Single Configuration of Coil and High-Permittivity Material Improves Performance for a Wide Range of Subjects

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Audience: MR engineers and physicists, RF engineers, Material scientists.

Purpose: Demonstrate feasibility of designing a single RF coil incorporating fixed High electric Permittivity Materials (HPMs) to improve performance for all subjects, making fixed HPM/coil combinations feasible for high throughput, high performance MRI.

Introduction: In recent years, HPMs 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 HPMs 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 HPMs with respect to the coil and the subject may have limited reproducibility. Here we examine the possibility of using a rigid HPM coil former that would ensure fixed position of HPM with respect to the RF coils and would eliminate the need for a separate step of positioning the HPM.

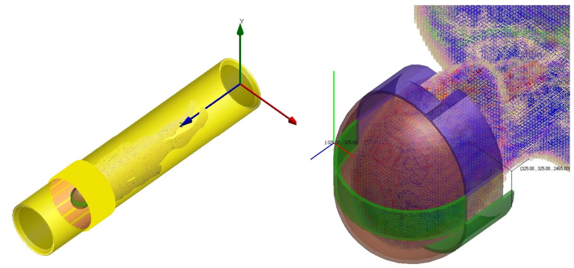

Figure 1. Geometry of body model in bore with stripline array and patch antennas present (left) and detail showing structure of sectioned HPM helmet (right).

Methods and Results: A 5mm-thick shell of HPM 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 B_1^+ 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 HPM former present than without in Duke (Figure 2). The exact same HPM configuration has also been shown to increase efficiency of a patch antenna even further (3). The ability for RF shimming was not diminished by the presence of the HPM (Figure 3). After this optimization on a single body model representing the average male, ability of the same HPM configuration to improve transmit efficiency and homogeneity of the same array with a quadrature type drive was examined in an additional 5 body models. The 6 models collectively covered a range in head circumference from the 13th to the 99th percentile. Results are shown Table 1 and demonstrate that the same configuration of HPM with respect to the coil can result in marked improvement in both transmit efficiency and homogeneity for all human subjects.

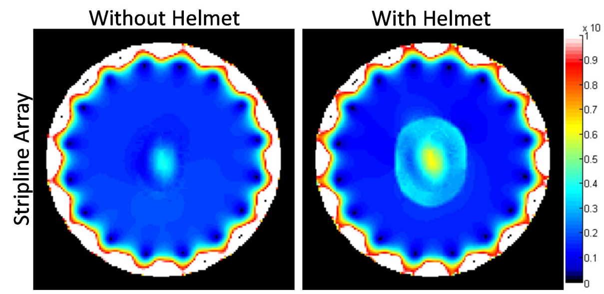

Figure 2. Simulated transmit efficiency (B_1^+/sqrt(P_{abs})) on axial plane through middle of ventricles for stripline array in quadrature-type drive at 300 MHz without (left) and with (right) an optimized dielectric helmet (relative permittivity of different sections from 75 to 125) for a single anatomical model ("Duke"). Efficiency is greatly improved by the HPM.

Discussion: A single HPM head coil former can be designed to improve transmit efficiency and homogeneity for all human subjects and does not interfere with the ability to accomplish RF shimming but rather adds to the efficiency of a transmit array regardless of drive configuration. This demonstration is an important step towards improving performance of MR in all systems with use of HPMs designed for high-throughput imaging.

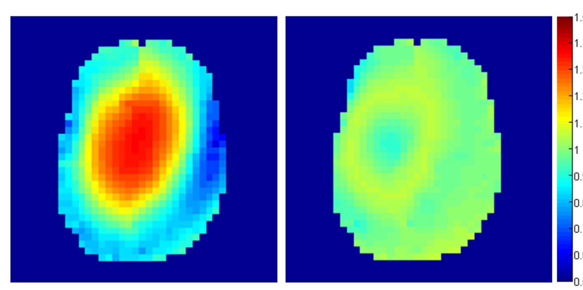

Figure 3. Simulated B_1^+ field distribution (normalized to mean in each case) in brain on axial plane through center of ventricles for stripline array with HDM helmet present before (left) and after (right) RF shimming, showing that RF shimming can be very effective in the presence of HPM coil former.

Table 1. Percent improvement in transmit Efficiency (mean $B_1^+/\sqrt{P_{sub}^+}$) and Homogeneity (inverse of normalized variance) and % decrease in SAR_{wb} for 6 different human models of differing Head Circumference (C_{Head}) in the same HPM helmet and stripline array (quadrature-type drive).

Model	C_{Head} (cm)	C_{Head} %ile	% increase		% decrease in SAR_{wb}
			Efficiency	Homogeneity	
Ella	54.9	13	152	35.1	84
Vis. Fem.	55.3	22	104	55.2	76
Norman	56.9	71	140	48.2	83
Naomi	56.9	71	97	34.5	74
Duke	57.8	90	116	49.3	79
Vis. Male	59.5	99	112	30.3	78

References:
1. Yang QX, et al. MRM 2011;65:358-362
2. Webb AG, Concepts in MR 2011;38A:148-84
3. Collins CM, 2013 ISMRM, p. 2797