Investigation of Receive-only Top-Hat Dipole RF Coil for Brain Imaging at 7 Tesla MRI

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INTRODUCTION

Brain imaging at 7 Tesla MRI, shows high resolution, higher signal-to-noise (SNR) and contrast-to-noise ratio (CNR), however there is problem of larger field-of-view (FOV). Prior solution is to make multichannel surface loop RF coil. However, increasing the number of channel increases the complexity in constructing and the decoupling problem. Recently, 8-channel top-hat dipole receive RF coil [1] had been proposed to extend the FOV and overall SNR compared to commercial multichannel RF coil. However, there was reduced SNR in brain region. The main objective of this paper is to increase the SNR in brain region with larger FOV covering up to cervical spine and better sensitivity. EM simulation for various multichannel receiver RF coils was performed and compared.

METHODS

In this work, multichannel receiver RF coil array were designed based on top-hat dipole antenna. In addition, a capacitive copper plate has been placed above the head, nearly 1~2 cm apart from the multichannel receive RF coil arrays. This copper plate act like a reflector which change the receiver (B1-) field pattern and increases the uniformity in the brain region of the human head. This theory is confirmed through Electromagnetic (EM) simulation and verified through MRI experiment. For RF transmission, quadrature birdcage coil is used (fig.1a) and excited with same amplitude and 90° phase difference between each port.

