Forecast:
New Instruments
on the way
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The Relaxation Times

2495 Main Street
Buffalo, NY 14214
716-885-4701
fax 716-836-1077

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Transforming Earth's Field NMR

Our "Chevrolet" becomes a "Ferrari"

David's been up to his old tricks. He, like George, never saw an instrument he couldn't improve. I'm speaking of Professor David Van Baak, our collaborating physicist from Calvin College, who, last year, purchased the Earth's Field NMR apparatus for Calvin's advanced lab and soon after wrote TeachSpin that he had significantly improved it. Now, EFNMR 1-A has been one of our most successful instruments and we believe it is probably the best apparatus to use when introducing students to the fundamental ideas of magnetic resonance in the sophomore, junior, or senior year. But now it's even better, I mean significantly better.

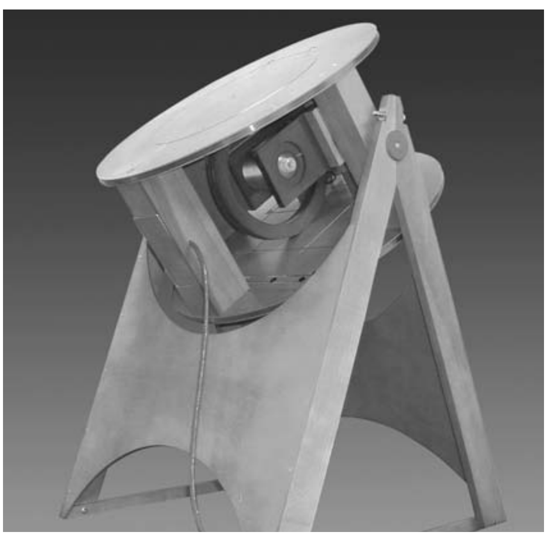


Figure 1: EFNMR Gradient and Field Coils

What David did was to design and construct a set of **gradient and field coils** that he incorporated into the EFNMR 1-A apparatus. Let's talk about the **gradient coils** first. These coils can be used to correct the three relevant first order gradients in the local ambient magnetic field. These coils, with their built-in current regulated power supply, are manually adjusted by the student to render the local magnetic field in the teaching laboratory environment significantly more homogeneous over the sample volume. This, in turn, allows the nuclei in all parts of the sample to precess at the same rate, resulting in a free-induction decay (FID) limited by the intrinsic spin-spin interaction T_2, rather than by the magnetic field inhomogeneity (T_2*).

For example, consider the FID time constant taken in TeachSpin's laboratory (and this is one of our best locations), shown in Figure 2.

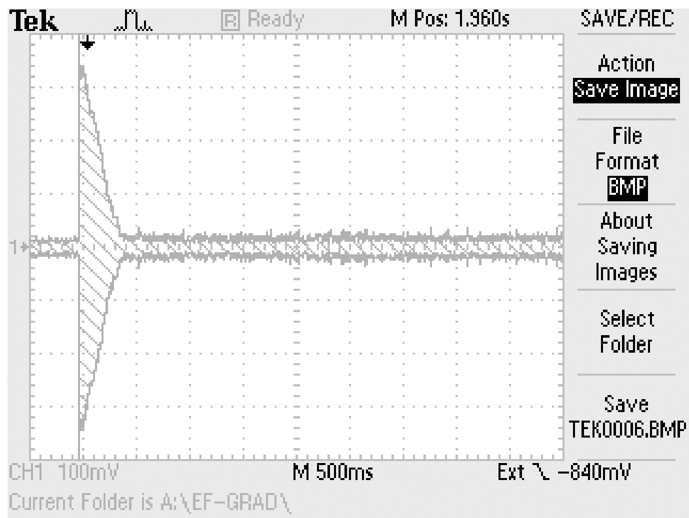


Figure 2: FID in Ambient Earth's Field

Figure 3 shows the FID signal from the same sample at the same location, with the gradient coils adjusted for a maximum decay time of the FID.

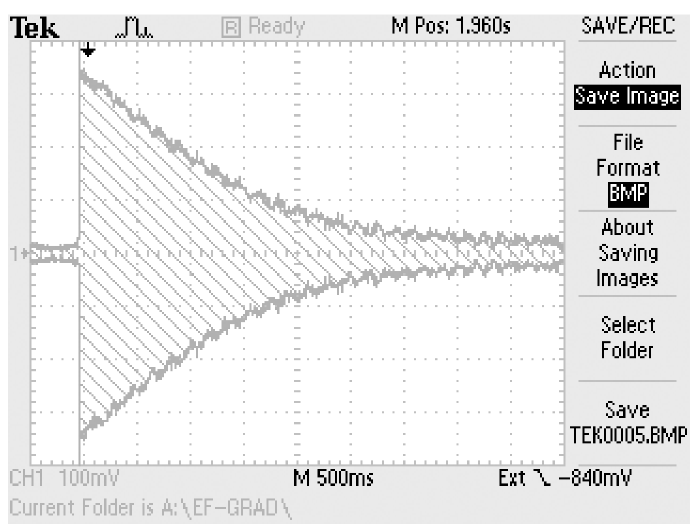


Figure 3: FID Optimized by Gradient Coils

(continued)

