

# Design and Prototype of MRI Knee Coil

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## Introduction

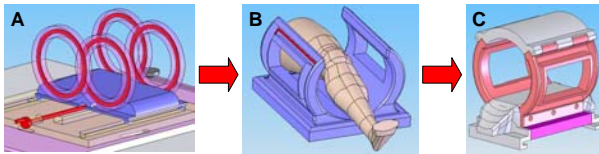
The medical field has made leaps and bounds in the diagnosis of injury through the use of non-invasive medical procedures such as magnetic resonance imaging (MRI). With the ability to distinguish between different types of tissues and fluids, MRI allows us to take a glimpse into the human body. Without the use of surgery or any other type of intrusive observation method, MRI allows doctors to visualize problems within a patient and make better decisions based on high resolution images.

## Market

Currently, companies such as General Electric, Philips, and Siemens are filling a niche for extremity RF coils in the MRI industry. While these systems require a large, tube-shaped magnet, they image only a small area thus increasing image resolution of the target area. The need for knee specific coil holders is especially high in the imaging system market. Due to the severity and complexity of typical knee injuries, it is beneficial to have an imaging system than could completely examine the injured area.

The existing coil holders on the market all have several common features. They each include a coil system of 2 to 8 channels (1 image per channel). Also, the existing models only image the sides and bottom of the knee without the ability to change the angle of imaging. Our project fills this market niche by offering a 4 channel rotating coil system that can image a full 360 degrees around the human knee. This innovation came through several different design iterations and feature evolutions.

## Design Iterations



In each of these preliminary designs, there were specific features that added strength to the previous design. We incorporated some of these strengths into the final design and tried to eliminate the weaknesses of its predecessor.

**Design A** → A basic, four-channel coil system with circular coils and a simple, open-air design that allowed for biopsy to be done on the knee while in the holder.

**Design B** → A side saddle coil design focused on ergonomics that would better enclose the knee. This design, however, reflected too many of the same design features that were already on the market for MRI knee coils.

**Design C** → A multiple saddle coil design with a removable top to image in fixed locations on each side as well as above and below the knee. This feature is also presently on the market in other similar designs.

## Materials Selection

Since the device would be used inside of a magnetic field, only non-magnetic materials could be used. Unfortunately, we were limited even further due to the fact that even non-magnetic metals can cause image distortion. For these reasons, a variety of different plastics with low dielectric constants were used in the construction of this project.

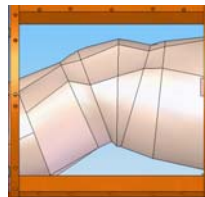
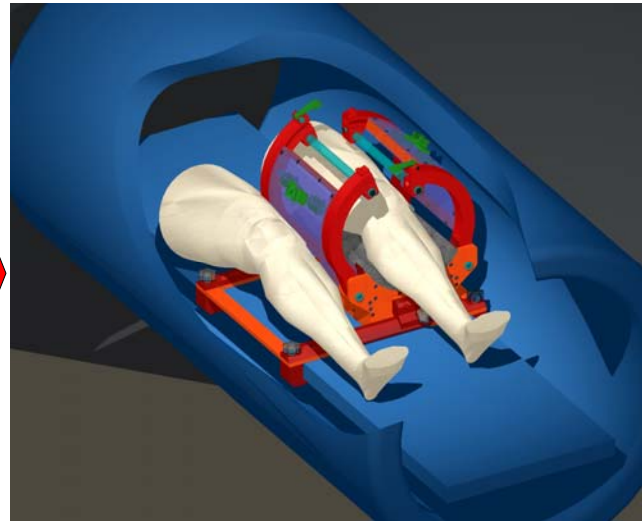
- ▶ [Delrin](#)
- ▶ [Polycarbonate](#)
- ▶ [Acrylic](#)
- ▶ [Nylon](#)

Each of the plastics were assessed based upon three factors: dielectric constant, machinability, and cost. The dielectric constant for each of these materials was important because it is a factor of how much the material will interfere with the magnetic field of the imaging magnet. Each of these materials feature a dielectric constant between 3 and 4 and are relatively easy to machine. Out of all of the materials, Delrin had the best properties for machining in the WPI facilities. However, it was the most expensive and its price had to be balanced with functionality.

