High Resolution Current Density Imaging at the Tip of an Electric Dipole

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INTRODUCTION: Implanted current delivering electric dipoles are used in a number of medical treatments. However, typically, the currents from such implanted electrodes can be a mystery. For example Activa Therapy, the trade name for Medtronics Inc. Deep Brain Stimulator (DBS), a Parkinson's disease treatment, is a very effective treatment whose physical mechanisms are poorly understood [1,2]. The purpose of this research was to investigate the currents emanating from an electric dipole employing Current Density Imaging (CDI) at high resolution, an MRI imaging modality. Typical CDI experiments are conducted by injecting current through electrodes that are at some distance from the region of interest (ROI), in the dipole experiments the region of electrical contact and the ROI overlap which requires more care in preparing the experiment.

METHOD: A cylindrical phantom, 15 cm in length and 4.5 cm in diameter was constructed from acrylic. An electric dipole was constructed using Microstock Inc. semi-rigid coaxial cable cut as indicated in figure 1. The length of the dipoles insulator matches the electrode separation from a deep brain stimulator. An agar/animal hide gelatin (1092mL H_2O, 540 mL glycerol, 18.85 mL dettl, 87 mL n-propanol, 62.25 mL n-propyl alcohol, 174 g Animal Hide Gelatin, 47.25 g agar, 13.5 g NaCl, 10 mL formaldehyde) was poured into the phantom with the dipole in place. Current pulses of various durations and intensities were attempted; pulses length ranged from 8-16 ms duration and amplitudes ranged from 20-50 mA. These were pulsed synchronously with the RF and gradient pulses of a spin echo sequence. Imaging was performed on a GE Signa® 1.5T MRI with 0.5 x 0.5 x 0.5 mm voxels using the GE Signa® 3-inch surface receive coil. CDI was performed as has been described elsewhere [3], imaging three orthogonal orientations of the phantom with synchronous current to enable the calculation of the three components of current density.

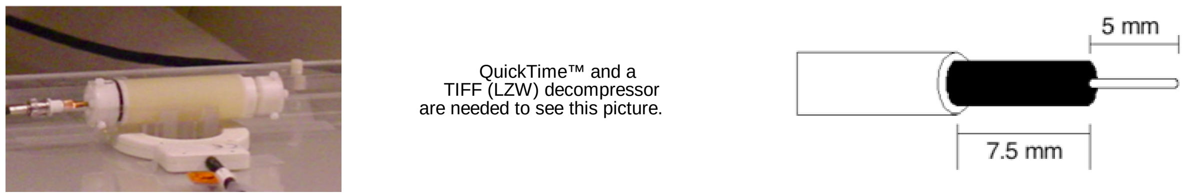

Fig. 1: Cylindrical shaped phantom filled with gel containing a dipole constructed from a semi rigid coaxial cable. Left: photograph of the phantom and the 3-inch coil. Right: dipole dimensions showing inner, outer and insulator dimensions. Middle: illustration of the phantom.

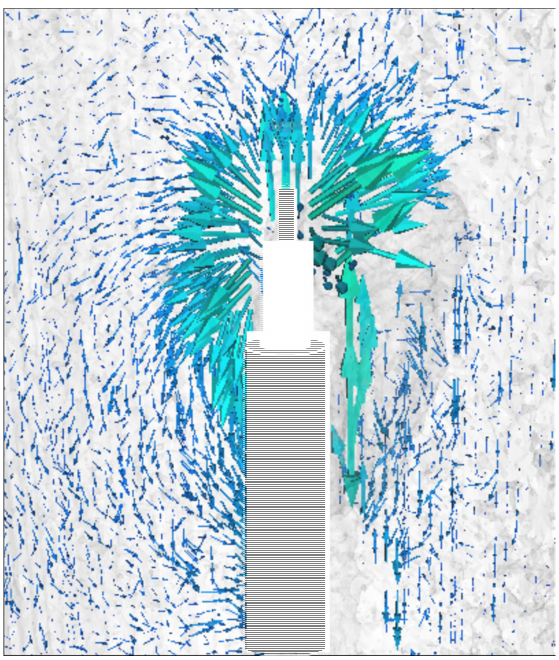

Fig. 2: Vector cut plane of the current density field from the dipole. The dipole is drawn in for clarity. There is a void in the gel, an air bubble on the right of the dipole through which no current flows which shows up as a dark spot in this image. This was accidental yet serves as a fortuitous feature in the experiment.

RESULTS: Three components of current density were measured at a higher resolution than had previously been performed. A vector cut plane of this current density is shown in figure 2. The current pattern was, predictably, that of an electric dipole. The current density was successfully calculated very near the dipole electrodes in spite of the susceptibility artifact caused by the dipole. If the current level was too high then gels were destroyed near the electrodes, spoiling the experiment. Although the exact threshold was not found, 20 mA was determined to be a safe level for maintaining the gels integrity throughout the experiments.

DISCUSSION: While the dipole current density fields are not terribly interesting the fact that CDI can be performed at such high resolutions is interesting. This experiment also found that CDI was possible about the tip of a dipole when the ROI and the electrical contact were in close proximity. This technique could be used to image a DBS electrode in a live rat brain, if not a human brain, which would be quite useful in helping further the understanding of deep brain stimulation as a medical treatment.

REFERENCES:

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