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JOINT EXPERIMENT ON THE SPECTRUM OF
EARTHQUAKE SOURCES - LONG PERIOD INSTRU-
MENTATION

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13. ABSTRACT

This report covers the design, construction and testing of a prototype long-period seismograph system utilizing digital telemetry. The system makes use of gain ranging amplifiers to obtain a dynamic range of 106 db. Using Geotech SL 210 seismometers, a magnification of 15,000 is obtainable in the pass band .05 - 1.0 Hz. The system noise in this band is 0.1 microvolt rms. The output is a frequency shift keyed tone (FSK) which is telemetered over VHF radio and telephone lines and recorded in direct mode on a tape recorder. A decoding system converts the serial FSK data back to parallel digital data compatible with a mini-computer.

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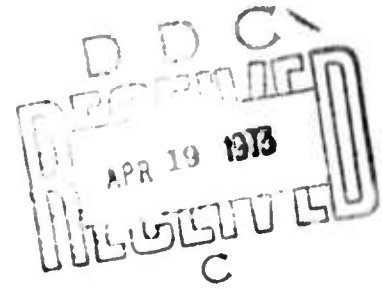
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Principal Investigator: Stewart W. Smith

1) Research Program

This grant covers the construction and operation of a set of three three-component long-period telemetry stations to be operated in conjunction with other instrumentation of the "Joint Experiment on the Spectrum of Earthquake Sources." The purpose of this experiment is to obtain reliable high quality long-period records of small to medium sized earthquakes to determine the effectiveness of long-period discriminants in the limit of small events. This report covers the design, construction and testing of a prototype long-period system.

2) Technical Report Summary

During the period covered by this report, a wide-band digital telemetry seismic system was developed and a prototype was built and tested. The system makes use of gain ranging amplifiers to obtain a dynamic range of 106 db and a dynamic resolution of 72 db. Using Geotech SL-210 and SL-220 long-period seismometers, a maximum ground motion magnification of 15,000 is obtainable in the pass band of .05 - 1.0 Hz. The electronic system noise in this band is .1 microvolt rms. The system output is a frequency shift keyed tone (FSK) which is compatible with standard FM telemetry channels such

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as VHF radio or voice grade telephone lines. The FSK tone can be recorded on a standard direct tape recorder channel.

A decoding system has been built to convert the serial FSK data back to parallel digital data compatible with a Varian 620F computer. Machine language code has been written and debugged to accept up to 6 FSK signals, take out the gain ranging steps, display the incoming data on a large CRT unit and write computer compatible digital tape.

A single channel visual monitoring system has also been built. It decodes a single FSK tone and selects one of the three seismic channels for conversion to an analog output. This analog signal can be recorded on a Kinometrics VR-1 drum recorder or other visual display equipment. Fig. 1 shows a block diagram of the entire system assuming six remote seismic stations.

After the construction of one complete station, a field test was conducted at the WWSSN station at Longmire, Washington. The FSK output signal was recorded for four days on magnetic tape. The system performed well with no excessive drift and with no failures of any kind. A few teleseisms were recorded to compare with the WWSSN data. (Fig. 5) Spectra of seismic background noise shows microseisms at 6-8 sec. and 20-25 sec. and a slight dip around 30 sec. before rising to long periods. (Fig. 4)

3) Details of the FSK System

The ultimate use for the FSK long-period system is in an array of six stations located around the probable epicenter of small to medium sized events at distances of 30 to 50 km. The University of Washington is constructing three of these stations while the University of Nevada constructs the other three using the University of Washington prototype as a model. A block diagram of the entire net including the playback and analysis section is shown in Fig. 1. The VHF radio links and tape recorder will be provided by the University of Nevada. The play-back tape machine, computer interface, and computer will be

provided by the University of Washington. The complete net should be in operation centered around Bear Valley, California, in early 1973.

