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FIELD TEST OF A THREE-CHANNEL SEISMIC EVENT DISCRIMINATOR

Sheldon W. Buck, et al

Charles Stark Draper Laboratory, Incorporated

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by

Sheldon W. Buck
David S. Burns
Lawrence S. Freier

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A practical three-channel seismic-event-discriminator breadboard was employed at the Harvard College Observatory located in Harvard, Mass. to monitor, in real time, three short-period seismometers. The major objective for placing this breadboard system in the field was to demonstrate that preprocessing of seismic data on-site (thereby reducing recording and transmitting requirements) was a viable and workable concept.

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Background information pertaining to the event-discriminator test plan; experimental test installation including the seismometer set up, interfaces and recording equipment; interface circuits, and calibration procedures and test results of the seismometers is provided.

The viability and advantages of event discrimination are clearly demonstrated from the in-field test results. Selection of the on-site parameters is definable within 1 month of field testing. A significant reduction in recording time was demonstrated during the later 3-week test period in which optimum site parameters were employed. During this period, recording of preprocessed seismic data required 1/100 the time of that required to record seismic data continuously.

A summary and interpretation of in-field testing data is presented.

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SECTION 1

INTRODUCTION

This report describes the field testing of an event discrimination system for an Unattended Seismic Observatory (USO). This test was performed at the Agassiz Station of the Harvard College Observatory located in Harvard, Mass. This particular USO event-discriminator design provides for the remote adjustment of critical detection parameters in order to tune the discriminator to a particular site location. The test program attempted to assess the sensitivity of these adjustable parameters with respect to providing a reliable seismic trigger and end-of-event signal. In addition, the test results indicate the reduction in magnetic-tape usage with respect to the tuning of the event discriminator and the sensitivity of the trigger threshold.

An interesting feature of the system is the use of an independent detector on each of the three short-period channels (vertical, north, and east). This feature was originally incorporated (a single vertical detector being more common) to provide a better probability of detecting a nearby event (this being a primary goal of the USO program). It was felt that the shear-wave energy near the source would be high enough to provide a reliable trigger. In fact, the three-axis system finally developed was not only able to detect nearby events on all three channels (providing the desired backup) but could also detect separate phases of teleseisms. In particular, the horizontal detectors could locate the delayed s-waves that the vertical channel missed.

This report is organized in the following manner. Section 2 presents an overview of the event-discriminator test plan and the basis on which the testing of an event discriminator was approached. Section 3 describes the experimental test installation at the Agassiz Station, including the seismometer setup, event-discriminator interface, and recording equipment. Section 4 summarizes the circuit changes made to the event-discriminator breadboard since the testing at the Vela Seismological Center in Alexandria, Virginia under a previous contract.

The results of this effort are documented in CSDL report R-765.*
These changes were required either to improve event-discriminator performance or to provide additional signal conditioning for the test installation at Agassiz. Section 5 documents the calibration of the three orthogonal short-period seismometers used for this test. Section 6 summarizes the test results obtained under the present contract. Section 7 presents conclusions on the performance of the seismic-event discriminator and its appropriate utilization.

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* Eterno, J. S., D. S. Burns, L. J. Freier, and S. W. Buck, "Special Event Detection for an Unattended Seismic Observatory", CSDL report R-765, March 1974.

SECTION 2

OVERVIEW OF TEST PLAN

From the testing at the Vela Seismological Center, optimum parameter settings were determined for the three-channel event discriminator, based upon seismic magnetic-tape recordings. It was well known that the parameters selected might change significantly when on-site, real-time seismic data was being obtained. Because of this, a test plan was defined so that proper evaluation of the three-channel event discriminator breadboard with three Geotech (S-13) short-period seismometers could be made.

The basic test plan was subdivided into three phases. During Phase 1, parameters were varied to determine which set would yield near-optimum results. The parameters varied included:

(a) Center frequency of frequency-select filter.

(b) Signal-to-noise (S/N) ratio setting.

(c) Long-term average time constant.

(d) Minimum time duration that the S/N threshold was exceeded.

(c) Strobed delayed time employed in converting the long-term average signal voltage into a digitally stored quantity.

After the objectives of Phase 1 had been achieved, Phase-2 testing, using constant parameter settings, was conducted.

Based on test results achieved during Phase 2, a slightly revised set of parameters for long-term-testing was used for the final test series, Phase 3, to yield optimum results.

SECTION 3

EXPERIMENTAL TEST INSTALLATION

This event-discriminator field test was performed at the Agassiz Station of the Harvard College Observatory located in Harvard, Mass. The seismology laboratory at the Agassiz Station consists of a small brick building which houses the recording, telemetry, and office equipment at ground level, and a 20- by 20-foot underground vault whose ceiling is covered by approximately 15 feet of dirt. Figure 3-1 shows a plan of the Agassiz Seismology Station. The underground vault contains three corner piers, in addition to the primary central pier. Using the corner piers, a pair of 19-foot long-period mercury tiltmeters were installed around the periphery of the vault. The principal instruments, located on the central pier, consist of a Lacoste-Romberg tidal gravimeter, a Geotech 7505A long-period seismometer, and three Geotech S-13 short-period seismometers arranged orthogonally. The three short-period seismometers were the sensors used in testing the seismic event-discriminator system. The recording equipment consisted of an eight-channel pressure-fed-pen chart recorder (Brush, Mark 200). Preamplifiers, located in the vault next to the seismometers, boosted the signal level at the input of a cable system running up a flight of stairs to the recording room. The event-discrimination circuitry was located next to the chart recorder in the recording room for convenience in adjusting the detection parameters.

