Feasibility of a local SAR monitoring for a 7 T body transmit array with single element power monitoring

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Introduction: 7 T prostate imaging with a radiative antenna (single-side adapted dipole antenna) surface array is beneficial in terms of high signal penetration into the body as well as low tissue heating [1]. This is due to its radiative design where the antenna geometry is optimized in terms of optimal power transfer to the target region. Recent studies indicate that parallel transmit can lead to complex SAR behavior. The local maximum SAR can vary over a large dynamic range (1 dB) for different RF shim settings but constant total RF power [2,3]. In this study we will investigate the local SAR behavior of a 8 elements radiative antenna array for 7 T prostate imaging.

Methods: The array was simulated with the finite difference time domain (FDTD) method using SEMCAD (SPEAG, Zurich, Switzerland) to investigate the local SAR distributions. The surface array comprises 8 radiative antennas each consisting of a dielectric substrate with a dipole antenna on top tuned for a standing $\lambda/2$ standing wave. The substrate was ε_r=37, 6.7x4.2x14.3 cm^3. The antenna elements were placed in a belt-like setup around the pelvis of the male model of the Virtual Family [4] (Figure 1). To ensure perfect element-skin abutment, blocks of skin and fat layers were modeled under the elements as well as air blocks around the substrates to avoid the tissue curling around the corners of the elements. Each antenna is tuned to 298.2 MHz and voltage source impedances are matched appropriately. The elements are driven individually in separate simulations (only 1 voltage source of an element is on, the rest of the array is off). Then, the worst possible SAR distribution is calculated from the sum of the magnitude of the E-fields of all elements. This distribution is compared to the SAR distribution of each individually simulated element. In this way we verify what the potential influence of an unfortunate shim setting is on the SAR levels under the elements. The SAR averaged over 10 g and normalized to 1 W input power was calculated. Note that the SAR distribution of the single elements is normalized to 1W delivered power, while the worst case SAR distribution for 8 elements is normalized to 8 W delivered power.

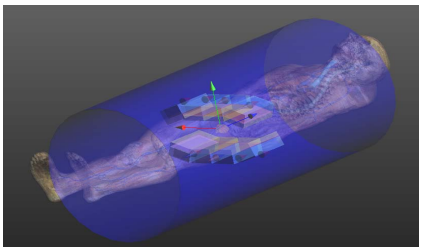

Figure 1: The male model with the radiative antenna array lying in the bore.

Results and Discussion: The SAR hotspots of the radiative array are observed under the elements, mainly in skin, and fat and muscle boundaries (Figure 2). Moreover, the locations of the SAR peaks are identical for the single element simulation and all simulations superimposed. However, the exact values of the SAR peaks are dependent on phase settings when the SAR values for single element and 8 elements are compared (Figure 3). The maximum average SAR over 10 g for the worst possible shim setting is located under element 7.

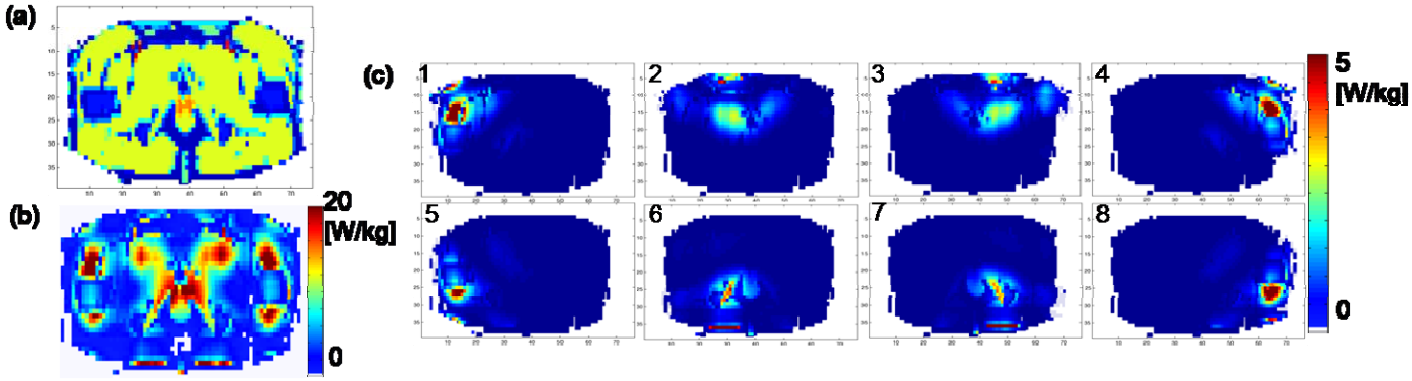

Figure 2:Transverse slice of electrical conductivity distribution of the male model (a) Local SAR distributions of radiative array on a male model calculated from the sum of squares of E-fields of 8 channels (b), individual channel simulations (c) .

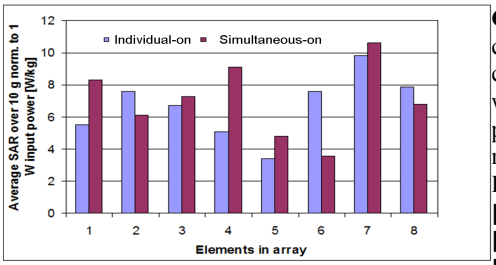

Figure 3: The maximum averaged SAR (W/kg) over 10 g tissue normalized to 1 W input power per channel for worst-case SAR and individually simulated radiative elements.

Conclusion: There is a correlation between the SAR hotspots for the single element and a worst case combination of all elements: 1) the location is identical 2) the single element values correlate with worst case combination but a maximum under estimation of 80% is possible. The worst case SAR is observed for element 7 which can be attributed almost exclusively to the power emitted by element 7 itself. A local SAR monitoring concept based on single power monitoring is thus feasible but requires a safety margin at least 80% margin.

References:

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