Dipole Arrays for MR Head Imaging: 7T vs. 10.5T

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TARGET AUDIENCE
Scientists and engineers, who have research interest in MRI at 300MHz and 450MHz

INTRODUCTION
Due to the better than linear proportion of signal-to-noise to field strength, high field MRI potentially has a lot of advantages over its low field counterpart. Meanwhile, shortened wavelengths at high field MRI bring new challenges, such as RF field non-uniformity, and lower transmission efficiency in terms of $|\mathbf{B}_1^+|/\sqrt{\text{Power}}$, which further raises concerns over RF safety. As the world's first whole-body 10.5T (450MHz) MRI[1] is getting ready to use, the RF difficulties we observed at 300MHz are expected to be exacerbated at 450MHz.
Dipole antenna are potential candidates for uniformly exciting MRI subjects in the far field zone, as proven feasible for body MRI at 300MHz[2]. In this abstract, we present a simulation study of a head dipole array to explore its performance from 300MHz to 450MHz and its feasibility in head MRI at 450MHz.

METHODS and MATERIALS
Each dipole in the array was driven at its center, ended with two floating copper ring sections (20mm wide x 86mm length), and tuned by the two inductors as illustrated in Fig. 1. The array consisted of 8 160mm-long elements, which were evenly distributed on a cylindrical surface (256mm diameter). For comparison a shielded dipole array was also studied at 300MHz and 450MHz. The cylindrical RF shield had a diameter of 312mm and a length of 195mm.
All simulations used the Finite Difference Time Domain method (XFdtd, Remcom, PA)[3]. In all simulations a medium male size HUGO head model[3] was loaded with its brain center located at the array iso-center. The electrical properties of its 17 tissues were adjusted to 300MHz and 450MHz respectively. A head gradient bore (400mm diameter x 750mm length) was included to simulate the wave propagation around head. No RF shimming was done and the array was driven with quadrature-mode phasing. All results listed in next Section were normalized such that a total of 1 watt RF power was dissipated within the body model.

Results and Discussions
The mean $|\mathbf{B}_1^+|$ and its standard deviation on the central transverse, sagittal, and coronal slices are listed in Table 1, where the standard deviation indicates the RF non-uniformity. The $|\mathbf{B}_1^+|$ distributions on these three central slices are present in Fig. 2. In Fig. 3 is the slice-averaged $|\mathbf{B}_1^+|$ along coil length direction. Comparing the 300MHz and 450MHz data, we observe following:
1). The peak 1g/10g power absorbed(SAR) by the tissues droped from 300MHz to 450MHz. To achieve the same mean $|\mathbf{B}_1^+|$ in the central transverse slice, the peak 1g/10g SAR increased by 10%. 2). If standard deviation is an effective indicator of the RF non-uniformity, it is interesting to note that the head dipole array offers even better RF uniformity at 450MHz, which is contrary to the common understanding that RF uniformity gets worse at higher frequency for traditional MRI RF coils. 3). With the presence of the head gradient bore, the RF shielding in general is not helpful in improving $|\mathbf{B}_1^+|$ uniformity, though it is helpful in reducing SAR at 300MHz. RF shielding may not be a necessary element in the dipole array design at 450MHz.
To guide the RF wave propagation from the dipole array to the subject, dielectric padding between the array and the head model will be added in next step simulation. An 8-ch head dipole array is being built now to test its performance at these two resonant frequencies.

Conclusion: Dipole arrays are a promising candidate for 10.5T Head MRI. They deserve further study.

References: 1. Vaughan T, ISMRM 2014: 4822. 2. Raaijmakdrs AJE, MRM 66 (2011): 1488-1497. 3. Collins CM, MRM 40: 847-56.

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Frequency (MHz)	RF Shielding	Max 1g/10g SAR (W/kg)*2	$|\mathbf{B}_1^+|$ Mean/Standard Deviation on Central Slices and within all tissues (μT)		
			Transverse Slice	Sagittal Slice	Coronal Slice
300	without	0.93*1/0.63*2	0.5554/0.0677	0.3193/0.2243	0.2477/0.2024
300	with	0.80*2/0.59*2	0.5689/0.0705	0.3173/0.2309	0.2482/0.2104
450	without	0.73*3/0.46*4	0.4680/0.0682	0.2814/0.1988	0.2384/0.1689
450	with	0.73*1/0.48*4	0.4642/0.0685	0.2447/0.1890	0.2202/0.1676

*1:muscle around left eye. *2: brain above nose. *3: CSF at bottom brain. *4: brain at the back.

Table 1. SAR and |B1+| Statistics

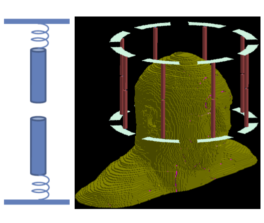

Figure 1. The dipole circuit (left) and head array (right)

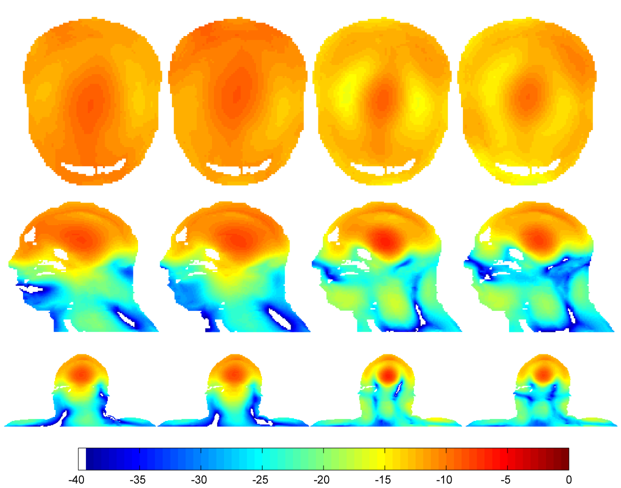

Figure 2. $|\mathbf{B}_1^+|$ distributions on central slices, 0dB=2μT.

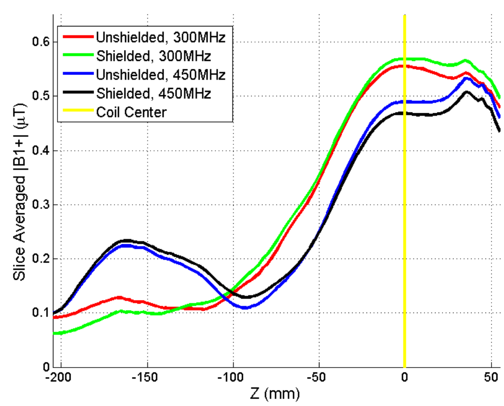

Figure 3. Slice Averaged $|\mathbf{B}_1^+|$ along Coil Length