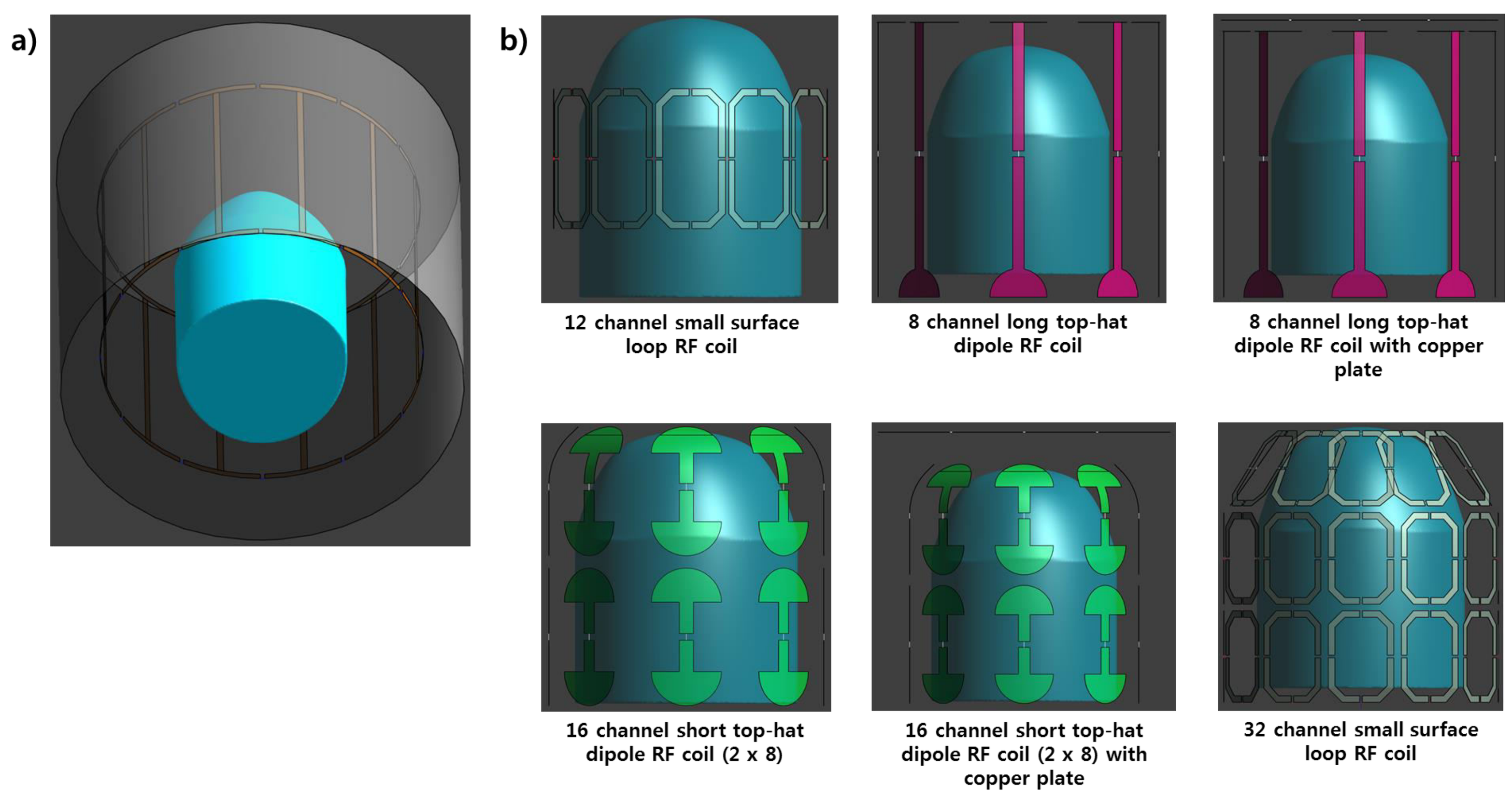

Figure 1. (a) Transmit highpass birdcage RF coil, (b) Configuration of various receive multichannel RF coils.

EM simulation analysis based on FDTD method was performed using Sim4Life [2]. Following receiver RF coils were simulated: (i) 12 channel small surface loop RF coil, (ii) 8 channel top-hat dipole RF coil, (iii) 8 channel top-hat dipole RF coil with copper plate, (iv) 16 channel top-hat dipole RF coil, (v) 16 channel top-hat dipole RF coil with copper plate, and (vi) 32 channel small surface loop RF coil. The 32 channel top-hat dipole RF coil could not be simulated due to unavailability of space for top-hat dipole antenna RF coil. Figure 1 shows the multichannel configuration of receive RF array.

The elements are equally distributed in radial direction (24.5 cm Dia) identical to inner diameter of the Achieva 7 T (Philips, The Netherlands) volume birdcage transmit RF coil. A uniform digital phantom of head shape (23 cm H × 18 cm × 16 cm W) with the dielectric property of average brain was used (relative permittivity of 59.82 and the conductivity of 0.972 S/m).

After the EM simulation were performed, the simulated gradient echo (GRE) image were simulated using following equation:

$$SI \propto sin(|B_1^+| * \gamma * \tau) * \sum conj(B_1^-)$$

where SI = simulated GRE image,
B_1^+ = transmit B1 field from birdcage RF coil (1.957 μT)
B_1^- = receive B1 field from receiver RF coil arrays
γ = gyromagnetic ratio (42.576 MHz/T)
τ = RF pulse duration (3ms, 90° flip angle).

The uniformity is calculated in a given region-of-interest (ROI) of around 7 cm diameter in the brain region as shown in fig. 2b.

In addition, g-factor maps were also simulated using MUSAIK toolbox, provided by SIM4Life EM simulation software. In parallel imaging technique [3], the SNR is reduced by the square root of acceleration factor as well as by g-factor. The ideal g-factor is 1, where no enhancement of noise occurs; g-factors below 1.5 are typically acceptable depending on application. The g-factor maps were calculated for the acceleration of 2, 3 4 and 5 in both frequency (x-direction) and phase (y-direction) encoding direction.

RESULTS

- All the dipole antennas were tuned and matched to 298 MHz using Sim4Life matching toolbox.
- Figure 2 shows the simulated GRE image of various receive RF coil array. It clearly shows less signal intensity in the upper part of the brain when capacitive copper plate is not implemented.
- Figure 2 clearly shows that the capacitive copper plate can improve the overall uniformity and sensitivity in the brain region. Also, top-hat dipole antenna RF coil show better uniformity than conventional 32 channel surface loop RF coil.

