SAR Behavior During Whole-Body MultiTransmit RF Shimming at 3.0T

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Introduction.

The electrical properties of human tissue influence the RF uniformity that is achievable in MRI. Clinical 3.0T MRI systems capable of MultiTransmit RF technology have recently been introduced [1]. With such functionality it has become possible to significantly minimize the RF uniformity issues encountered at these higher field strengths. Electromagnetic (EM) simulations have been used to evaluate the relationship between whole-body SAR, local SAR and head SAR as a function of patient and anatomy specific uniformity optimized RF shim settings. Results indicate that improved RF uniformity is generally consistent with reduced SAR thereby enabling shorter scan times in cases where SAR is limiting [2-4].

Materials & Methods.

A stylized 3D model of the human female torso was constructed in HFSS (Ansoft, USA). The model was positioned within a multi-channel transmit-receive RF body coil model tuned for operation at 3.0T. EM simulations were performed for various body placements and complex B1 maps, for each independent transmit channel, were generated covering anatomies including breast, abdomen, cardiac and brain. Optimum RF shim settings for each anatomy were obtained by weighted amplitude and phase summation of the individual channel complex B1 maps in which the weightings were selected to minimize the coefficient of variance of the total magnitude B1 field within the anatomy of interest. The obtained shim settings were then used in the HFSS simulation to obtain whole-body, local and head SAR estimates for each of the shimmed anatomies. The B1 normalized SAR values in the shimmed cases were compared with the normalized SAR values obtained under quadrature excitation.

Results.

Figure 1 shows results of simulations for the breast imaging placement. In each case, the horizontal axis represents relative phase between the two independent transmit channels and the vertical axis represents the relative amplitude between the transmit channels. The left plot shows contours of uniformity (coefficient of variance of B1 within the slice) as a function of relative amplitude and phase (RF shim settings) normalized to the value for quadrature operation (green dot). The middle plot shows contours of relative whole-body SAR (normalized by mean $B1^2$ in the slice) as a function of RF shim settings (normalized to quadrature). The right plot shows similarly treated contours for local SAR. The yellow dot shows the mean RF shim setting for optimum RF uniformity obtained from human studies for breast imaging. The position of the yellow dot coincides well with the region for best uniformity obtained from the EM simulations. The RF shim settings for optimum uniformity in breast imaging also coincide, in this case, with the required settings for lowest whole-body SAR (~80% of SAR at quadrature) and lowest local SAR (~40% of local SAR at quadrature).

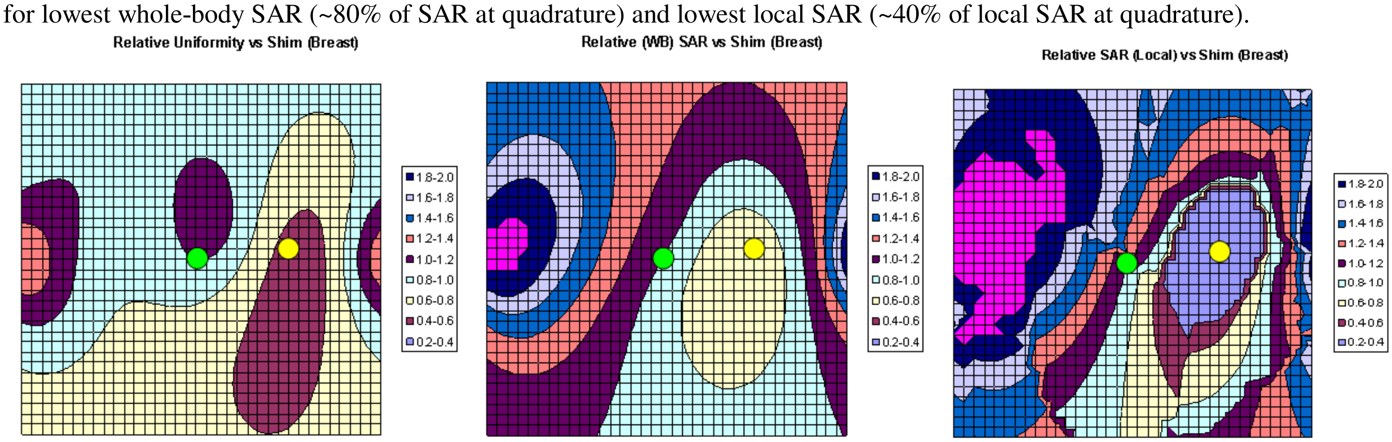

Figure 1: (Left) Relative uniformity (compared to quadrature) versus RF shim settings. (Middle) Relative whole-body SAR versus RF shim settings. (Right) Relative local SAR versus RF shim settings.

Conclusions.

EM simulations indicate that, for various anatomies, improved RF uniformity by RF shimming is consistent with reduced whole-body and/or local SAR. The optimum RF shim settings derived from simulation also correlate well with those obtained from human RF shim studies.

References.

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