An In vivo Method for Correcting Transmit/Receive Non-uniformities with Phased Array Coils

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ABSTRACT

A simple method is proposed for correcting the inhomogeneous signal intensity (SI) from non-tissue characteristics based on the *in vivo* transmitted field map of the body coil, and the reception sensitivity map of phased array coils obtained by segmented-EPI sequence in under 2 minutes. A uniform phantom and in vivo brain images are employed to evaluate the proposed method and compared with body coil method as well as the low pass filtering method. This new approach displays advantages over previous methods and is not limited to brain applications but can be applied anywhere in the body.

INTRODUCTION

Phased array coils and parallel imaging techniques are becoming more widely used in MRI because they can increase SNR and FOV, and reduce imaging time. However, the presence of intensity nonuniformities in phased array coils restricts their application, particularly at high field. The correction of such signal nonuniformities is important not only for extending phased array coils' application, but also for improving the diagnostic quality of MRI and quantitative MRI.

THEORY

Field map method: This method is based on in *vivo* measurement of the transmission field and reception sensitivity maps and combined with the Bloch equations [1,2], can be used to correct the measured signal intensity. The signal intensity is given by $SI_{corrected}(x) = SI_{measured}(x) / (S_{phased}(x) \cdot T(x))$

(1) where S_{phased} is reception sensitivity of phased array coils. T(x) is excitation function of the image being corrected, which is determined by Bloch equation. $SI_{measured}$ and SI corrected are the measured and corrected signal intensity of the image being corrected, respectively.

Body coil method: The transmitted field and reception sensitivity of the body coil is assumed to be uniform. The reception sensitivity of phased array coils can be obtained using a reference image acquired with body coil reception.

Low-pass filter method: Based on the assumption that the signal nonuniformity changes slowly, the low-frequency nonuniformities can be filtered and the corrected image is given by: $SI_{corrected}(x) = SI_{measured}(x) / SI_{smooth}(x)$ (2)

where $SI_{smooth}(x) = SI_{raw}(x) \otimes G(x)$. $G(x)$ is a three-dimensional low-pass filter, and $\otimes$ is the convolution operator.

METHOD

Example images from phantom and human studies were obtained using a Siemens 3.0 T Trio system with a body coil for transmission and 8 channel phased array coils for reception. The transmission field maps of both the phantom and in vivo images were estimated using two images obtained with segmented spin echo-EPI (excitation flip angles of 60^o and120^o and refocusing flip angles of 120^o and 240^o, matrix 128^2). For the homogeneous phantom, the reception sensitivity map can be obtain from either image used to calculate the field map. For in vivo applications, a third image with minimal contrast must be acquired using with an excitation flip angle of 90^o and refocusing flip angle of 180^o with TE, TR set to minimize contrast (TR/TE=2000/16) in order to determine the reception sensitivity. Conventional GE and SE images of the phantom and the brain with high spatial resolution (matrix 256^2) were acquired to evaluate these three methods.

RESULTS AND DISCUSSION

To quantify intensity uniformity, we use $\alpha = SD/mean$, where the mean is the average signal intensity of image, and SD is standard deviation of the mean. Fig.1 shows the transmission field of the body coil and reception sensitivity of phase array coils. α of the transmission field, 14.7%, is comparable to that of reception field of 15.7%, suggesting that the contribution of the body coil to the nonuniformity can not be neglected. The two images acquired by the SE and GE sequence were corrected using different correction methods, shown in Fig.2**a-d** and 2**f-i**, respectively. Their histograms are shown in Fig. 2**e** and 2**j,** respectively. The results demonstrate that the field map method has significant advantages over the other methods. In Fig.3**a** and 3**e**, the original images display high signal intensity in the posterior brain regions primarily reflecting coil sensitivity. The primary limitation of the body coil method is poor SNR, due to the poor SNR in the reference images. The low pass filter method does an excellent job of improving signal uniformity, as shown in Figs. 3**c** and 3**g**, but can lead to reduced contrast between gray matter and white matter and some edge enhancement particularly at the edge of the brain. The proposed method improves the signal uniformity without these edge effects and reduced contrasts, as shown in Figs. 3**d** and 3**h**.

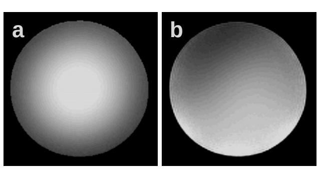


Figure 1. The calculated transmission field map of body coil (**a**) and reception sensitivity of phased array coils (**b**)

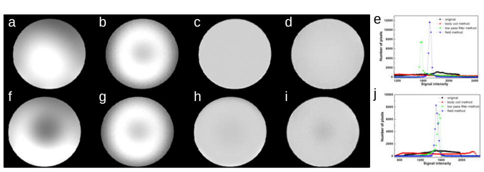
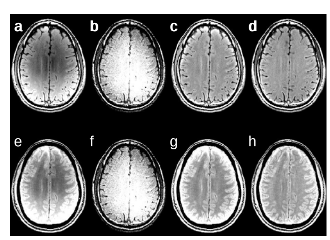


Figure 2. Original phantom image acquired using conventional gradient echo (**a**) and spin echo (**f**) sequences. Corrected images using body coil (**b**,**g**), low-pass filter (**c**, **h**), the field map (**d**,**i**) method, and their histograms (**e,j**) respectively.

Figure 3: Comparison showing original spin (**a**) and gradient (**e**) echo images corrected using the body coil method (**b**,**f**), the low pass filtering method (**c**,**g**), and the field map method (**d**,**h**) respectively.



CONCLUSIONS

At low field, the contribution of the transmission field of the body coil to signal nonuniformity can usually be ignored. At high field, it is similar in magnitude to the contribution of the reception sensitivity for phased array coils and both factors should be considered. The results of the phantom and human brain studies illustrate that the proposed transmit/receive correction approach works well. The additional time required for acquiring the correction matrix is short, and thus this approach can be adapted for routine application.

REFERENCE: 1. Wang J et al Magn Reson Med. In press.
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