

## INSTRUCTIONS

- Complete this application form in English. Once complete, please upload it to our online portal.
- Please do not modify, remove text or instructions in each section/subsection or reformat this form in any way. A modified form will result in a delay in the internship evaluation process.

## 1. PROJECT DETAILS

1.1 Student name	Devin Morin
1.2 Supervisor name	Dr. Bruce Balcom
1.3 Academic institution	University of New Brunswick

## 2. DESCRIPTION OF PROPOSED RESEARCH

### 1. Student statement of interest (approximately 0.5 pages)

Explain how participating in this Mitacs Research Training Award opportunity will benefit your academic studies and research career (e.g., identification of new research connections or directions, experiential skills acquisition, potential for further collaboration both domestically and globally, benefit to the community).

This award will aid in furthering my research skill in experimental physics, more specifically in magnetic resonance. It will also provide me with an opportunity to develop new skills such as computer simulation, and design. The construction of a new generation of handheld, single sided magnets will allow us to explore applications, and develop measurements of interest, to a wide variety of users. Magnetic resonance is well known for clinical diagnostic imaging with large and expensive magnets, in dedicated labs. In this project we will bring the power of magnetic resonance to simple handheld devices. The UNB MRI Centre, where this work will be undertaken, is among the world leaders in this technology with established connections to a variety of international partners. This includes University of Oriente in Santiago de Cuba who wish to use these devices for below-skin blood measurements in community health care clinics, University of California Davis who wish to use these devices for Food and Agriculture measurements, NIST in Colorado who wish to use these devices for on-line process monitoring, and Central Research and Development for Procter and Gamble in Cincinnati who wish to use these devices for similar on-line sensing applications. Where commercialization possibilities exist, local spin off company Green Imaging Technologies will commercialize viable technologies, as they have been doing with the MRI Centre for more than 10 years. There are community benefits that are realizable with this project that span economic development and health care, which have both regional and international benefits.

### 2. Research training plan (approximately 1-2 pages single spaced)

#### 2.1 Background

Explain the research or innovation focus of your project, including references as appropriate.

We're interested in the construction of a unilateral magnet which is motivated by the many applications of unilateral magnetic resonance (UMR). These devices are helpful for in-field work as they are portable and

have a decreased hazard due to the relatively low magnetic field compared to a conventional MRI magnet. Low field devices have been used in the past to characterize food spoilage [1], and wood moisture content [2]. UMR has a wide range of applications in many fields. In some cases, specific magnet parameters (sensitive spot region, gradient strength, gradient direction) are needed to achieve the desired goal. For example, a magnet with a sensitive spot of 1 cm from the surface would be useful for blood measurements below the human skin.

[1] Michele N. Martin, Bruce J. Balcom, Michael J. McCarthy, and Matthew P. Augustine, “Noninvasive, Nondestructive Measurement of Tomato Concentrate Spoilage in Large-Volume Aseptic Packages”, **Journal of Food Science**, (84), 2019

[2] Clevan Lamason, Bryce MacMillan, Bruce Balcom, Brigitte Leblon, Zarin Pirouz, “Field Measurements of Moisture Content in Black Spruce Logs with Unilateral Magnetic Resonance”, **FOREST PRODUCTS JOURNAL**, (67), No. 1/2

## 2.2 Anticipated research activities

Provide a description and objectives of the project. Include the kinds of research question(s) you may be addressing and/or hypotheses you would like to test. Include a description of all the anticipated project activities.

Unilateral magnet designs will first be simulated in software. The simulation software of choice is CST Studio. CST is a software package that enables design, optimization and analysis of electromagnetic systems. It is also used to simulate MRI technology, such as radio frequency (RF) probes, and permanent magnets. The goal is to develop a realistic simulation of a handheld unilateral magnet. The unilateral magnet will consist of a three-magnet array, each spaced by the appropriate distance to achieve the desired result (gradient strength, gradient direction, sensitive spot location). An RF coil will be placed at the appropriate distance to obtain magnetic resonance (MR) signal. RF magnetic field interactions with the magnet array will be simulated in CST.

From there, we will begin the design process and reference relevant literature to avoid unwanted effects of enclosing the magnet array in a case (unwanted acoustic ringing) [3]. Then, by using the 3D magnetic field plotter at UNB’s MRI Centre, the magnetic field will be characterized and compared to the theoretical model. As the purchased magnets will have inconsistencies in magnetic field strength (~8%), some slight adjustment might be needed to correct for this [3]. Constructed magnets will be tested with a range of samples suggested by and provided by our international collaborators. Such samples depend on the experiment of interest. For example, water would be the sample of choice when performing a flow velocity experiment. This project should be viewed as the initial stages of a more substantial future sponsored research projects with our international collaborators, particularly with NIST and Procter and Gamble.

This project is the beginning of a potentially very impactful technology. We aim to answer questions about the validity in using low-field handheld magnets to acquire data about certain materials. The MR research performed with high-field magnets to characterize materials is important, however society in general can benefit immensely from research performed on developing small MR devices. The devices have potential to be applicable in any environment, or in any use that conventional high-field MR devices already exist in.

