Effects of head size and position on SAR

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Purpose: SAR is coupled to two different electrical fields, conservative and non-conservative. The first is the E-field penetrating from the distributed capacitors commonly used in high field coils, the second is the E-field that accompanies the propagating magnetic field. It is not easy to predefine head position exactly in MRI studies, but in typical RF coil simulations the influence of head position on SAR has generally been neglected. When using a time-domain solver it is challenging to rotate a voxel-based head model to any specified angle relative to the coil, while keeping the same mesh layout, but this can be performed easily using a frequency-domain solver and surface based head models. Our goal was to compare peak local 10 gram SAR SAR_{10gr} and total head SAR SAR_{head}, placing a head model in different positions within a commercially available Rapid BioMed 7 T 8-element head coil [1].

Method: We employed co-simulation of the RF circuit (Agilent ADS) and 3-D EM (Ansoft HFSS) fields [2]. The realistic coil 3-D EM model includes all construction details for the resonance elements, simulated with precise dimensions and material electrical properties. Values of tuning capacitors were obtained using the standard vendor-provided coil tuning set-up, with a Siemens water-based phantom. Because this coil cannot be re-tuned once installed in the MRI scanner, we kept tuning capacitor values fixed for all simulations. The simulated in-vivo load consisted of the head and part of the shoulders of the Ansoft surface based human body model (Fig.1), with different spatial scaling factors. The models were rotated by 14 and 20 degrees in both directions relative to the XY plane, translated by +/- 15 mm in the XY plane, and translated up to +/- 20 mm in Z direction. Coil excitation power was 8 W at the coil plug.

Results and Discussion: When the conservative E field has a significant effect, the SAR can be up to twice as high as that produced by the non-conservative E field alone (Fig.3). In the rest of this investigation, the head models were moved away from the capacitors by more than 20 mm, sufficient to avoid almost all the influence of their conservative E fields. Because the head SAR profile is not axially symmetric in the transverse (XY) plane, rotation by positive and negative angles yields different SAR profiles (Fig.2). However, the variation of both SAR_{10gr} and SAR_{head} is relatively small (less than 10%) as shown in Table 1. The main effect on SAR of head shifts in the Z direction arises from variations in coil loading. For the coil simulated, the largest SAR was found when the head was only partially inserted into the coil. For all centrally positioned head models, SAR_{head} was found to be a more limiting factor than SAR_{10gr}, because the 3.2 W/kg whole head SAR limit is reached sooner than the 10W/kg local SAR limit. For models with scaling factors of 0.9 and 0.8, both the SAR_{10gr} (2.13 W/kg, 2.52 W/kg) and the SAR_{head} (0.81 W/kg, 0.98 W/kg) increased for the smaller head size.

Conclusion: For the coil simulated there is no safety concern with axial rotations of the head, provided that the distance to the lumped capacitors is more than 20 mm. It could be more dangerous to use the coil with the head only partly inserted. SAR_{head} should be counted as the important safety limit, and the scanner SAR monitor should be adjusted for the actual head mass within the coil for every scan.

[1] A. Weisser, T. Lanz, A volume head array with 8 transmit / Receive Channels for 7 T, Proc. ISMRM. 14 (2006) 2591.
[2] Kozlov, R. Turner, Journal of Magnetic Resonance 200 (2009) 147–152.

Position	Centered	Angled 14°	Angled -14°	Angled 20°	Shift x=15mm	Shift z=20mm	Shift z=-20mm
SAR_{10gr}, [W/kg]	**2.13**	**2.08**	**2.05**	**2.10**	**2.25**	**2.47**	**1.99**
SAR_{head}, [W/kg]	**0.8067**	**0.8024**	**0.8014**	**0.8051**	**0.8060**	**0.8509**	**0.7548**

Table 1. Data for head model scaled 0.9 in different positions, excitation power 8 W.

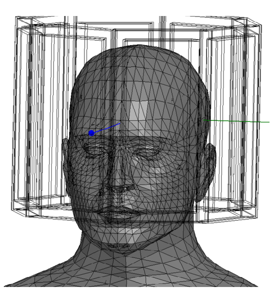

Fig. 1. Simulation setup.

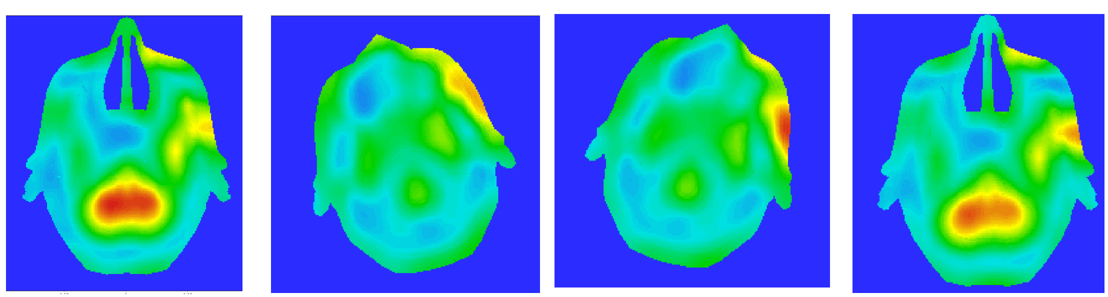

Fig. 2. SAR of head 0.9 scaled models, from left to right: centered, rotation +14, rotation -14, X shift 15mm.

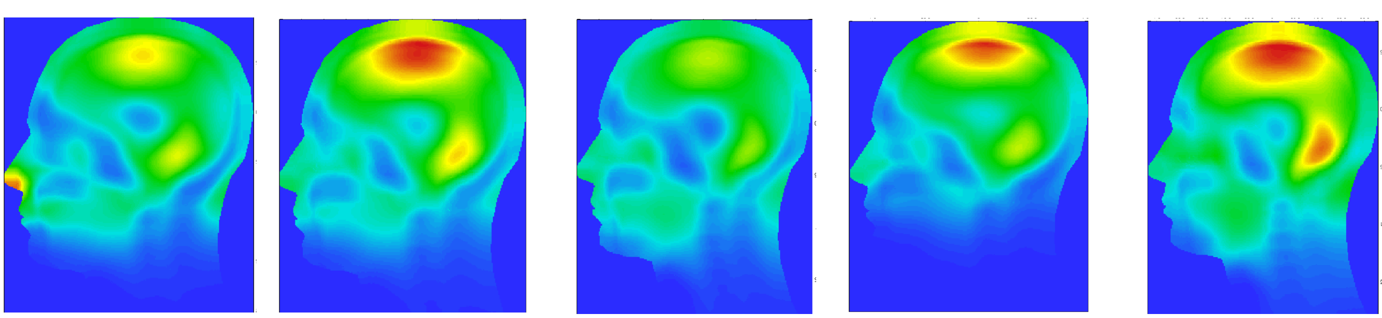

Fig. 3. SAR of Head models, from left to right: scale factor 1, scale factor 0.9, scale factor 0.9 Z shift -20mm, scale factor 0.9 Z shift 20mm, scale factor 0.8.