Field shaping arrays: a means to address shading in high field breast MRI

Ileana Hancu[1], Seung-Kyun Lee[1], W. Thomas Dixon[1], Laura Sacolick[2], Ricardo Becerra[3], Zhenghui Zhang[3], Graeme McKinnon[3], and Vijayanand Alagappan[4]

[1]*GE Global Research Center, Niskayuna, NY, United States,* [2]*GE Global Research Center, Munich, Germany,* [3]*GE Healthcare, Waukesha, WI, United States,* [4]*GE Healthcare, Aurora, OH, United States*

Introduction: High field imaging increased the diagnostic power of MRI. Some of the disadvantages of imaging at high field, such as the fact that a homogeneous excitation is not a solution of Maxwell's equations, have, however, slowed the transition of some clinical exams to 3T. Shaded images, reported by users of all manufacturers' scanners [1-3], have, for example, limited the use of high field systems in breast MRI. While elliptical, dual or multiple drive systems were shown to mitigate this problem and may soon become the clinical standard, they can't address this issue for legacy scanners. Here, we investigate the origin of breast shading in phantom experiments on such a legacy 3T scanner with a quadrature drive RF body coil. We then develop a solution for this problem based on modification of a standard, 8 channel receive (Rx) array. The field focusing (or passive parallel transmit) effect, obtained through selective un-blocking and up-tuning of one of the Rx elements during the transmit (Tx) phase, is shown to improve B_1^+ homogeneity, fat suppression and image SNR in all the volunteers studied in this system.

Methods: All experiments presented in this work were performed on a 3T HDx scanner (GE, Waukesha, WI), and all B_1^+ maps were acquired using a Bloch-Siegert approach [4], and displayed using a threshold of 95% of the signal intensity. A phantom simulating a female torso, filled with oil, de-ioninzed (DI) water or 2.2g/l NaCl dissolved in DI water was first scanned to understand the source of the shading artifact. The B_1^+ maps in these 3 configurations are presented in Figure 1. The very homogeneous B_1^+ field observed in oil converts to a focused B_1^+ profile in DI water, with high signal intensity in the center, low at the periphery, and of equal signal intensities over the two "breasts". Left to right (L/R) imbalance only appears in the presence of salt (Figure 1d), indicating that this effect is mostly due to eddy currents, therefore being more of a "conductivity effect" than a "dielectric effect". Figure 2 presents B_1^+ maps acquired in 4 different volunteers scanned initially in the standard system configuration (quadrature drive Tx coil and standard Rx coil); the L/R ratio in these people ranges between 1.37 and 1.53, with an average of 1.44. Given the limited variability of this ratio, we developed an approach, somewhat similar to the one described in [5,6], in which one of the Rx elements, located at the entrance of the right breast (which is always the "missing-field" breast) is un-blocked and up-tuned during Tx. The exact tuning in Tx is decided experimentally by tuning the L/R ratio of B_1^+ maps in the oil phantom to 1/1.43=0.7 (the inverse of the ratio seen *in vivo*). Different than in the approach of [5,6], however, the element is returned to 128MHz in Rx, therefore preserving the Rx profile. Electromagnetic simulations were performed using Comsol to insure the safety of the approach; a fuse was added to limit the current in the loop during Tx.

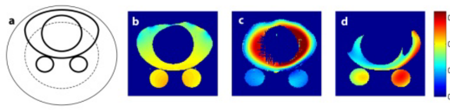

Figure 1: a) Geometry of experiments. B_1^+ maps in **b)** oil **c)** DI water and **d)** 2.2g/l NaCl in DI water

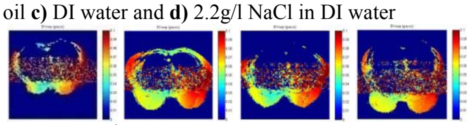

Figure 2: B_1^+ maps in 4 different volunteers

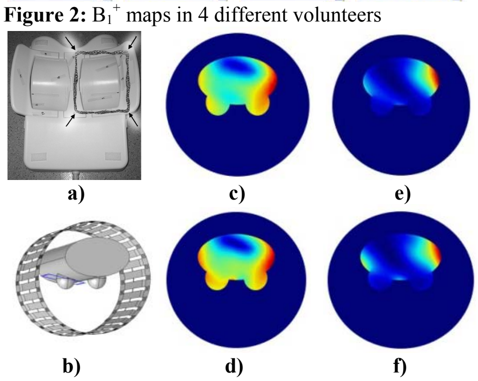

Figure 3:a) location of un-blocked Rx coil **b)** geometry of simulations. Simulated B_1^+ maps **c)** in normal configuration **d)** with unblocked coil. Simulated SAR maps **e)** in normal configuration **f)** with unblocked coil