After the seismometer calibration had been assured and the signal conditioning and cable electronics had been debugged, the vault was closed for the duration of this test. Regularly scheduled maintenance on an alternating-day basis was performed in order to make routine chart-paper changes and assure clean ink flow on the pressurized pen system. Chart-recording speed was 1 mm/second in order to preserve high-frequency seismic signal information for later analysis with respect to event-discrimination parameter settings.

A block diagram of the experimental test installation is shown in Figure 3-2.

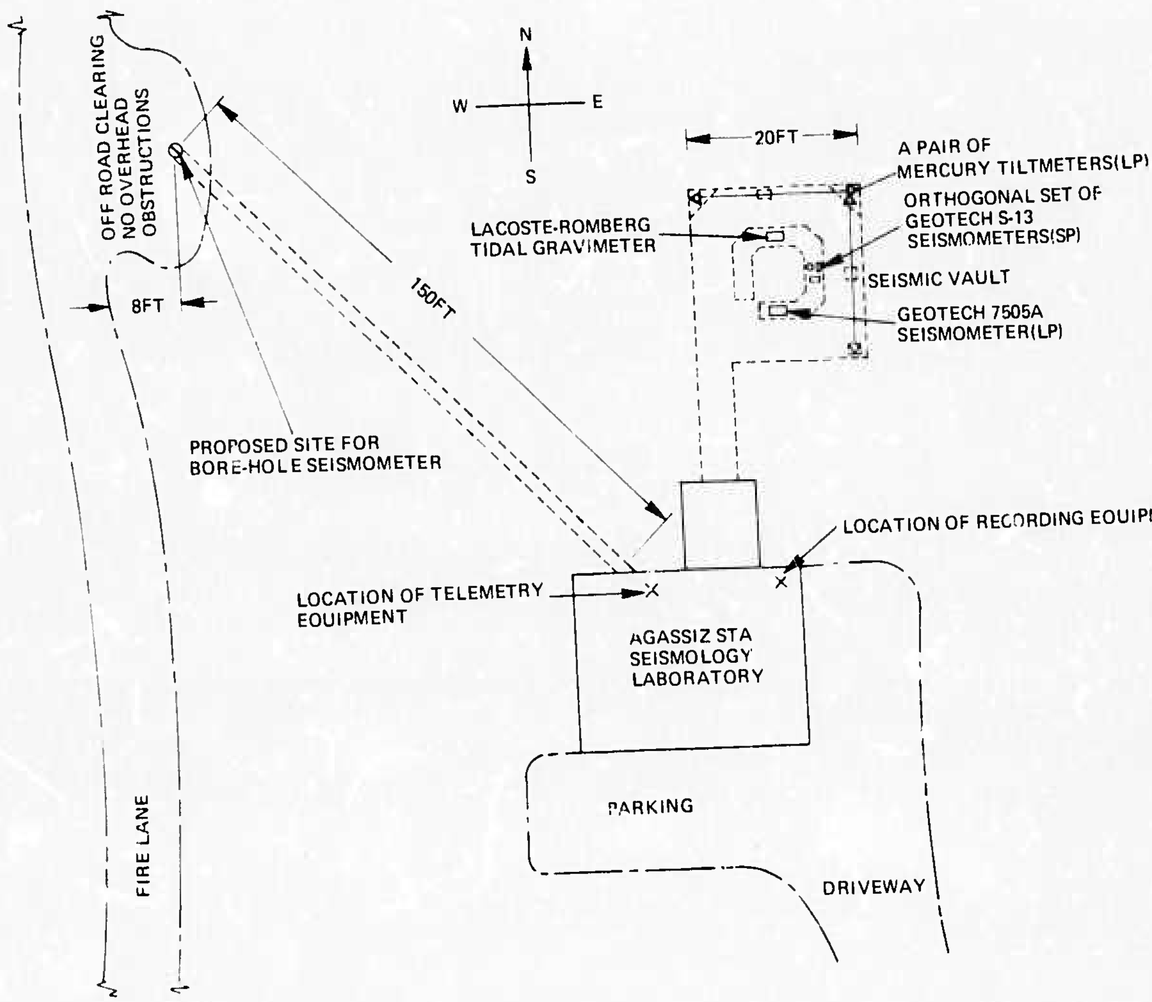

Figure 3-1. Experimental test installation.