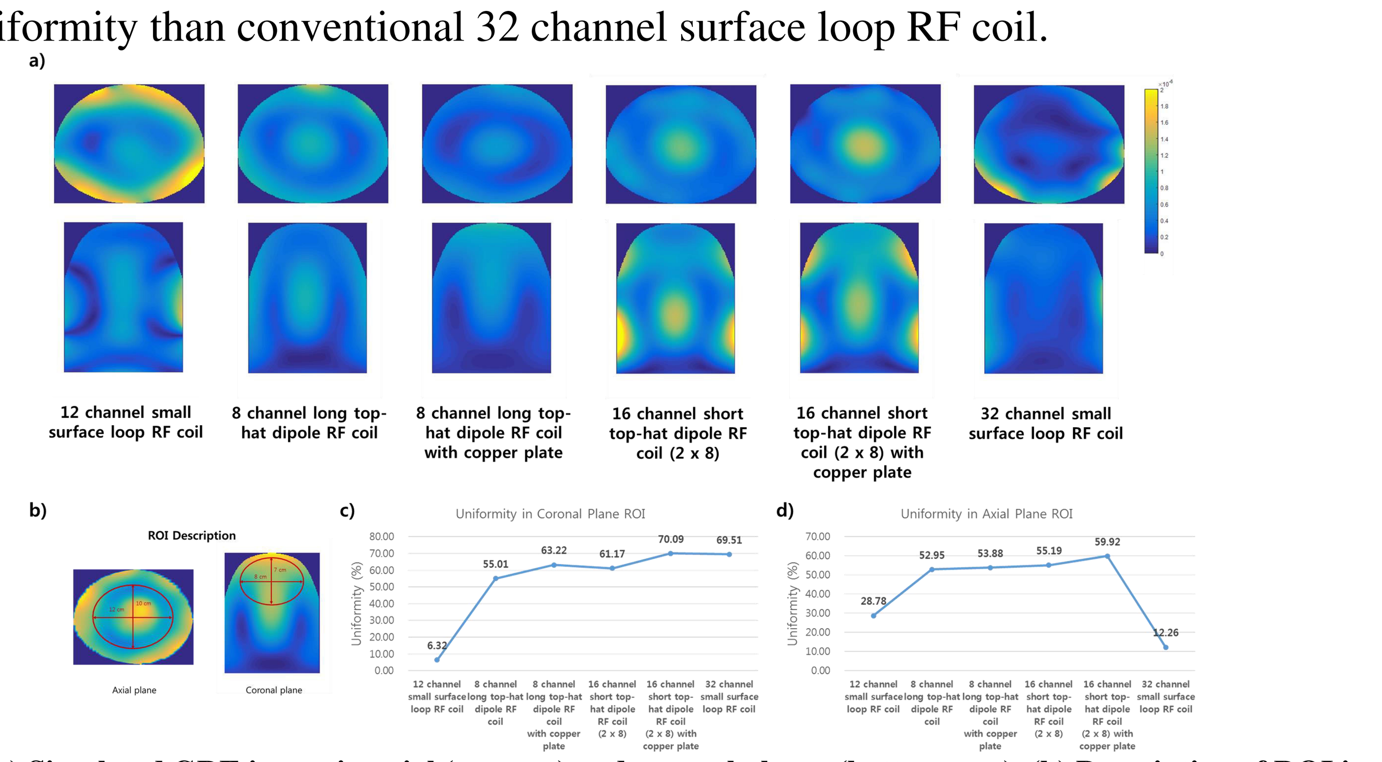

Figure 2. (a) Simulated GRE image in axial (top row) and coronal planes (bottom row), (b) Description of ROI in axial and coronal planes, and uniformity comparison graph in (c) coronal plane ROI and (d) axial plane ROI.

- Figure 3 shows the simulated g-factor maps for simulated RF coils in frequency (top row) and phase (bottom row) direction for the acceleration of 2, 3, 4 and 5, and graph representation of the average g-factor in frequency (g) and phase (h) encoding direction for above mentioned RF coil for the acceleration of 4X and 5X.

