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Magnetic Recording of Neutron Cross-Section Data from an Underground Nuclear Explosive Source*

by

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MAGNETIC RECORDING OF NEUTRON CROSS-SECTION DATA FROM AN UNDERGROUND NUCLEAR EXPLOSIVE SOURCE

by

H. D. Arlowe and A. P. Furnish

Abstract

A small portion of the neutron cross-section data obtained from physics shot 8 (an event at the Nevada Test Site) was recorded in frequency modulation form on a rotating hard-surfaced magnetic disc. This is a novel way of recording these data. Magnetic recording allows electronic digitizing of the data, and thus eliminates the need for time-consuming film reading.

Introduction

A small portion of the neutron cross-section data obtained from physics shot 8, an event at the Nevada Test Site, was recorded in magnetic form. This novel way of recording these data departs widely from the conventional oscilloscope and moving photographic film method. The experiment was a proof of the magnetic recording method. No new or unusual data were to be recorded, and similar data were recorded at the same time by conventional methods.

Frequency-modulation recording was used, with a rotating hard-surfaced magnetic disc as the recording medium. Advantages realized include electronic data digitizing, with no time-consuming film reading process, and elimination of the cable run between detectors and recording stations.

Recording System

Figure 1 is a block diagram of the recording system. Analog signals from solid-state detectors viewing the targets are fed first through logarithmic preamplifiers that reduce variation in signal amplitude (but raise the amplitude precision required). Each signal next modulates a voltage-controlled oscillator. The resulting frequency is then recorded on the disc. Elements of this recording system are described below.

Disc Recorder and Associated Electronics

The disc used for the physics 8 shot was made by Data-Disc, Inc., of Palo Alto, California. This particular machine, as purchased, included only the basic transport with head driver and playback preamplifier electronics. The basic machine records to saturation, like a disc memory for a computer. It does not use a bias oscillator, and cannot be used for linear recording.

It turns at 3600 rpm, and will record an rf signal up to 6 or 7 MHz. At Sandia Laboratories, Albuquerque, FM electronics for the machine were designed and built to have a center frequency of 4.5 MHz and a deviation of ±33%. The playback discriminator is of the pulse type with a low-pass, constant-delay output filter. The resulting system is down 3 dB at 2 MHz and has a rise time of $<$ 200 nsec and a 100:1 signal-to-noise ratio (rms to rms). The present system has 16 channels of FM capability, but it could easily be expanded to 24 channels. The total recording time is 1/60 sec. The system is triggered, like an oscilloscope, and recording starts within 1μsec after the initial rise of the trigger pulse.

The disc is aluminum, 12 in. in diameter and 1/4-in. thick. The recording medium is a nickel cobalt coating, covered with a thin layer of rhodium. The outer inch or so on both upper and lower surfaces of the disc is used. The heads are not mounted side by side, but are spiraled across the surface to reduce crosstalk. The heads contact the surface at rest, but are separated from it by an air cushion ($\sim$ 5-μin. thick) when the disc is rotating at 60 rps.

