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# **SEISMIC DATA LABORATORY QUARTERLY TECHNICAL SUMMARY REPORT JANUARY - MARCH 1972**

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## TABLE OF CONTENTS

<u>SECTION</u>		<u>PAGE NO.</u>
	ABSTRACT	
I.	INTRODUCTION	1
II.	WORK COMPLETED	1
	A. Single Station and Array Methods for Improved Surface Wave Spectral Estimates, No. 264	1
	B. Generalized Linear Filtering of Seismic Array Data, No. 269	1
	C. Analysis of Short-Period Seismic Signals and Noise Recorded at LASA and TFO, No. 276	2
	D. Effects of Propagation Paths On Surface-Wave Magnitude Estimates, No. 279	2
	E. A Comparative Study of the Elastic Wave Radiation From Earthquakes and Underground Explosions, No. 284	2
	F. Automatic Network Detection, No. 285	3
	G. Source Time Functions and Spectra for Underground Nuclear Explosions, No. 288	3
III.	SUPPORT AND SERVICE TASKS	
	A. Data Cataloging, Classifying and Retrieval	4
	B. Equipment Modifications	4
	C. Maintain and Operate Equipment	4
	D. Digital Programming	5
	E. VELA and PRIME ARGUS Data Copies	5
	F. Analog Field Tape Supply	5
	G. Array Data Service	5

## ABSTRACT

This report summarizes the work done by the SDL during the period January through March 1972, and primarily concerns the seismic research activities related to the detection and identification of nuclear explosions and earthquakes. The report also contains brief discussions of the support tasks and data services which were performed for other government contractors and for participants in the VELA-UNIFORM and PRIME ARGUS projects.

## I. INTRODUCTION

This quarterly report summarizes the technical work, support effort, and data services completed during the period January through March 1972. Current and past work are mentioned only if related to the present discussions.

Reviews of technical reports completed during the reporting period are contained in Section II under descriptive headings. Section III is a summary of the support and service tasks performed for other government contractors and for VELA-UNIFORM and PRIME ARGUS participants.

## II. WORK COMPLETED

### A. Single Station and Array Methods for Improved Surface Wave Spectral Estimates

This report discusses combined matched filtering and array summing methods which have been developed to yield improved spectral estimates for weak surface waves. Both theoretically and experimentally the best spectral estimates are obtained by first beaming an array of individual matched filtered seismograms and then computing a single noise-corrected spectrum. Spectral results for test cases and actual events are compared using three different techniques. Computer programs implementing these spectral methods have been written which are suitable for routinely processing many events.

### B. Generalized Linear Filtering Seismic Array Data

In this investigation the theory of generalized linear filtering is applied to the problem of averaging the transfer functions between a seismic source and seismic recording stations on a continental-sized array.

To provide synthetic data for a test of the processor, a simple source signal is passed through nine different random perturbations of a velocity-depth structure yielding nine different synthetic seismograms. Two nuclear explosions (LONG SHOT and MILROW) and an Andreanoff Island event (22 November 1965) are also processed using stations from the Long-Range-Seismic-Measurement net. Most of the reverberations are removed from the synthetic seismogram by generalized linear filtering. The explosion and the earthquake seismograms are simplified by this process.

The earthquake appears to have longer time terms remaining after generalized linear filtering and the nuclear events appear more similar (before the arrival of the depth phase).

### C. Analysis of Short-Period Seismic Signals and Noise Recorded at LASA and TFO

Short-period beams were formed for twenty-four events recorded at both the LASA and TFO arrays. The mean rms noise in the frequency range 0.4-3.0 Hz for the LASA beams was 0.16  $\mu$ , and for the TFO beams 0.13  $\mu$ . Noise reduction by beam forming in the frequency range 0.4-3.0 Hz varied from 17 to 23 db for LASA, from 12 to 18 db for the 37-sensor TFO array, and from 6 to 14 db for the 19-sensor TFO subarray. When averaged over events from several source regions in the distance range  $250^\circ < \Delta < 90^\circ$ , the signal-to-noise ratio for LASA beams was about 1 db better than that of TFO beams for common events. The improvement in signal-to-noise ratio for LASA beams was found to increase 4 db by changing the number of sensors employed in the beams from 48 to 340 while keeping the minimum sensor spacing  $\Delta > 1$  km.

### D. Effects of Propagation Paths on Surface-Wave Magnitude Estimates

In this report we investigate the effect of realistic propagation paths on the visual and spectral amplitudes of fundamental mode Rayleigh waves. We show that the Harkrider amplitude response factor of a layered media should relate directly to a station correction; it varies by a factor of nearly three between oceanic and continental sites. Attenuation due to effective Q losses may cause scatter, of over one-half magnitude unit, in teleseismic amplitudes but is unimportant at regional distances. Differences in recorded amplitude caused by dispersion over oceanic and continental paths are sufficient to warrant the application of path corrections to visually measured amplitudes. These differences can be avoided by computing spectra of the signals, or they can be suppressed somewhat by using the results of stationary-phase approximations. More uniform propagation path effects at periods longer than 20 seconds suggest that use of 40 to 50 second waves would provide better seismic discrimination capability and better yield estimation.

