# Earth's Field Nuclear Magnetic Resonance


## ABSTRACT

This set of experiments is designed to introduce you to nuclear magnetic resonance. The magnetic moments of protons, particularly the nuclei of hydrogen atoms in a sample of water, can be manipulated with applied magnetic fields. The motion of the nuclear spins can be studied by detecting and amplifying the magnetic flux these moments produce. You will use a set of inductors (coils) to watch the time rate of change of the flux that arises from nuclear spin precession about the Earth's magnetic field.


## I. INTRODUCTION

One of the interesting and useful facts about nuclei is that they can carry a magnetic moment, $\vec{m}$, and that this moment is directly proportional to the angular momentum, $\vec{L}$, of the nucelus i.e.,

$$\vec{m} = \gamma \vec{L}$$

Here, $\gamma$ is the so-called 'gyromagnetic ratio'. Because of the magnetic moment, nuclei can interact with magnetic fields. Because of the interesting equations of motion for angular momentum (think about precession of gyroscopes) and the coupling between magnetic moment and angular momentum, nuclear spins are happy to precess about the direction of the local magnetic field. The frequency of precession is given by $\gamma B$. Furthermore, because the magnetic moments carry magnetic flux, if you wrap a coil around a set of nuclear spins, you can see their motion due to the time changing flux through the coil. The study of this periodic precessional motion of nuclear spins is generically referred to as Nuclear Magnetic Resonance (NMR)

Starting in with the initial experiments in 1946, in the labs of Edward Purcell at Harvard, and Felix Bloch at Stanford, the NMR field has grown to be enormously important. For example, NMR is now the favorite technique used by chemists to study new compounds. It is sensitive and the nuclear precession measures the local environment, so you can tell the difference between a proton bonded to an oxygen or a proton bonded to a carbon. NMR is used as an imaging technique for studying soft tissue, the so-called Magnetic Resonance Imaging (MRI) found in hospitals. 'Nuclear' was eliminated from the name as a marketing ploy!

Usually, NMR experiments use magnetic fields of order 1 Tesla or larger, and, given the gyromagnetic ratio for protons of $2\pi$ x 42.5 MHz/Tesla, usually involve measuring time varying voltages in the radio frequency region. RF electronics is an interesting and complicated story on its own, so a typical NMR experiment can be a difficult learning experience just because of the RF techniques.

In the case of the Earth's field NMR apparatus, you will study the precession of spins in the Earth's magnetic field, roughly 0.5 Gauss, or $0.5 \times 10^{-4}$ Tesla. Therefore, the spins precess at a much lower frequency near 2 kHz. The lower frequencies allow for simpler electronics, and for a more familiar feel: You can connect your amplifier to a speaker and actually hear the spins precess! However, the price you pay for the simplfied electronics is a much higher sensitivity to local variations in the magnetic environment. The Earth's field is small and local magnetic materials e.g., steel reinforcing in the concrete floors and ceilings of our laboratory, can cause the field to vary across your sample of spins. That causes the spins in different parts of the coil to precess at different rates and makes the signal harder to understand.

Your job is to hunt around the lab looking for a region of nearly uniform magnetic field (you may even end up outside the building at the end of a long extension cord), where you can then study nuclear spin properties.

The apparatus is a commercial object bought from TeachSpin. Look for their documentation near the experiment. Read and enjoy!