In vivo Receive Sensitivity Measurement

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INTRODUCTION

Inhomogeneous receive sensitivity, which is object-dependent, strongly affects the uniformity of MRI signal intensity acquired with parallel imaging techniques at high field. Various methods have been proposed to estimate the receive sensitivity in order to reduce spatial variations in signal intensity caused by the receive sensitivity nonuniformities. A primary challenge is to separate the contribution of tissue contrast, inhomogeneous transmit field and receive sensitivity to signal intensity so that the *in vivo* receive sensitivity can be estimated alone. Here, we propose a novel rotating object method to estimate the receive sensitivity of a transmit/receive coil. The proposed method is validated using phantom experiments at 4.0 and 7.0 T. The receive sensitivity of receive-only or other complex coils can be estimated using this estimated receive sensitivity as a reference.

THEORY AND METHODS

Signal intensity for the free induced decay in magnetic resonance imaging is given by

$$\varepsilon = -i\omega_0 M_0 \cdot B_{receive}^{right} \cdot \sin\left(\int_0^{t_p} \gamma B_{transmit}^{left} dt\right) \qquad (1)$$

In Eq.(1), transmit field $B_{transmit}^{left} = B_{transmit} \cdot \exp(-i\omega_0 t)$ is a left-handed circularly polarized component of the transmit field and receive sensitivity $B_{receive}^{right} = B_{receive} \cdot \exp(i\omega_0 t)$ is a right-handed circularly polarized component of the receive RF field which rotates in the opposite direction to the precessing magnetization.

Minimal contrast method [1]: One method that has previously been proposed to measure the transmit and receive sensitivity assumes that non-uniform signal intensity only results from transmit field and receive sensitivity if the contrast is minimized. The results from the rotating object method will be compared with the minimal contrast method in this work.

Rotating object method: In Eq.(1), the measured transmit field is a left-handed circularly polarized component of a transmit/ receive coil. When the relative direction between equilibrium magnetization and main magnetic field is reversed by either rotating object or inverting main magnetic field, the measured pseudo-transmit field is a right-handed circularly polarized component of the coil before rotating object or inverting the field. Thus, this right-handed component is the receive sensitivity of the transmit/receive coil.

EXPERIMENTS

Images were obtained using a sphere and a disk shaped phantom filled with distilled water and $NiSO_4 . 6H_2O$ (4.8mM) with a surface coil at 4.0 and 7.0 T. Transmit fields and pseudo-transmit fields were estimated using the double flip angle method [3]. After the transmit fields are measured, the objects are rotated with 180^o to invert the relative direction between previous magnetization and main magnetic field allowing an estimate of the pseudo-transmit field. In vivo receive sensitivity of the surface coil can be estimated when the images for the pseudo-transit field is co-registered to the images for transmit field. The multi-slice images of the phantom are acquired using the conventional GE sequence with the flip angles of α, and 2α to estimate the transmit and pseudo-transmit fields. At 4.0 T, the imaging parameters: TR/TE 1000/10 ms, FOV 180 x 180 mm^2, matrix 128 x 128, slice number 1, slice thickness 4 mm, gap between slices 2 mm. At 7.0 T, the imaging parameters: TR/TE 1000/7.5 ms, FOV 180 x 180 mm^2, matrix 128 x 128, slice number 8, slice thickness 0.8 mm, gap between slices 6.2 mm for the spherical phantom**;** slice number 4, slice sickness 0.8 mm, and gap between slices 3.2 mm for the disk shaped phantom.

RESULTS AND DISCUSSIONS

Figure 1 shows the asymmetry of transmit field and receive sensitivity for a symmetric coil-object system. The asymmetry arises from eddy current contributions [4]. Additionally, the transmit field indicates that the right-hand-side is stronger than the left-hand-side in Fig. 1**a**, while the receive sensitivity demonstrates that left-hand-side is stronger than the right-hand-side in Fig. 1**b**. There exists a significant difference between transmit field and receive sensitivity at 4.0 T.

Figure 2 shows the transmit field (**a**) , receive sensitivity of a surface coil using a uniform phantom acquired with the minimal contrast (**b**) method and rotating phantom method (**c**) at 7.0 T. The asymmetry of both the transmit field and receive sensitivity becomes apparent, confirming that eddy currents strongly affect the distributions of the transit field and receive sensitivity with increasing static field strength. The receive sensitivity measured with the minimal contrast method (**b**) is similar to that measured with rotating object method (**c**), which provides indirect evidence to validate the rotating object method. The rotating method has advantages over the minimal contrast method in reducing scan time, and according to error propagation analysis, the rotating object method leads to smaller errors than minimal contrast method. Rotating objects, however, obviously has its limitation when considering *in vivo* work.

Figure 3 demonstrates the transit field (**a**) and the receive sensitivity (**b**) for a non-uniform object. The transmit field is estimated using the double flip angle method, and the receive sensitivity is estimated using the rotating object method. In Fig. 3a, the right-hand-side of the transmit field is stronger than its left-hand-side, while the left-hand-side of receive sensitivity is stronger than its right-hand-side. It is a good agreement with the results from the uniform phantom

CONCLUSIONS

With increasing field strength, the transmit field of a surface coil becomes significantly different from its receive sensitivity. (2) The rotating object method can be used to estimate the *in vivo* receive sensitivity for a transmit/receive coil, and then the receive sensitivity of a receive-only or complex coil can be obtained using this estimated receive sensitivity as a reference. (3) The rotating object method is validated by the experiments at 4.0 and 7.0 T. (4) The rotating object method has an advantage over existing methods in terms of reduced scan time and improved accuracy.

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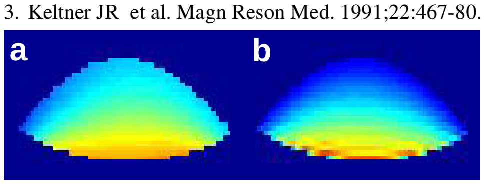

Fig 1. A transit field (**a**) and receive sensitivity (**b**) of a surface coil with a uniform phantom are estimated by the images acquired using a GE sequence and minimal contrast method at 4.0 T.

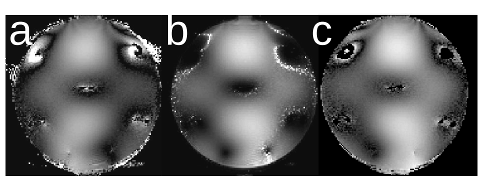

Fig 2. The transmit field (**a**) , receive sensitivity of a surface coil with a uniform phantoms acquired by minimal contrast method (**b**) and rotating phantom method (**c**) at 7.0 T

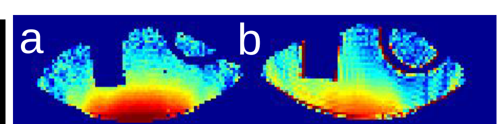

Fig 3. A transit field (**a**) and receive sensitivity (**b**) of a non-uniform phantom are estimated by the images acquired using a GE sequence and rotating object method at 7.0 T.