Improved B1 Homogeneity and Reduced Transmit Power with 4-channel Regional RF Shimming for Breast Imaging at 3 T

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Target audience: Researchers and engineers who have interest in RF transmit technology in high field MRI.

Purpose: The B_1 inhomogeneity is one of the problems for breast imaging at 3 T. Various methods using multiple channel RF transmit coil or using some additional dielectric absorptive material are investigated to overcome this problem [1, 2]. These studies showed the number of channels of RF coil increased the homogeneity of B_1 improved [1]. However, the RF transmit power also increased by using RF shimming without using additional passive RF coil in some cases [1]. Recently, regional RF shimming was proposed and evaluated numerically in torso region to improve B_1 homogeneity [3]. It showed that spatially asymmetric RF field can be created and the homogeneity of B_1 in partial region of interest can be improved when the number of RF transmit channel is equal or higher than 4.

In this study, the regional RF shimming using 4-channel RF transmit coil was evaluated both in B_1 homogeneity and RF transmit power for breast imaging *in vivo* at 3 T. The results demonstrate that the 4-channel regional RF shimming has an advantage in improvement of B1 homogeneity and reduction of RF transmit power compared to the QD and conventional volume RF shimming.

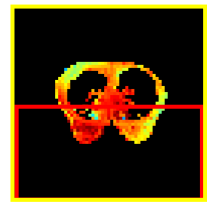

Fig.1 Positions of entire and partial regions used in RF shimming

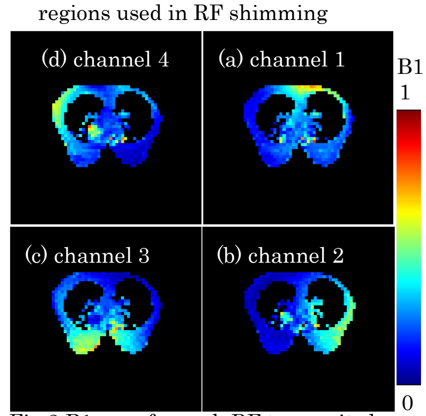

Fig.2 B1 map for each RF transmit channel.

Materials and Methods: 3-T whole body MRI system equipped with 4-channel RF transmit/receive coil [4] was used for this study. B_1 maps for each transmit channel was measured by using multi Td method [5, 6]. Scan parameters of B_1 mapping sequence are as follows, FOV =500mm, TR/TE =7.5/1.0ms, slice thickness=10mm, and measurement matrix=64×64×3. FA of pre-pulse was $\pi/2$ and Td_1/Td_2 =20/550ms. Scan time was 3 sec for acquiring B_1 maps for 4-channels of RF transmit coil. The B_1 homogeneity was evaluated by Usd defined as (standard deviation of B_1)/(average of B_1). RF shimming parameters (amplitude and phase for each RF transmit channel) were calculated by using steepest descent method to minimize Usd. The Usd in breast region and RF transmit power for the following three transmit modes were compared for 6 healthy volunteers;

QD mode: Amplitude of each channel is the same, and phase of each channel was 0, $-\pi/2$, π, and $\pi/2$, respectively.

Volume mode: Calculate RF shimming parameters those minimize Usd of entire region (yellow ROI in Fig. 1). The entire region covered the entire breast and back region along axial plane.

Regional mode: Calculate RF shimming parameters those minimize Usd of breast region (red ROI in Fig. 1). The ROI was set lower half of axial plane for all volunteers.

Relative RF transmit power of each mode was calculated as square sum of all channel amplitudes relative to that of QD mode.

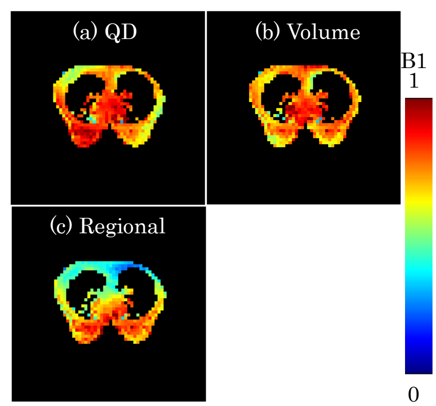

Fig.3 B1 map for each RF shimming

Results and Discussion: Figure 2 shows the B_1 maps for each transmit channel. The contribution to B_1 in breast region from channel 1 and 4 were smaller than that from channel 2 and 3. Figure 3 shows B_1 maps of a volunteer's breast. B_1 maps of breast region by using both RF shimming modes (b, c) were more homogeneous than that by using QD mode (a). The mean and the standard deviation of Usd of 6 volunteer's in breast region (ROI was defined as same as the partial region shown in Fig. 1) and the relative RF transmit power are shown in the table 1. Usd was improved 26% for the volume mode and 35% for the regional mode from QD mode. The relative RF transmit power was reduce by 18% using the regional mode compared to QD mode. By using the regional mode, B_1 of back side was lower than that of breast region, because the homogeneity of B_1 in back side does not affect Usd in breast region and the relative transmit power decreased. Figure 4 shows RF shimming parameters for the volume mode and the regional mode of all volunteer in 2D complex plane. The complex RF shimming parameters were calculated as follows:

$$\mathrm{Re}(ch) = \mathrm{amplitude}_{ch} \times \cos(\mathrm{phase}_{ch}), \quad \mathrm{Im}(ch) = \mathrm{amplitude}_{ch} \times \sin(\mathrm{phase}_{ch}).$$

The amplitude of channel 1 and 4 were smaller than 1 for the regional mode. In total, the relative RF transmit power can be reduced by using the regional mode. This is because the contribution of channel 1 and 4 to B_1 in breast region are smaller than channel 2 and 3, the amplitude of channel 1 and 4 became smaller than QD mode. These results clearly show that the regional RF shimming in breast region increase the homogeneity of B_1 and decreases RF transmit power.

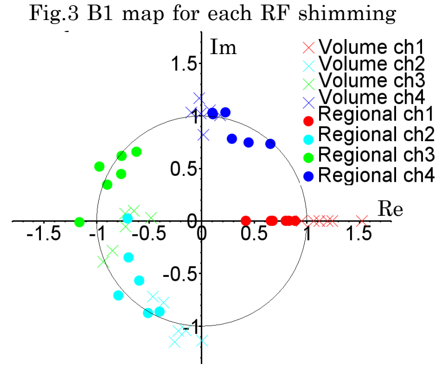

Fig.4 RF shimming parameters for each mode

Table 1. Estimated Usd and relative RF transmit power for three modes.

Mode	QD	Volume	Regional
Usd	0.24±0.01	0.17±0.01	0.15±0.02
Relative RF transmit power	1	1.04±0.01	0.82±0.05

Conclusion: Regional RF shimming using 4-channel transmit coil was evaluated for breast imaging at 3-T. Our results demonstrate that the regional RF shimming can improve the B_1 homogeneity in breast region and can decrease the transmit power simultaneously.

References: [1] L. Sacolick et al; 3478 ISMRM(2012), [2] S. A. Winkler et al; 397 ISMRM(2013), [3] Y. Kaneko et al; 2756 ISMRM(2013), [4] Y. Soutome et al; 2750 ISMRM(2013), [5] K. Ito et al; 2598 ISMRM(2013), [6] K. Ito et al; 2599 ISMRM(2013)