homogenization effect of the smaller coil and the dielectric pad, no visible difference was found. Both, the dielectric pad and the coupling coil A with a resonant frequency of 139 MHz resulted in an optimization of the signal in T_2 weighted imaging in all slices (c.f. Fig 1). Comparing the coil and the dielectric pad, the coil has two advantages. First of all it is not visible in images, acquired with a short echo time TE. The dielectric pad, however, can result in artifacts in the abdomen due to infolding of the bright pad signal, which also might hamper the diagnosis. Another advantage is the weight of the coil which is very low (~0.5 kg) compared to the dielectric pad. This makes the use of the coil more easy in clinical routine, particularly in very ill patients. Moreover, future investigations could concentrate on incorporating the coupling coil into the acquisition coils, for example the spine coil and the body array coil, which would further improve the coil handling in body imaging at high field strength.

Conclusion:

In this investigation we propose a new method to improve the B_1 uniformity at 3T. The method demonstrates an easy and effective way to reduce B_1-inhomogeneity, which is of particular importance in high field abdominal MRI. Our results demonstrate improvements in slim patients/subjects, where B_1-related signal drops are most severe. Moreover compared to previously proposed methods, resonant coupling coils are light-weighted and not visible in T_1 weighted images.

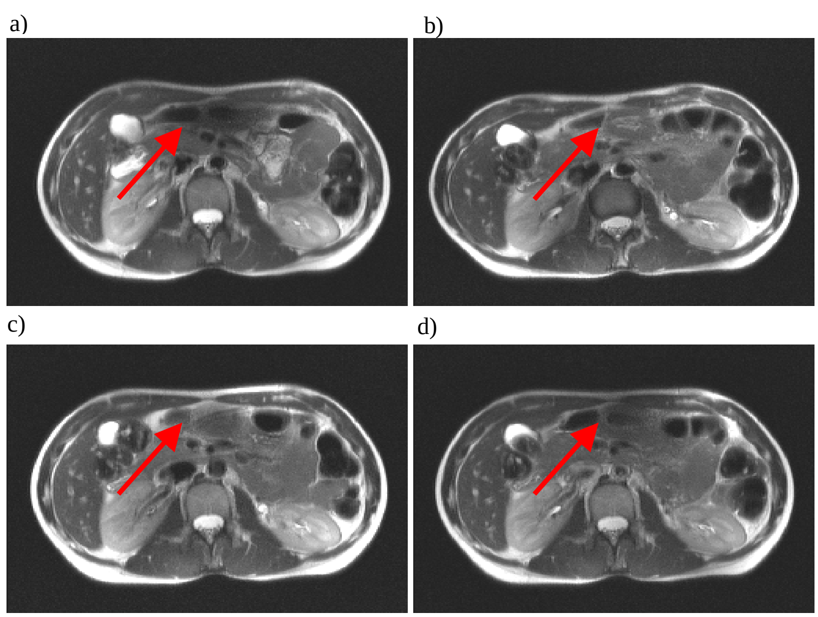

Figure 1: Images acquired with the HASTE sequence, a) without any off-resonant coupling coil, b) with dielectric pad, c) with coil A and d) with coil B. It is clearly visible that the signal drop is drastically reduced with coil A.

References:

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