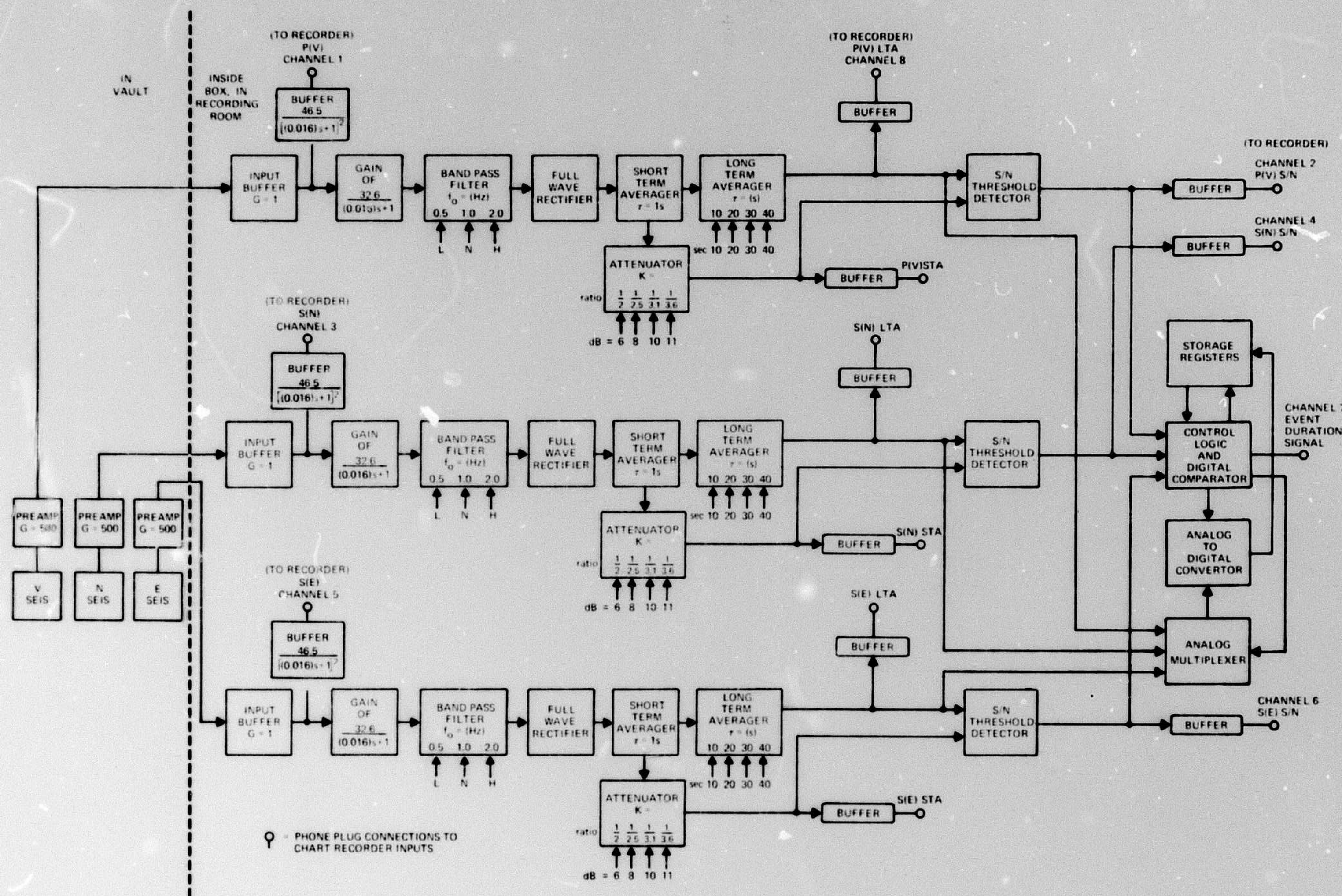

Figure 3-2. Event discriminator, block diagram.

SECTION 4

DOCUMENTATION OF CIRCUIT CHANGES

In addition to the event-discriminator box that was taken to the Vela Seismological Center for testing, some additional circuits were needed for interfacing with the Agassiz Station seismometers. A low-noise preamplifier was designed using the Precision Monolithics SS725E. The principal characteristics of this preamplifier are: a differential input with balanced input resistance to the common; a common mode rejection ratio of >105 dB (at the temperature measured and trimmed); low offset voltage and drift; and very low input noise (1.45 μV pk-pk predicted maximum). The gain of this stage was set at 500 and the differential input impedance was fixed at 10 kΩ to allow a resistance to be shunted across the input to bring the seismometer load resistance down to 6.5 kΩ for critical damping without changing the gain. The output of the preamplifier drives a twisted, shielded pair of wires over which the signals are transmitted from the vault to the event-discriminator box. A modular power supply for the preamplifiers was mounted in a separate metal box to keep power-line noise to a minimum.

Considerable effort was expended to eliminate the sources of 60-Hz noise in the vault. Originally it was assumed that the noise was a result of improper grounding and shielding. Several variations of earth, case, and shield grounding were tried, with minimal effect. About 1 mV pk-pk of 60 Hz (referred to the input) remained after all grounding and shielding attempts were made. Finally, it was determined that this signal was actually coming from within the seismometers and appeared as a differential voltage out of the instruments. Since no solution could be found to eliminate the noise, it was decided to employ filtering in the electronics.

The event-discriminator box was essentially the same as the one employed in the second Vela trip. Since the box already contained input and output buffers for recording the raw seismometer signals, the three input wires from the vault were tied directly into the event-discriminator box. The differential input buffers in the box provide ground translation and convert the signal to a single-ended signal with unity gain. At this point the signal is sent to the event discriminator and the recorder buffer. The recorder buffer had a gain of unity but this proved to be insufficient for the raw seismometer output, as the background noise level was barely visible on the recordings at 50 mV/mm (the most sensitive scale). The gain was increased in the recorder buffer to 4.65 and later (June 17, 1974) to 46.5 to provide for more sensitivity when recording on quiet days. Currently the overall sensitivity from the seismometer output to the recorder is 8.0 μV/mm (this assumes that the recorder is set on 0.2 V/mm for the raw-data channels). In addition to the gain provided by this buffer, low-pass filtering was added to cope with the 60-Hz problem so as to discern the seismic data more easily. A single-order pole at 10 Hz was added to the buffer and an RC filter (also at 10 Hz) was placed between the buffer and the recorder input. Therefore, the overall gain from the seismometer output to the recorder input is as shown in Figure 4-1. Figure 4-2 is a schematic diagram of the input buffer circuitry.

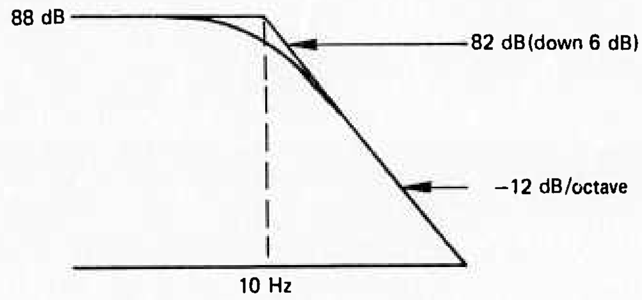

Figure 4-1. Overall gain, seismometer output to recorder input.