For this system to function correctly, the axis of the z-gradient (dB_z/dz) must lie along the axis of the local field. This is accomplished with the help of a sensitive dip compass inserted between the coil forms, at the place where the sample resides. The entire gradient coil assembly is then rotated about a horizontal axis until the local field is collinear with the z-axis of the coils. The coil assembly is then locked in place.

The magnitude and direction of the current passing through each of the three gradient coils is controlled by a 10 turn potentiometer on the front panel of the controller. These currents can be individually monitored by measuring the voltage across a 0.1 ohm standard resistor in series with the coil selected on the front panel. (See Figure 4.)

Figure 4: Earth's Field and Gradient Coil Controllers

This unit also includes a set of Helmholtz **field coils** which produce a uniform 270 μT magnetic field when connected to a separate 3 A current regulated power supply. These field coils can be accurately modeled from their geometry and thus used to determine, with high precision, the absolute values of the gyromagnetic ratios of various nuclei. The increased range of magnetic fields allows other nuclei to be brought into the tuning range (1.6 – 2.5 kHz) of the EFNMR instrument. These nuclei include the biologically relevant ^{23}Na and ^{31}P as well as the deuteron in heavy water D_20.

The EFNMR Field Coils and controller are designed to provide a "pulsed gradient" along one dimension of the sample. These pulsed gradients create a spin-echo in which the precessing spins dephase due to a deliberate field gradient, but then are rephased after the deliberate gradient is quickly reversed. Figure 5 shows a "pulsed gradient spin echo" in a water sample.

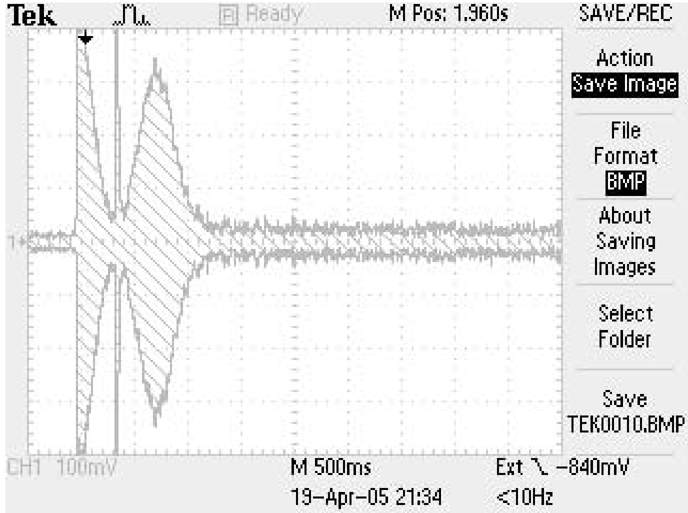


Figure 5: Pulsed Gradient Spin Echo

But this is a spin echo the student can actually hear! More than that, with a little practice, the student can manually time the gradient reversal and thus set the time for the echo to occur. *This is truly magnetic resonance carried out on a human scale, with FID in the audio range and spin echo manually produced!*

Control of the magnetic field gradients allow the creation of a deliberate one dimensional gradient of the magnetic field to be imposed along a sample. This, in turn, maps spatial locations in the sample to precession-signal location in frequency space. Using TeachSpin's "Segmented Sample Container," and a user supplied Fourier transform analysis, students can perform experiments in one-dimensional magnetic resonance imaging. This is a logical introduction to the widely used medical MRI technique that most students have encountered.

TeachSpin's EFNMR Field Coils, together with their controller unit, form an add-on that can be retrofitted to the existing EFNMR1-A, or they can be supplied with the EFNMR1-A in place. Either way, this coil system markedly increases the number and character of experiments in nuclear magnetism that can be performed directly under student control.

TeachSpin expects to be delivering these units by mid May. Please inquire as to price by phone, fax, or email.

