Design and Implementation of a Quadrature RF Volume Coil for In Vivo Brain Imaging of a Monkey in a Stereotaxic Device

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INTRODUCTION: Accuracy of targeting is critical for the success of cell transplantation and many other procedures [1]. When such procedures are to be performed in the brain with minimally-invasive methods, it is necessary to have exact knowledge of the position and orientation of the head and brain during both the acquisition of 3D whole-head images and during performance of the procedure. This can be accomplished with use of a stereotaxic positioning device [1]. Use of such a device in the MRI environment, however, can prohibit the use of conventional coils due to both its size and the unusual posture of the subject. In our case, to facilitate use of a stereotaxic frame the coil must accommodate the head of Rhesus or Cynomologus Macaque monkeys in a sphinx position (facing in the direction of B_0), allowing for ear bars, eye posts, and bite bar to connect the frame to the monkey's head. The coil must also be capable of being positioned and removed without disturbing the monkey or any parts of the frame, and provide homogeneous coverage and adequate SNR throughout the monkey's brain. These requirements precluded use of any existing coils or conventional designs.

METHODS: We devised a design based on use of a 2-coil array where the first coil consisted of a 2-loop solenoid oriented to produce a vertical field and the second consisted of a saddle coil oriented as to produce a horizontal field through the monkey head (Figure 2). The finite difference time domain (FDTD) method was used to design the two coil system for optimal homogeneity in the region of interest. In xFDTD, (Remcom, Inc., State College, PA) the coil was modeled with a mesh resolution of 2x2x2 mm^3 at 125.44MHz, the larmor frequency of our 3T system. In simulation, both models were tuned to the proper frequency using a previously-published method [2], and a low-loss dielectric medium was assumed inside of the coil to approximate the boundary conditions of the monkey head. It was that found 8 evenly-spaced capacitors were necessary in the saddle coil and 4 evenly-spaced capacitors in the solenoid coil for homogenous B_1 field. During construction, some deviations from this basic geometry were necessary to accommodate the monkey's neck, ear bars, eye posts, and bite bar (Figure 3). The coils were connected in quadrature and could be installed over the monkey head without disturbing the monkey or the frame (Figure 4). Orthogonality of fields provided adequate decoupling between the coils. The coil was designed to fit over the monkey head, rather than around the frame and monkey, for optimal SNR.

RESULTS: Simulation results are given in Figure 5 and show a homogeneous B1 field throughout the region of interest. Images of a monkey head acquired with the coil are shown in Figure 6. Thin channels of vitamin E oil in the ear posts and eye posts (designed to ensure exact alignment of imaging planes to frame) are seen in the images. Excellent SNR throughout the entire brain is seen.

DISCUSSION: To allow for MRI of the brain of a monkey in a stereotactic frame with a number of design constraints, we devised a fairly simple and unique 2-coil array connected in quadrature that met all requirements. Deviation from the basic design to allow for our specific geometric considerations did not have a notable adverse affect on homogeneity or SNR. This coil will facilitate important research at our site, and its simple and unusual design may be used to overcome challenges in future research at other sites as well. It may be interesting to note, for example, that the original basic design could meet many of the requirements for MR of the breast.

REFERENCES
[1] T Subramanian *et al*., Experimental Neurology 2005;193:172-180
[2] G McKinnon and Z Wang, Proc. ISMRM, 2003 p. 2381

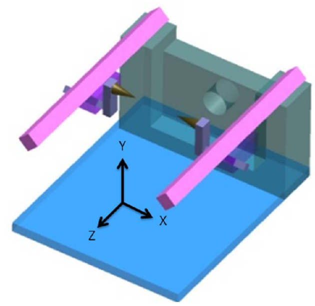

Figure 1: Computer model of stereotaxic frame showing ear bars. (Eye posts and bite bar not shown.)

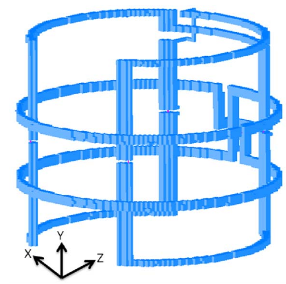

Figure 2: Basic premise for coil is a 2-coil array consisting of a 2-turn solenoid and a saddle coil connected in quadrature.

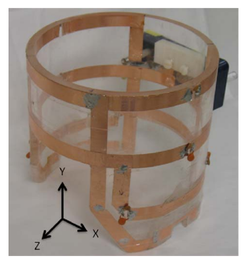

Figure 3: Actual coil with allowances for monkey's neck, ear posts, eye posts, and bite bar.

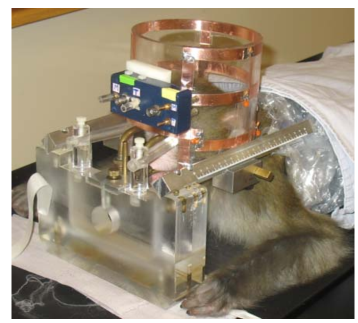

Figure 4: Monkey in stereotaxic frame and head coil.

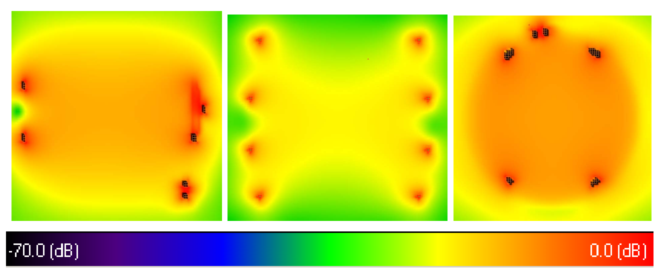

Figure 5: Simulated B_1 distributions on three orthogonal planes (left to right: sagittal, axial, and coronal) through coil.

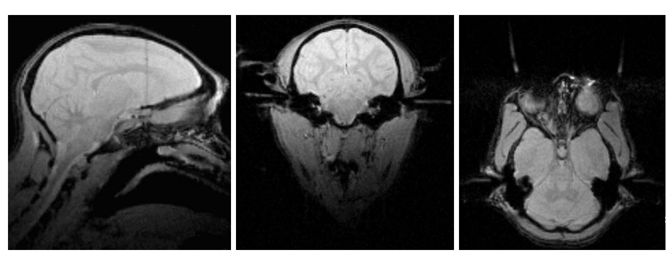

Figure 6: MR images on three orthogonal planes through monkey head. Vitamin E oil placed in ear posts and eye posts to ensure exact orientation of scans is seen on coronal (ear posts only) and axial (ear and eye posts) images.

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