Improvement of parallel imaging using high permittivity material (HPM) - demonstration with liver imaging at 3T

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Target Audience: RF engineers interested in improving imaging speed and SNR with multichannel receive arrays.

Introduction: Utilization of high permittivity low loss material (HPM) has been demonstrated to improve transmit efficiency and field homogeneity for various clinical applications for MRI [1]. Initial results also showed that it can be used not only to improve the receive efficiency of multichannel receive arrays but also to significantly alter the B1 field distribution of the surface coil. Therefore, it can effectively be used to manipulate B1 of receive coil elements to reduce the g-factor and improve parallel imaging performance. Based on initial reported success with HPM on g-factor reduction demonstrated through EM simulation [2], this study aims at validating the same principle with experimental body imaging at 3T.

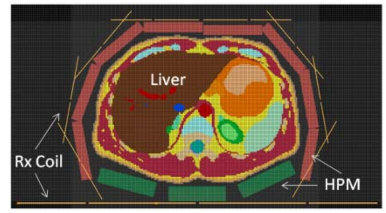

Figure 1. Schematic diagram of the arrangement of HPM, receive coils, and the human body.

Method: To demonstrate improved g-factor with the use of HPM, liver imaging was performed on a Siemens 3T system. Five human volunteers were imaged with two eight-channel receive flex arrays on the top, and a three channel receive array at the bottom, totaling 11 available channels in-plane for transverse liver imaging (Fig. 1). Correspondingly, eleven HPM blocks with relative permittivity of ~900 were placed between the body of the volunteer and the array, each centered with a different coil (Fig. 1). A gradient echo sequence was used with parameters: 6 imaging slices with 7 mm slice thickness, 4 ms TE, 8.6 ms TR, 20 degree flip angle, 256 by 256 matrix size, and 1 mm in-plane voxel size. To avoid motion artifacts, the imaging was administrated with breath-hold. Noise matrices were also collected with no RF driving current. In order to evaluate the effect of blocks on parallel imaging, fully-sampled MR images were collected with Cartesian trajectory. These images were then retrospectively undersampled and processed to evaluate the effect of HPM on parallel reception performance of the combined 11-channel receive array. Specifically, three important aspects were evaluated: 1) SNR of fully-sampled channel-combined liver images, 2) SENSE g-factor maps [3], and 3) quality of the undersampled and GRAPPA [4] reconstructed liver images. For 1), the fully-sampled images of each receive element were combined with adaptive reconstruction [5] and monte-carlo based SNR quantification method [6]. For 2), receive sensitivities were also retrieved with adaptive reconstruction method [7] and they were used to calculate SENSE g-factor maps with reduction factors R = 2, 3, and 4. For 3), the fully-sampled MR image of each channel were retrospectively undersampled and reconstructed with GRAPPA, R = 4.

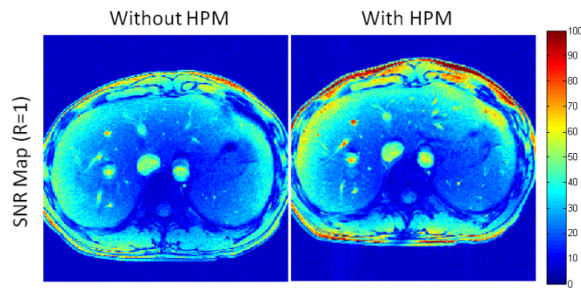

Figure 2. SNR maps of fully sampled liver images without and with HPM.

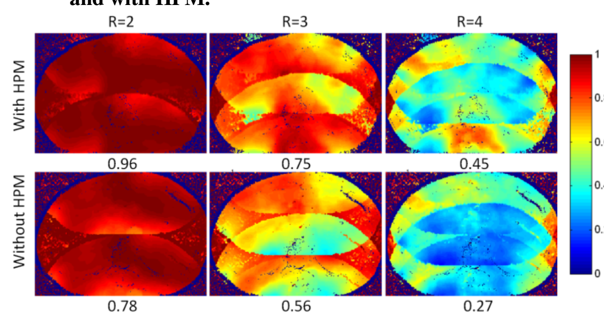

Figure 3. Inverse SENSE g-factor maps (1/g) with different undersampling factors without and with HPM. The mean value of 1/g at the center is shown under the corresponding map.

Results: As shown in Fig. 2, the SNR improvement with HPM with full-data sampling is approximately 10% SNR improvement at the center but more prominent in the periphery of the body. As demonstrated in Fig. 3, the inverse of g-factor map at the center of the body is increased by 67% with R=4. This predicts equal amount of SNR-loss reduction for higher accelerated imaging as inverse g-factor is proportional to the SNR of undersampled image as shown in Fig. 4. This study provided experimental data to demonstrated a new way of "shaping" the receive coil field distribution to improved parallel imaging. The improvement with HPM presented used the standard receive array coils under sub-optimal conditions. Yet for all volunteers, similar improvements were observed (Table 1). More deliberate optimization is needed to explore the full potential of HPM for parallel imaging.

Conclusions: Utilization of HPM can improve parallel reception performance of multi-channel receive arrays for body imaging at 3T. Particularly, HPM reduced the g-factor at the center of the object of interest and improved SNR in the images with high acceleration factors.

References: [1] Yang et al., JMRI 2013; 38:435–440. [2] Cao et al., ISMRM 2013; 2802. [3] Pruessmann et al., MRM 1999; 42: 952–962. [4] Griswold et al., MRM 2002; 47:1202–1210. [5]Walsh MRM 2000; 43:682–690. [6] Robson et al., MRM 2008; 60:895–907. [7] Griswold et al., ISMRM 2002; 2410.

Subject	1	2	3	4
Waist (cm)	84	94	96	100
Total SNR Increase (R=1)	81%	29%	62%	59%
Center 1/g Increase (R=4)	64%	43%	70%	62%

Table 1. Total SNR increase and center 1/g increase for four different human subjects.

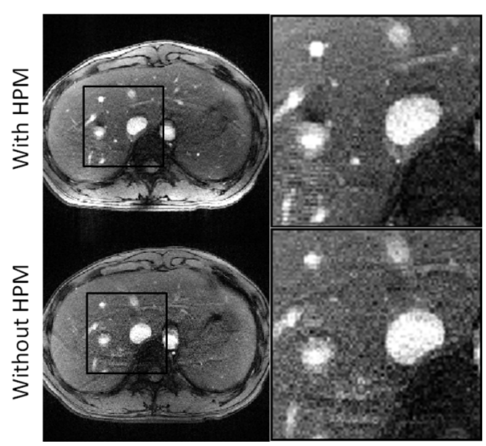

Figure 4. T1 liver images with R=4 reconstructed with GRAPPA and zoomed images in the rectangular region.