Potential for a single high-dielectric head coil former to reduce SAR and improve SNR in brain for a wide variety of coils at 7T

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Introduction: In recent years, high dielectric materials (HDMs) have shown great promise for improving SNR and reducing SAR in a number of applications at 3T and 7T (1, 2). To date, many of these applications require positioning of HDMs between the RF coils and the subject after the subject is positioned in the coil. This results in an additional step, requiring additional time and producing additional uncertainty and variability, as the positioning of the HDMs with respect to the coil and the subject may have limited reproducibility. Here we begin to examine the possibility of using a rigid HDM coil former that would ensure fixed position of HDM with respect to the RF coils and would eliminate the need for a separate step of positioning the HDM. Also, many current demonstrations have been for cases where the sample and coil are relatively large compared to the region of interest (1, 2), whereas in most of MRI, a large coil is used in transmission, but an array of small coils are used in reception. Here we also begin investigating the effect of a dielectric coil former optimized for minimizing SAR from a large transmit array on the fields of relatively small receive coils placed on the surface of the HDM.

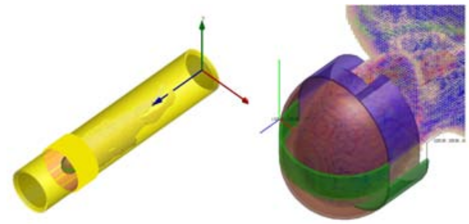

Figure 1. Geometry of body model in bore with stripline array and patch antennas present (left) and detail showing structure of sectioned dielectric helmet (right).

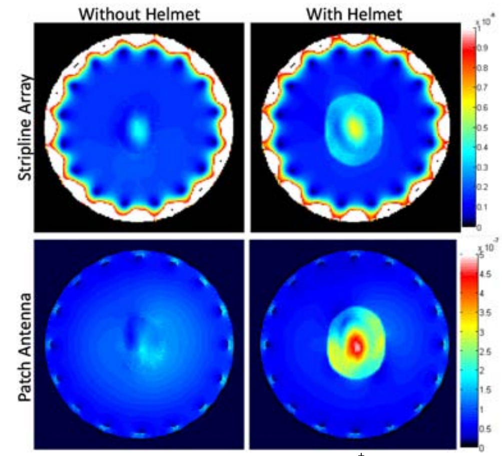

Figure 2. Simulated transmit efficiency (B_1^+/sqrt(P_{abs})) on axial plane through middle of ventricles for stripline array (top) and patch antenna (bottom) in quadrature-type drive at 300 MHz without (left) and with (right) an optimized dielectric helmet (relative permittivities of different sections ranging from 75 to 125) present. In both transmit coil types, efficiency is greatly improved by presence of the helmet.

Methods and Results: A 5mm-thick shell of HDM was modeled in the shape of a helmet about the head of a numerical model of the human body ("Duke,"), as shown in Figure 1. The helmet consisted of several sections that could be assigned different dielectric properties (Figure 1, right). A 16-element body-size stripline array and magnet bore were modeled about the body, with the array centered around the head (Figure 1, left). The properties of the helmet were optimized in a manual process with the body array driven in a quadrature-type mode. Optimal relative permittivities (ε_r) of the various sections were found to range between about 75 and 125. The transmit efficiency (average B1+ in brain divided by square root of power dissipated in the entire body model) of the quadrature body array was found to be 70% better with the HDM former present than without (Figure 2, top). Simulations of a patch antenna positioned superior to the head indicated even greater (250%) improvement of transmit efficiency (Figure 2, bottom). Examination of the ability for RF shimming in the presence of the HDM former showed no detrimental effects (Figure 3). Finally, a rectangular surface coil was modeled alternately on the inner and outer surfaces of the HDM former adjacent the occipital lobe (Figure 4). The presence of the HDM former had a similar effect on field pattern whether the coil was placed inside or outside the former with improvements to receive efficiency being slightly greater when the coil was placed on the outer surface. As shown in Figure 5, the presence of the HDM former resulted in more homogeneous sensitivity distribution and greater sensitivity near the center of brain with the HDM former present than without. Overall receive efficiency (average B1- in brain divided by square root of power dissipated in the body model) was found to be more than 20% better with the HDM former present than without. If the small surface coil was also used to transmit, the presence of the HDM improves homogeneity of both the transmitted magnetic and electric fields, making local SAR less of a concern relative to head average SAR.

