Unshielded Dual Tuned Birdcage for High Field MRI/MRS

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Introduction

An unshielded double-tuned hybrid birdcage resonator that can produce both high sensitivity and homogeneity at high field strengths is presented. Recent unpublished data suggests that the single tuned hybrid birdcage is more sensitive and uniform without a shield at 4 T. Patient visibility is important for patient comfort to decrease the feeling of claustrophobia and is crucial to present a visual stimulus to the eye when performing functional MRI. Furthermore, the unshielded RF coil suffers less from eddy current induced artifacts in gradient intensive pulse sequences like EPI and DWI. For all of these reasons, it is important to assess coil performance in the absence of a shield at very high field strengths.

Methods

A new 16 element (8 high gamma elements, 8 low gamma elements) dual tuned birdcage design [1] has been implemented for operation at 3.95, 4, and 7 T. Through the use of a direct drive coupling scheme and the use of highpass and lowpass matching networks for the ^{1}H and ^{31}P feeds respectively, coupling between channels can be reduced and the image homogeneity is improved (as compared to an inductively driven coil [2]) at 4 T. Three unshielded dual tuned hybrid birdcages (length = 21 cm, i.d. = 26.7 cm, o.d. 27.9 cm) were tested on a 3.95 T Bruker, 4 T Varian , and 7 T Siemens whole body MRI systems to assess image homogeneity and sensitivity.

To demonstrate the quality of in vivo data, 3D whole-brain, multi-voxel ^{31}P MRS was collected using the Siemens "CSI_FID" on the Bruker system at 3.95 T. The axial slab is placed parallel to the AC-PC line and covers the whole-brain. The key parameters include: 14x14x8 phase encoding steps (nominal voxel size=2.0x2.0x2.0cm^3), zero-filled to 16x16x8, TR= 0.54sec, 24 weighted averages, elliptical k-space sampling and acquisition time 23 minutes. *The total setup and sequence acquisition time to collect the ^{31}P MRS data is approximately 27 minutes.* The 16x16x8 grid is shifted in all three directions relative to the MRI images to ensure optimal voxel placement. A mild spatial apodization (i.e., a 75% Hamming window) is applied. The estimated effective voxel size is 16cm^3. A 5Hz Gaussian line broadening is applied to the time-domain signal. In fitting the PE, PC, Pi, GPE, GPC, PCr, dinucleotides (DN) and ATP (two doublets and a triplet) resonances, the FIDs are modeled with 14 Gaussian damped sinusoids in the time domain.

Results

Negligible loss in sensitivity was measured for both nuclei in the unshielded dual tuned birdcage as compared to similar single tuned shielded coils at 4 T. The ^{31}P spectrum and accompanying representative transverse slice acquired at 3.95 T are shown in Fig. 1 A and B respectively. The ^{1}H image homogeneity and signal penetration at 4 and 7 T are shown in anatomical images in Fig. 2 and phantom images in Fig 3 respectively.

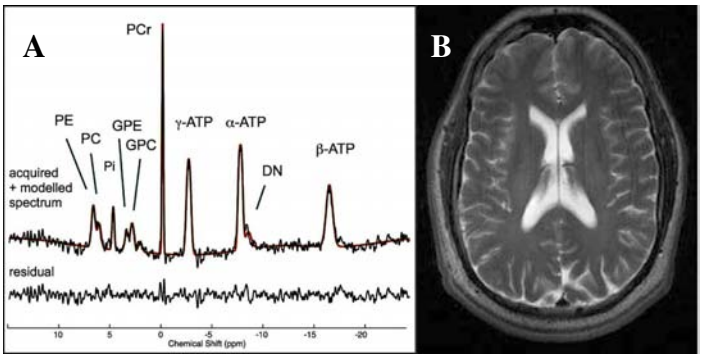

Fig 1: a) A sample ^{31}P spectrum of a single voxel extracted from a 3D CSI data set acquired at 3.95 T with b) corresponding ^{1}H T_2 weighted transverse anatomical image of a human volunteer

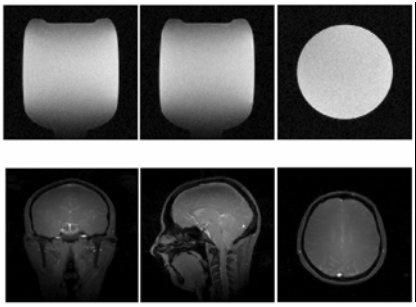

Fig 2: ^{1}H Proton density weighted FLASH images of a human subject and oil phantom are shown for three orthogonal planes acquired at 4 T

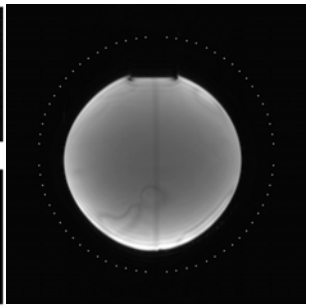

Fig 3: ^{1}H Proton density weighted images of a 17.8 cm spherical saline phantom at acquired at 7 T

Discussion

Homogeneity in the periphery was expected to decrease at the higher gamma nucleus due to the reduction of effective number of rungs relative to a single tuned coil (8 per nuclei vs 16) within the unshielded dual tuned birdcage. As seen in Fig 1 B and Fig 2, the homogeneity in the periphery is not compromised, even with a very close filling factor. Considering the measuring time is 23 minutes to collect this whole brain 3D CSI data set and the effective voxel size is 16 cm^3, the S/N of the ^{31}P metabolites is excellent, which provides greater precision and sensitivity in detecting differences in pathology. The results at 7T are very promising for coil performance and preliminary results suggest the unshielded dual tune birdcage suffers less from EPI eddy current artifacts (data not shown). Additionally, the confinement of the stray magnetic field to the imaging volume of interest is consistent with previous work [3] and can be seen in Fig 2. These results from both 4 and 7 T suggest that an unshielded dual tuned birdcage is not only possible, but provides additional advantages at the highest field strengths commonly used on human patients.

References

[1] US Patent # 7,119,541, 2006. [1] Barberi et al, Proc. of the ISMRM 2002 [2] Wald LL et al Proc. of the ISMRM 2005