Potential Advantage of High Modes of Birdcage for Parallel Imaging

C. Wang[1], P. Qu[1], B. Wu[1], G. X. Shen[1]

[1]Electrical and Electronic Engineering, The University of Hong Kong, Hong Kong, China, People's Republic of

Introduction:

Generally, there are n resonant modes and (1+n/2) resonance frequencies for an n-rung birdcage coil. If it is totally degenerated, all the modes can be resonant at the same frequency. Due to spatially different sensitivity profiles of each mode, these modes have potential for parallel imaging. Standard homogeneous mode (mode 1) and first gradient mode (mode 2) of an eight-rung low pass birdcage coil have been applied for parallel imaging at 1.5T successfully [1]. In this study the potential advantage of using high modes of a 12-rung low pass birdcage coil for parallel imaging is investigated for 7T. Since more modes are employed, the improved ability for SENSE acceleration is expected.

Methods:

Finite difference time domain (FDTD) method [2] is used to calculate sensitivity profile of each resonant mode through time-dependent Maxwell's equations at resonant frequency of 300MHz. A region of interest (ROI), 26×26×28 cm^3 is divided into a mesh of 2,366,000 Yee cells, where the basic element of 3D meshes in FDTD method is 2 mm/cell in each dimension. A 12-rung birdcage coil (20-cm i.d. and 21-cm length) is modeled in the ROI. The conductivity of copper (5.95×10^7 S/m) is assigned to the coil cells. Voltage sources are placed at each rung to model capacitors. The phantom is modeled by a sphere with 18cm diameter (relative permittivity = 51.898, conductivity = 0.553 s/m) which represents average brain tissue at 300MHz. Geometry factor (g-factor) describes the ability with the used coil configuration to separate pixels superimposed by aliasing, and it is regarded as one of most important factors for parallel MRI. G-factor can be calculated through Eq.(1) [3]:

$$g_\rho = \sqrt{\left(\left(S^H \psi^{-1} S\right)^{-1}\right)_{\rho,\rho} \left(S^H \psi^{-1} S\right)_{\rho,\rho}} \qquad (1)$$

where S is reformatted coil sensitivity matrix, Ψ is the noise correlation matrix and ρ is the index of the voxel within the set of voxels to be separated.

Results and Discussion:

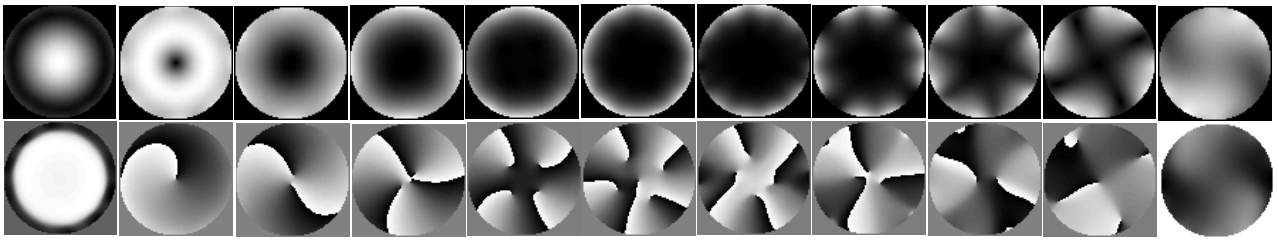

Fig.1 magnitude and phase of $\mathbf{B_1}^+$ field for 12 modes of 12-rung birdcage coil

The amplitude and phase of 11 modes $\mathbf{B_1}^+$ field of 12-rung birdcage is illustrated in Fig. 1. The resonant frequency of the mode 0 is always 0Hz for low pass birdcage; it can't be used for imaging. So, only modes 1 to 11 are used for calculating G-factor here. The geometry maps (g-map) at different acceleration rates are shown in Fig.2, and the detail information about g-map is listed in Table.1. Because of symmetry of the birdcage coil, the SENSE direction can be any directions on axial plan. Here we set SENSE direction as left to right.

The average g factors are still less than 2 even the acceleration factor up to 5 when all modes 1 to 11 are used. If R>5, the g factor increases dramatically. In order to find out appropriate modes combination for a certain number of channels, we select different combination of 6 modes out 11modes to calculate g-maps. The results show the best choice for the lowest average g factor is modes (1, 2, 3, 5, 9, 10). With these modes applying, average g-factor of 1.5810 and 2.4067 can be reached for acceleration factor of 4 and 5 respectively. The similar cases for other number of channels are also investigated.

acceleration factor (R)	2	3	4	5	6
average g	1.0193	1.1020	1.3991	1.9919	5.0995
maximum g	1.0539	1.2425	1.8796	3.6093	10.2909

Table 1 Average and maximum g-factor for different acceleration rates

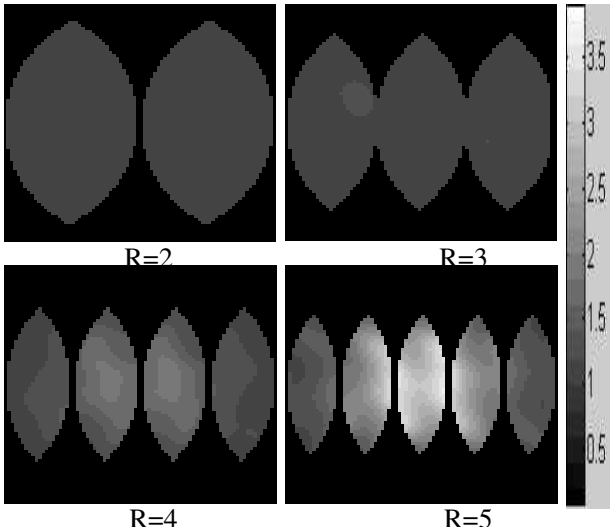

Fig.2 Geometry factor map of different acceleration factors (R=2, 3, 4, 5)

Conclusion:

The average g-factor can be less than 2 and maximum g-factor is 3.61 even if acceleration factor is as high as 5 when 11 modes of 12-rung birdcage coil are incorporated. For certain number of channels, the optimized combination of corresponding modes can be obtained (for 6 channels, the optimized modes combination is mode 1, 2, 3, 5, 9, 10).

Acknowledgement:

This work was supported by RGC Grant 7045/01E, 7170/03E and 7168/04E

References:

[1] F.H. Lin, et al. *Magn Reson Med,* 50: 1107-1111, 2003

[2] KS Yee, *IEEE Trans. on Ant. and Propag.* 14:302-307, 1966

[3] K.P. Pruessmann, et al. *Magn Reson Med,* 42: 952-962, 1999