January 2007

Nuclear Magnetic Resonance – *DRAFT* Phy 462

Introduction:

Nuclear magnetic resonance (NMR) is an important experimental technique in many scientific disciplines. In the presence of an external static magnetic field, nuclear spins will align with the field with an energy difference between the parallel and antiparallel configurations which scales with the field strength. Resonant rf pulses tuned to this energy difference can be used to manipulate the orientations of the spins. The subsequent precession and relaxation of the magnetization can be studied to reveal a wealth of information about the substance which contains the spins.

This apparatus just arrived in January 2007 and is being run in this course for the first time. There will likely be some adjustments to the procedures and assignments as the students (and the instructor and TA!) learn the operation of the system. Please be patient. It should be an exciting project!

Objectives

- Understand the principles of NMR.
- Study the various pulse techniques available for rotating the magnetization vector of the nuclear spins in a sample of mineral oil.
- Use appropriate pulse sequences to measure the relaxation times T_1 and T_2.
- Apply this knowledge to investigate NMR further and study another substance.

Suggested Reading: Read the introduction to NMR in the manual from TeachSpin (copies are present in the lab). The classic textbook by Abragam, *Principles of Nuclear Magnetism* is available in the lab. The library has a copy of the textbook by Slichter, *Principles of Magnetic Resonance.*

Suggested Apparatus:

1. Pulsed NMR system from TeachSpin
2. Two-channel digital oscilloscope.
3. Vials with appropriate samples for measurements.

Avoiding damage:

- Please be extremely careful with the magnet, as described in the TeachSpin manual. Do not drop the or shake the magnet, do not bring magnetic objects near the magnet, and do not drop magnetic objects in the sample probe. Do not force the sample probe past its limits of travel.
- Do not operate the power amplifier without attaching the TNC cable from the sample probe. Follow the precautions on p. 21 of the TeachSpin manual.

Investigating the Pulse Programmer
For this portion, you will not be using the magnet, but rather studying the pulse envelopes directly with an oscilloscope. This will help with appreciating the pulses which will be used ultimately for manipulating the spins.

- Follow the *Getting Started* instructions in the TeachSpin manual, pp. 26-27.

Investigating the Receiver
In this section, you will study the operation of the receiver using the "dummy signal" probe.

- Follow the *Getting Started* instructions in the TeachSpin manual, p. 28.
- Connect the spectrometer modules according to the TeachSpin manual, pp. 28-29.

Free Induction Decay
In this section, you will use a single pulse to tip the spins, then measure the decay of the transverse magnetization.

- Follow the *Getting Started* instructions in the TeachSpin manual, pp. 29-31.
- Connect the spectrometer modules according to the TeachSpin manual, pp. 28-29.

Measurement of T_1
Here you will use a two-pulse sequence to measure the spin-lattice relaxation time T_1.

- Follow the *Getting Started* instructions in the TeachSpin manual, pp. 32-34.

Spin Echo
In this section, you will study a two-pulse echo sequence to compensate for magnet inhomogeneities and determine the spin-spin relaxation time T_2.

- Follow the *Getting Started* instructions in the TeachSpin manual, p. 34.

- Investigate the Meiboom-Gill echo sequence, described in the *Getting Started* instructions in the TeachSpin manual, p. 35.

Memoranda
Some other possible topics of investigation include:

- NMR with off-resonant pulses?

- NMR of different substances besides mineral oil?