The most complex parts of the net are the electronic packages which amplify the seismometer outputs, gain range, multiplex the three components of seismic data, convert the signals to digital form and output this digital data in an FSK tone. The details of the specifications for this unit are given in Table 1. The step by step operation of the unit is as follows:

The unit input consists of three channel preamplifiers with differential input to improve common mode rejection. The voltage gain of each preamp is 200 and the input impedances can be matched to their respective seismometers to obtain the proper damping. Following this first stage is a low pass Bessel type filter with two corners. One corner is at .05 Hz with a 6 db/octave rolloff and the second at 1 Hz with a 24 db/octave slope. Therefore, the total rolloff beyond 1 Hz is 30 db/octave giving an attenuation of better than 70 db at 6 Hz. The output of each filter is sampled for 30 msec, 11 times per second, in a sequential manner. This time multiplexes the three signals into one. The multiplexed signal is next processed by two gain range amplifiers (X8 each), to allow the logic unit to sort through the ranges starting with the highest gain until it finds one within the ± 10 volt range of the A to D converter. The logic triggers a sample and hold unit when this condition is met and the ADC converts this held voltage to a 12 bit digital number. A "LARSE" send module converts the 12 bit word and 4 additional bits from the logic circuit into serial FSK tone bursts. The additional 4 bits contain the range information and the channel number. The control logic receives a sync pulse from the LARSE when it has finished transmitting a word. (The LARSE has an internal crystal for timing.) Utilizing the sync pulse, the logic controls all channel switches, operates the sample and hold module, decides which gain range to use, changes range switches, stops while the LARSE accepts the digital word with address, and waits for the next LARSE sync pulse. Fig. 2 shows a block diagram of this operation.

A single channel data monitor has been built to aid in the testing of the complete system and as an on-line visual monitor of the data being recorded on magnetic tape. This unit consists of a LARSE read module which processes the incoming FSK tone back into a 16 bit word. LARSE bits 0 through 11 are data, 12 and 13 are range information, and 14 and 15 are channel address. The LARSE read module also has a data ready pulse indicating a complete data word is ready to be sampled. This pulse triggers a D to A converter to convert the 12 bit data word into an analog voltage which is given to a sample and hold depending on the channel address. The choice of channels can be made manually with a channel selection switch or if in the automatic mode the channels are switched by a remote switch located on the visual drum recorder. The output analog signal is normally used to drive a pen motor on a drum recorder which revolves once every half hour.

To analyze the data recorded on tape, a computer interface has been constructed to read the FSK data and produce a computer compatible digital output. Up to six FSK inputs are processed simultaneously by six LARSE read modules. Each module produces 16 bits of digital output per FSK word and a data ready pulse. This pulse triggers the interface logic to release the data through a digital portal in the Varian 620F computer. If more than one LARSE read unit has data ready within a computer sampling frame (4 msec) the interface logic can stack the LARSE read outputs.

A machine language code has been written to operate the Varian computer while the interface is processing the FSK data into digital form. This program has two basic parts: A) An interrupt loop which takes the digital data from the entry portal on command from the interface and stores it into a location dependent on the data words address bits. B) An independent section which manages the CRT drivers and the digital tape write drivers. Tapes are written which are compatible either with the Varian itself or with a CDC 6400 computer. Associated soft-ware has been developed or is being developed to process the data in numbers of ways. (Filters, plotters, Fourier transforms, etc.)

4) System Field Tests

After the construction was completed on one station, a field test was made at Longmire, Washington. The three Geotech long-period seismometers were set up on the same pier as the WWSSN Sprengnether long-period instruments. The data monitor unit was placed with the FSK electronics package in an adjacent room and the FSK data were recorded on a Sangamo tape deck located in a nearby trailer.

A complete frequency response was run on the system which is shown in Fig. 3 for three different playback modes. The seismometer free periods were set to 20 sec. No special consideration was taken for barometric pressure or temperature effects on the instruments. There were no failures of any kind during the four days of testing at Longmire. The electronics drifted 2 microvolts referenced to input over the four day period. The seismic background noise was analyzed for a period of two hours. Amplitude spectra for this data are shown in Fig. 4. The peaks around .12 - .20 and .04 - .05 Hz correspond to normal microseisms. There is a slight dip in the curves around .03 Hz indicating the beginning of the 40 sec earth noise minimum. Because of no special environmental isolation of the instruments, the curves then rise sharply to longer periods. FSK system magnification for this event is 3000.

Fig. 5 shows a comparison between the Longmire WWSSN seismogram with the FSK system recording of a teleseism. The event was near surface in the New Hebrides Islands. ($\Delta = 90^\circ$ $M_b = 5.7$) Note the broadband nature of the FSK system brings out more of the high frequencies than the standard long-period system.