The frequency response from the seismometer input (ground velocity) to the recorder was determined (June 17, 1974) as part of the calibration of the instruments and was plotted (see Figure 4-3). The low-frequency roll-off is a result of the seismometer response, and the high-frequency effect (above 10 Hz) is caused by the electronic filtering.

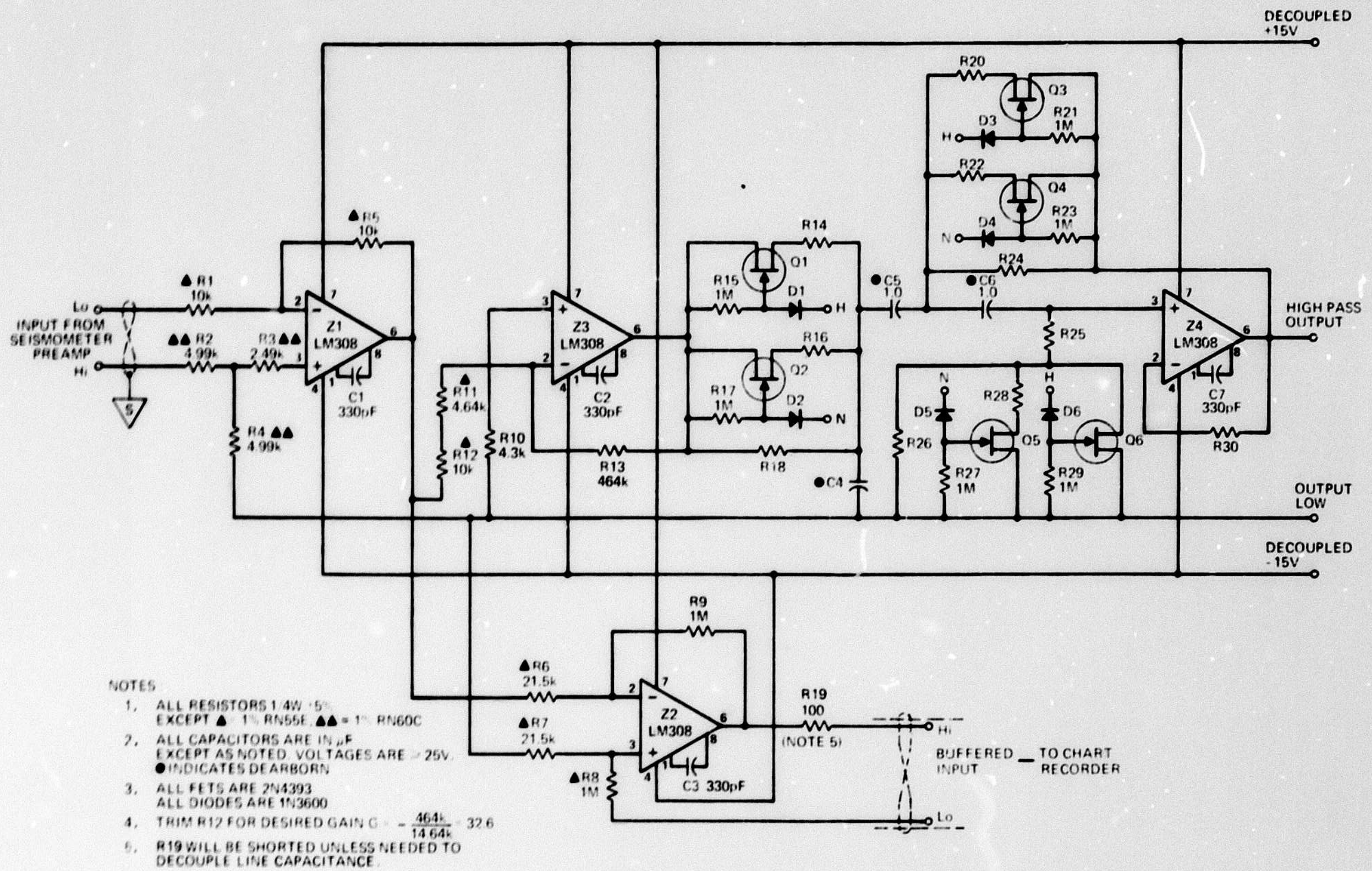

Figure 4-2. Input buffer and low-pass filters, schematic diagram.

The output of the differential input buffer also goes to the event discriminator. This signal is amplified and then band-pass filtered. For the Vela tests and for the initial tests at Harvard, the gain of the amplifier stage was 3.26. The initial tests showed that the event discriminator did not have sufficient sensitivity to trigger reliably on small events during quiet days. The gain was raised to 32.6 and a low-pass filter at 10 Hz was incorporated to help the band-pass filter reject the additional 60-Hz noise. This permitted the event discriminator to trigger reliably on signals as small as 8 mV pk-pk at center frequency (f_o) as recorded on the chart recorder. This corresponds to 0.35 μV pk-pk at the instrument output or 0.4 millimicron pk-pk of ground motion at 1.0 Hz.

