Simple approach for increasing SNR, reducing breast shading and improving fat suppression at 3T

I. Hancu[1], L. Sacolick[2], S-K. Lee[1], W. T. Dixon[1], R. Giaquinto[1], G. McKinnon[3], and V. 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

Due to its exquisite sensitivity, breast MRI is becoming more and more popular for screening high-risk patients and for detecting high-grade ductal carcinoma *in situ* [1]. While 3T breast imaging yields clear benefits, such as increased SNR, allowing higher temporal or spatial resolution, it also comes with certain drawbacks. Most importantly, complaints about image shading and improper fat suppression emerged [2], slowing down the transition of breast MRI studies to 3T. Inhomogeneous B_0, inhomogeneous $B_1^{receive}$, and inhomogeneous $B_1^{transmit}$ were all blamed in the past as main sources of these problems [2]. Typical image post-processing approaches, used in the past for shading correction [3], cannot recover lost SNR due to improper local flip angle. While parallel transmit systems were suggested in the recent past as possible solutions [4], such systems are not the current clinical standard. Consequently, simpler solutions, capable to mitigate breast image artifacts in the thousands of existing 3T MRI scanners are needed. In this work, the origin of shading and improper fat suppression at 3T is investigated. It is found, through simulations and experimental data acquisitions, that a bimodal distribution of the excitation field is the main source of the artifacts. A simple solution, based on the addition of a tuned loop over the right breast mitigates image shading, improves fat suppression, and increases image SNR in all volunteers studied.

Methods

B_0, $B_1^{transmit}$ maps, and fat-suppressed T_2 weighted fast spin echo (FSE) images were acquired on a 3T, GE scanner in 4 volunteers using a gradient echo sequence with TE=9,10ms (B_0 maps), and a recently developed Bloch-Siegert method ($B_1^{transmit}$ maps) [5]. While B_0 maps showed small variability (<250 Hz over the 2 breasts), changing between volunteers, and within slices in the same volunteer (data not shown), $B_1^{transmit}$ maps showed an almost constant bimodal distribution between multiple slices of the same volunteer/different volunteers. Figure 1 displays a slice of $B_1^{transmit}$ maps for 3 of the volunteers studied (1st column), and the corresponding fat-suppressed FSE image (2nd column). Note the variable performance of fat suppression, getting worse in subjects with larger, fatty breasts (3rd row in Fig 1). Given the consistency of these results [$B_1^{transmit}$(left)/ $B_1^{transmit}$(right) varied between 1.4 and 1.8 for the 4 volunteers and 5 slices/volunteer studied], a simple solution was designed to mitigate the problem. Similar to [6,7], a resonant loop (made out of copper tape, with a Q of 150), tuned higher than 128MHz, was built and affixed to a standard, 8 channel breast coil, over the entrance area of the right breast. Figure 2 presents a view from the top, and one from below of this setup, with the location of the tuned loop (marked by the arrow). The tuning of this loop was experimentally varied to obtain homogeneous $B_1^{transmit}$ in a single subject; the loop remained tuned to 150MHz for the remaining 3 subjects, and was positioned identically for all 4 *in vivo* scans.

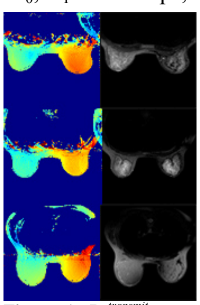

Figure 1: $B_1^{transmit}$ maps (1st column) and FSE images (2nd column)

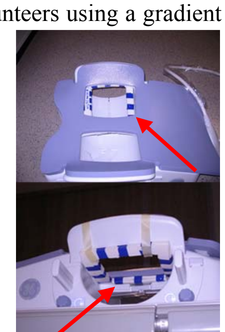

Figure 2: 8 channel breast coil + correction loop (red arrow)

Results and Discussion

Figure 3 presents $B_1^{transmit}$ maps (1st column) and fat suppressed FSE images (2nd column) in the same volunteers and same slices as presented in Figure 1, this time with the correction loop in place. Figures 1 and 3 are displayed on the same scale. Note the improved homogeneity of the $B_1^{transmit}$ maps (resulting in $B_1^{transmit}$(left) / $B_1^{transmit}$(right)=1.08), coupled to significantly improved fat suppression. This improvement was obtained with lower transmit power (transmit gain values given by prescan were, on the average, 1.5dB less in the presence of the transmit loop). 22% improved SNR was also observed in the presence of the correction loop, consistent with achieving the intended excitation flip angle in both breasts. A simple Comsol simulation, presented in Figure 4, confirms the experimental results. The geometry of the setup is displayed in the middle of Figure 4, together with the $B_1^{transmit}$ maps and local specific absorption rate (SAR) maps in a conventional acquisition (top row), and with the correction loop (bottom row). Identical voltages were used to drive the body coil in the two rows of Figure 4, resulting in higher overall $B_1^{transmit}$ for the correction loop case (which would be corrected by prescan). It is expected that this approach will not only result in higher $B_1^{transmit}$ homogeneity, better fat suppression, higher SNR, but it will also come with lower total and local SAR. In this first implementation, the passive loop was (semi)permanently affixed to the breast receive array, being active both during the transmit (Tx) and receive (Rx) phase. While tuned high, it still impacts the tuning of the right array elements, resulting in worse Rx profile over the right breast. A better implementation will include a diode in the circuit of the correction coil, allowing this coil to be turned off during the Rx phase, and resulting in even higher SNR increases. Better yet, one of the elements of the receive array (already usually existent in the proper location) can be selectively unblocked and up-tuned during the transmit phase of the imaging sequence. In this manner, good transmit and receive fields can be obtained with minimal modifications to a single element of the receive array.

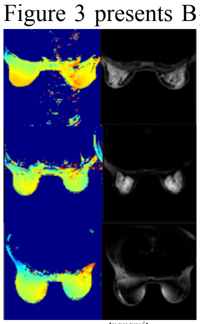

Figure 3: $B_1^{transmit}$ maps (1st column) and FSE images (2nd column) – with correction coil

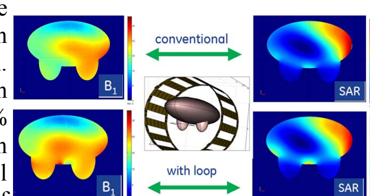

Figure 4: Simulations for $B_1^{transmit}$ maps (1st column) and SAR (2nd column) – without (top) and with correction coil (bottom)

Conclusions

The main cause of the shading and improper fat suppression artifacts in breast imaging at 3T was identified as a bimodal distribution of the excitation field. A correction approach, based on the permanent placement of a passive loop tuned to 150MHz over the (always "weaker") right side of a standard 8 channel breast receive array, was shown to mitigate the problem, result in more uniform $B_1^{transmit}$ and better fat suppression. Higher SNR is obtained with this approach due to optimal flip angles over both breasts. Lower SAR is also expected in the presence of the correction loop.

References: **1.**Turnbull, NMR Biomed. 2008. 22:28-39; **2.** Harvey et al, Radiographics. 2007. 27: S131-S145; **3.** Behrenbruch el al, British Journal of Radiology (2004) 77, S126-S132; **4.** http://www.medical.philips.com/in/products/mri/systems/achievatx/index.wpd; **5.** Sacolick et al, Magn Reson Med 2009, in press; **6.** Wang et al, IEEE TMI. 2009. 28(4):551-554; **7.** Schmitt et al, Proc ISMRM 2005, 331;

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