5) Work in Progress

During this report period the prototype FSK unit has been built, tested, and converted to a field operational unit. Work has begun on the additional two units for the University of Washington and all equipment lists, schematics, and construction procedures have been sent to the University of Nevada to enable them to begin constructing their units. A complete manual for building and operating the FSK unit is being written.

TABLE 1

FSK Unit Specifications

Input Impedance	$\sim 10k\Omega$ (adjustable to seismometer)
Filters (low pass Bessel)	
1st corner	.05 Hz at 6 db/oct.
2nd corner	1.0 Hz at 24 db/oct.
Total below 1 Hz	30 db/oct.
Gain Ranges	
Maximum	12,800 (83.6 db)
Middle	1,600 (64.8 db)
Minimum	200 (46.0 db)
Linearity	.01%
Input Signal Range	$\pm 50\text{mv}$
System Noise Relative to Input	0.1 μv rms (ground displacement equivalent .04 microns)
System Bandwidth	1 Hz
Output	
Impedance	600 Ω isolated
Level	-40 to 0 dbm
FSK Frequencies	1200 and 2400 Hz
System Power	
Input Voltage	+20 to +28 volts
Input Current at 28v	0.3 A
Input Power at 28v	7.2 watts
Physical Dimensions	24" x 12" x 6"
Weight	28 lb.
Package	Water Tight

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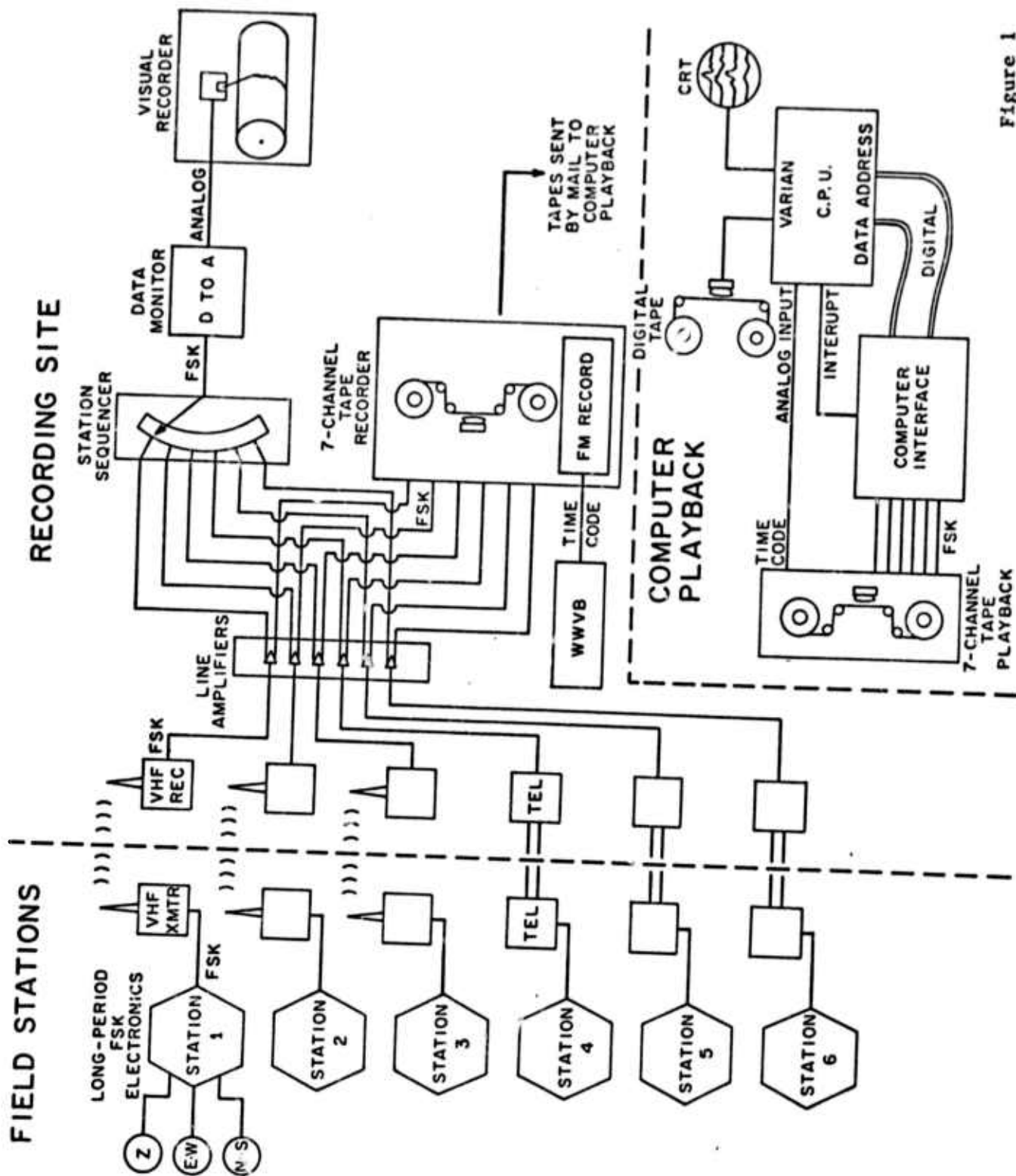