Results: The approximate location of the unblocked and up-tuned Rx loop is shown in Figure 3a (top view); Figure 3b presents the geometry of the simulations- including the lateral view of the un-blocked coil (blue). Figures 3c and 3d present the predicted B_1^+ field in the standard configuration and with the unblocked coil, respectively, while Figures 3e and 3f present the local SAR maps in the standard configuration and with the unblocked coil, respectively. The shading effect is predicted by the simulations, as is the correction effect of the unblocked coil. As also evident from the comparison of Figures 3e and 3f, no additional local SAR is expected with this approach. Four additional volunteers were scanned using both the standard system configuration and the unblocked Rx coil approach. Figure 4 presents the B_1^+ maps and GRE images acquired from two of these volunteers. A smaller L/R imbalance is seen in both the B_1^+ maps and the signal intensities of the GRE images. In fact, while last 4 volunteers showed the same average L/R B_1^+ ratio (of 1.43(±0.1)) as the first 4 volunteers, this ratio decreases to 1.08(±0.1) with the unblocked Rx coil. Additionally, with this approach, the power to obtain a 90º flip angle is reduced, on the average, by 0.6dB in the 4 volunteers. This was expected, as a flatter RF excitation profile limits over-flipping of spins in the left side, therefore requiring less power.

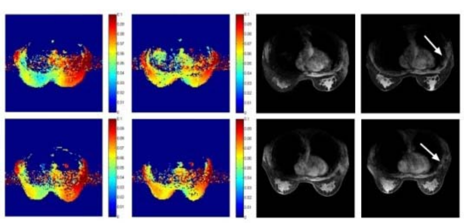

Figure 4: B_1^+ *maps* in 2 volunteers (separate rows) in standard configuration (1*st* col.) and with unblocked coil (2*nd* col.). 3D GRE images in standard configuration (3*rd* col.) and with unblocked coil (4*th* col.)

Discussion and Conclusions: This study investigated breast shading in a legacy 3T system using a quadrature drive RF body coil. The flat excitation field seen in an oil phantom converted to a focused excitation field in a water phantom, and only evolved to an unbalanced L/R profile when the same phantom was filled with a high conductivity material (Figure 1). The extent of shading was then studied in a number of normal volunteers, and found to be similar in different people. The L/R ratios seen in this study are also similar (or smaller) to the ones documented in previous reports, which used scanners from different manufacturers, with different RF body coils [1-3]; this indicates that shading is mostly related to the physics of imaging at high field, and less to the particular engineering approaches (including choices of RF body coils) chosen by different MRI equipment manufacturers. A simple correction approach, based by un-blocking and up-tuning of one of the Rx elements during Tx was shown to mitigate this problem, and result in more homogeneous B_1^+ profiles, better fat suppression, higher image SNR, all with lower SAR. While elliptical or dual drive may be the preferred future solution, this simple field focusing (or passive parallel transmit) approach may be a viable solution for legacy 3T scanners.

References: **1.** Azlan et al, J Magn. Reson Im **31**:234-239 (2010) **2.** Zheng et. al, Proc 19-th Intl Soc Magn Reson Med, 1042 (2011) **3.** Sung et al, Proc 19-th Intl Soc Magn Reson Med, 3086 (2011) **4.** Sacolick et al, Magn Reson Med **63**: 1315-1322 (2010) **5.** Hancu et al, Proc 18-th Intl Soc Magn Reson Med, 2470 (2010) **6.** Schmitt et al, Proc 13-th Intl Soc Magn Reson Med, 331 (2005).

Grant support: 5R01EB005307, 1R01CA154433