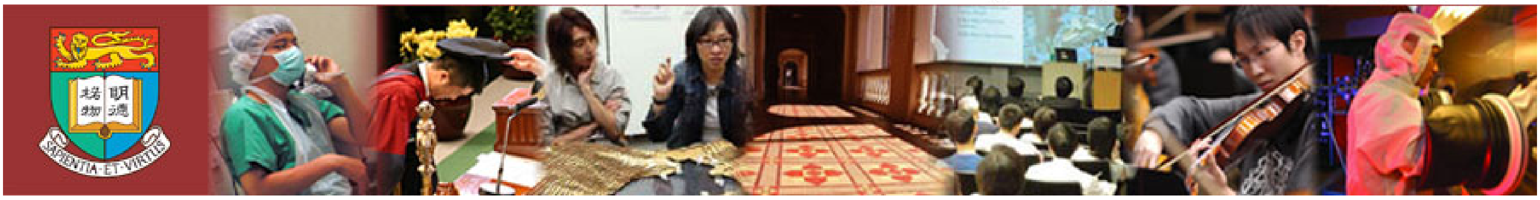
View metadata, citation and similar papers at core.ac.uk

brought to you by CORE

provided by HKU Scholars Hub

The HKU Scholars Hub The University of Hong Kong 香港大學學術庫



Title	Optimization of a multi-channel transmit, Quadrature Receive Birdcage Coil
Author(s)	Wang, C; Shen, GG
Citation	The International Society for Magnetic Resonance in Medicine 14th Scientific Meeting & Exhibition (ISMRM2006). Seattle, WA, 6-12 May 2006, p. 3539
Issued Date	2006
URL	http://hdl.handle.net/10722/99316
Rights	This work is licensed under a Creative Commons Attribution-NonCommercial-NoDerivatives 4.0 International License.

Optimization of a multi-channel transmit, Quadrature Receive Birdcage Coil

C. Wang[1], G. X. Shen[1]

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

Introduction:

Although ultra high field (7T to 9.4T) MRI has signal-to-noise ratio (SNR) advantages, the associated RF inhomogeneity is a challenge for some applications. This is mainly caused by RF wavelength effects [1]. Some methods for reducing transmit $\mathbf{B_1}^+$ field inhomogeneity [2-3] of multi-channel coils are proposed by varying amplitude and phase of individual driving ports. Normally, it is difficult to use the same method for receive of birdcage-like volume coils. In this work, we optimize by varying amplitude and phase of multiple driving voltages during transmission, and quadrature reception is used for a multi-port birdcage-like volume coil. For comparison, a conventional transceiver quadrature birdcage coil is also investigated. The optimization procedure is based on a set of $\mathbf{B_1}^+$ field of all modes of 12-rung birdcage loaded with a sphere phantom. They are used to estimate the modes distribution of the desired $\mathbf{B_1}^+$ (homogeneous) field, and then the port voltage distribution of each port, with singular value decomposition (SVD) method.

Methods:

Normally, there are n resonant modes and (1+n/2) resonant frequencies for an n-rung birdcage coil. But we can generate all resonance modes at the same resonance frequency by controlling the amplitude and phases of driving voltage of each port for a multi-channel birdcage-like coil, regardless of the degree of degeneracy. The finite-difference time-domain (FDTD) method is used to calculate the transient $\mathbf{B_1}$ fields 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 and driving ports. The phantom is a sphere with 16cm diameter (εr= 51.898, σ = 0.553 s/m) which represents average brain tissue at 300MHz. Transmit $\mathbf{B_1}^+$ fields and receive $\mathbf{B_1}^-$ fields of each mode are calculated from two sets of transient $\mathbf{B_1}$ fields which are a quarter period apart in time [4]. The target $\mathbf{B_1}^+$ is assumed as a homogeneous 1.17μT (for 5ms duration 90^0 pulse). By using SVD method, the coefficients of the mode distributions and the port voltage distribution for generating desired $\mathbf{B_1}^+$ field can be obtained [3]. For comparison, SNR of conventional transceiver birdcage and optimized multi-port birdcage are calculated by Eq.(1) [5], where τ is pulse duration, γ is gyromagnetic ratio, ρ is material density. The $\mathbf{B_1}^-$ fields for both cases (calculated based on mode1) are the same.

$$SNR \propto \frac{\sum_{N} \left|\sin(\gamma\tau\left|\vec{B}^{+}_{1n}\right|)\left|\vec{B}^{-}_{1n}\right|\right|}{\sqrt{\sum_{N} SAR_n \times \rho_n \times \Delta V}} \qquad (1)$$

