Development of a Magnetohydrodynamically Driven Actuator for Use in MRI

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Target Audience:
This research is intended for investigators pursuing novel surgical techniques utilizing magnetic resonance imaging (MRI), surgical robotics, or wireless endoscopy. The nature of this application also extends itself to researchers with interest in microfluidics.

Purpose:
Microscopic medical robots capable of translating in a bloodstream or similar liquid represents a new type of therapeutic technology for endo-vascular interventions. Local drug delivery of diagnostic and chemotherapeutic agents could be delivered to tumors, blood clots, and infections. Microcapsule control in such a situation presents a barrier for the implementation of this technology. Magnetohydrodynamic (MHD) voltages are created in major vasculature when blood ejected into the aortic arch during early systole interacts with the strong magnetic field of the MRI. By utilizing the MHD effect within the strong magnetic field of the MRI (Fig. 1), the opportunity to propel a device and provide imaging is presented simultaneously. We hypothesized that a wireless MHD-driven thruster could be developed for the application of controlling microscopic endo-capsules within the strong magnetic field of the MRI scanner.

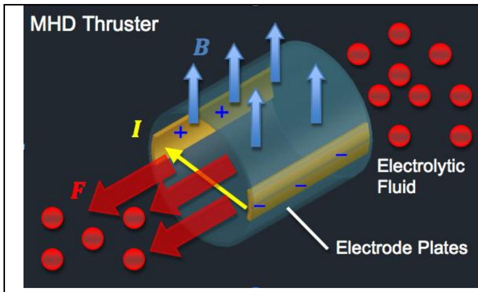

Figure 1: Translation of the MHD effect to the application of a MHD-based thruster

a) Principle of Wireless Energy Transfer | b) System Block Diagram

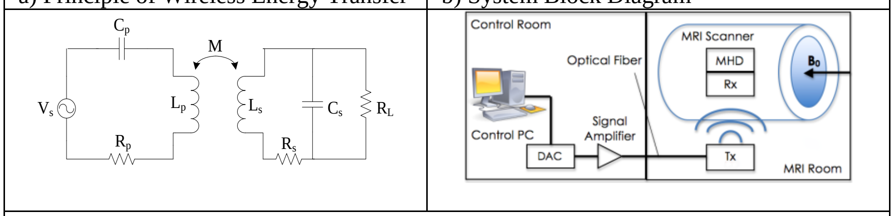

Figure 2: Utilization of the MHD effect for the design of a thrusting mechanism to be used in the presence of the strong magnetic field of the MRI.

Methods:
A model capsule (4.27g) was constructed using an inductive coil and a rectifying circuit mounted upon a 40mm dia. rapid prototyped raft. Through a half-bridge amplifier circuit, a 1.1 MHz signal was used to drive the on-board rectifier to produce a driving current for the MHD thruster. The primary coil of the system was placed about a 50 x 50 x 20 mm neodymium magnet (spec. $B_{r\ max}$ = 14,500 gauss), which provided a scaled static magnetic field. The plastic raft was positioned in a saline bath (0.9% w/v) above the magnet and the device was filmed above a grid to verify the model's performance (Fig. 3). The voltage across the model's driving electrodes was recorded to assess system power output.

Results:
The power output of the primary coil and the capsule were recorded, indicating a wireless transfer efficiency of 27.56%. In the saline bath, a mean device acceleration of 68.2 mm/s^2 was determined, implying that a 0.291 mN force was generated in opposition to the surface tension of the saline.

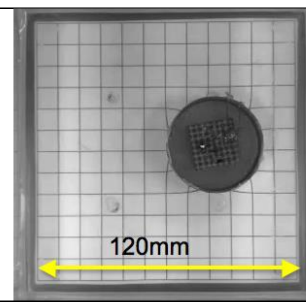

Figure 3: Implementation of a magnetohydrodynamically-driven wireless thruster in a bath of normal saline.

Discussion and Conclusion:
The preliminary model provided fundamental evidence that a MHD-drive wireless endo-capsule is sustainable in a MRI-like environment. Using a small test current, the capsule was capable of propelling itself out of the magnetic field and reach of the MHD effect. Decreases in device size should allow the device to travel at an increased velocity. Limitations to the current model include limited applied field strength. Future work will involve parameter and circuit optimization, and model miniaturization.