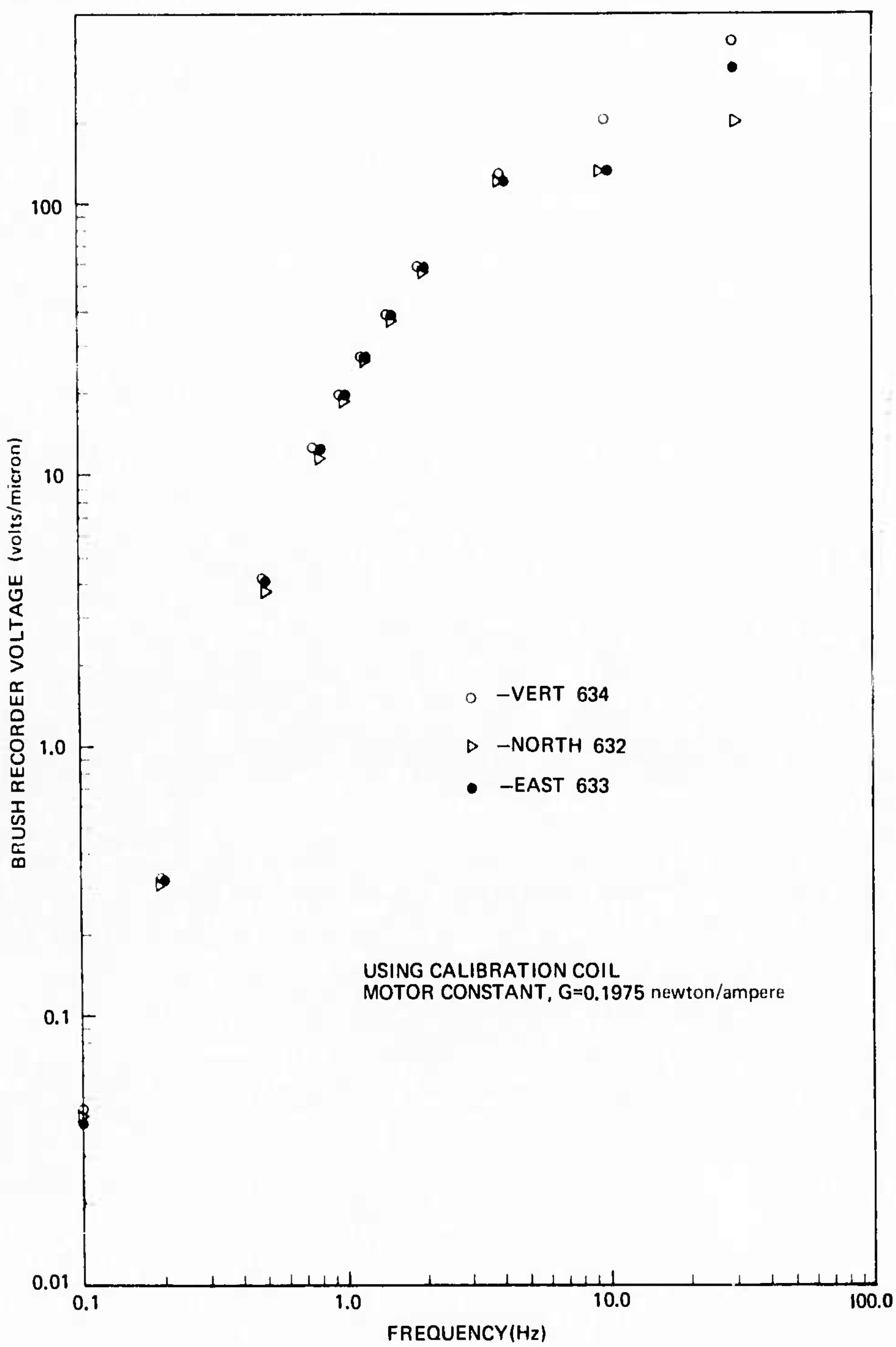

Figure 4-3. Seismometer frequency response.

SECTION 5

CALIBRATION DATA ON SEISMOMETERS

On June 17, 1974, the three Geotech Model S-13 seismometers were calibrated. This involved:

(a) Adjustment of the seismometer natural frequency to 1 Hz.

(b) Determination of the calibration-coil motor constant.

(c) Sinusoidal excitation of the calibration coil and calculation of equivalent earth motion.

(d) Calculation of earth-motion sensitivity (volts/micron earth motion) as a function of frequency.

These tests were conducted as specified in the operation manual for this seismometer. A brief description of each test follows:

(a) The seismometer natural frequency was determined by applying a dc pulse to the calibration coil with the output loaded as shown in Figure 5 of the operation manual. The natural frequency of oscillation was observed by displaying the output on an oscilloscope. This was adjusted to 1 Hz using the instrument's period-adjust control.

(b) The motor constant of the calibration coil was determined using the procedure outlined in Section 4.7 of the manual. The results did not agree well with the motor constant specified in the manual. The constants were determined to be:

Seismometer 632	G = 0.185	newton/ampere
633	G = 0.175	
634	G = 0.185	

while according to the manual,

$$G = 0.1975 \pm 0.002 \text{ newton/ampere}$$

In all later calculations, G = 0.1975 newton/ampere was used rather than the calculated values.

(c) To determine equivalent earth motion, the calibration coil was driven by a sinusoidal current of amplitude I and frequency f. The amplitude of equivalent earth motion y is given by

$$y = \frac{GI \times 10^6}{4\pi^2 f^2 M} \text{ microns}$$

where

G = motor constant = 0.1975 newton/ampere

M = seismometer mass = 5 kg (Section 4.8 of operation manual)

I = sinusoidal current (amperes)

f = frequency (hertz)

(d) The sensitivity was determined by recording the output voltage while driving the calibration coil with the sinusoidal current. It is given by the ratio of output-voltage amplitude to equivalent earth-motion amplitude and then plotted as a function of frequency.

Table 5-1 lists the values for equivalent earth motion and sensitivity for the three seismometers.

Table 5-1. Equivalent earth motion and sensitivity.

