Correction of Transmission and Reception Fields Induced Signal Intensity Nonuniformities In Vivo

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ABSTRACT Signal intensity (SI) nonuniformity becomes a significant problem for high field MRI. Intensity nonuniformities misrepresent quantitative information and compromise diagnostic scan quality. A simple method is demonstrated for correcting the nonuniformity artifact based on the transmitted field and reception sensitivity maps determined with either gradient (GE) or spin (SE) echo imaging. In a uniform phantom, this approach reduces nonuniformity from 30% before correction to approximately 6% with the SE and 9% with the GE approach after correction. The application of the SE approach is demonstrated *in vivo* at 3 Tesla.

INTRODUCTION The problem of signal intensity (SI) nonuniformity caused by wave behavior and eddy currents in the human body becomes more prevalent at high field strengths. Intensity nonuniformity affects not only the ability of MR images to provide quantitative information, but can also negatively impact diagnostic scan quality. We describe a simple method for correcting the SI nonuniformity artifact based on the transmitted field, and reception sensitivity maps measured *in vivo*.

THEORY The SI acquired by SE with excitation flip angle $\alpha(x)$ and refocusing angle $\beta(x)$ can be written as follow [1,2]: $SI(x) = C(x) \cdot S(x) \cdot \sin\alpha(x) \cdot \sin^2(\beta(x)/2)$ where S(x) is the sensitivity of receiving coil and C(x) depends on proton density, T_1 and T_2 and acquisition parameters (TE and TR). For a GE sequence, the SI is given by: $SI(x) = C(x) \cdot S(x) \sin\alpha(x)$. The transmission field map can be calculated by the ratio of two images with different excitation flip angles, while the reception sensitivity map can be obtained subsequently by taking the ratio of image acquired with low flip angle and the calculated transmission field. To acquire images for calculations of transmitted field and reception sensitivity maps in vivo, the contrasts factor, C(x), among gray matter (GM), white matter (WM) and CSF must be minimized by selection of TE and TR.

METHOD Phantom and human brain images were obtained on a Siemens 3.0 T Trio system with TR/TE =6000/15 ms, FOV 200 x 200 mm^2, matrix 256 x 256, slice thickness of 5 mm. The transmitted field and reception sensitivity maps of phantom were calculated using two SE images acquired with FA = $60^o/120^o$, and $120^o/240^o$, respectively. The maps with GE method were calculated with two GE images acquired with the FA = 30^o and 60^o, respectively. The human brain images for calculation of transmitted field and reception sensitivity maps were acquired by the SE method with TR/TE=1720/50ms to minimize contrasts among CSF, GM and WM. A T1-weighted image was acquired by MPRAGE with TR/TI/TE=2000/700/15 ms, FA = 12^o and identical geometric parameters.

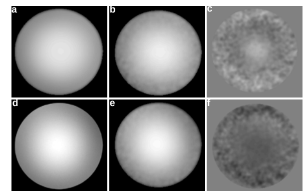

Fig.1. The transmitted field and reception sensitivity maps by the SE (a,d) and GE (b, e) sequences, and the difference between these two methods (c,f).

RESULTS AND DISCUSSION Fig.1 shows the transmitted field, reception sensitivity maps measured with SE and GE methods, and the differences of the maps with the two methods. The ratios between the standard deviation and mean of the signal intensity in the transmitted field and reception sensitivity maps are 18.6% and 19.7% for SE method, 20.6% and 21.0% for GE method, representing a significant inhomogeneity in transmitted and reception RF fields. The standard deviations of the difference maps (Fig.1c and 1f) with the two methods are 0.018 and 0.02, respectively. This suggests that the difference of the measured transmission field and reception sensitivity maps by the SE and GE sequences is insignificant. The two images acquired by SE and GE sequences before and after correction are shown in Fig.2. The image intensity nonuniformity is entirely removed with the SE method. A quantification of the improvement with different FA for the GE sequence (10^o, 45^o 75^o and 90^o) and SE sequence (50^o, 80^o, 90^o and 110^o) is shown in Table 1, which indicates that the SE method improves the SI nonuniformity to a greater extent than the GE method. α reduces from around 30% for original images to around 6% for the images corrected by SE method, and to around 9% for the images corrected by GE method. The SE approach is used to correct the non-uniform signal intensity in the human brain *in vivo* images. The in vivo transmission field and reception sensitivity maps shown in Fig. 3**a**-**b** were determined with SE images with minimized contrast (TR/TE=1720 /50ms). Comparing the original and corrected images in Fig. 3**c** and 3**d**, it is evident that a significant improvement in image uniformity without compromising tissue contrast can be achieved with our method.

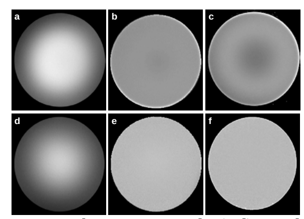

Fig.2. The uncorrected (a,d), and corrected image by SE method (b,e) and GE method (c,f) of images acquired by SE (a) and GE (d) sequence.

CONCLUSION A method for correcting transmission and reception field induced SI nonuniformity at high field is proposed and demonstrated with phantom and human brain. The transmitted field and reception sensitivity for a volume coil can be measured with GE or SE methods. Results indicate that the SE method performs better than the GE method in all cases. This method is independent of the coil configurations and image acquisition procedures, and thus can be extended to simultaneous trans-receive coil or separate transmit and receive coil systems.

Table.1 The comparison of effectiveness of SI correction for spin echo with gradient echo

	Mean	SD (Original)	SD (SE method)	SD (GE method)
SE-50	671	385	28	143
SE-80	1078	383	46	81
SE-90	1253	387	57	89
SE-110	1178	217	78	210
GE-10	246	81	13	13
GE-45	1010	314	63	45
GE-75	1419	375	117	135
GE-90	1504	350	153	207

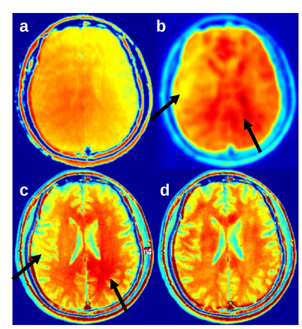

Fig.3 The transmitted field (a) and received sensitivity (b) maps for the brain, and an uncorrected (c) and corrected (d) brain image.

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