A Quadraure RF Coil with Reduced Heating of DBS Implants

Hai Lu[1] and Shumin Wang[1]
[1]Auburn University, Auburn, AL, United States

Introduction: DBS implant heating inside MRI scanner is a major safety concern for scanning implant patients[1]. In order to prevent catastrophic ablations of surrounding tissues, current approaches include using head-only transceiver coils with much reduced SAR limits or redesigned lead wires with RF chocks. Such procedures prevent many clinical useful protocols that are based on the spin-echo sequence from being applied, and exclude patients with different types of implant leads from being scanned. The aim of this study is to develop a new RF transmitter based on the transverse electromagnetic (TEM) mode of parallel-plate waveguide. The electric field of this mode is orthogonal to the main trajectory of implant lead wires. This feature reduces the amount of current induced on lead wires and, therefore, reduces the heating effect.

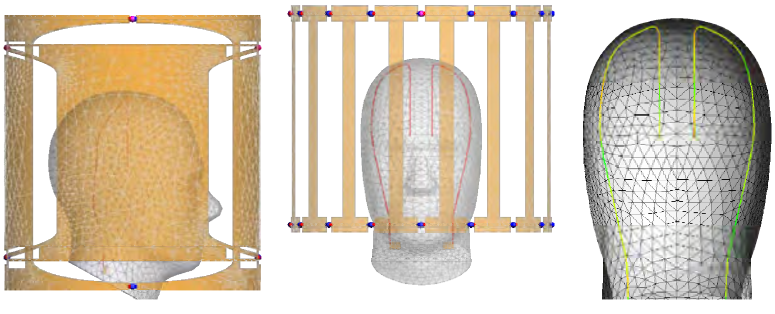

Figure 1. (a) The parallel-plate waveguide for MRI with DBS implant lead model. (b) The same implant lead model in birdcage coil. (c) The induced charge distribution on implant lead wires.

Methods: The coil consists of two sets of parallel parallel-plate waveguide that are orthogonal to each other. Each set of parallel-plate waveguide consists of two parallel conductors of width *w* and separated by a distance *d* (Fig.1). The electromagnetic field between the two conductors is the combination of TEM, transverse electric (TE) and transverse magnetic (TM) modes. Both the electric and the magnetic field of the TEM mode are uniform and perpendicular to the axis of the parallel plates. Thus the magnetic field of the TEM mode can be utilized for imaging. Because the trajectory of most DBS implants are parallel to the main axis of the parallel plates, the parallel-plate waveguide induces less current on implant leads as compared with the main-stream birdcage coil, which generates an electric field that is primarily parallel to the trajectory of implant leads.

Circular polarization can be implemented by using this pair of parallel-plate waveguide excited in quadrature. Because the electric field of each parallel-plate waveguide points from one conducting plate to the other, this arrangement naturally decouples the two sets of parallel-plate waveguide so that the correct phase difference can be implemented.

Computer simulations were performed by using FEKO® to study the magnetic field distributions, peak local SAR and induced charge distributions on lead wires at 3 Tesla (123 MHz) of both the proposed circularly polarized coil and a 16-rung quadrature birdcage coil (Figs. 1a and 1b). The diameters of both coils are 35 cm. The proposed coil only needs impedance matching, not frequency tuning, because the TEM mode is broadband in nature. The birdcage coil was numerically tuned with a head-shaped phantom to 123 MHz by using thirty two 20pF capacitors. The local SAR was calculated in a 0.3-by-0.3-by-3 mm^3 cubic mesh in the post-processing of the simulated electric field. A prototype circularly polarized parallel-plate waveguide was constructed by taping copper foils on the outside of an acrylic tube (Fig. 3a). Chebyshev matching network was applied to match 50-Ohm cable impedance to 280-Ohm TEM wave impedance. A four-channel receiver coil array was developed for signal reception. The entire coil system was tested on the human calf in a 3-Tesla Siemens' Verio scanner.

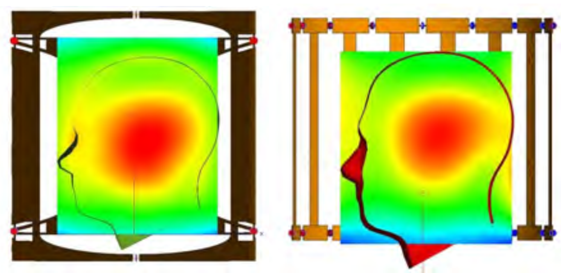

Figure 2. The B1+ distribution in the human head model generated by (a) the proposed circularly polarized coil and (b) quadrature birdcage coil of the same size.

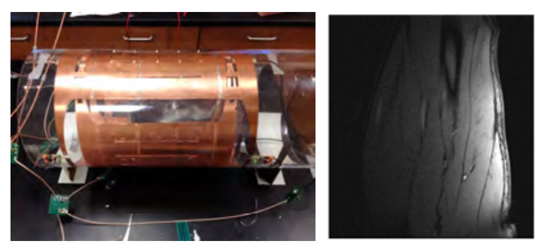

Figure 3. (a) The constructed coil set and (b) the human calf image acquired with a 4-channel surface array on a 3T scanner.

Results and Discussion: Figure 2 compares the simulated magnetic field distribution inside a head-shaped phantom at 3 Tesla. The magnetic field uniformity of the proposed coil is similar to that of a birdcage coil. Figure 3b shows the acquired FLASH image at 3T by using the proposed coil and a 4-channel surface receiver array. This demonstrates its feasibility. The peak local SAR of the proposed coil at the tip of the electrode and that of the quadrature birdcage was 523 Watts/kg and 767 Watts/kg, respectively. This represents a 34% reduction of peak local SAR.

Conclusions: A novel quadrature parallel-plate waveguide was developed to reduce the RF heating effect of DBS implant leads. Experimental results demonstrated its feasibility and simulations indicate the peak local SAR was reduced by 34% compared with quadrature birdcage coil.

References: 1) Cabot, Eugenia, et al. "Evaluation of the RF heating of a generic deep brain stimulator exposed in 1.5 T magnetic resonance scanners." Bioelectromagnetics 34.2 (2013): 104-113.