Frequency (hertz)	I_{pk-pk} (mA)	Equivalent Earth Motion Y_{pk-pk} (microns)	Recorder Output (V_{pk-pk})			Sensitivity (volt/micron)		
			North 632	East 633	Vert 634	North 632	East 633	Vert 634
0.1	3.5	350.19	14.0	15.0	15.5	0.0399	0.0428	0.04426
0.2	2	50.02	15.5	15.5	16.0	0.310	0.3098	0.320
0.5	1	4.002	15.0	16.5	16.5	3.75	4.123	4.123
0.8	1	1.562	18.0	19.5	19.5	11.52	12.48	12.48
1.0	1	1.0005	18.5	19.5	19.5	18.50	19.5	19.49
1.2	1	0.6948	18.0	18.5	18.5	25.9	26.63	26.63
1.5	1	0.4444	16.5	17.5	17.5	37.1	39.38	39.37
2.0	1	0.2500	14.0	14.5	14.5	56.0	58.00	58.00
4.0	1	0.0625	7.5	7.5	8.0	120.0	120.00	128.00
10.0	1	0.0100	1.3	1.3	2.0	130.0	130.00	200.00
20.0	2	0.0025	0.5	0.8	1.0	200.0	320.00	400.00

SECTION 6

FIELD TESTING

From June 17 through August 8, 1974, real-time, on-site testing was performed at Harvard, Mass. employing a three-channel event-discriminator breadboard. During this period, over 22 850-foot rolls of strip-chart recording paper were expended. (They were arbitrarily numbered 98 through 118.) The testing period has been subdivided into three data-evaluation phases:

(a) Data-Evaluation Phase 1 (rolls 98 through 105) - Initial parameter settings for the vertical, north, and east channels were altered to determine their optimum or near-optimum settings.

(b) Data-Evaluation Phase 2 (rolls 106 through 110) - Approximately 2 weeks of seismic data were obtained with constant parameter settings employed.

(c) Data-Evaluation Phase 3 (rolls 113B through 118) - Data was recorded for 3 weeks with a slightly revised set of parameters.

The remainder of this section describes procedures employed to critically evaluate recorded test data, analysis of data acquired during Phases 1, 2, and 3, and test conclusions drawn from on-site, in-field testing of the three-channel event-discriminator breadboard.

6.1 Seismic-Data-Evaluation Procedure

Proper evaluation of strip-chart (850 ft/roll) recorded data was a time-consuming process. Each roll contained three channels of pre-amplified raw seismic signals (vertical, north, and east), the signal-to-noise (S/N) ratio signal from each of the three channels, an event-duration signal, and a long-term average signal from one of the channels.

To reduce this data properly and efficiently, a seismic-data worksheet was devised. This permitted the reduction of 850 feet of strip-chart recorded data onto several 8-1/2 x 11 inch sheets of paper. Summarized on each data worksheet were the initial event-discriminator parameter settings per channel (vertical, north, and east), center frequency of the frequency-select filter, long-term average time constant, S/N ratio, the single minimum event-duration time, and the long-term average sampled delay employed for all three channels.

A real or false seismic event was determined from a review of strip-chart recorded data. Visual analysis of each of the three raw (after preamplification) seismic signals was performed to identify the presence of an event. If an event was deemed to have occurred, then a check of the event-duration signal was made. When the above conditions were simultaneously met, an indication of a real event would be recorded on the data worksheet. A false event would be recorded when an event-duration signal was present but could not be substantiated from the raw seismic signals.

In addition to the above, the following information about real and false seismic events was recorded on the seismic-data worksheets.

(a) Block number of the strip-chart recording, identifying where an event (real or false) had occurred.

(b) Time of an event.

(c) The channel(s) detecting an event. This was established by the presence of an output signal from the respective (S/N) ratio detector.

(d) S/N duration time (seconds) for each of the channels tripped.

(e) Length of time (seconds) the event-duration signal was present and its desired length of time. The latter is the actual time a seismic event would be recorded.

(f) An indication of whether the event was considered real or false plus pertinent comments about the event.

Missed seismic events were also reported. This was accomplished in the following manner. Raw seismic data, monitored in parallel with the three-channel event discriminator at Harvard, Mass., was transmitted via a telephone link to the MIT Earth and Planetary Science building.

This information was continuously recorded and evaluated by Mr. Al Taylor of MIT. On a weekly basis, he published a bulletin which specified the seismic events for the week. With this data it was possible to determine the events that were missed.

6.2 Data Evaluation

A summary of all seismic-data worksheets, covering the period June 17 through August 8, 1974, is presented in Table 6-1. The following subsections provide an evaluation of the test results obtained during each of the three phases.

6.2.1 Data Evaluation - Phase 1

As stated previously, this phase covered the period June 17 through July 1, 1974 in which data was recorded on strip-chart rolls 98 through 105. Data obtained during this phase, as mentioned earlier, was intended to establish initial parameter settings for future testing (Phases 2 and 3) of the three-channel event-discriminator breadboard. The interpretations and conclusions drawn from the recorded data during Phase 1 are presented below.

(a) Cultural noise, as sensed by the three seismometers, indicated a 2- to 3-Hz frequency component. Frequencies in this range (possibly caused by local trains) are extremely close to the center frequency (f_o) of the frequency-select filters. This, therefore, places an upper bound as far as selecting a higher center frequency. Attenuation to these frequencies ranges from 0 to 22 dB, based upon the center frequency selected.

Frequencies in the 2- to 3-Hz frequency band are not uncommon in the New England area. This has been observed at the Weston Observatory.*

(b) Real events, as sensed by the vertical, north, and east short-period seismometers, occurred within the 0.8- to 1.4-Hz frequency range. This was higher than

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* A Study of the Seismic Background Near Kendall Square, Cambridge, Mass. (Semi-Annual Report #1), March 1966, by Frances A. Cowley and Henry Assing, affiliated with the Wave Propagation Branch, AFCR Laboratories, Bedford, Mass.

Table 6-1. Summary of seismic-data field testing.

