Asymmetric field distribution in B_1^+ and B_1^- maps are caused by phase differences in field components in the laboratory frame

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Introduction

Higher signal intensities in the central region of human brain images and lower in peripheral area are caused by RF interference effects at high B_0 field. Although these human brain images are almost symmetric, field distribution in the magnitude of transmission RF is asymmetric. Recently, Hoult has reported that transmission and reception RF fields are represented as B_1^+ and B_1^{-*}, respectively (1). These are complex vectors and * denotes complex conjugate. By using this definition, an asymmetric distribution pattern in $|B_1^+|$ is derived. In this work, we investigated the source of this asymmetry through simple changes of the formula on the relationship between the rotating and laboratory frames. We found that the origin of the asymmetry was phase difference of RF field components in the laboratory frame.

Method

Relationship of magnitude of RF fields between rotating and laboratory frames

RF fields in the rotating frame are expressed using the laboratory frame field components as $B_1^+ = (B_{1x} + iB_{1y})/2$ and $B_1^- = (B_{1x} - iB_{1y})^*/2$ (1). These components can be expressed using magnitude and phase as $B_{1x} = B_{1x}\exp(i\theta_x)$ and $B_{1y} = B_{1y}\exp(i\theta_y)$ where B_{1x}, B_{1y}, θ_x and θ_y are dependent on position and frequency. Magnitude of complex vector of B_1^+, $|B_1^+|$ is defined as $|B_1^+ B_1^{+*}|^{1/2}$ and then the following expressions are derived.

$$|B_1^+| = (B_{1xyMag}^2 + B_{1xyPhase})^{1/2} \qquad [1]$$
$$|B_1^{-*}| = (B_{1xyMag}^2 - B_{1xyPhase})^{1/2} \qquad [2]$$

where $B_{1xyMag} = 1/2*(B_{1x}^2 + B_{1y}^2)^{1/2}$ and $B_{1xyPhase} = 1/2*B_{1x}B_{1y}sin(\theta_x - \theta_y)$. B_{1xyMag} and $B_{1xyPhase}$ represent magnitude and phase of RF fields in the laboratory frame, respectively. These equations show that $|B_1^+|$ and $|B_1^{-*}|$ differ in the phase difference of x- and y-components in the laboratory frame. Since that phase difference is negligible at lower B_0 field, $|B_1^+|$ and $|B_1^{-*}|$ are all the same, equal to B_{1xyMag}. We thought that asymmetry of these maps might be caused by this phase difference at higher B_0 field. Then, we investigated distributions of B_{1xyMag} and $B_{1xyPhase}$ in the laboratory frame by the following formula changed from Eqs. [1] and [2].

$$B_{1xyMag} = [(|B_1^+|^2 + |B_1^{-*}|^2)/2]^{1/2} \qquad [3]$$
$$B_{1xyPhase} = (|B_1^+|^2 - |B_1^{-*}|^2)/2 \qquad [4]$$

Experiments

Volunteer studies were performed using a 4.7 T whole-body NMR spectrometer (*INOVA*, Agilent). A volume TEM coil with 300 mm diameter was used both for transmission and reception. Magnitude of transmit RF field $|B_1^+|$ maps of human brains were measured by a phase method (2) and that of receive field $|B_1^{-*}|$ maps were calculated from $|B_1^+|$ by the reported method (3). Maps of B_{1xyMag} and $B_{1xyPhase}$ were calculated by Eqs. [3] and [4].

Results & Discussion

Figure 1 shows a spin echo image (a), $|B_1^+|$ map (b) and $|B_1^{-*}|$ map (c) of a subject. Figure 2 shows B_{1xyMag} (a) and $B_{1xyPhase}$ (b) maps. Surface plots of RF field maps viewed from posterior position were also shown in both figures. Asymmetry along the lateral direction was shown on maps of $|B_1^+|$ and $|B_1^{-*}|$. The B_{1xyMag} map had an almost symmetric profile with higher amplitude in the center (Fig. 2a). This appearance was similar to the SE image (Fig. 1a). These symmetric profiles were consistent with the fact that RF coil is designed for homogeneity and human brain has almost symmetric structures along the lateral direction. In contrast, the $B_{1xyPhase}$ map showed an asymmetric distribution (Fig. 2b), which is likely to be derived from phase difference $\theta_x - \theta_y$ between x- and y-components. From these results, we concluded that asymmetry in magnitude of B_1^+ and B_1^- maps is caused by the phase differences of x- and y-components in the laboratory frame.

References

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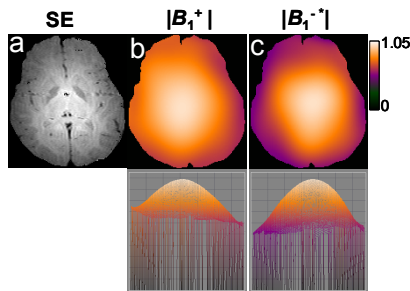
Fig. 1. A SE image of a subject (a) and $|B_1^+|$ (b) and $|B_1^{-*}|$ (c) maps. RF fields in rotating frame have a feature of asymmetry along the lateral direction.
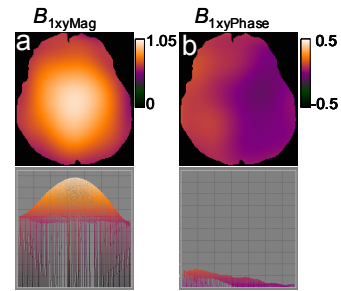

Fig. 2. Maps of RF fields in laboratory frame; a: a magnitude component and b: a component of $1/2*B_{1x}B_{1y}sin(\theta_x - \theta_y)$. The magnitude (a) and phase difference (b) components have symmetric and asymmetric profiles, respectively