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by

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*Work performed under the auspices of the U. S. Atomic Energy Commission, Contracts W-7405-Eng. 36, Los Alamos Scientific Laboratory, and AT(29-1) 789, Sandia Laboratories, Albuquerque.
MAGNETIC RECORDING OF NEUTRON CROSS-SECTION DATA FROM AN UNDERGROUND NUCLEAR EXPLOSIVE SOURCE

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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.

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 1 μsec 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 (~ 5-μin. thick) when the disc is rotating at 60 rps.
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
were put on the signal lines ~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 prob-
lem 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 fre-
quencies 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 ~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 ~+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 ~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

*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.

ground zero virtually eliminated the long noise-
producing cable runs used with the conventional
oscilloscope-filled recording vans. Our detectors were
~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 back-
ground 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) X (10 bits/sample) X (10^6) = 50 X 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
Fig. 3.
Magnetic disc recording data. $^{235}$U signal from physics shot 8.
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**

This experiment was done jointly with Sandia Laboratories in Albuquerque. The authors wish to acknowledge particularly the help of R. D. McAvoy of Sandia in developing the recording system; of E. R. Shunk, A. N. Ellis, and J. M. Anaya of LASL in designing and constructing the mechanical package and shock mounting system; of W. K. Brown and M. G. Silbert of LASL in providing and installing the semiconductor detectors and bias system; and of A. H. Greenwood and J. S. Levin of LASL for digitizing the data. W. K. Brown also spent much time helping set up the entire system and working out an operating procedure suitable for Nevada Test Site conditions.

**References**

1. A. Hemmendinger et al., Los Alamos Scientific Laboratory report LA-3478, June 1968.