Investigation of field dependence of high dielectric insert properties in parallel imaging arrays

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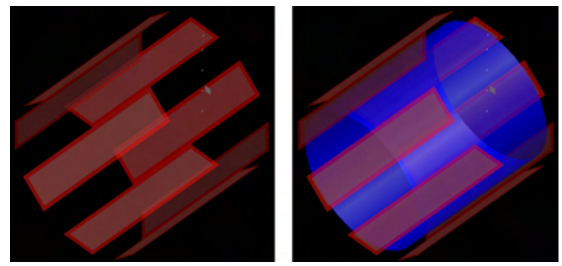
Introduction

Signal-to-noise ratio (SNR) and specific absorption rate (SAR) are two key merits in evaluating radiofrequency (RF) coil performance. In order to increase coil sensitivity and transmit field efficiency and to reduce noise and power loss, high B_1 field and low electric field (*E* field) are desired. High-permittivity pads have been demonstrated as an efficient method to increase SNR and manipulate RF field distributions for MR imaging [1, 2]. Current studies have also verified the capability of high-permittivity insert to increase transmit field efficiency and RF safety at ultra-high field MRI [3-5] and NMR [6]. In this project, we investigate the field dependence properties of high permittivity inserts in parallel imaging arrays in terms of B_1 field improvement and *E* field reduction. The B_1 and *E* field distribution with and without high dielectric insert of an 8-channel array were studied numerically at the different field strengths of 3T, 4T and 7T.

Methods

As shown in Fig. 1(a), the 8-channel array consisted of 8 square loop coils with 51 mm width and 250 mm length. The inner diameter of the array was 250 mm. The high dielectric insert (blue tube in Fig. 1(b)) was of 220 mm inner diameter, 250 mm length and 2 mm thickness. The simulations of the array with and without high dielectric insert were carried out using commercial FDTD software XFDTD 6.5 (REMCOM, Inc., State College, PA) to evaluate the insert performance. The conductors were set as copper tapes ($\sigma = 5.8\times10^7$ S/m, $\mu_r = 1$ and 6 mm width). The permittivity of tube was 130. A three-dimension FDTD simulation was performed at 128 MHz, 171 MHz and 300 MHz, corresponding to the proton Larmor frequency at 3T, 4T and 7T respectively. Each element of the arrays was excited by sinusoidal current source with peak value of 1 A and phase of cylindrical coordinate azimuthal angle. Outer boundaries were absorbing perfectly matched layer (PML) with 7 layers. The meshing cells of the simulation were 1 mm × 1 mm × 2 mm.



(a) 8-channel array (b) array with dielectric insert

Fig. 1 Configurations of 8-channel array and dielectric insert

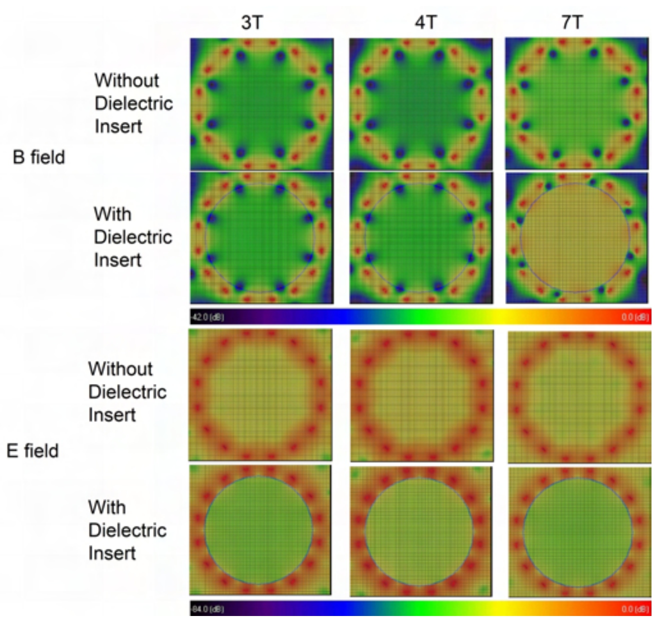


Fig. 2 Electromagnetic field distribution comparison of 8-channel array with and without high dielectric insert at 3T, 4T and 7T

Results

The B_1 and *E* field distribution with and without the high dielectric insert at 3T, 47 and 7T were shown in Fig. 2. The input power of each simulation was scaled to 1.6×10^{-6}W. The ratio of B_1 with and without the high dielectric insert was utilized to quantitatively evaluate sensitivity improvement. The ratio of *E* field with and without the insert was calculated to evaluate noise and power loss reduction capability. The 1D profile of B_1 improvement and *E* reduction crossing the center of the array were shown in Fig. 3 respectively. The results showed a 2-fold increase of B_1 field at 7T and 50% reduction of *E* field at 3T and 4T. The *E* field close to the insert reduced more than that in the center region. The B/E ratio improvement was calculated as well. As shown in Fig. 3, the B/E ratio improvement increases by a factor of 3 at 7T and by 2 at 3T and 4T.

Conclusions

The study indicates the high-dielectric inserts in parallel imaging arrays are capable of increasing B_1 field and decreasing *E* field at all three field strengths of 3T, 4T and 7T. The *E* fields close to the insert decrease faster than that in the center of the array. The performance of the high dielectric insert is better at 7T than at 3T and 4T, indicating that higher field strength may benefit more from the high dielectric inserts in MR signal reception efficiency and safety.

References

1) Q. X. Yang, *et al. J Magn. Reson. Imaging*, 2006, 24:197-202; 2) K. Haines, *et al. J Magn. Reson.*, 2010, 203:323-327; 3) C. Wang, *et al. 17th annual meeting of ISMRM*, 2009, p3054; 4) Q. X. Yang, *et al. Magn. Reson. Med.*, 2011, 65:358-362; 5) W. M. Teeuwisse, *et al. Magn. Reson. Med*., 2011, DOI: 10.1002/mrm.23108; 6) A. Neufeld, *et al. J Magn. Reson*., 2009, 200:49-55.

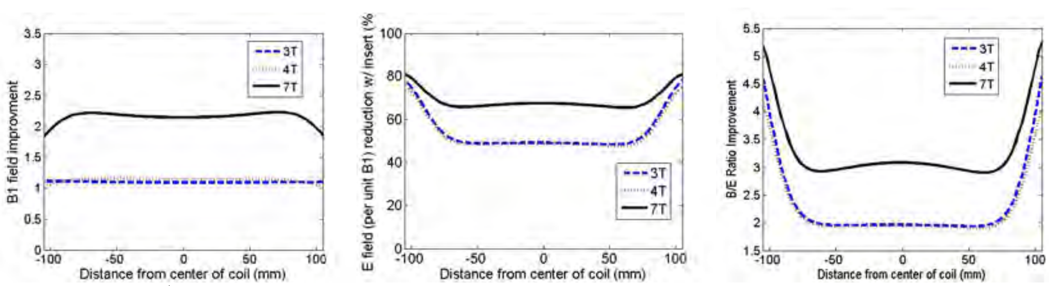


Fig. 3 1D profiles of B_1^+ field, E field reduction and B/E ratio improvement crossing the center of ROI with and without the dielectric insert

Acknowledgments

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