Muons on Parade

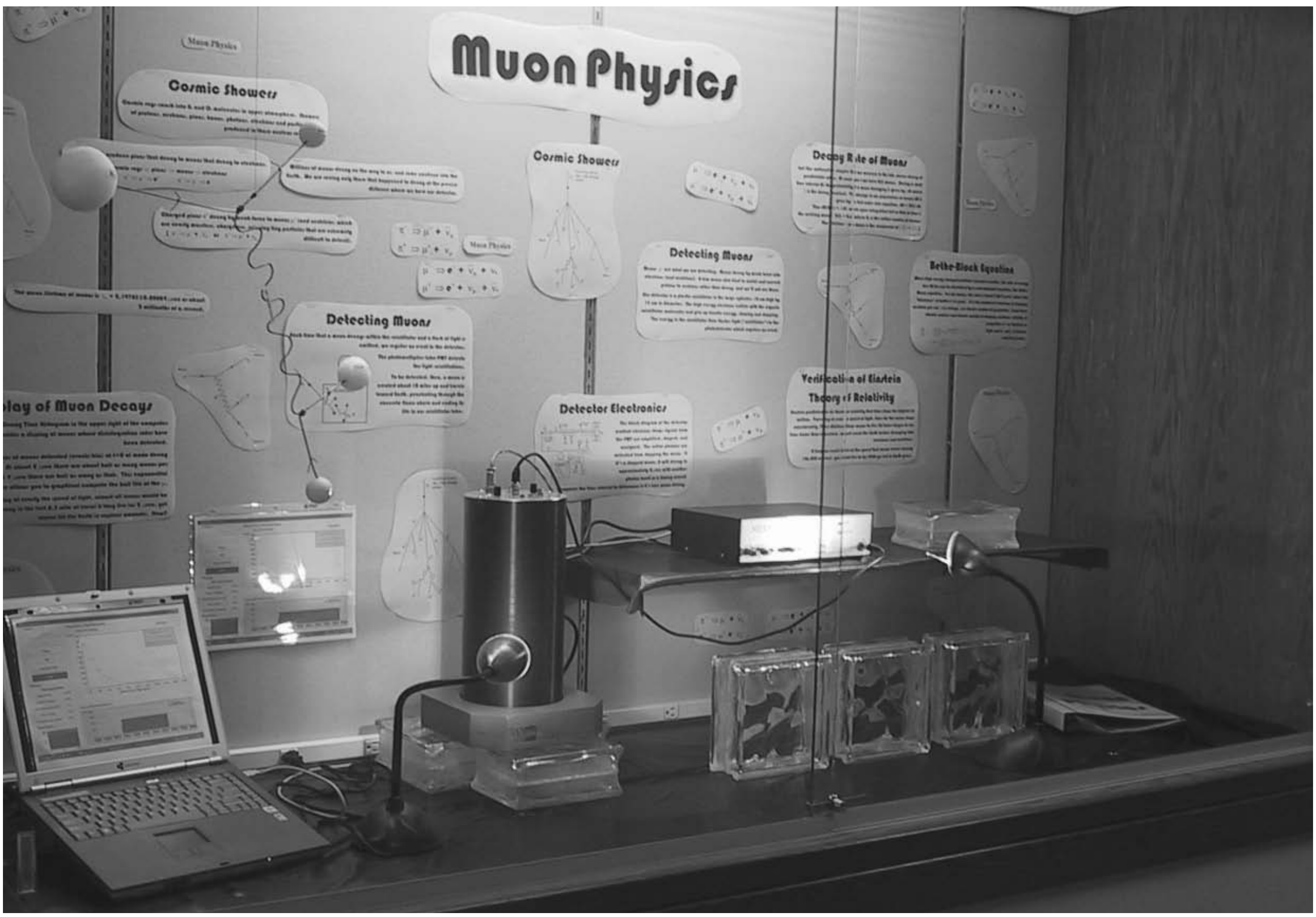
What better way to pique the curiosity of passing students than a hallway display doing physics in "real" time. Dr. Gerald Smith of Huntington College, Huntington, Indiana made sure that the new science building he helped design in 2002 included such spaces. Last fall, he set up his Muon Physics apparatus to "collect live muon data that is displayed on a laptop screen inside the case." He sent us this wonderful picture of the display case he created.

To help his students understand what they are seeing, Dr. Smith created a "wire representation of the Feynman depiction of muon decay," and used images from the operating manual to illustrate other explanations. Once set in action, the system records the passage of these mysterious particles through the apparatus, as well as indicating the apparent lifetime of those captured in the system itself. For Dr. Smith's students the presentation brought to life some of the topics they discuss when talking about relativity and helped set the tone for the World Year of Physics celebration at the college.

