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Honors Prospectus
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Measurement of Magnetic Fields in Incubators

Introduction and Goal

The Barnes lab is investigating evidence [1-5] that low level magnetic fields can affect biological systems. One point of particular interest is effects at the cellular level. Experiments on this topic are typically performed by applying a magnetic field to cells and tracking either movement or health indicators of these cells. Such experiments must be performed in cell culture incubators to provide viable environmental conditions for the cells. However, incubators present distortions to the earth's DC magnetic field and generate AC electromagnetic fields. The fields created by incubators are of similar amplitude to the fields under investigation for biological effects and could thus skew results. This fact concerns the experiments performed at our lab and is also potentially relevant to any cell culture experiment due to the possibility that these low level magnetic fields could affect cell behavior.

Some attempt has previously been made to characterize the nature of magnetic fields in incubators. It has been shown that the amplitudes involved are of the order of magnitude that can have biological effects [2]. However, there is limited literature available on the spatial dependence and no literature on the frequency characteristics of the AC field. My goal in this project is to design, build, and calibrate a probe that is capable of measuring these AC fields with high sensitivity (~1 μT). I further intend to utilize this probe to make AC field measurements in a sample group of incubators in addition to making static field measurements with a gaussmeter. When the characteristics of these fields are known, their effects can be accounted for to improve the accuracy of our lab's experimental results.

Background

It has been suggested [4] that biological systems have evolved such that their functions are 'fine-tuned' to the earth's Geo Magnetic Field (GMF). The mechanism behind this hypothesis is a shift in free radical recombination rates and concentrations due to changes in ambient magnetic fields [3]. Therefore, exposure to an altered GMF may induce an altered state in a biological system's metabolism. Consequently, such a system may display an observably differential behavior in highly metabolic activities such as chemotaxis (cellular movement along a chemical gradient). This is exactly the type of experiment that our lab is currently performing in incubators. In one such example, our lab has found that upon exposure to electromagnetic fields, chemotactic neutrophils, a type of white blood cell, may tend to turn off course and travel in a different direction [1].

Method

The AC magnetic field probe that I have designed is a tri-axial induction coil. In order to detect low amplitude fields, very small induced currents must be detected precisely. To accomplish this, the probe signal must be amplified 1000x before being processed by a fast Fourier transform (FFT) oscilloscope. Once properly calibrated, the recorded amplitudes can be correlated with the amplitudes of the magnetic field at individual frequencies. This process will be done independently on each of the three axes to get an overall picture of the fields. Using this method, the magnetic field amplitude and direction can be determined for any specific frequency.

Calibration of the probe requires the creation of a mapping of voltage reading on the oscilloscope to applied field strength. To accomplish this, the probe must be exposed to a magnetic field at known frequency and magnitude. This is best to generate with a Helmholtz coil that I will also built. I will then compare this signal reading to background noise. I expect to find a voltage peak at the applied field frequency that I will associate with the amplitude of the magnetic field. It will be necessary to perform this test at several frequencies and amplitudes to create a calibration curve. A theoretical calibration curve will also be calculated by means of Faraday's law. The caveat of this design resides on being able to obtain an instrument which can detect the smallest field amplitudes that we are interested in above noise levels. Accomplishing this accuracy will mainly include the redesign of the triaxial square probe coils and the implementation of filters as needed in combination with the amplifier and oscilloscope.

References:

[1] F. Barnes et al., Effects of 900-MHz Radio Frequencies on the Chemotaxis or Human Neutrophils in Vitro. Biomedical Engineering, vol (55), NO. 2, 795-797, 2008

[2] M. Simko et al., Background ELF magnetic fields in incubators: A factor of importance in cell culture work, Cell Biology International, vol. (33): 755-757, 2009

[3] U. Steiner and T. Ulrich. Magnetic Field Effects in Chemical Kinetics and Related Phenomena. Chem. Rev., vol (89): 51-147, 1989.

[4] R. Wadas, *Biomagnetism*, Ellis Horwood Ltd. 1992

[5] Barnes, Frank S., and Greenebaum, Ben. Handbook of Biological Effects of Electromagnetic Fields. CRC press, 2006.

Measurement of Magnetic Fields in Incubators - Time Schedule

October 2010:

- Build probe based on calculations already performed
  - Have probe base/support machined
  - Wind coils
  - Attach appropriate connections
- Acquire 1000x amplifier
  - OSP-1 oscilloscope preamplifier
- Setup testing equipment
  - Connect all components
  - Learn operation of FFT oscilloscope
  - Test probe functionality

November 2010:

- Finish setting up equipment
- Test that probe responds properly to applied fields

December 2010:

- Start locating incubators to take measurements in and get permissions
- Develop method to take DC field measurements
  - Determine the necessary parameters to control to get consistent measurements.
- Start recording DC field data

January 2011:

- Continue collecting data on DC fields
- Continue searching for incubators to measure
- Get distracted helping with other lab projects

February 2011:

- Continue DC field measurements
- Continue distractions with other projects

March 2011:

- Continue DC field measurements
- Begin analyzing DC data

April 2011

- Complete search for incubators
- Complete collecting DC field data
- Continue data analysis
- Begin AC probe calibration

May 2011:

- Work on theory for calibration curve
    - Calculate self-inductance
    - Calculate induced current as a function of field amplitude and frequency
    - This will pull from the background calculations used to build the probe
- Take measurements to create calibration curve
    - Figure out spectrum of frequencies of interest based on other experiments
    - Follow procedure outlined in the methods section of this paper

June 2011:

- Address any issues that arise in use of the probe
    - S/N ratio
    - Sensitivity
    - Accuracy
- Finish probe calibration

July 2011:

- Make AC field measurements
- Begin AC data analysis
- Begin writing thesis

August 2011:

- Finish field measurements
- Continue analyzing data
- Continue writing thesis

September 2011:

- Finish data analysis
- Help write paper on results. I intend to be part of a Barnes lab publication on my results.
- Continue writing thesis

October 2011:

- Finish writing thesis
- Defend thesis