Implications of Dielectric Pads on Dual-Transmit SAR Behaviour

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Target audience: Clinicians and researchers concerned about SAR issues when using high permittivity dielectric pads.

Purpose: Previous studies have shown a substantial reduction in local SAR when introducing dielectric pads in a quadrature driven body coil. One concern is that, when using dual-transmit B_1^+ shimming, the SAR estimate provided by the scanner could be incorrect since it is typically based on models that do not include the presence of dielectric pads [1]. This work explores the implications of using high permittivity dielectric pads on the SAR and B_1^+ shimming behaviour of a dual-transmit system at 3 T.

Methods: The RF field in a dual-transmit 3 T body setup was simulated using xFDTD (Remcom inc., State College, PA, USA). The body coil was modeled as a two-port 16-rung high pass birdcage tuned to resonate at 128 MHz. The male body model 'Duke' [2] was centered at the heart and high permittivity (ε_r = 290) dielectric pads were introduced with an optimized geometry for cardiac imaging as described in [3]. A Q-matrix formalism was applied to model local SAR during B_1^+ shimming [4], and 10-g averaging of the Q-matrices was performed using a FFT based kernel growing method [5].

The RF shimming behaviour was simulated without and with dielectric pads by introducing a relative power ratio from -20 to +20 dB between the two channels of the body coil, and a relative phase difference ranging from -180° to +180° with respect to quadrature mode. The local torso SAR, defined as the peak 10-g averaged SAR within the torso, was evaluated as well as the B_1^+ inhomogeneity in the heart volume. All SAR data were normalized to the average B_1^+ in the transverse cross-section of the body.

Results: Figure 1 shows transverse B_1^+ maps and maximum intensity projections of the local SAR in a B_1^+ shimmed setup, without and with dielectric pads. Figure 2 shows the variation in B_1^+ inhomogeneity within the heart and local torso SAR as a function of shim settings. The horizontal axis represents the relative phase difference ($\Delta\phi$) between the two channels, and the vertical axis represents the relative power ratio (P_1/P_2). The optimal shim settings are indicated with the star.

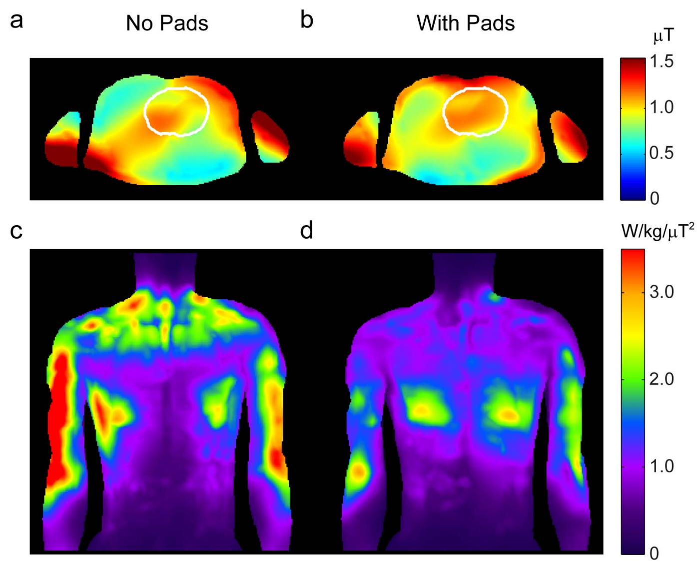

Figure 1. Simulated transverse B_1^+ maps (top) and maximum intensity projections of the 10-g averaged SAR (bottom) without (left) and with (right) dielectric pads in the B_1^+ shimmed body coil. The heart ROI is encircled in white. Both datasets were normalized to the average B_1^+ in the transverse cross-section of the body.

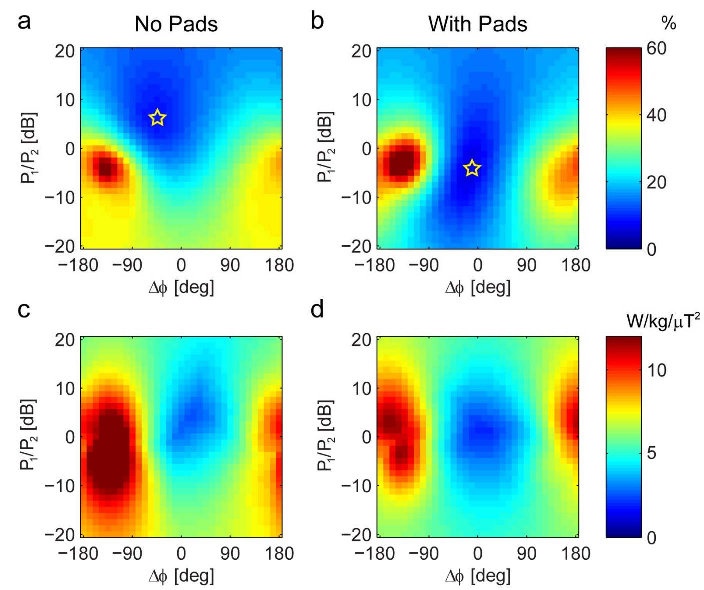

Figure 2. Relative B_1^+ inhomogeneity in the heart (top) and local torso SAR (bottom) without (left) and with (right) dielectric pads. All SAR data was normalized on the mean B_1^+ in the transverse cross-section of the body.

Discussion: Our results show that dielectric pads reduce the local torso SAR for a wide range of shim settings, meaning that the SAR estimate provided by the scanner is in fact too conservative when dielectric pads are used, i.e. the actual SAR is less than that reported. The variational maps of the B_1^+ inhomogeneity show that the optimal shim setting moves closer to quadrature when dielectric pads are introduced. Moreover, the variation of the B_1^+ inhomogeneity with relative power ratio is reduced. This improves the power-balance between the two transmit channels which is advantageous in sequences that are peak-power limited. A similar shift to quadrature is also visible in the local SAR maps. In general, a clear redundancy between both shimming strategies can be observed.

Conclusion: The use of dielectric pads changes the RF shimming behaviour of a dual-transmit system; however the actual local torso SAR will be less than that reported by the scanner, thus ensuring safe operation.

References: [1] Harvey et al., *Proc. ISMRM 2009*, 4768; [2] Christ et al., *Phys Med Biol 2010*, 55:N23–N38; [3] Brink et al., *MRM 2013*, doi: 10.1002/mrm.24778; [4] Graesslin et al., *MRM 2012*, 68:1664-74; [5] Kuehne et al., *Proc. ISMRM 2012*, 2735.