Searching for the Optimal Body Coil Design for 3T MRI

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INTRODUCTION: For ultra-high field MRI the RF wavelength is short compared to dimensions of the anatomy. Consequential interference patterns result in nonuniform RF excitation fields and SAR contours. To investigate the means and methods of mitigating these high-field short wavelength problems, RF field uniformity and SAR contours were calculated and compared for ten different candidates for whole body coils to be used at 3T, including a conventional high pass bird cage for reference, coils with loop and transmission line elements distributed in two and three dimensions, inductively coupled and with multi-channel B1 shims [1-3].

METHODS and MATERIALS: Three types of RF volume coils were simulated and compared: 1). Inductively coupled coils, including 32-rung shielded high-pass birdcage (BC) and 16-rung TEM coils, 2). 2D arrays, including TEM 1x16, TEM 1x8 and Loop 1x16, and 3) 3D arrays, including TEM 2x8, TEM 2x16, TEM 3x8, TEM 3x16 and Loop 2x8. In arrays listed above, MxN explains the array element distribution: M rings along Z or coil length direction, and each ring has N elements evenly distributed on trans-axial planes. The coils have following dimensions: BC coil length=500mm, TEM coil length=450mm; For all coils: diameter = 704mm, RF shielding length = 1200mm, and RF shielding diameter=744mm. Both the TEM micro-strip traces and the loop flat wires were 20mm in width. The coils were loaded with a 34-year adult male, Duke (180cm, 72kg), from Virtual Family[3]. All simulation was done with XFDTD (Remcom, USA). In comparisons, 1Watt RF power was input in the BC. All other coils were normalized such that all coils have the same global SAR within a 50cm(D)x45cm(L) cylindrical FOV. Static shimming was implemented followed single-channel calculations for the arrays. $|\mathbf{B}_1^+|$ was averaged on the central slices (red lines in the 2nd row in Fig. 1) in 2D statistics and in the FOV in 3D statistics. $|\mathbf{B}_1^+|$ homogeneity was defined as the percentage of cells whose $|\mathbf{B}_1^+|$ is within 20% deviation from the $|\mathbf{B}_1^+|$ averaged within all cells in statistics. Both the magnitude average and homogeneity statistics are based on the $|\mathbf{B}_1^+|$ values within the FOV in the tissues excluding arms.

Results: $|\mathbf{B}_1^+|$ distributions on the central body image slices are presented in Fig. 1. Table 1 lists the $|\mathbf{B}_1^+|$ mean and homogeneity within the 3D FOV in body tissues, together with the total RF power required to reach same global SAR within the defined FOV, and the peak 10gram SAR within the whole body.

Discussions and Conclusions: 1). Compared to the birdcage, all designs improved the RF field homogeneity, with 3D arrays performing better than 2D arrays for same type of array elements. 2). Coils with a higher element count required more RF power input to reach same global SAR within the defined FOV, due to the reduced element sizes. 3). TEM arrays provided better $|\mathbf{B}_1^+|$ homogeneity, and less peak 10gram SAR than loop arrays.

References: 1. Adriany G, Proc ISMRM 2007,168. 2. Adriany G, Proc ISMRM 2010,3831. 3. Vaughan J.T., Chapt. 13, RF Coils for MRI, Wiley, 2012. 4. Christ A, Phys. Med. Biol 55: 1767-1783. **Acknowledgement:** R01 EB007327, R01 EB006835, P41 EB015894, S10 PR26783, Keck Foundation

Table 1. 3D Statistics for the Coils

	Birdcage	TEM CP	TEM 1x16	TEM 1x8	TEM 2x8	TEM 2x16	TEM 3x8	TEM 3x16	Loop 1x16	Loop 2x8
Mean $|\mathbf{B}_1^+|$	0.1297	0.1251	0.1334	0.1354	0.1373	0.1374	0.1324	0.1359	0.1348	0.1338
$|\mathbf{B}_1^+|$ Homogeneity	45.59%	53.02%	79.66%	81.12%	85.81%	85.34%	83.74%	94.88%	64.70%	78.28%
Input Power Pt	1.00	1.00	1.11	1.39	2.61	1.75	13.28	18.88	3.69	14.83
Peak 10g SAR	0.0920	0.1477	0.0681	0.0658	0.0706	0.0764	0.0767	0.2000	0.0657	0.1446

Fig. 1. Body coil structures, $|\mathbf{B}_1^+|$ field distribution and its mean values (μT) on three central slices