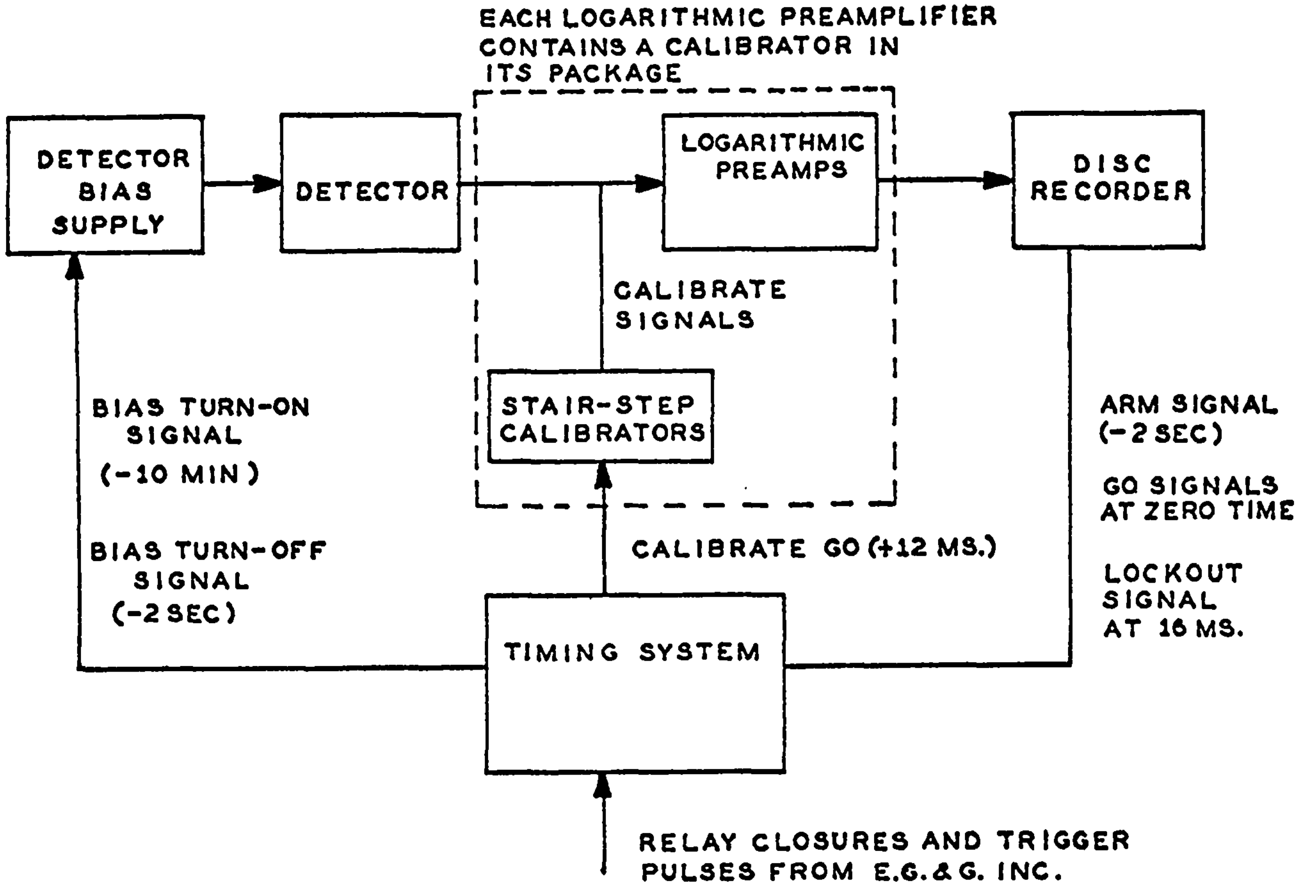

Fig. 1.
Simplified block diagram of the recording system.

The magnetic disc offers many advantages over other methods of recording transient events. First, the disc is its own high-mass transport. Therefore, it is simpler, more rugged, more reliable, and less expensive to produce than conventional tape transports. Second, the recording medium is actually part of the disc, thus eliminating tape-handling problems such as alignment. Third, there is no tape or film storage required, so the overall machine is smaller and lighter.

Fourth, the data are played back at a repetition rate equal to the disc rpm. This means that the data are easy to locate, because they can be displayed on an ordinary oscilloscope. Furthermore, because the data can be played back repeatedly, all data-analysis methods formerly applied only to repetitive signals can now be applied to transient data.

Fifth, the equipment is simple and easy to set up. There is no film loading or adjustment of oscilloscope intensity and focus.

Detectors, Amplifiers, and Timing System

The detectors and logarithmic preamplifiers are similar to those used in previous Los Alamos Scientific Laboratory (LASL) neutron cross-section experiments with bomb neutrons. They are described in Refs. 1 and 2. An input-output characteristic of the log preamplifiers used on this experiment is shown in Fig. 2.

