SAR Analysis for Transmit SENSE at 7T with a Human Head Model

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Introduction:
Transmit SENSE (1,2,3) shortens multidimensional selective excitation by transmitting independent RF pulses through multiple channels. One useful application of Transmit SENSE is to compensate for transmit B_1 inhomogeneity, especially at high field strength. However, the specific absorption rate (SAR) has to be considered if Transmit SENSE is to be used in human studies. Thus far, the relation between SAR behavior and different parameters of Transmit SENSE has been investigated to some extent (4,5). However these studies were primarily based on phantom models. In this study, impact of reduction factors and coil setup (i.e. coil geometry and the number of coil elements) on SAR behavior in Transmit SENSE was investigated at 7T with a human head model using electromagnetic fields from simulations.

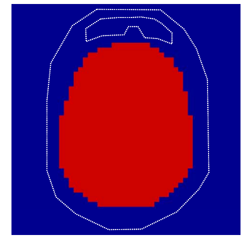

FIG. 1. Desired homogeneous excitation pattern. The ROI Mask is indicated by the dashed shape.

Methods:
RF stripline coil arrays of two different geometries were used in this study. One is a larger coil array mounted on a cylindrical holder with 32cm in diameter (6), and the other is a smaller one mounted on an elliptical holder with 24cm in major axis and 20cm in minor axis (7). All elements are assumed to be totally decoupled. Transmit B_1 and electric field maps within an axial slice of the brain for the two types of coil were obtained from simulations using the XFDTD software (REMCOM Inc.). 2D-selective RF pulses for Transmit SENSE were calculated for a region of interest (ROI) using the spatial domain method (8) with a spiral excitation k-space trajectory designed with Glover's algorithm (9). The conjugate gradient algorithm was used to solve the minimization problem for RF pulses. As the desired excitation pattern, homogeneous excitation (30-degree flip angle) covering the brain tissue was defined on a 48x48 matrix with a field of excitation (FOX) of about 21cm (Fig. 1). For each type of coil, RF pulses were calculated for different reduction factors (R = 1, 2, 4, 8 and 16) using different number of coil elements (N = 1, 2, 4, 8 and 16) with $N \geq R$. Finally, the corresponding SAR behavior within the axial slice was calculated (10) using the electric field maps from the simulation. All calculations were performed in MATLAB (The MathWorks Inc.).

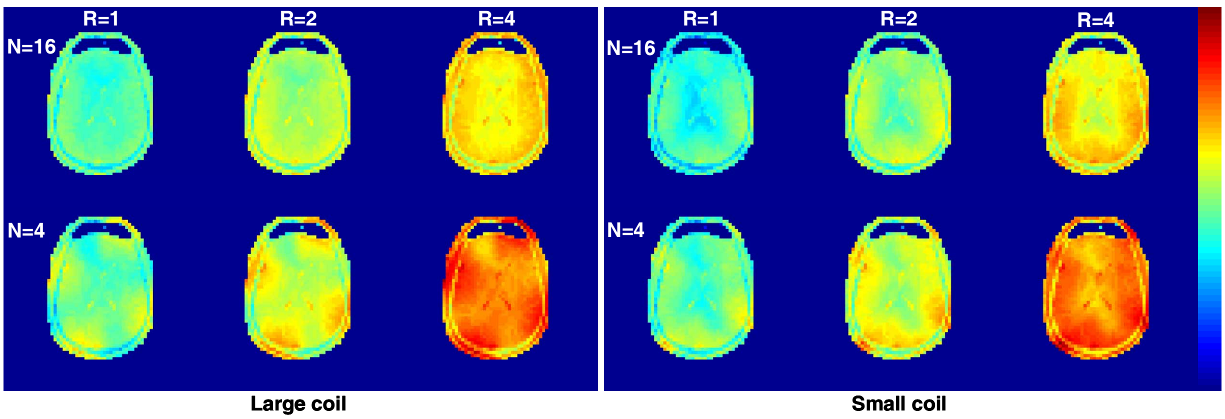

FIG. 2. Spatial distributions of the absorbed energy. (All maps are in arbitrary unit and are scaled to the range [0 1] before being displayed with a logarithmic color scale.)

Results and Discussion:
Fig. 2 shows the spatial distributions of the absorbed energy in the axial slice during a Transmit SENSE pulse for reduction factors of 1, 2 and 4 when transmitting through 16 and 4 coil elements of different geometries. One can see that the overall absorbed energy increases with reduction factors. Given a reduction factor, the absorbed energy of 16 elements is less than that of 4 elements, and the hot spots are somewhat smoothed out with 16 elements as compared to 4 elements. By contrast, keeping other parameters the same there are only small differences between the two different coil geometries in terms of overall absorbed energy. With the small coil there seems to be less energy deposition at the center of the brain than with the big one. Fig. 3 shows plots of the absorbed energy versus the number of coil elements for different reduction factors and different coil geometries. Interestingly, the curve for the small coil (red), but not for the large coil (blue), keeps decreasing even at the highest N value (16 in our case). This indicates that, using a smaller coil, even lower stable amount of absorbed energy may be reached with more coil elements. In good agreement with Ref.(4), our data show that the absorbed energy decreases with larger N and increases with R, especially when the ratio N/R is small.

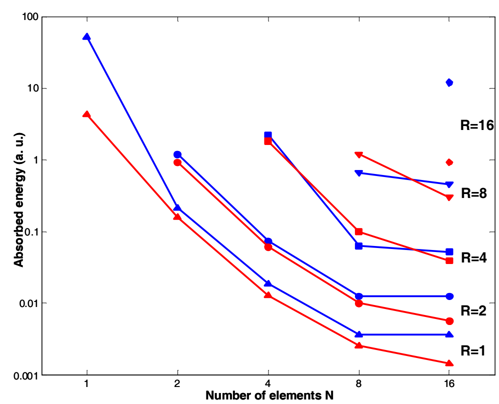

FIG. 3. Absorbed energy versus the number of coil elements for different reduction factors. (red: small coil; blue: large coil.)

Conclusion:
Our results show that, in the human brain at 7T, SAR for Transmit SENSE strongly depends on the reduction factor and the number of coil elements. By comparison, coil geometry had a much weaker impact on SAR behavior.

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