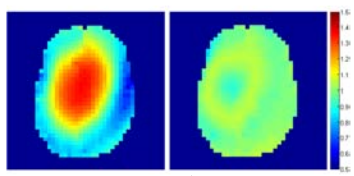

Figure 3. Simulated B_1^+ field distribution (normalized to mean in each case) in brain on axial plane through center of ventricles for stripline array with HDM helmet present before (left) and after (right) RF shimming, showing that RF shimming can be very effective in the presence of HDM coil former.

Discussion: We have begun evaluation of a helmet-shaped HDM coil former for use in 7T imaging of the brain. The situation simulated is for large excitation coils relatively far from the region of interest (ROI) and a small receive coil near the ROI. This type of setup is currently more common at 3T than at 7T in part because RF power systems being used in most 7T systems today provide only a fraction of the power available in clinical systems. As we become more confident of safety measures at 7T we expect available RF power to increase, allowing for systems more similar to what is known to work well at lower field strengths, but the ability for energy to propagate far from the ROI at 7T points out the need for improved efficiency. Strategic use of HDMs can be shown to provide this improved efficiency, providing improved SNR with reduced SAR in a number of cases (1, 2). In most of these cases, however, coils significantly larger than the ROI are used. Success of HDMs at improving SNR in the presence of receive coils which may each be small relative to the ROI is relatively unexplored. Results presented here indicate that a well-designed HDM helmet can simultaneously improve transmit efficiency of a large transmit coil and improve receive efficiency of a small surface coil. Ongoing studies include exploration of effects of the HDM on parallel imaging (e.g., sensitivity and g-factor for an array of receive coils) and robustness of performance on a variety of head geometries (examined with use of many human models in a given configuration of HDMs and coils). Strategies for manufacture are also under development.

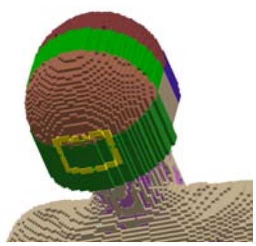

Figure 4. Geometry of surface coil placed on outer surface of the HDM helmet (bore and Tx array as in Fig. 11).

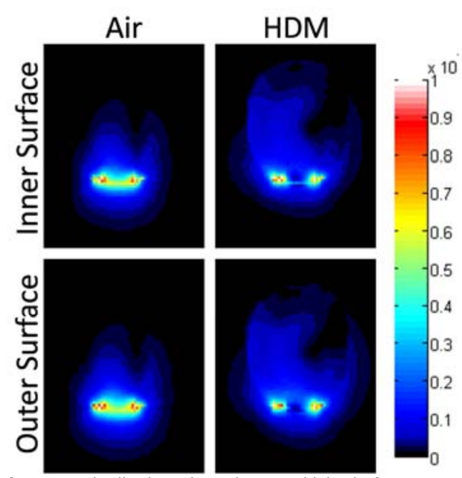

Figure 5. Distribution of receive sensitivity (B_1^- /sqrt(P_{diss})) on axial plane through occipital lobe for surface coil laid on inner surface (top) and outer surface (bottom) of helmet consisting of air-equivalent material (left) and HDM (right). Although some subtle differences are apparent, HDM has similar effect on sensitivity distribution whether coil is inside or outside the helmet.

References:

1. Yang QX, et al. Magn Reson Med 2011;65:358-362
2. Webb AG, Concepts in MR 2011;38A:148-84