### E. A Comparative Study of the Elastic Wave Radiation From Earthquakes and Underground Explosions

A detailed analysis of the surface wave radiation from two underground explosions (BILBY and SHOAL) and an earthquake (near Fallon, Nevada) whose epicenter is only 60 km from SHOAL indicates that: (1) at long periods the surface wave radiation from the earthquake can be explained by a pure quadrupole (double-couple) source, but at higher frequencies the radiation pattern shows asymmetries which suggest effects due to rupture propagation which require higher-order multiple terms in the source equivalent representation; (2) the surface waves from the explosions can be explained by superposed monopole and quadrupole sources, with no indication of high-order multipole terms, at least in the frequency range comparable to that in which the earthquake signal was recorded; (3) a principal conclusion of the study is that the anomalous radiation from explosions is probably due to stress



relaxation around the shock-generated shatter zone and not due to earthquake triggering.

A comparative analysis of SHOAL and FALLON shows that: (1) the ratio of the Love wave amplitude generated by the earthquake to the Love wave amplitude from the explosion is proportional to the period, which implies a larger source dimension for FALLON; (2) the normalized spectral ratio of Love wave amplitude to Rayleigh wave amplitude, considered as a function of period, is near unity for the explosions but larger for the earthquake by a factor of two or three, and increasing with period. These differences might be useful in distinguishing earthquakes from explosions (at least in the magnitude range of the events used in this study, 4.4 and above), as well as for estimating source parameters (such as stress) which are of fundamental geophysical interest.

#### F. Automatic Network Detection

The theory of automatic detection at a seismic array by means of an F statistic is extended in this study to a network of such arrays. The arrays may have equal or different expected signal-to-noise ratios. Two techniques are discussed: (1) the composite F detector in which a vote is taken among the arrays; (2) a multi-array F detector in which the original data from the independent arrays are combined to form one F statistic. The detectors are found to be nearly equal in detection capability, with the multi-array detector superior by 1-2 dB in the cases examined. For example, with 22 independent arrays of 6 elements each, assuming equal expected signal-to-noise values, the two detectors are 5.4 and 4.3 dB worse, respectively, than an F detector would be operating on a beam of  $6 \times 22 = 132$  channels with perfect signal correlation.

#### G. Source Time Functions and Spectra for Underground Nuclear Explosions

This analysis reveals that Haskell's model for explosion source time functions and spectra fails to satisfy data in the short-period band recorded teleseismically from the three Amchitka Island underground nuclear tests: LONG SHOT, MILROW and CANNIKAN. A more recent model due to Mueller and Murphy satisfies the data quite well. The difference in the two models is basically in the falloff at high frequencies. A simple revision of Haskell's model produces waveforms and spectra nearly identical to ones from Mueller and Murphy's model. This revision requires velocity waveforms to have a rise time of extremely short duration at the elastic boundary, a premise validated by actual near-field measurements.

Waveforms are derived from the revised Haskell model and the Mueller and Murphy model and illustrated for pressure at the elastic boundary, reduced displacement potential at the elastic boundary, and far-field displacement. Corresponding spectra are derived and illustrated.

### III. SUPPORT AND SERVICE TASKS

In addition to the research studies discussed above the SDL completed the following support and service tasks:

#### A. Data Cataloging, Classifying and Retrieval

The library contains digitized seismograms and digital and analog magnetic tapes. Station logs corresponding to each data set are arranged chronologically either in loose-leaf binders or in file cabinets.

At the end of the first quarter of 1972 the library contained approximately:

20,154	digitized seismograms;
4,323	digitized magnetic tapes;
33,099	analog magnetic tapes;

as well as 16 mm film data recorded at seismic observatories during the period September 1960 to the present, and 35 mm film data recorded at LRSM and portable stations during the interval September 1961 to the present.

Although the proportion of digital tapes assigned to a specific function changes constantly, the library consisted of the following groups at the end of the reporting period:

279	UBO multiplexed;
1,615	LASA multiplexed;
409	LASA demulti;
432	TFO-37 multiplexed;
98	TFO-37 permanent data;
1,490	Scratch, save and A/D (approximate).

The analog magnetic tape library consisted of the following groups at the end of March:

8,765	compressed;
488	composites;
18,007	save (uncompressed)
5,839	uncompressed field tapes (March 1970 through March 1972)

#### B. Equipment Modifications

No equipment modifications were made during the reporting period.

#### C. Maintain and Operate Equipment

The armature on disk number zero shorted to ground during March and was replaced with a comparable unit from disk number 15. Although disk 15 was rendered inoperable as a result,

the overall capability of the 818 Disk File is only slightly impaired, and the bad armature will not be replaced.

The purchase order is fully approved for the acquisition of the PDP-15/50 system. The Digital Equipment Corporation has confirmed a delivery date of 01 June 1972 for all the system excluding the 1600 b.p.i./9 track tape units which will be delayed about 60 days.

D. Digital Programming

The conversion of Fortran 63 programs to Fortran IV is now proceeding at a faster rate.

E. VELA and PRIME ARGUS Data Copies

During the past year the SDL supplied data or computer services to the following:

Air Force Cambridge Research Laboratory  
Air Force Office of Scientific Research  
American Electronic Laboratories  
Brown University  
California Institute of Technology  
Commonwealth of Australia, Dept. of National Development  
Department of Energy, Mines and Resources, Ottawa, Canada  
General Atronics Corporation  
IBM  
Lawrence Livermore Laboratory  
MIT, Lincoln Laboratory  
National Oceanic Atmospheric Administration  
Pennsylvania State University  
Stanford University  
University of Alaska  
University of Washington  
University of Wisconsin  
U. S. Arms Control and Disarmament Agency  
U. S. Department of Commerce  
Wright-Patterson Air Force Base

F. Analog Field Tape Supply

No analog tapes were returned to the field during the reporting period. About 525 TFO analog tapes will be prepared for shipment to Garland early in April.

G. Array Data Service

LASA weekly event summaries through 25 March 1972 were distributed to a revised list of addressees approved by the government.