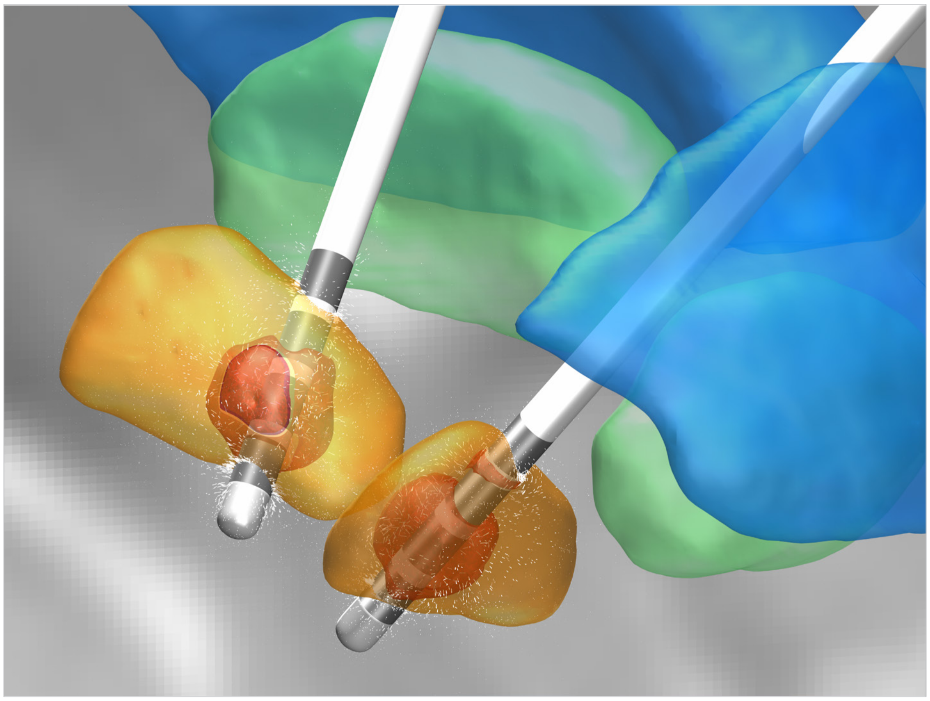
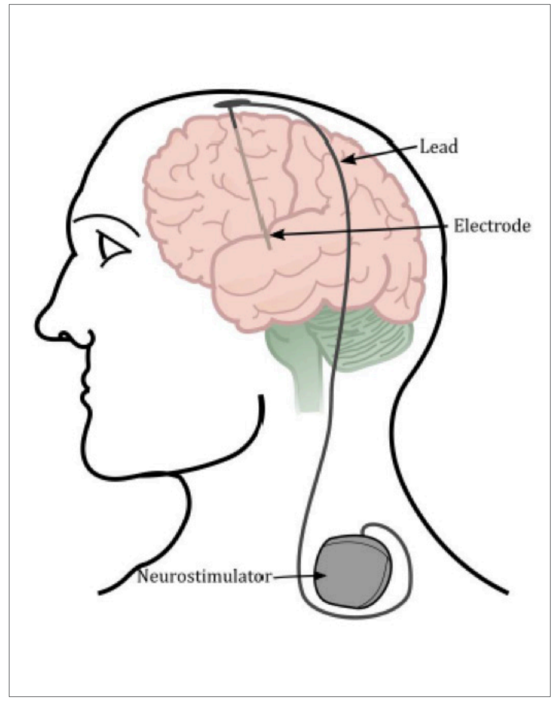
Sunnybrook Research Institute

Using Altair Feko™ to reduce heating during MRI for Deep Brain Stimulation





Customer Profile

Dr. Simon J. Graham, is a Magnetic Imaging Resonance (MRI) Physicist and Scientist at the Department of Medical Biophysics at the Sunnybrook Research Institute (SRI) affiliated with the University of Toronto, Canada. His research program develops and demonstrates the application of new technologies for brain imaging. Dr. Clare McElcheran, who recently completed her Ph.D. under Dr. Graham's guidance, led a recent project at the lab involving the development of ways to try and safely image patients with Deep Brain Stimulation (DBS). Implanted devices cause a safety concern due to heating at exposed tips of long conductive leads. The project objectives focus on the reduction of heat created during the MRI process as a result of implant interaction with radiofrequency (RF) transmission fields.

Having emerged as a successful neurosurgical procedure approved by the Food and Drug Administration (FDA) in 2002, Deep Brain Stimulation (DBS) has since been used for treating a variety of neurological conditions such as Parkinson's disease, Dystonia, Essential Tremor, Epilepsy, and Chronic Pain. It works by implanting neurotransmitters that send electrical impulses to certain parts of the brain using electrodes, which then work to regulate abnormal impulses. In the treatment of Parkinson's disease, it is used to reduce a patient's dependency on the drug Levodopa (a dopaminergic medication used to treat Parkinson's) which, in general, is a good treatment for it but patients can develop a resistance to its effects after extended use. It eventually stops working and there are also side effects to the medication, making DBS a more attractive option.