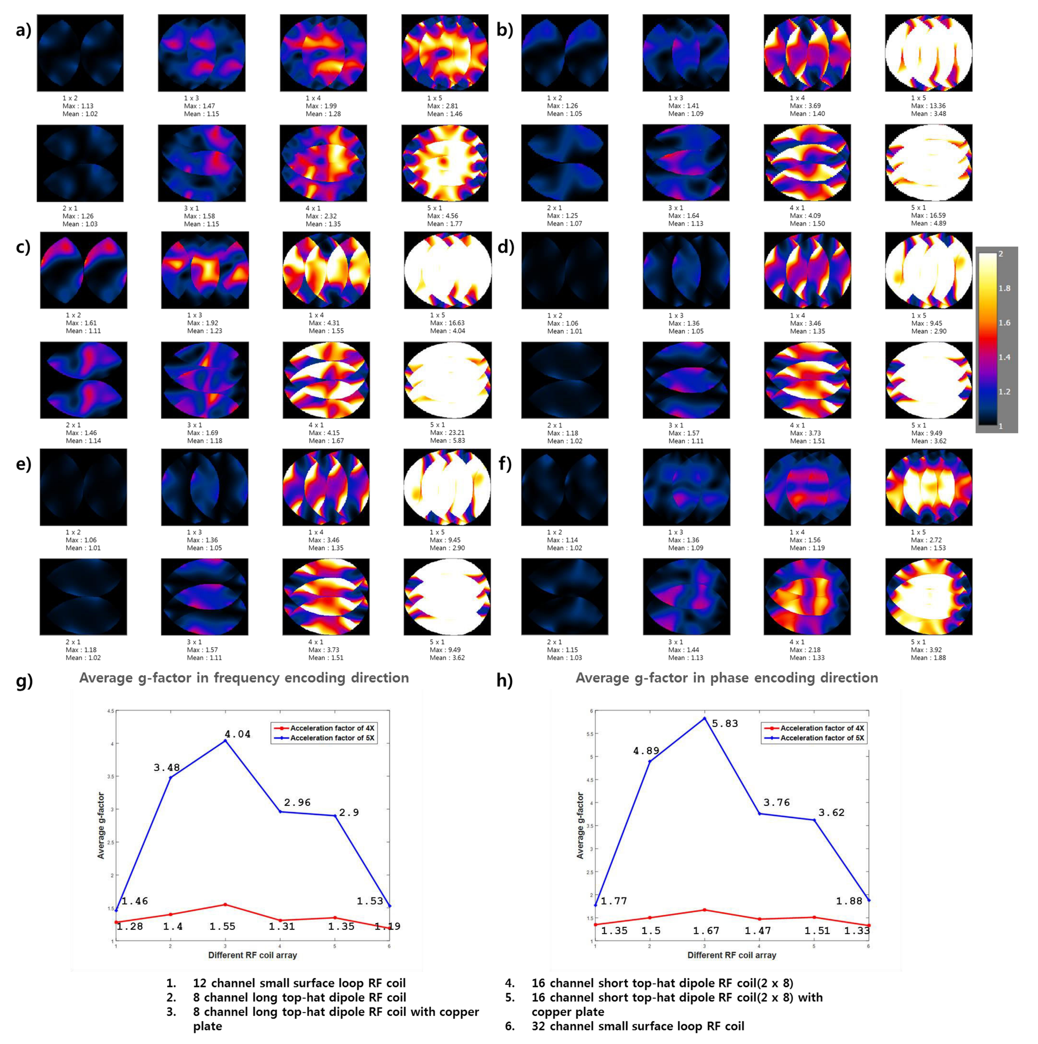

Figure 3. Simulated g-factor maps for various multichannel receiver RF coils in frequency (top row) and phase (bottom row) directions for the acceleration of 2, 3, 4 and 5, and graph representation of the average g-factor in frequency (g) and phase (h) encoding directions for mentioned RF coils.

DISCUSSIONS AND CONCLUSIONS

The B1 sensitivity improved overall by placing a capacitive plate above dipole antenna RF coil in the brain region. The top-hat dipole antenna array offers the highest B1 uniformity and sensitivity compared to the conventional dipole antenna array. The g-factor simulation shows that the top-hat dipole have acceptable value for 4X and 5X acceleration. For future work, the optimized 16 channel top-hat dipole antenna RF coil will be constructed and validated through the MRI experiment in both in-vivo and phantom studies.

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REFERENCES

1. C. H. Oh et al. ISMRM, pp. 6598, 2017.
2. Sim4Life by ZMT, <http://www.zurichmedtech.com>
3. G. C. Wiggins et al., MRM, vol. 62(3), pp. 86–94, 2009.