Figure 1

LONG-PERIOD FIELD STATION

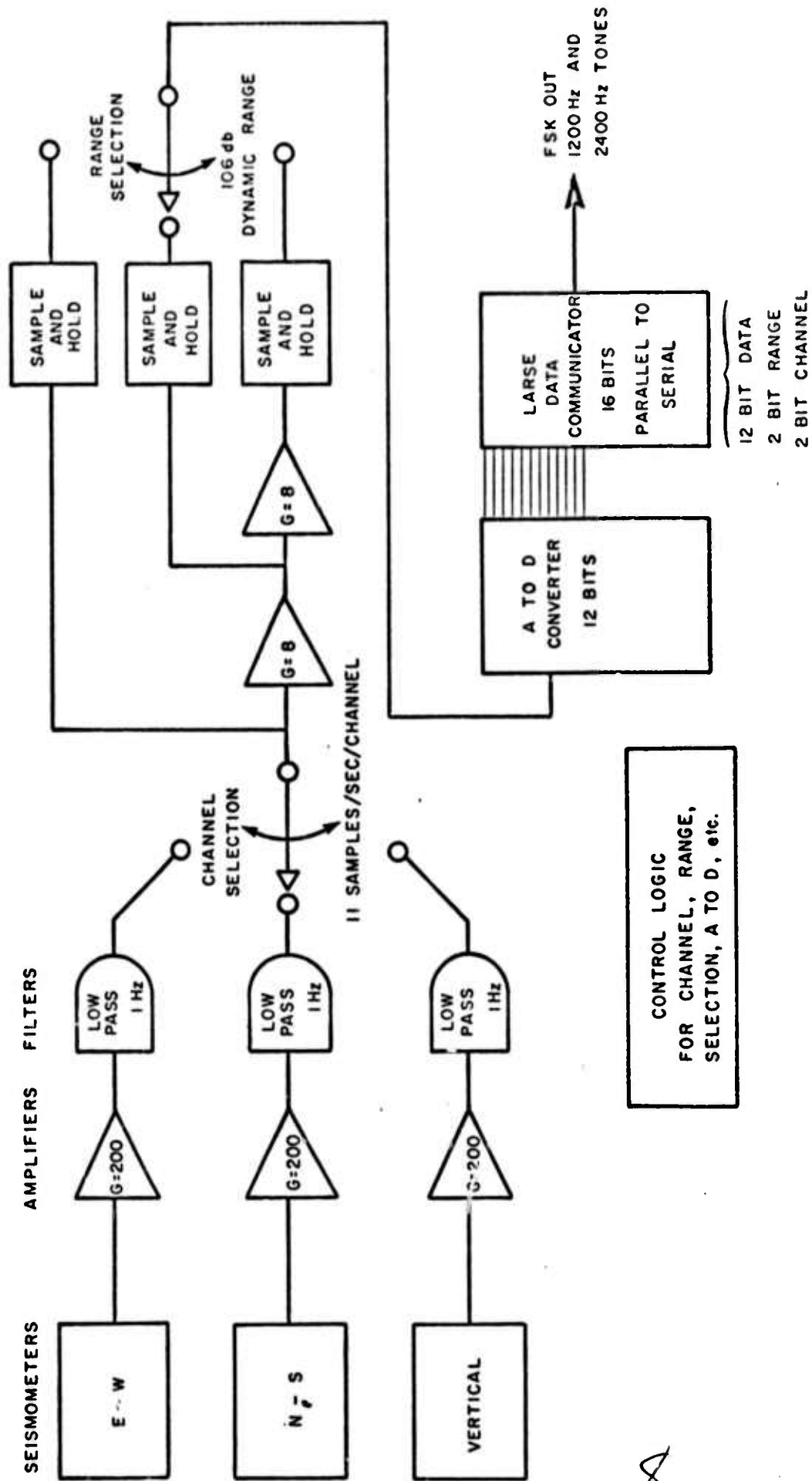


