High Dielectric Constant (HDC) Pad for High Field MRI: Reducing SAR and Enhancing SNR

Zhangwei Wang[1], Mike Lanagan[2], and Qing X Yang[3]
[1]*Coils, GE Healthcare, Aurora, OH, United States,* [2]*Electrical Engineering, The Pennsylvania State University, University Park, PA, United States,* [3]*Radiology and Neurosurgery, The Pennsylvania State University, Hershey, PA, United States*

INTRODUCTION:
Dielectric shimming and focusing of the RF field has been proposed for high field MRI applications [1]. Recent studies at 7T [2] showed that local RF field in the human head can be enhanced by placing high dielectric constant (HDC) material in between the targeted region of the sample and coil elements. Experimental results at 3T demonstrated that HDC pads significantly enhanced RF field in the human brain, leading to an increase in SNR and decrease in SAR[3]. In this computer modeling study we explored the potential utilization of HDC pads for ultra-high field human head imaging.

METHODS: The computer modeling was carried out with commercially available finite-difference time-domain(FDTD) software SEMCAD X (SPEAG, Schmid & Partner Engineering AG, Zurich, Switzerland) on a human head with 23 tissue types model modified from Visible Human Project with size 333x210x191 at 2mm isometric resolution. The tissue dielectric properties were obtained with Four-Cole-Cole extrapolation at 128(3T), 300(7T), 400(9.4T) and 600MHz(14T), respectively. A 16-rung (29-cm coil diameter and 26-cm length, 32-cm shield diameter and 30-cm length) high-pass birdcage coil was modeled and driven with 32 current sources in the end-rings and with 22.5-degree phase-shift between adjacent rungs. The HDC pad ($\varepsilon r = 100$) were 1-cm and 2-cm thick "helmet" covering the head model to the level of mouth with face exposed. The geometry with pad thickness=2cm is shown in Fig.1.

Fig.1 The model geometry with HDC pad thickness=2cm

RESULTS: Placement of HDC pad introduced large changes in B1+ and SAR distributions at all frequencies as shown in Fig. 2. Notice in Table 1 that B1+ in the area close to HDC pad appeared to be stronger in some cases. With the HDC pad and given geometry, the overall absorption power and average SAR in the head decreased.

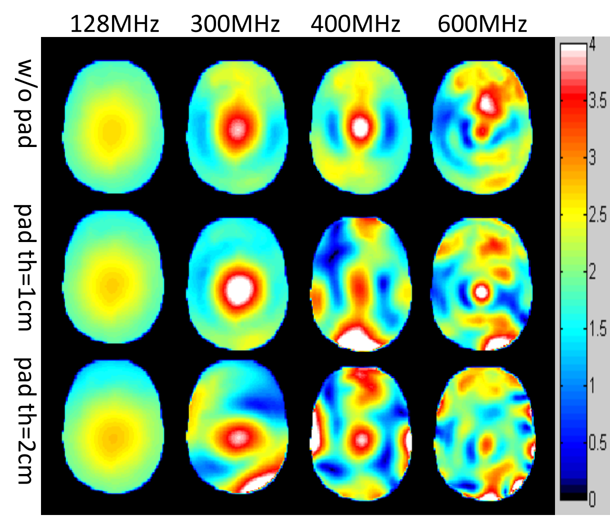

Fig. 2 Central axial B1+ distribution (normalized to slice average |B1+|=2uT)

Table 1. The SAR and absorption power(normalized to slice average |B1+|=2uT)

Frequency	HDC pad thickness	Pabs,total (w)	Pabs, head (w)	SARmean,head (w/kg)	SAR1g, peak (w/kg)	SAR10g,peak (w/kg)
128MHz	w/o	13.97	12.38	2.06	10.16	6.98
	1cm	13.25	11.93	2.06	10.75	5.74
	2cm	12.38	11.43	1.90	19.18	7.48
300MHz	w/o	42.58	30.72	5.39	28.56	17.25
	1cm	31.55	26.83	4.71	25.38	19.22
	2cm	28.31	24.49	4.13	33.40	18.77
400MHz	w/o	36.47	29.96	5.21	147.20	66.43
	1cm	25.52	23.07	3.93	63.31	28.95
	2cm	31.91	28.08	4.47	109.75	52.32
600MHz	w/o	90.89	59.08	10.60	127.24	92.40
	1cm	91.81	58.57	9.50	177.30	107.64
	2cm	56.32	38.54	6.92	178.85	61.26

DISCUSSION: The goal of this computer modeling study is to explore the potential utilization of using HDC materials for RF engineering in ultra-high field. As demonstrated, the significant changes of RF field by the HDC-pad could be utilized for RF field engineering in various ways: 1) The computer experiments showed a simple and effective approach for enhancing local RF field performance. 2) The results suggest a novel approach of incorporating dielectric material directly into RF coil designs. Further implementation of this approach requires a systematic computer study to determine optimal dimensions and permittivity values of dielectric materials at various configurations for optimal RF field performance. 3) There is potential to apply this method to transmit-array technology for local SAR reduction.

REFERENCE:
1. Q.X.Yang et al., J Magn Reson Imag, 2006.
2. K. Haines et al., J Magn Reson. 2010
3. Q. X. Yang et al., Magn Reson Med. 2010
Acknowledgments: Funding has been provided in part through NIH R01 EB006563, R01 AG02771 and the Pennsylvania Department of Health.