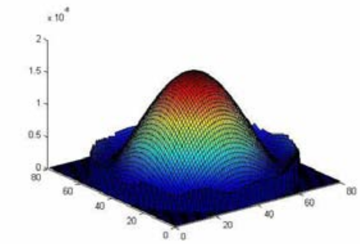


Fig.2 Non-optimized $\mathbf{B_1}^+$ field profile of conventional Birdcage (mode 1)

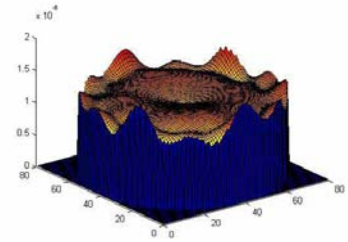


Fig.3 Optimized $\mathbf{B_1}^+$ field profile of multi-port driving Birdcage

Results:

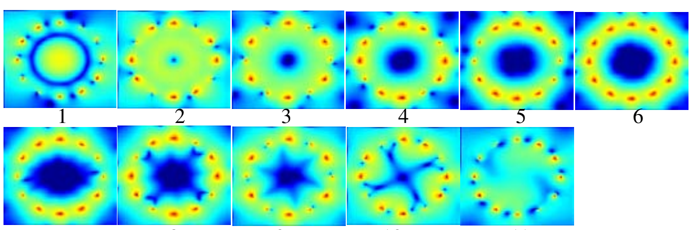


Fig.1, Amplitude patterns of 11 modes $\mathbf{B_1}^+$ field (phase patterns are not shown here)

The $\mathbf{B_1}^+$ field of the 11 modes for the 12-rung birdcage coil are shown in Fig.1 (the rung current is 0 for mode 0 of birdcage). The $\mathbf{B_1}^+$ field of mode 1, which is the operational mode for conventional birdcage, is extracted and shown in details in Fig.2. The 'peak' at center indicates wavelength effects. The $\mathbf{B_1}^+$ field of the multi-channel birdcage optimized by SVD method is illustrated in Fig. 3. The percentages of the samples on axial plane having a $\mathbf{B_1}^+$ field magnitude within ±10% of the average $\mathbf{B_1}^+$ field magnitude on that plane are 23.47% and 80.06% for conventional quadrature birdcage and optimized multi-channel birdcage-like coil, respectively. The homogeneity of $\mathbf{B_1}^+$ field improves dramatically by optimization. Compared with the SAR of conventional birdcage (2.72W/kg), the SAR of the optimized multi-channel birdcage increased slightly to 3.04 W/kg. After normalization, the relative *SNR* on central axial plane for conventional birdcage and optimized multi-channel birdcage are 1 and 1.73 respectively. The simulated image intensity of phantom is shown in Fig.4. Although the phantom in this work is homogeneous, this method also can fully handle heterogeneous samples.

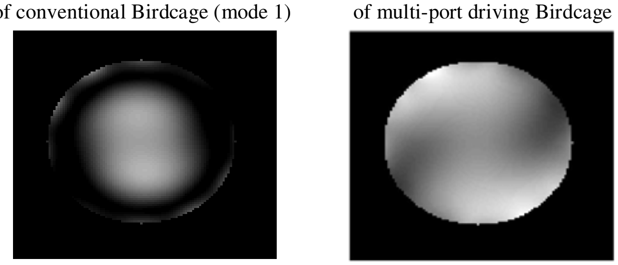


Fig.4, Axial signal intensity distributions for sphere phantom in conventional quadrature birdcage (left) and multi-port birdcage-like coils with optimized driving voltage distribution (right) at 300MHz

	$\mathbf{B_1}^+$ homogeneity within 10% variety*	Average SAR (W/kg)	Normalized SNR
Quadrature Birdcage	23.47%	2.72	1
Optimized multi-port coil	80.06%	3.04	1.73

Table11. $\mathbf{B_1}^+$, SAR and SNR comparison for conventional birdcage and optimized multi-channel birdcage. *The percentages of samples on axial plane having $\mathbf{B_1}^+$ field magnitude within ±10% of the average $\mathbf{B_1}^+$ field magnitude on that plane

Conclusions:

Compared with conventional transceiver quadrature birdcage, optimized multi-channel-transmit, quadrature-receive birdcage coil has dramatically improved $\mathbf{B_1}^+$ filed homogeneity and relative SNR, with slight penalty of increased average SAR.

References:

[1] J. Tropp, *J. of Magn. Reson.* 167: 12-24, 2004
[2] CM Collins, et al. *12th ISMRM,* p1566, 2004
[3]RF Lee, *13th ISMRM,* p823, 2005
[4]DI Hoult, *Concepts in Magn Reso.* 12(4): 173-187, 2000
[5]CM Collins, et al. *Magn.Reson. Med.*40:847-856,1998