RF safety evaluation of different configurations of high-permittivity pads used to improve imaging of the cerebellum at 7 Tesla

Andreas K. Bitz[1,2], Oliver Kraff[2], Stephan Orzada[2], Tim Herrmann[3], Johannes Mallow[3], Johannes Bernarding[3], and Mark E. Ladd[1,2]
[1]*Medical Physics in Radiology, German Cancer Research Center (DKFZ), Heidelberg, Germany,* [2]*Erwin L. Hahn Institute for Magnetic Resonance Imaging, University Duisburg-Essen, Essen, Germany,* [3]*Department of Biometrics and Medical Informatics, Otto-von-Guericke-University Magdeburg, Magdeburg, Germany*

Target Audience: Researchers involved in RF safety and/or high-field MRI

Purpose: It has already been shown that dielectric pads with high permittivity can be used to improve transmit/receive sensitivities and, consequently, image quality in brain imaging. [1,2] In this current study configurations of three pads were investigated with the objective to improve the coverage of a 32-channel head coil in the region of the cerebellum. Since for these configurations the size and spatial arrangement of the pads are different to the published data, a detailed RF exposure analysis based on RF simulations was performed to check whether the maximum permissible input power of the transmit coil needs to be readjusted due to the underlying manipulations of the RF field distribution.

Methods: The simulated dielectric pads were made of calcium titanate (CaTi, permittivity 110, loss tangent 0.05) with dimensions of 170 x 110 x 10 mm³ (L x W x H). Two pads were placed left and right of the head with their longitudinal axes parallel to the body axis. The third pad was placed at the back of the head in two different orientations: (1) with its longitudinal axis parallel and (2) perpendicular to the body axis. The pads were bent around the 'Duke' male head model [3] to realize a close fit to the head's contour (cf. Fig. 1). A head coil (Nova Medical, Wilmington, MA, USA) with a detunable volume transmit coil and a 32-channel receive-only array was utilized. The volume coil was modelled as a shielded bandpass birdcage coil with 16 rungs, diameter of 30 cm, and length of 26 cm. Dimensions of the shield were 36 cm in diameter and a length of 34 cm. Field calculations (CST Studio Suite, CST, Darmstadt, Germany) were performed by use of a network co-simulation approach which enables matching and tuning of the birdcage subsequent to the numerical solution of the field distribution of the individual excitation ports by connecting circuit elements to the ports in the network simulation. Finally, the specific absorption rates for the different configurations (two with pads, one without) were determined and normalized to an input power of 1 W.

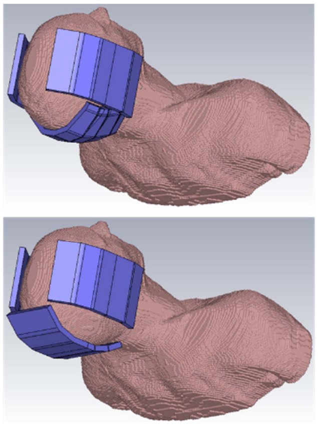

Fig. 1: 'Duke' male head model with high-permittivity pads

Results: Figures 2 a-c show the distribution of the localized (10g-averaged) SAR in the central sagittal plane for the configuration without pads (a) as well as with pads for perpendicular (b) and parallel (c) orientation of the pad located at the back of the head. Figures 2 d-f show the locations of the max. localized SAR. For the two configurations (a) and (b), the max. localized SAR is quite similar (0.53 W/kg, 0.5 W/kg), although the location of the max. SAR varies. In (d) the max. SAR is located below the left frontal lobe (a typical region for a circularly polarized excitation field), whereas in (e) it is located central in the cortex in the median sagittal plane. However, in configuration (c) the max localized SAR is elevated by about 64 % (0.87 W/kg) compared to the configuration without pads and located occipital at one of the shorter edges of the central pad (f).

Discussion: The results indicate that the SAR distribution is influenced by the high-permittivity pads and depends on size and orientation of the pads. This is in contradiction to published data which found that the SAR was not affected by the pads for the investigated configurations. [1,2] Indeed, pad configurations exist for which the max. SAR value remains similar to the max. SAR of the exposure scenario without pads, and where only the SAR distribution and location of max. SAR varies. However, there can also be other pad configurations with strong SAR elevations. It is well known from constitutive relations that media with high permittivity have a direct effect on the electric field distribution. For example, normal electric field components show a discontinuous behavior at the boundary between low (air, tissue) and high permittivity media, with field elevations inside media with lower permittivity. Additionally, there are further coupling mechanisms which are responsible for the dependency on the pad orientation and size. It is also obvious that the degree of these effects strongly depends on the field distribution of the birdcage coil. The effect of the pads on the B_1^+ distribution is rather indirect due to the coupling between the electric and magnetic fields.

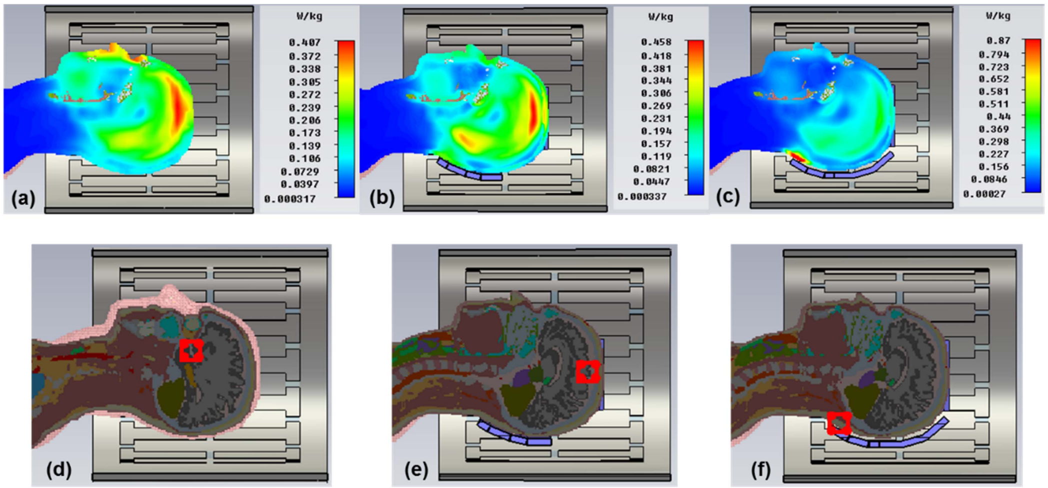

Fig. 2 a-c: Localized (10g-averaged) SAR in the central plane for configurations without pads (a), with 3 pads of which the central one located at the back of the head is oriented perpendicular to the body axis (b), as well as with parallel orientation (c). Note the different scales.
d-f: Locations of the max. localized SAR in the corresponding sagittal planes for configurations in a-c, respectively.

Conclusion: High-permittivity pads are a useful tool to manipulate transmit and receive sensitivities of RF coils. To achieve this, the positions of the pads have to be optimized individually for each examination, leading to different configurations which need to be analyzed with respect to RF safety. The results show that certain variations in pad positions can lead to strong SAR elevations. To account for the increased RF exposure of the volunteer, the maximum permissible input power of the RF coil must be decreased.

References: [1] Teeuwisse, MRM 67:912-918(2012). [2] Teeuwisse, MRM 67:1285-1293(2012). [3] Christ et al. Physics Med Biol 2010;55(2):N23-38.