Enhanced RF Excitation Homogeneity by Combining TEM and Counter Rotating Current Surface Coil Array: Numerical Simulations and Experiments at 4.0 T

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Introduction:

In MRI, a volume coil is often used for excitation while an array of surface coils is used for reception. Although a number of advantages could be realized by using the volume coil and the array simultaneously in transmission and reception, this is rarely done due to challenges in achieving adequate decoupling between the volume coil and the array elements when all are active. Recently, use of counter rotating current (CRC) surface coils for improved decoupling from the volume coil in reception has demonstrated improved SNR, especially near the center of the head. Here we present simulations and experiment using the combination of a 4-element CRC array and a volume coil in transmission for improved excitation homogeneity. We also explore the excitation homogeneity that could be achieved by increasing the number of CRC elements to 8.

Methods:

To verify experiments at 4.0 T [1], we modeled a TEM volume coil and CRC coil array using XFDTD electromagnetic field calculation software (Remcom, Inc.) as shown in Figure 1(b). The geometry of the 16-element TEM volume coil was 390 mm shield diameter, 245 mm length, and 330 mm element inner diameter. The distance between the two loops of each CRC coil was 10 mm. The length and width of each CRC coil was about 100×90 mm^2. The cell and matrix size of the FDTD model were 5×5×5 mm^3 and 120×120×120, respectively. An initial power calibration was performed by exciting the TEM and CRC array separately in order to determine what input sources would be required to match the experimental power ratio between TEM and CRC array of 2:1. When this ratio was achieved, the $B1^+$ distribution of the combined TEM and CRC array was calculated. The similarity of flip angle (FA) maps between experiments and calculations was examined during combining process. To maximize the similarity, the phase of the CRC array was adjusted (0-360°) while the current amplitude of CRC array was fixed to keep the power ratio of 2:1. To explore possibilities for future designs, we added 4 more CRC coil elements in numerical simulations and simulated the resulting $B1^+$ fields. Each CRC coil was added between existing CRC coils to make an 8-channel CRC coil array as shown in Figure 1(c). The length and width of left/right CRC coils was 95×85 mm^2, and top/bottom CRC coils was 65×45 mm^2. In this case, the current amplitude and phase of each CRC element was adjusted to determine the maximum achievable $B1^+$ homogeneity.

Results and Conclusion:

The experimentally acquired flip angle map at 4.0 T is shown in Figure 1(e). The TEM and 4-channel CRC array combination enables more homogeneous RF excitation than the TEM alone as shown in Figure 1(f). There is very good agreement between experiment (e) and simulation (f). The maximum correlation (R=0.93) between experiment and numerical calculation was found at 195° (relative) phase adjustment of the CRC coil array while the power ratio between TEM and CRC coil array of 2:1 in experiment was maintained in the simulation. For the 8-channel CRC coil array, the maximum homogeneity was found at 146° (relative) phase adjustment of the CRC array and with a power ratio of 1:2.4 between TEM and CRC array. The flip angle homogeneity for the 8-element array (g) was much improved over that of the 4-channel CRC array (f). The standard deviation of the 8-channel CRC coil array combination was about 52 % lower than that of the 4-channel CRC array, or which means two times improvement.

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References: [1] Avdievich *et al*., NMR Biomed 2009;22:960-974

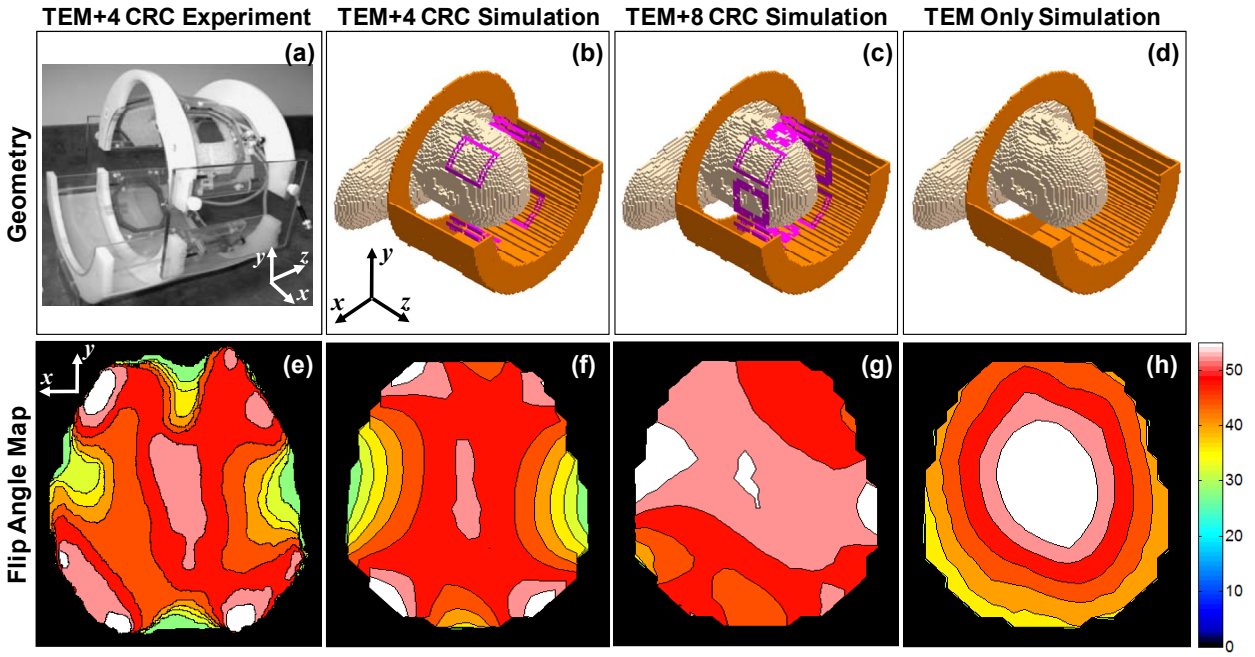

Figure 1. Top: (a) Experimental setup of TEM volume coil and 4-channel CRC coil array (TEM coil removed for better visibility) (b) numerical simulation model, (c) TEM and 8-channel CRC coil array combination, and (d) TEM only. TEM elements and half of shield were removed for improved visibility. Purple materials indicate the CRC elements. Bottom: Flip angle maps for (e) experiment and simulated (f) 4-channel CRC/TEM combination, (g) 8-channel CRC/TEM combination, and (h) TEM alone. The scale is in degrees.