Figure 2

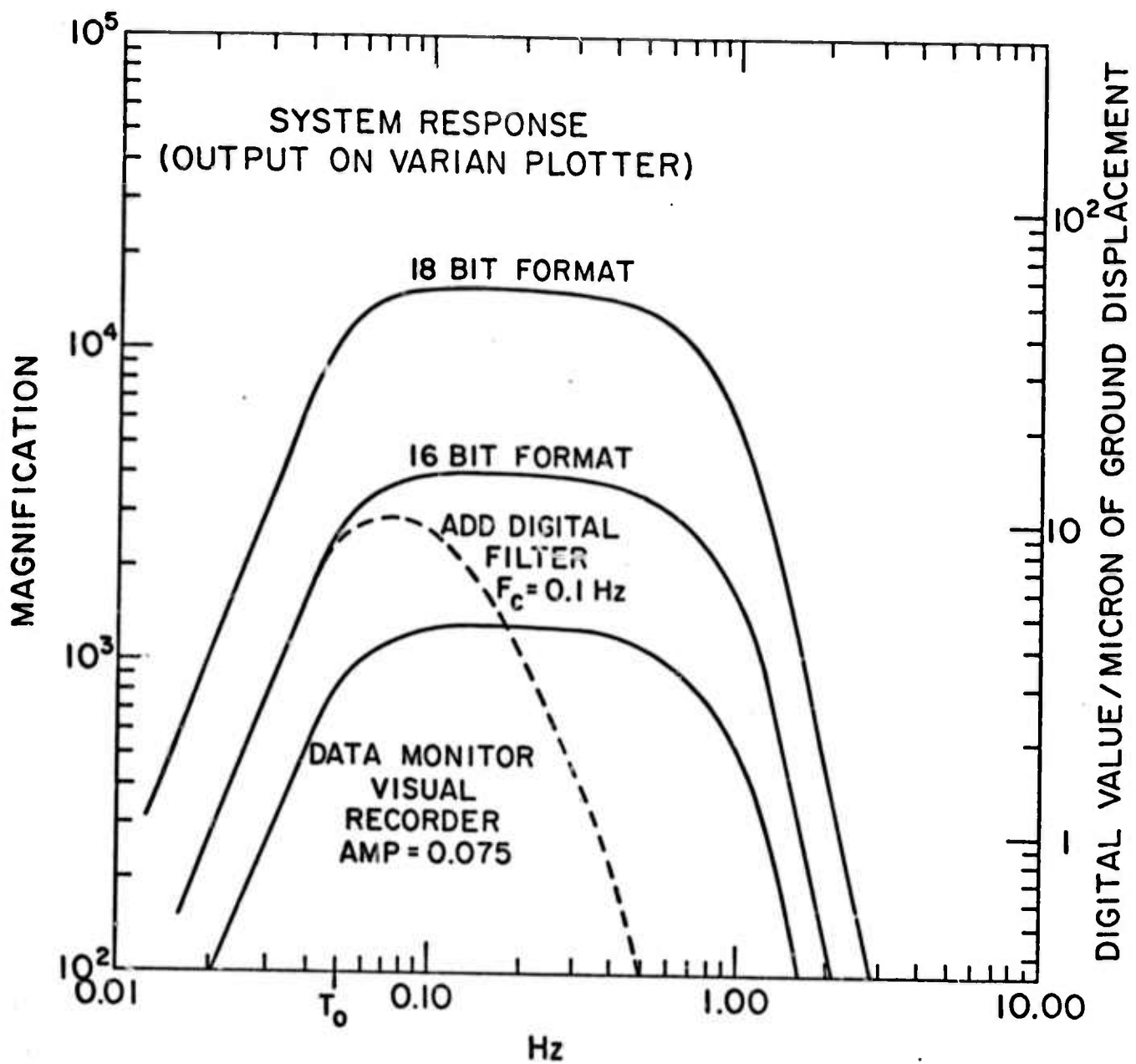