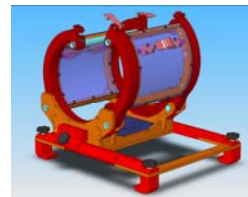
## Final Design

After four design iterations, the final design was created as seen in the progressive figures below. This updated design featured many key improvements that resulted in a product that accounted for increased ergonomics, functionality, and compatibility with commercial magnet systems, including:

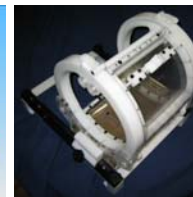
- ▶ 9.5 inch inner diameter to accommodate 99.0% of the population by measure of leg geometry,
- ▶ Larger field of view in the rotating coil enclosures to capture the knee and surrounding tissue at preset locking positions,
- ▶ A two position table rail to which the base is mounted, allowing imaging of both the left and right leg,
- ▶ A separate compartment for electronics, top latches and crossbars to ensure arm sturdiness, and ergonomic padding for comfort and support of injured patients.



Coil Holder Imaging Area



SolidWorks CAD Model



Physical Model

## Cost Analysis

For this project, an expense analysis was completed to estimate the cost of the materials required for fabrication. A brief outline of this analysis can be seen in the table to the right. While the overall cost of the project may seem large, a commercial coil holder unit could be sold for 20 to 30 thousand dollars. Also, material cost could be reduced if the stock was purchased in bulk quantities for larger scale manufacturing.

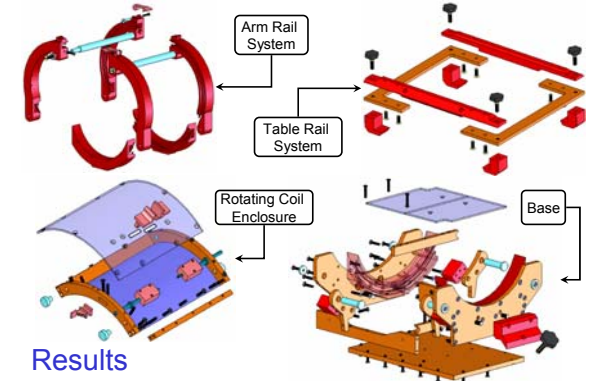
Total Delrin Price	\$636.63
Total Polycarbonate Price	\$31.83
Total Nylon Price	\$58.04
Total Fastener Price	\$42.10
<b>Total Materials Cost</b>	<b>\$768.60</b>

## Fabrication and Assembly

Over 70 individual parts were machined to complete the project. All parts were constructed by the project team in the WPI machine laboratories. Most were created using manual mills and lathes, while the more complex parts required use of the HAAS CNC mini mills. For components that were CNC milled, GibbsCAM was used to generate the NC code. These parts also required the construction of custom fixtures to clamp the part in the CNC mini mills. Examples of these fixtures can be seen in the following figures.



For organizational purposes, the model was divided into four main subassemblies. These assemblies were the base, base clamp, arms, and the coil enclosure. For each subassembly, a bill of materials and an exploded balloon diagram were created. Exploded views of the subassemblies can be seen in the following figures.



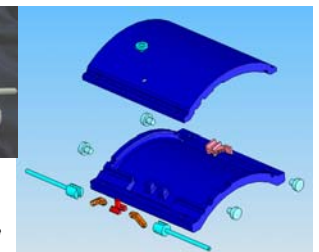
## Results

The success of the project depended on the precision in machining and assembling the CAD modeled subsystems. In regards to the main goal, the entire device met the original vision of having a rotating coil design that was not only sturdy and resilient but also practically designed and safe for its application.

A suggestion from the project group entails a further redesign of the coil enclosures. The original design featured thin plates of polycarbonate which were determined to be insufficiently rigid for insertion of necessary electronics. The suggested revision would therefore include two solid CNC milled coil holder halves to be fabricated from thicker two inch Delrin instead of the thin walled stock. A comparison of the constructed coil holder and the suggested design revision can be seen below. Overall, the project concluded successfully and was transferred to Professor Reinhold Ludwig of the WPI Electrical Engineering Department to finalize modeling of the RF circuitry.



Current Coil Enclosure



Proposed Redesign of the Coil Enclosure