Transmit Strategies for Body Imaging at 3T - Comparing Multitransmit and Dielectric Shimming

Wyger Brink[1] and Andrew Webb[1]
[1]*Radiology, Leiden University Medical Center, Leiden, Netherlands, Zuid-Holland, Netherlands*

Target audience: Clinicians and researchers performing body imaging at 3T and RF engineers working on high field systems.

Purpose: To explore the similarities and differences between RF shimming using multiple transmit channels and high permittivity materials for body imaging at 3T.

Methods: Electromagnetic simulations of a single-, two- and eight-channel 3T body coil were performed using XFDTD (Remcom inc., State College, PA, USA). The two-channel system was modeled as a 16-rung high pass birdcage using 32 voltage sources driving the system in its two linear modes. The single-channel system follows from the two-channel setup driven in quadrature. The eight-channel system was modeled after [1] by rotating a single MBC element with 10 voltage sources along eight azimuthal positions. Verification in a tuned and matched model confirmed a discrepancy below 5% for both coil models. The coils were loaded with the 'Duke' human body model centered at the liver [2]. High permittivity pads (ε_r~300) were introduced as described in [3]. RF shimming was performed using the magnitude least squares method [4] in order to maximize the B_1 homogeneity in a transverse cross-section of the abdomen (excluding the arms).

Experimental verification was performed in 9 healthy volunteers on a Philips 3T TX Achieva, which can be operated in either single (quadrature)- or two-channel mode. MR images were acquired using a six channel coil array and a T1-weighted 3D TFE sequence. Imaging parameters were: TR/TE = 10/2.3 ms; flip angle = 15°; resolution 1 x 2.2 x 10 mm^3. B_1 maps were acquired using a double-TR method [5]. The mean transmit efficiency was determined by dividing the average B_1 by the square root of the required RF power.

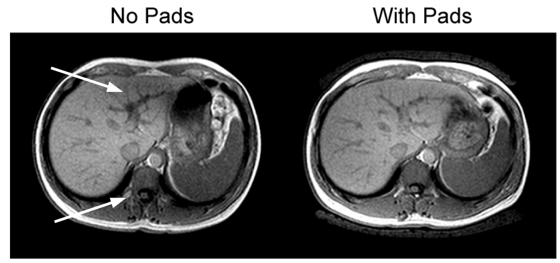

Figure 1. Transverse TFE images showing the effect of introducing the high permittivity pads in the single-channel system. Shading artifacts are clearly reduced by the pads.

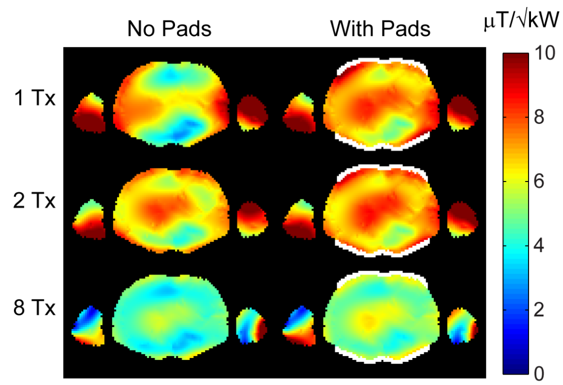

Figure 2. Simulated transmit efficiency maps for the three transmit configurations without and with the high permittivity pads. The pads are illustrated in white.

Results: Figure 1 shows a transverse TFE image indicating the improved contrast uniformity by introduction of the high permittivity pads in quadrature mode. The simulated transmit efficiency maps for the different transmit configurations are shown in figure 2. Figure 3 presents a pairwise plot of the mean transmit efficiency and the relative B_1 inhomogeneity of the simulated setup and a scatter plot of the measured gain in efficiency (n=9). Improvements in both the transmit efficiency and B_1 homogeneity were found in the simulated and measured configurations after introducing the dielectric pads. The drop in efficiency when going to eight channels without a significant improvement of the B_1 homogeneity agrees with previous work [6].

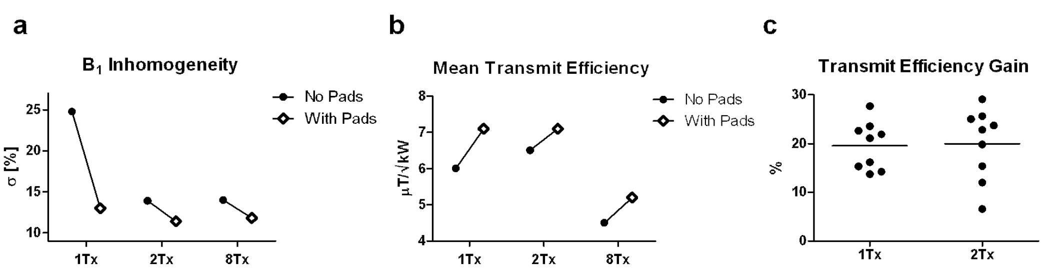

Figure 3. Pairwise plot of the simulated B_1 inhomogeneity (a), simulated mean transmit efficiency (b) and scatter plot of the experimentally measured gain after introducing the high permittivity pads (c). In (c) horizontal lines indicate the mean gains.

Discussion: These results indicate that the high permittivity pads improve B_1 homogeneity and transmit efficiency for any given number of transmit channels, and even for a single channel transmit system they improve the homogeneity to similar levels as obtained for either two- or eight-channel systems. Overall, a two-channel system with pads provides the best B_1 homogeneity with highest efficiency.

A general feature that can be observed from the simulations is the fact that the eight-channel system is intrinsically less efficient, which has been observed also in a degenerate birdcage [6]. While the eight-channel system offers additional degrees of freedom for homogenization of the B_1 field and local SAR management [4], this clearly comes at the cost of being intrinsically less efficient than a single channel quadrature birdcage. High permittivity shims are shown to provide similar degrees of freedom for improving the B_1 homogeneity as multi-transmit systems, but without reducing the transmit efficiency of the system.

Conclusion: High permittivity pads are shown to improve the B_1 homogeneity for single- and two-channel systems to a level similar to that of an eight-channel system, without the penalty of reducing the transmit efficiency. The best transmit setup for 3T body imaging is shown to be a two-channel system with high permittivity pads.

References: 1. Vernickel et al., *MRM 2007*, 58:381–389; 2. Christ et al., *Phys Med Biol 2010*, 55:N23–N38.; 3. de Heer et al., *MRM 2012*, 68:1317–1324; 4. Homann et al., *MAGMA 2012*, 25(3):193–204; 5. Yarnykh, *MRM 2007*, 57:192–200; 6. Harvey et al., Proc. ISMRM 2010, 1486.