Safety Concern During MRI for DBS

Patients routinely undergo Magnetic Resonance Imaging (MRI) testing both pre- and post-implantation. Pre-operative MRI testing is done to determine target placement as well as implant positioning, whereas post-operative testing helps verify implant positioning and evaluate potential side-effects as well as other health conditions. Although Computed

Industry
Medical

Challenge
To create a method for heat reduction during MRI procedures in DBS implants

Altair Solution
Using Altair Feko for simulations allowing investigation of several different input parameters without actually having to do large amounts of overt experiments.

Benefits
- Lowered cost testing
- Ability to predict adn reduce globalized heating at the tips of the electrodes

Tomography (CT) can also be used for this procedure, it does not provide an image contrast as good as MRI does. However, using MRI for post-operative procedures is restricted due to the risk of heating. The DBS and other elongated implants interact with the RF fields used in MRI, potentially causing unsafe levels of localized tissue heating. The oscillating RF field induces a current along the implant which generates a charge build-up at the tip of a wire thus creating higher electrical fields resulting in high power deposition and higher local Specific Absorption Rate (SAR) that causes this increase in temperature. There are many factors that influence this type of heating. The length of the lead, the position and orientation of the wire relative to the RF field, the frequency of the RF field and total power deposited onto the subject can vary the extent of coupling and subsequent heating.

The project's goal at the lab has therefore been to create a method for imaging patients that reduces the heating in DBS implant MRI procedures.

Parallel RF Transmission for Heating Reduction

While other methodologies have been identified to mitigate heating in the leads, the lab research project follows a technique called parallel RF transmission. This methodology demonstrates a great deal of potential by modifying the electromagnetic field, thereby resulting in lower coupling with an implant. In order to determine the input, Dr. McElcheran's team uses Altair Feko extensively to simulate the environment. Using Feko they perform pTx (parallel RF transmit) to create the electrical and magnetic fields required for imaging, thus being able to calculate the electromagnetic field.

"Feko was integral to the success of our project. It allowed us to evaluate the feasibility of our technique prior to building the hardware and helped inform design decisions to build the optimal system to achieve our goal. Their technical support was excellent. The staff who responded to our questions were quick and extremely knowledgeable in both Feko software and the science behind the software." Said Dr. Clare McElcheran.

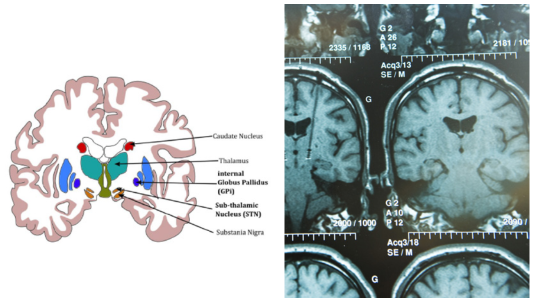
Simulation is Key

These simulations are key to the research, as the instrumentation is not yet fully built and developed in order to do comprehensive hardware testing. The simulated environment allows investigation of several different input parameters and optimization of the parallel RF transmissions hardware characteristics without actually having to do large amounts of overt experiments.

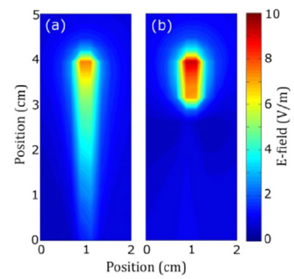
The current MRI systems for clinical applications operate 2 different magnetic field strengths, 1.5 tesla and 3 tesla. The parallel RF transmission strategy being developed is for 3 tesla, where the existing hardware is very rudimentary. Parallel RF transmission consists of 2 channels that can be manipulated on commercial systems, and so the prototype parallel RF transmission capability that is being developed for this application might have channels that are up to counts like 16 or 32 channels; it is not known what the alternate channel is, nor is the hardware available. The simulations therefore help determine how to design hardware in the future to maximize its capabilities.

Promising Results

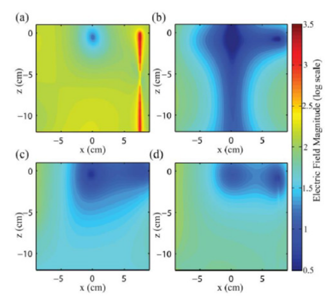
With experimentation, the general finding has been a very large reduction in the globalized heating at the tips of the electrodes. The team has been able to demonstrate essentially negligible heating when parallel RF transmission was used in tissue equivalent test objects. Although this is the early phase in the four year young research and there is no verification in humans yet, the results are suggestive of an ability to reduce or suppress heating such that there will not be more than a 1 degree Celsius temperature elevation which is the critical safely threshold for the regulatory agencies. Although there is a long way to go for this to become a clinical procedure, the initial results are very promising for this enterprising, enthusiastic team.



Targets for DBS are the subthalamic nucleus (STN) and the internal globus pallidus (GPi)



Electric field at tips of 12 cm wire: (a) bare wire and (b) insulated wire at 3T excited with birdcage coil



Contour plots of E-field magnitude on a log scale in the plane parallel to the wire

Visit the Altair Library of Customer Stories at altair.com