Figure 3

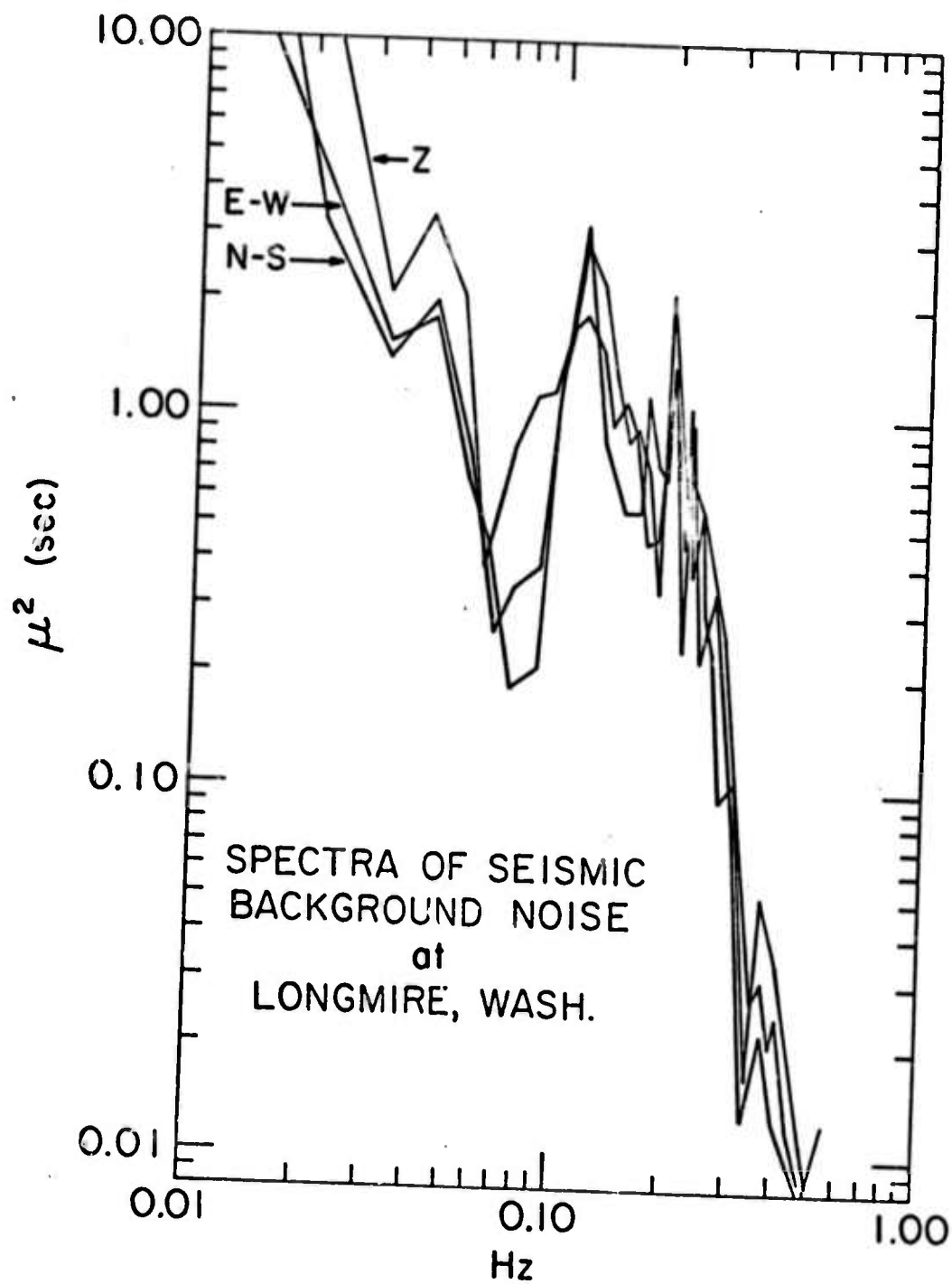