ROLL ID	DATE (1974)		MINIMUM EVENT DURATION	VERTICAL					NORTH					EAST					MISSED EVENTS
				INITIAL SETTING			EVENTS		INITIAL SETTING			EVENTS		INITIAL SETTING			EVENTS		
	START	STOP	(s)	f_o (Hz)	LTA(τ) (s)	S/N (dB)	FALSE	REAL	f_o (Hz)	LTA(τ) (s)	S/N (dB)	FALSE	REAL	f_o (Hz)	LTA(τ) (s)	S/N (dB)	FALSE	REAL	
PHASE 1																			
98	6/17	6/18	0.5	1.0	30	6	40	1	0.5	30	8	7	—	0.5	30	8	6	—	1
99	6/18	6/19					43	2				20	—				11	—	—
100	6/19	6/19					6	4				6	3				2	1	—
101	6/19	6/21			20		31	10		20		7	5		20		1	6	2
102	6/21	6/23					55	4				9	2				4	—	—
103	6/23	6/25					101	4				16	—				7	2	4
104	6/25	6/25	1.0			8	no events				10	no events				10	no events		—
104B	6/25	6/26		0.5		6	46	—	1.0		6	15	2	1.0		6	9	2	—
104C	6/26	6/28		1.0			9	8			8	2	6			8	1	6	4
105	6/28	7/1					53	2				—	3				1	3	2
PHASE 2																			
106	7/1	7/4	2.0	1.0	20	6	15	19	1.0	20	8	1	6	1.0	20	8	—	6	5
107	7/4	7/6					64	4				5	4				—	7	Note 1
108	7/6	7/9					27	6				—	6				2	5	Note 1
109	7/9	7/11					41	15				—	9				—	10	6 small events
110	7/11	7/13					5	6				—	7				—	6	1
113A (Note 2)	7/20	7/22	1.0	1.0	20	6	26	—	1.0	20	8	2	—	1.0	20	8	2	—	
PHASE 3																			
113B	7/23	7/24	1.0	1.0	20	8	—	7	1.0	20	8	1	8	1.0	20	8	—	3	2
114	7/24	7/27					1	13				1	14				3	12	1 small
115	7,27	7/30					2	10				3	9				1	6	2
116	7/30	8/2					2	9				2	9				2	6	3 (1 small, 2 emerging)
117	8/2	8/5					2	—				1	—				—	—	1
118	8/5	8/8					5	11				3	14				3	13	3

NOTES: 1. Telemetry system inoperative from 7/5 to 7/10. Hence, determination of missed events from Al Taylor's MIT seismic bulletin was not possible.

2. Reported but not uniquely evaluated. Data interpretation similar to Phase 1.

the frequencies noted in the Vela Seismological Center, Alexandria, Va. magnetic tapes employed for three-channel event-discriminator breadboard tests. Their significant energy for the horizontal seismometers was located in the 0.5-Hz region.

(c) Background (natural) noise fell within the 0.2- to 0.6-Hz region. The peak-to-peak magnitude of the voltage recorded on the Brush recorder could vary by a factor of 1.6 from a quiet period to a noisy one. This is discussed further in paragraph (g).

(d) A long-term average (LTA (τ)), set for 30 seconds, was too long a time constant to properly handle slowly emerging events and permitted greater susceptibility to spurious noise in the S/N ratio detector than one with a shorter time constant. This can best be noted by reviewing the reduction in false events detected (Table 6-1) in the north and east channels when the LTA (τ) was reduced from 30 to 20 seconds.

(e) A minimum event duration of 0.5 second was too short for the specified initial parameter settings. Most of the real events (where S/N = 8 dB and LTA (τ) = 20 seconds) exhibited minimum event durations greater than 1.0 second. For real events (where S/N = 6 dB and LTA (τ) = 20 seconds), the minimum event-duration signal was greater than 1.5 seconds.

(f) A S/N = 6 dB setting for the vertical channel yielded a large number of false events when combined with a minimum event-duration setting of less than 1 second.

(g) The following compares the vertical data obtained from runs 104C and 105, both of which had identical initial parameter settings but yielded different false/real event results.

Run 104C is considered one of the best runs during this phase. There existed an excellent ratio of real to false events. The events that were missed (four) were relatively small, lasting not longer than 1 minute.

Run 105 exhibited a marked increase in false events over the previous run. A review of the two data runs disclosed a significant difference in background noise. Run 104C was much noiser (1.6 V pk-pk, f $\approx$ 0.3 Hz) than run 105 (1.0 V pk-pk, f $\approx$ 0.4 Hz).

Theoretical computation of the noise average voltage (N), employed in the S/N ratio detector, disclosed that run 104C was 2 to 3 times higher than that of run 105. The former voltage was approximately 0.15 Vdc, well above the drift level of the electronic components. This was not the case with run 105. Hence, a higher voltage level, representative of background noise, would tend to reduce the false alarm rate.

(h) Based upon the test results and data evaluation during Phase 1, the following initial settings were recommended for Phase 2. The settings, defined below, pertain to all three channels unless noted otherwise.

Band-pass filter center frequency (f_o)	1.0 Hz
Long-term average (LTA (τ))	20 seconds
Signal-to-noise ratio (S/N)	
(1) Vertical	6 dB
(2) North and East	8 dB
Minimum event duration	2.0 seconds
Long-term average sampled delay	2.0 seconds

6.2.2 Data Evaluation - Phase 2

This testing phase covered the period July 1 through July 13, 1974 in which seismic data was recorded on strip-chart rolls 106 through 110. The intent during this period of testing, as postulated earlier, was to obtain 2 weeks of continuous data in which optimum or near-optimum channel criteria were employed. The selection of channel criteria was an outgrowth of Phase-1 testing. Evaluation of the results, summarized in Table 6-1, for Phase 2 follows.

(a) The ratio of real/false events in the north and east channels improved significantly from that reported during Phase 1. Hence, the parameters defined in paragraph 6.2.1 (h) were proper for this particular site (Harvard, Mass.).