[3] Juan C. García-Naranjo, Igor V. Mastikhin, Bruce G. Colpitts, Bruce J. Balcom, “A unilateral magnet with an extended constant magnetic field gradient”, **Journal of Magnetic Resonance**, (207), 337-344, 2010

## 2.3 Significance of the project

What specific contributions will the project provide to industry, the not-for-profit community, society or Canada? What are the challenges facing these sectors that you will address?

UMR has been used as a nondestructive method of determining fat content in dairy products, fish, ground meat, margarine, and mayonnaise, as well as range of many other applications, such as exploring adulteration of olive oil, and water loss in pears. A lot of promising, and exciting research is happening to develop this field as there are many applications towards improving human health and general material characterization. For example, UMR could be used for determining blood characteristics below the human skin. This could also potentially be used for measuring blood flow velocity. Water flow velocity measurements have been done in the past by researchers using high-field magnets, however, one could imagine using similar methods to achieve flow velocity measurements at low-field [4]. Similarly, one could characterize materials using low-field magnets. The challenge that low-field presents, is a decreased signal to noise ratio, which will yield an overall decrease accuracy.

By constructing a unilateral magnet, we motivate future collaborations with NIST, Procter and Gamble, University of Oriente in Santiago de Cuba, UC Davis, and Green Imaging Technologies that can potentially have an impact on monitoring health. UMR is especially exciting, as the cost of constructing such magnets is relatively low compared to the conventional MRI magnet. Unilateral magnets are generally small and can fit in the palm of your hand. MRI magnets found in hospitals are very expensive, not portable, and high-field so are therefore a hazard. This system could be a great benefit to society and aid people in areas of the world where a conventional MRI magnet may be less practical.

The basic three magnet array design platform that we will initially employ is the subject of an awarded US patent. Successful additional research has a high probability of being commercialized.

[4] Richard, S., Newling, B. "Measuring Flow Using a Permanent Magnet with a Large Constant Gradient", **Applied Magnetic Resonance** (2019) 50, 627-635.

### 3. Skills enhancement (approximately 0.5 page)

Please use the drop-down boxes to select the top three skills areas expected to be enhanced as a result of the completion of the research project outlined above.

Use of analytical and software tools to answer research questions	Knowledge in a research field	Research development and design skills
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Please elaborate how completion of your proposed project will provide opportunity to enhance the above-mentioned skills. If "Other" is selected in the drop-down box above, please provide a short description of the skill area.

1. Magnet simulation software in Matrix Laboratory (MATLAB) will be used to develop a theoretical design of the three-magnet array. Once the magnet is constructed, it will be plotted in a 3D field plotter program such that we can check for differences between the theoretical and experimental magnetic fields. Radio frequency simulation software, Computer Simulation Technology (CST) Microwave Studio, will be employed to design and improve the RF probe which excites and detects the experimental signal.
2. This award will allow me to gain knowledge in the very large scientific field of MR/MRI. Magnetic resonance in all of its manifestations is a multi-billion dollar per year industry. By reading about the relevant MR research I will gain knowledge about general MR theory. I will also learn about CST Microwave Studio, which allows me to further my research by developing a sophisticated model of the unilateral magnet I will construct. By constructing, and modeling the radio frequency probe, I will learn about circuits and electronics.

3. My practical design and hands-on research skills will be enhanced by the design, fabrication, testing and utilization of magnet arrays that I construct. The fabrication of both the radio frequency probe and magnet will enhance my hands-on research skills by allowing what I've done in simulation to be constructed into a physical device. Associated with this, there will certainly be problems during the construction that will enhance my hands-on problem-solving skills.

#### **4. Interaction and deliverables (approximately 0.5 pages)**

Provide detailed information on the interaction between the academic supervisor and the student, including the supervision and mentorship that the student will receive, as well as the frequency of these interactions and meeting structure. Please comment on the access to university resources, and final project or presentation expectations and deliverables. We suggest presenting this information in the form of a timeline.

The interaction between myself (the student), and my academic supervisor will be frequent throughout the project. Communication over voice call or email should occur no less than once per week. Meetings will give the opportunity to make sure things are on track, and plan for the next steps in the project.

1. **Simulation Software, June**

The unilateral magnet(s) will be simulated in the magnet array software. Radio frequency probes will be designed with CST Microwave studio.

2. **Begin Construction, July**

Materials will be assembled, and construction of the unilateral magnet(s) will begin.

3. **Magnet Characterization, August**

The magnet will be characterized in detail to create a reference document for researchers in the future. The magnetic field plotter will be used to determine the magnetic field topology. Trial MR measurements will be undertaken.

4. **Final Report, Mid-August – End of August**

A final report will be made to catalog the work done over the summer. This will also serve as a reference document for researchers in the future that plan to use the unilateral magnet.

As of May 25, 2020 UNB is moving to reopen research labs. While this research will commence off campus with design and simulation, it is virtually certain that it may be completed on campus. If however this is not possible, we may extend the design and simulation stages to explore a wider array of single sided magnets for magnetic resonance.