Each preamplifier includes a stair-step amplitude calibrator as shown in Fig. 1. Amplitude calibrations

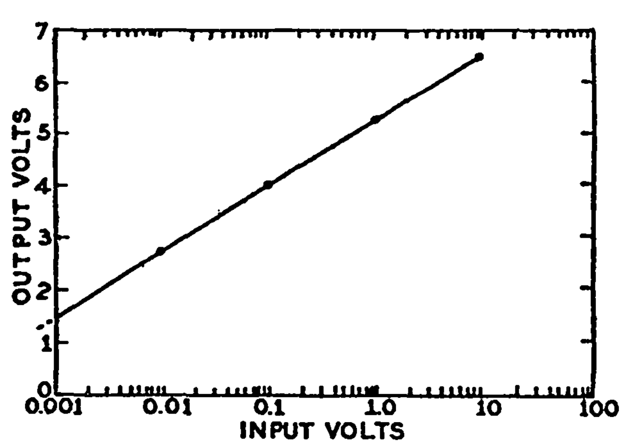

Fig. 2.
LASL Model 6 logarithmic preamplifier, input-output characteristics.

were put on the signal lines $\sim$ 10 msec after the event.

Smoothers, low-pass RLC filters with 0.6-μsec impulse response, were used on all three signal channels. These performed two functions. First, they helped make the disc recorder impulse response similar to that of the photographic recording system (similar smoothers were used on the oscilloscope inputs that displayed the corresponding data). Second, they minimized the problem of "aliasing," misleading presentation of signals that occur above the 4.5-MHz recorder carrier. An 8-MHz signal at the recorder input produces components that can appear as false 1-MHz data (8 MHz - 4.5 MHz = 3.5 MHz, which is 1 MHz away from the carrier frequency). The smoothers greatly attenuated all signals with frequencies above the carrier frequency.

Time calibrations consisted of crystal-controlled sine waves recorded on two disc tracks, one at 1 MHz and the other at 5 MHz. The purpose of these two frequencies is shown in the section on data reduction.

System timing was quite simple. At -10 min, the detector bias supply was connected. At -2 sec, this supply bias connection was removed (this is the practice followed by the other experimenters in Groups P-3 and W-8)* and the disc record circuits were electronically armed. Recording started within $\sim$1 μsec of the zero-time fiducial trigger. At +10 msec, the amplitude calibrations were done, and at +13 msec, recording stopped and a lockout relay was closed to preclude further recording. All power was removed at $\sim$ +110 msec.

Mechanical Considerations

The recorder's ability to withstand shock was a matter of some concern. Shortly before this experiment, the recorder was sent back to the factory where the frame holding the disc was equipped with nylon "snubbers" to limit disc distortion under shock.

The equipment was mounted on the sixth floor of the physics shot 8 tower at ground zero. The recorder and most of the other equipment used was mounted in a double-walled box. Inflated inner tubes filled the space between the walls. An accelerometer mounted above the recorder indicated a peak acceleration of 6 G for $\sim$ 30 msec. None of the equipment seems to have been damaged by this shock.

Cables and Grounding System

Mounting our compact data-gathering system at ground zero virtually eliminated the long noise-producing cable runs used with the conventional oscilloscope-filled recording vans. Our detectors were $\sim$25 ft from the equipment box. In the future, however, this advantage may vanish if the disc recording system grows and adds much peripheral equipment, as seems to be true of all recording systems. It would probably then be mounted in a van.

A double-shielded cable system was used, with an inner shield, or braid, and an outer shield, or armor. Armor shields were tied to each other and to the braid at one point only, and the braids, in turn, were tied to each other at only one point. AC power was isolated from ground and from power-line transients by a motor generator set.

Data Obtained

Recording was done simultaneously on five tracks, three data and two clock tracks. Signals from ^{235}U, ^{6}Li, and a blank foil were recorded on the data tracks. Amplitude stair-step calibrations were put on the signal channels milliseconds after the event. No unusual background signal was noted from the blank foil, and no magnetic effects were observed.

Data Reduction

A first look at the data was obtained by playing it back repetitively on an oscilloscope, which permits determination of the time between the disc trigger and the data of interest. This delay is then set in on a digital-delay counter that runs off the prerecorded, 1-MHz clock signal. Finally, the scope sweep and gain are adjusted to display the data as desired.

For a permanent record, a picture can be taken; or, as we have done, a sampling-type display converter can be used to record the trace onto an X-Y plotter. Because no speed reduction is needed, the maximum signal-to-noise ratio is maintained. Figure 3 is a plot obtained in this manner, showing a portion of the data from the ^{235}U detector.