(b) A noticeable improvement in the ratio of real/false events occurred in the vertical channel (approximately a factor of 4 improvement over Phase 1) and is reported in Table 6-1. Although this is considerable, it was believed that greater improvement could be realized. With this in mind, the reported false events were carefully reevaluated.

Approximately 80% of the false vertical events had a minimum event duration of less than 1.8 seconds, while 90% of the false vertical events had a minimum event duration of less than 2.0 seconds.

Due to the desire to employ a completely coherent timing system, a 4-Hz reference signal, available from the commercial analog-to-digital converter, was used. This, then, placed an uncertainty when detecting the minimum event-duration signal of ±0.25 second from an initially selected value. In future systems, this limitation can be easily overcome by employing a higher frequency clock.

Even considering the uncertainty of the above clock, greater than 70% of the reported false vertical events occurred below the specified (theoretical) minimum event-duration time.

This may have resulted from the following:

(1) A human error. Although the data sheets indicated the selection of a 2-second minimum event-duration setting, in reality, it may have been 1.0 second.

(2) An electronics error within the breadboard permitted a shorter time interval minimum event-duration signal to be interpreted as being acceptable. Sufficient time was not available to effectively pursue this possibility. Hence, it was decided to minimize the electronics problem, if it did exist, by setting the S/N ratio detector of the vertical channel to 8 dB and the minimum acceptable event-duration signal to 1.0 second.

6.2.3 Data Evaluation - Phase 3

July 23 through August 8, 1974 (strip-chart rolls 113B through 118) covered the period for Phase-3 testing. The criteria selected for all three channels are listed below.

Band-pass filter center frequency (f_o)	1.0 Hz
Long-term average (LTA (τ))	20 seconds
Signal-to-noise ratio (S/N)	8 dB
Minimum event duration	1.0 second
Long-term average sampled delay	2.0 seconds

A review of Table 6-1, indicates the excellent results achieved. Interpreting the data further reveals the following.

(a) There was a slight increase in the ratio of false/real events in the north and east channels, over Phase 2, due to the reduction in the (selected) minimum event-duration time. Overall, the north and east channels performed extremely well.

(b) A marked improvement in the false/real events ratio (greater than 12) was achieved in the vertical channel due primarily to the increase of its S/N detector setting (8 dB).

(c) Over 80% of the reported false events (in all three channels) had S/N ratio signals less than 2 seconds, while 80% of all real events had S/N ratio signals greater than 2 seconds. Hence, under the condition that a single minimum event time be established for all channels, the 1-second time selected for this site was near optimum.

(d) A major reason to employ a three-channel event discriminator (in the field) is the potential advantage it could provide in reducing data to be recorded or transmitted. With this in mind, an examination of Phase-3 (a most successful testing period) results follows.

(1) Time to record data continuously 179 hours (rolls 113B through 118)

(2) Time to record events
(Time of event plus 30 seconds of prior storage time/event.)

Real events	102 minutes
False events	36 minutes

(3) Recording time attenuation

$$\frac{\Sigma \text{ Real event times}}{\text{Continuous recording time}} \times 100\% = 0.95\%$$

$$\frac{\Sigma \text{ False event times}}{\text{Continuous recording time}} \times 100\% = 0.34\%$$

(4) Magnetic-tape usage per channel for t = 138 minutes (Tape recorder--800 bits/inch; capacity--1200 feet; 9 tracks) — 275.42 feet

(5) Unattended recording time (Dual magnetic recording capability doubles this time.) — 32.5 days

From the above, it is clear that one of the prime objectives is readily met. In addition to the tremendous reduction in actual continuous recording time, the contribution of false events was only 1/4 of the actual total recorded time.

SECTION 7

TEST CONCLUSIONS

The final testing period (Phase 3), in which final on-site parameters were employed (for a 3-week test period), successfully demonstrated the merits of preprocessing seismic data prior to magnetic-tape recording or transmitting. This technique is not solely limited to seismic signals. It can gainfully be utilized in instrumentation packages where data discrimination is required.

From the in-field tests conducted, the following conclusions can be made.

(a) Event discrimination, in real time, on site, is a viable and workable concept. (The ability to adjust near-optimum event-discrimination parameters at a local recording site should exist.) It was demonstrated that these selectable parameters could be defined within 1 month of field testing.

(b) A significant reduction in recording time was demonstrated (during Phase 3). During this period, actual events (real and false) required only 1/100th the time required for continuously recording seismic data.

(c) Missed events did occur and were reported. They were, nonetheless, primarily small or slowly emerging events, lasting only a short time. Their scientific contribution was considered to be insignificant. At the expense of increasing false events, which would result in increased magnetic-tape usage or data transmission, these events could be caught.

(d) For future work in this area, the following should be considered.

(1) Increase the noise average voltage (N) into the S/N ratio detector so as to be well above potential electronic drift errors. This can simply be accomplished by increasing the gain of several amplifiers or by incorporating an AGC (automatic gain control) circuit. The latter employs a feedback system and thus has the inherent advantage of compensating for variations in background noise from day to day.

(2) Employ fifth-order Butterworth filters for the frequency-select filters. This would provide greater attenuation for cultural noise in the 2- to 3-Hz frequency range and for background (natural) noise in the 0.2- to 0.6-Hz range, thereby preserving amplifier dynamic range.

(3) Decrease the sampled delay time from 2 seconds to 1 or 1.5 seconds. Data reviewed, primarily during Phase-3 testing, indicated that the projected recording time (indicated by the event-duration signal) was too short. This was not, and is not, considered to be a problem. As stated above, it can easily be adjusted by decreasing the sampled delay time. (The major emphasis during field testing was to establish criteria for detecting the start of an event--not the end of an event.)