Figure 4

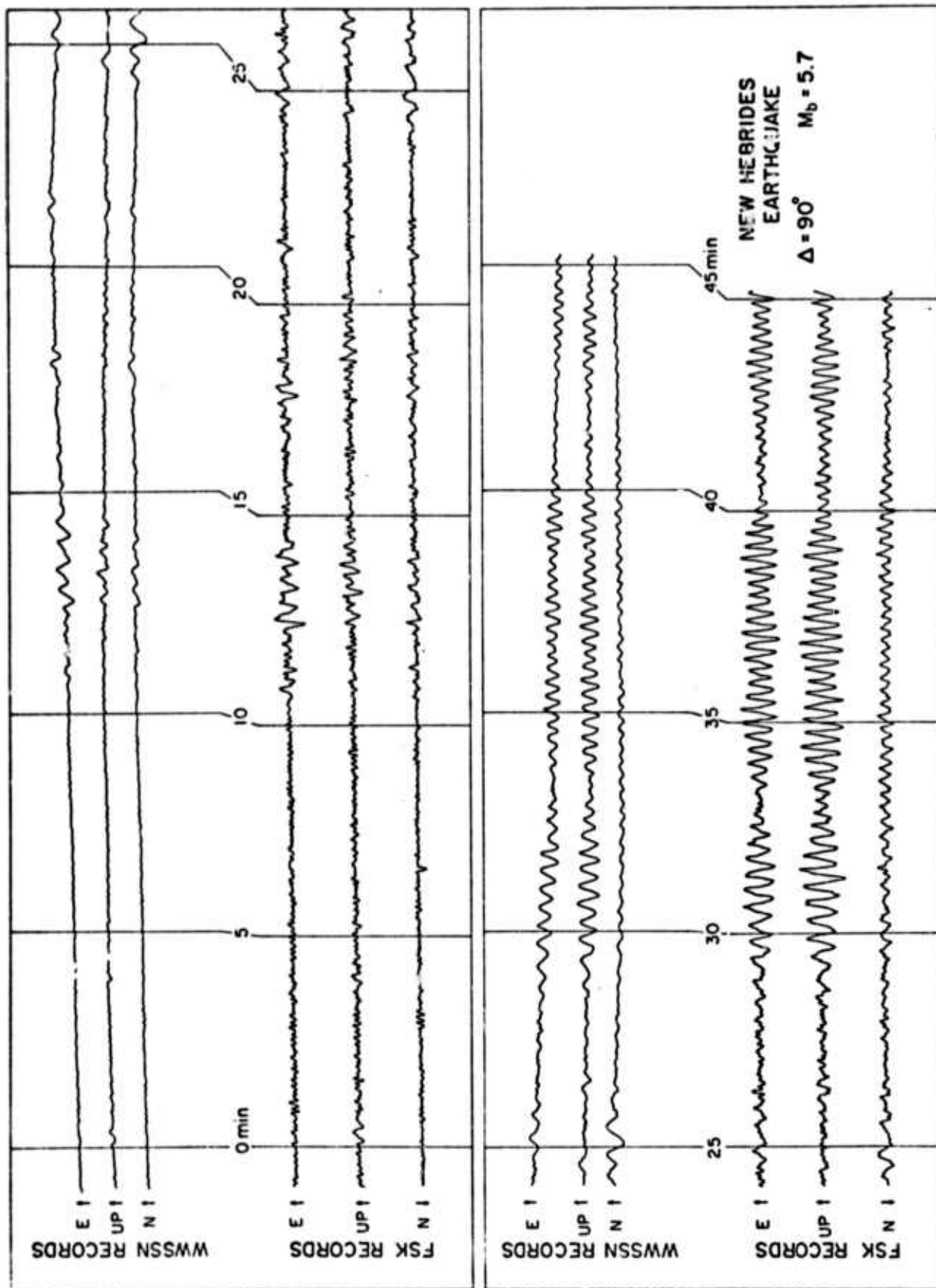


Figure 5