A major advantage for the disc recorder is its adaptability to digitizing. Using the sample-and-hold method, we were able to digitize our physics 8 data at 480 samples/sec (8 samples/revolution) and yet have an apparent digitizing rate of 50 million bits/sec. [Our 5-MHz clock track allowed 5 samples/μsec. We used 10 bits of amplitude information on each sample: (5 samples/μsec) $\times$ (10 bits/sample) $\times$ (10^6) = 50 $\times$ 10^6 bits/sec.]

Figure 4 is a simplified block diagram of the digitizing system. Each amplitude sample was located in time by counting the 5-MHz clock track. A 1/2-μsec gate sampled the data at that time. The resulting sampled data pulse was stretched to several microseconds wide

*The charge on a 5-μF capacitor in each signal line between detector and amplifier provides bias voltage at shot time. Breaking the bias supply connection at -2 sec eliminates any possibility of charging current flowing to this capacitor during data-gathering time. Such current would appear as a negative signal at the log amplifier input.

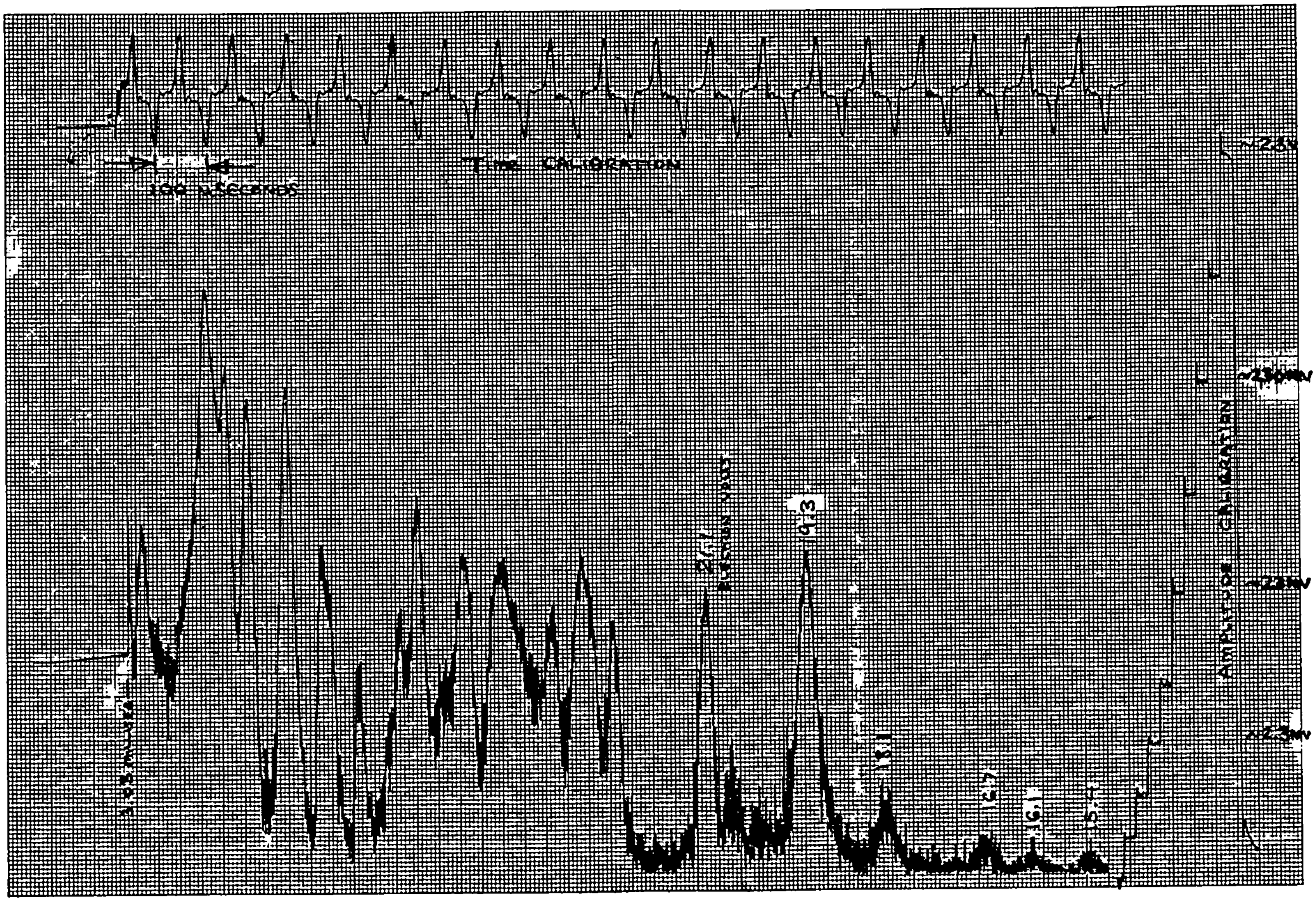

Fig. 3.
Magnetic disc recording data. 235 U signal from physics shot 8.