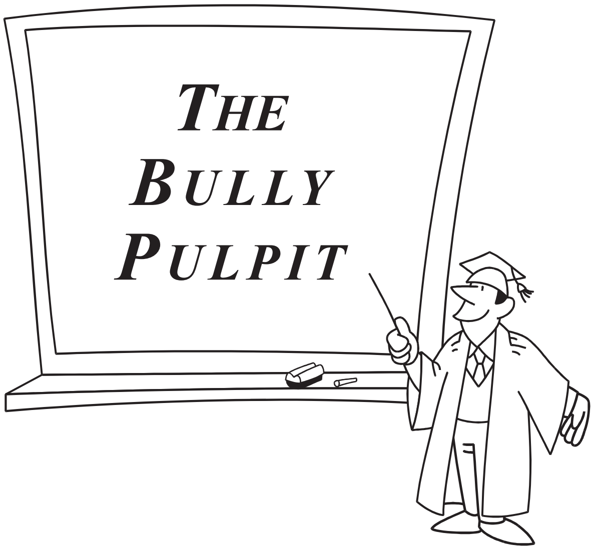
According to designers, Jingbo Ye and Thomas Coan of Southern Methodist University, the Muon Physics apparatus is particularly well suited to hallway displays. Not only can it be run continuously for days or weeks with no problem, but the longer the data collection time, the better the fit for the muon lifetime calculations. Students can check back for updates and get a sense of how much data is truly "enough" to make a valid measurement. In addition, watching the numbers of non-trapped muon events accumulate gives students a sense of the way we are continually bombarded by these subatomic particles.

Partial Muon Systems Now Available

In response to inquiries by a few of our customers, it will now be possible to buy either the Detector Module or the Controller and Software system of the Muon Physics apparatus individually. This may make it possible to hold down the cost of introducing this wonderful experiment by using apparatus you already own or can build. Within one semester, however, additional modules ordered will be priced as if they were part of the initial purchase.



The Bully Pulpit



We begin a new feature in the "Relaxation Times" with this issue, which, being a rabbi's son and grandson, I will call "The Bully Pulpit." It is a chance for me and Barbara (a nationally honored teacher) to discuss our teaching philosophies and concerns with you. Although we are completely consumed in running this company, neither of us has lost our "itch" for teaching and interacting in a creative and productive way with students.

We welcome your input. If you disagree with the essay, please write your response; we will likely publish it. If you also have a pedagogical "itch," please scratch it here. We would be delighted to print your guest column. You can add it to your vita, and let your dean try to figure out what "The Relaxation Times" is. It is a refereed journal, and I am the referee! Let's begin the dialogue.

Suppose I was given a Hobson's Choice (look it up in Webster's or Google) that I could give only one piece of advice to a new faculty member teaching any laboratory course. What would I choose? This would not be too difficult a decision for me. I would tell them to design their labs so that students do multiple experiments on the same equipment over a time span of at least two separate laboratory periods. Let the students become familiar with the equipment; in fact, let them "play" with it, see what all the knobs do, make the signal get smaller and larger, change the masses, change the connections, jot down some preliminary data, etc. You get my point!

Let me relate my own experience many years ago with a new set of microwave experiments I designed for sophomore physics majors at SUNY Buffalo. The series of experiments lasted several months, meeting one entire afternoon (4-5 hours) once a week. For the first two weeks, I had a near mutiny by the students. No one knew what a reflex klystron was, nor, for that matter, a waveguide, an attenuator, microwave horn, a detector, a decibel, in short almost every piece of equipment and definition was new to them.

TEACHSPIN
Tri-Main Center 409
2495 Main Street
Buffalo, NY 14214

From the students' point of view, the equipment alone was overwhelming, much less the physics and the experimental techniques I wished to explore. They were upset and confused. I suppose they could have followed detailed instructions, taken data, and produced some report, but I doubt if any real learning would have occurred.

But, after six weeks of using ***the same instruments***, the students had become so familiar with the apparatus, and so skillful with it, that they confidently attacked a sophisticated measurement of the microwave attenuation of multiple slabs of absorbers. A few students even made important contributions to the experimental design and, almost all of them, took ownership of these measurements. By ownership, I mean they made choices as to the way the measurement was to be carried out, the number of data points, sometimes the exact setup, as well as the mathematical analysis of the data.

We are teaching experimental physics, not training technicians to follow detailed orders. We do not need them to know what button to push on the computer, or what menu to pull down to run the unit automatically. For students to make the lab course a learning experience, they need "ownership" of the equipment. They need to develop their own experimental strategies. They need to make mistakes and rectify them. To do this, ***students need time***.

I used to tell the class, it is not what we "cover," it's what we "uncover," that really matters.

Rethink your labs. Air tracks can be used for many experiments. At least five different experiments can be done with Magnetic Torque, but not in one or even two sessions. Give the kids the same "courtesy" you give yourself when you are confronted with a new piece of unfamiliar equipment. You may be surprised at the results.

Jonathan