Experiments and quantification of lumped elements volume coil for B1+ excitation at 7T

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Introduction

In an environment of ultrahigh field (UHF) MRI, B_1^+ inhomogeneity causes contrast difference and spatially varying image signal in region-of-interest (ROI). Recently, several designs of radiofrequency (RF) coils have been suggested to compensate this B_1^+ inhomogeneity. Using parallel transmission system [1-2] is also meaning for compensating B_1^+ inhomogeneity. However, most of available 7T system does not have parallel transmission systems. Therefore, the finding of optimal circularly polarized (CP) volume coils with lumped element components is meaningful for compensating B_1^+ homogeneity. In this study, we applied four different types of volume coil (hybrid birdcage (hybrid BC), dual Helmholtz (DH), hybrid spiral birdcage (hybrid SBC), and slotted tube (ST)) for image acquisition using double-angle method (DAM) [3].

Methods

All scans were performed on a 7T system (Siemens Medical Solutions, Erlangen, Germany). For RF excitation, a single RF amplifier was used (CPC, Brentwood, NY, USA), and the RF power was split by quadrature coupler. The output of coupler was divided into two signals, usually with equal magnitudes, 90° out of phase. All coils were placed on identical formers with a diameter of 300 mm and length of 150 mm respectively. The hybrid BC (Fig. 1a) consists of 16-rung with 10 mm in width. The hybrid SBC (Fig. 1b) was designed almost identical to hybrid BC, except the rotation of rung angle (45°). DH (Fig. 1c) coil, based on a one-turn helmholtz coil design, has 8-conducting wire element. DH coil arrangement consists of two orthogonal coils with general-rectangular (box-like) shape. ST (Fig. 1d) coil was modified from the Alderman and Grant probe design. The ST coil width of each horizontal band covers angle of 40°. In other words, window angle was chosen angle of 50°. The SNR of images was measured on transverse gradient recalled echo (GRE) of same volunteer and scan parameter (TR / TE / α = 750 ms / 17.8 ms / 30°, acquisition time = 3m 12s, slice thickness = 2 mm). For comparison of the B_1^+ inhomogeneity, DAM, which involves acquiring with two flip angles α and 2α GRE images (TR / TE / α = 10000 ms / 2.9 ms / 30°, acquisition time = 21 m 15 s, slice thickness = 2 mm) was used.

Results

All coils were matched to 50Ω and tuned to 297MHz (7T) being loaded with human brain. The degree of isolation in each coils between the quadrature ports was greater than -20dB and the reflection coefficient was also better than -30dB. The SNR of images was compared by examining profiles across the image center in left-right (L-R) direction (Fig. 2). The profiles of SNR using hybrid BC coil indicated homogeneous B_1 field than using other coils, despite of some variance across the center of the image with high SNR. The DH coil provided lower SNR (average -21%) compared to hybrid BC coil at periphery in L-R direction (Fig 2). The SNR of the hybrid SBC coil (average -48%) and ST coil (average -19%) compare hybrid BC coil was significantly decreased at the periphery. All SNR profiles were strongly peaked in the center compared to the periphery, because of the convex field attributed by dielectric phenomenon in the center of L-R direction. Quantitative B_1^+ maps were acquired in-vivo with the human brain (Fig. 3). All maps were Gaussian filtered with factor of three. Flip angle maps of the DH coil (Fig. 3c) and hybrid SBC coil (Fig. 3b) compare to hybrid BC coil (Fig. 3a) and ST coil (Fig.3d) were smaller, less than α = 30°. The flip angle map of hybrid BC coil indicated larger, compared to other coils in anterior-posterior direction. The flip angle map in B_1^+ field was profiled in superior-inferior (S-I) (Fig. 4a) and L-R direction (Fig. 4b) as shown in Fig. 3. The difference of effective flip angle (α=30°) of DH coil was obtained at ±15.4° and ±10.3° except edge part of image. The profile of DH coil was more homogeneous in B_1^+ field than profiles with other coils (in L-R / S-I direction, hybrid BC: ± 26.2°, hybrid SBC: ± 16.0°, and STC: ± 35.5°/ hybrid BC: ± 13.6°, hybrid SBC: ± 11.8°, and STC: ± 14.4°).

Conclusion

The hybrid BC coil at transmit and receive mode provides B_1 homogeneity with high SNR in UHF brain imaging, whereas DH coil provides more B_1^+ homogeneity compared to other coils. A comparison of experimental data, obtained with a 7T DH head coil in B_1^+ field can probably confirm this fact.

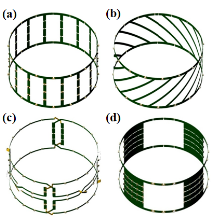

Fig. 1. The coil geometries. (a) hybrid BC, (b) hybrid SBC (c) DH, and (d)ST

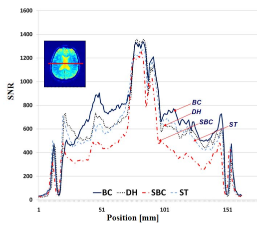

Fig. 2. SNR profiles in L-R direction of axial slice

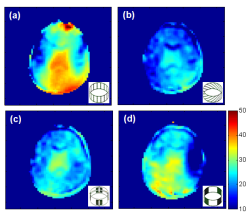

Fig. 3. Flip angle maps for α=30° of (a) hybrid BC, (b) hybrid SBC, (c) DH, and (d) ST in the human brain.

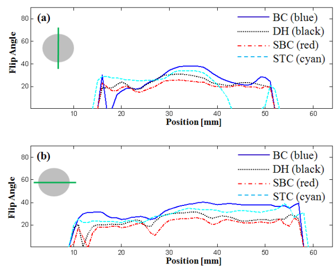

Fig. 4. Profiles of flip angle for α=30° in (a) S-I direction and (b) L-R direction.

Reference

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