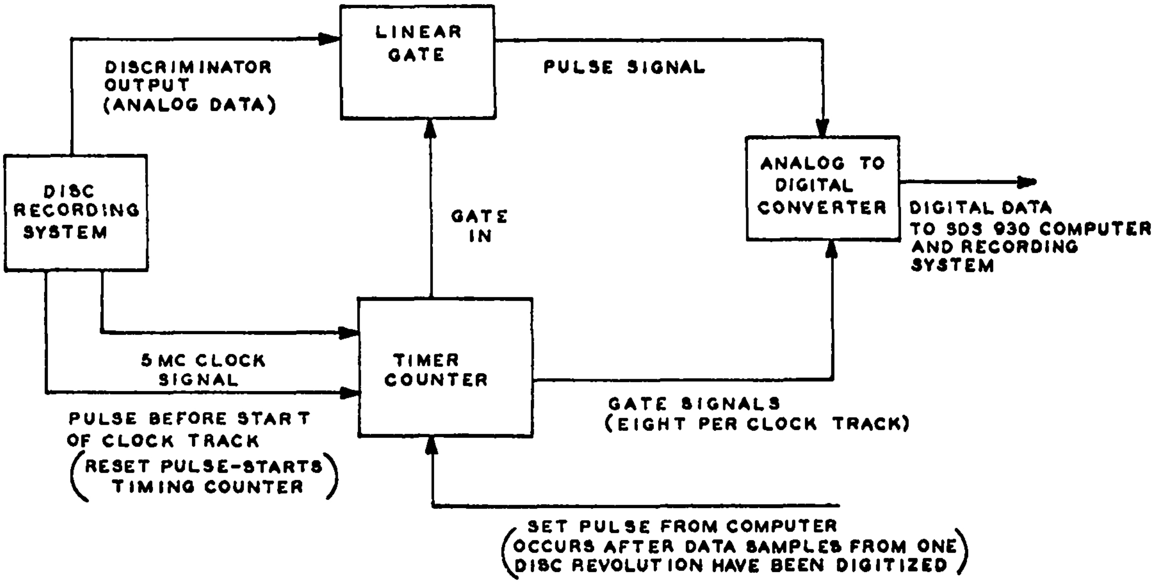

Fig. 4.
Simplified block diagram of digitizing system.

and put on tape in digital form.

The computer sampled the data at points 2^{13} counts apart on the 2^{16} -pulse clock track. (This resulted in eight samples per revolution, and speeded up readout time.) It then added 1 to the count at each sampling point and repeated the operation.

Digitizing time was 2 min 20 sec per track. An additional 15 sec per track was required to record this information on magnetic tape. The digitizing time could have been reduced by another factor of 8 if the computer had been used to capacity, but its time was being shared with other experimenters.

After the data was on tape, it was checked by reading it out on an X-Y plotter.

Conclusion

The experiment was a complete success. It seems possible that this type of equipment may eventually replace the oscilloscope-camera system for recording many types of nuclear-transient data. Magnetic disc recorders are now available with signal-to-noise (peak-to-peak video rms noise) ratios of 300/1, dc bandwidths to 4 MHz, and a cost of about $1500.00/channel.

Acknowledgments

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