Comparison of 3 RF Head Arrays for 7T MRI

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INTRODUCTION

Among the challenges of high frequency MRI is the RF field inhomogeneity within tissues due to the shortened wavelength and resulting interference patterns. Traditional 2D arrays, with coil elements distributed on same trans-axial planes, are limited in generating a uniform RF field across the whole head. This often results in lower SNR from the lower temporal lobe and the cerebellum. By including coil elements distributed in the "z" direction as well as in the x and y, resulting 3D transmit and transceive arrays offer some correction of the RF inhomogeneity within the lower brain regions [1,2]. To investigate new design options and tradeoffs for 7T head coils, two new 3D coil designs were compared through numerical simulation to our in-house standard reference, the 2D (x,y), TEM array.

METHODS and MATERIALS

Three different arrays (Fig. 1) were simulated. 1). Shielded 32-loop 3D array: 32cm (Diameter) x 19cm (length) RF shielding, 32 loop coils on a plastic former which consists of an elliptical cylinder (diameter: 22cm and 20cm, length: 8cm) at the bottom and a dome with a minimum diameter of 15.6cm at the top. The 32 loops are distributed on the former evenly with some exceptions: the loops above the two eyes are split in four smaller loops and the space above the nose is open. 2). TEM 2D array: all elements are 16cm long except the two shorter elements which are 7.5cm above noses. 3). TEM 3D array: the 16 elements in the bottom ring are 7.5cm long and the 14 upper ring elements are 8cm long. Both the TEM 2D and 3D arrays were built with micro-strip elements on 0.5"-thick elliptical (24cmx20cm) Teflon former with 0.5" wide copper foil traces.

The loop array was geometrically decoupled in simulation to -10dB or better, while the TEM 2D and 3D arrays were decoupled to <-25dB with variable capacitors (Fig. 2).

All simulations were done with Finite Difference Time Domain method (XFDTD, Remcom, USA). All coils in simulation were loaded with a medium size (50 percentile in USA) male head model based on National Library Visible Human Project, with a resolution of 2mm in trans-axial planes and 2.5cm along coil axial direction [3].

In comparisons, all values are normalized such that the total RF power deposition within head tissues was 1Watt for all three coils.

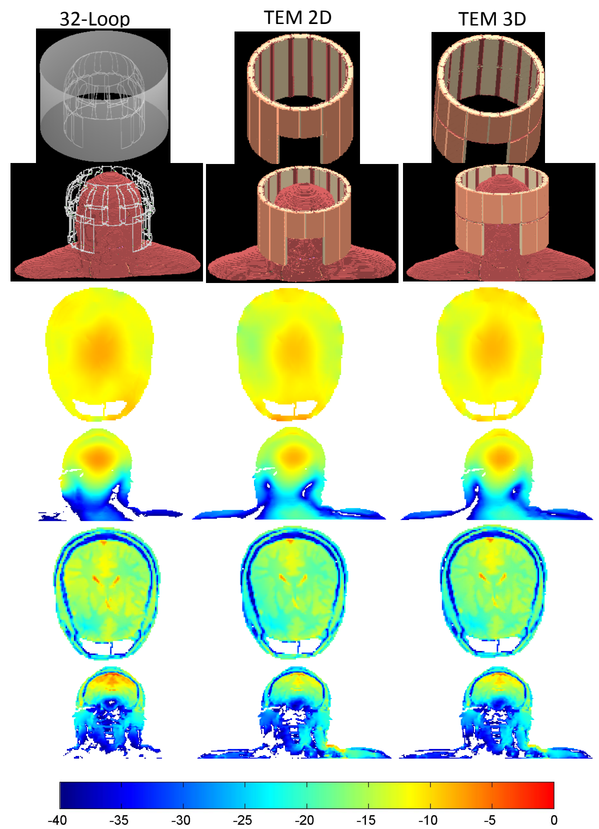

Figure 1. Coil structures and head loading positions are shown in the three coils, together with the $|\mathbf{B}_1^+|$ and SAR distributions on three slices. Shown are the trans-axial slice across center brain, and the central sagittal and coronal slices.

Results

All coils were simulated first with circularly polarization phases. $|\mathbf{B}_1^+|$ and SAR distributions on the central slices were presented in Fig. 1. Table 1 listed the $|\mathbf{B}_1^+|$ mean on the central brain slice and central sagittal and coronal slices in the body tissues, together with the averaged SAR on these three central slices, and the peak 1gram and 10gram SAR across the whole head.

Discussions and Conclusions

1). The 3D loop array has the highest $|\mathbf{B}_1^+|$ on central trans-axial plane. This is due to the existence of the current flowing along trans-axial direction on the top and bottom wires. It functions in a similar way as the current flowing on birdcage coil end-rings: to increase the $|\mathbf{B}_1^+|$ on the central trans-axial slices, at the cost of a reduced FOV in Z or coil length direction. 2). The loop array also has highest SARs in all three slices, together with the highest peak 1gram and 10gram SAR across the whole head. 3). The SAR at the middle of the two 3D arrays does not exhibit major difference compared with the SAR of the same location by the 2D array, when circular polarization was implemented. 4). Static $|\mathbf{B}_1^+|$ shimming will be performed to improve the RF homogeneity, and the 3D arrays are expected to demonstrate advantage over the 2D array.

References: 1. Adriany G, Proc ISMRM 2007,166. 2. Adriany G, Proc ISMRM 2010,3831. 3. Collins CM, MRM 40: 847-56.

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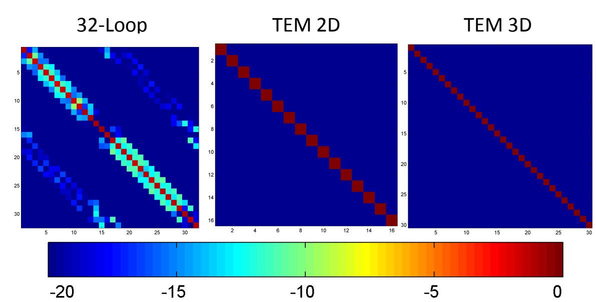

Figure 2. Decoupling Matrix

	Mean $|\mathbf{B}_1^+|$ on Trans-axial	Mean $|\mathbf{B}_1^+|$ on Sagittal	Mean $|\mathbf{B}_1^+|$ on Coronal	Mean SAR on Trans-axial	Mean SAR on Sagittal	Mean SAR on Coronal	Peak 1gram SAR	Peak 10gram SAR
Loop|	0.56	0.31	0.25	0.28	0.19	0.14	1.19	0.89
TEM 2D	0.50	0.32	0.24	0.24	0.16	0.13	0.79	0.56
TEM 3D	0.53	0.33	0.26	0.25	0.18	0.13	0.95	0.67

Table 1. Mean $|\mathbf{B}_1^+|$ (μT) and SAR (W/kg) on the three central slices, together with the global peak 1gram and 10gram peak SAR across the whole head