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VELA NETWORK EVALUATION AND AUTOMATIC PROCESSING RESEARCH

QUARTERLY REPORT NO.4

10 APRIL 1976 TO 10 JULY 1976

TEXAS INSTRUMENTS INCORPORATED
Equipment Group
Post Office Box 6015
Dallas, Texas 75222

Contract No. F08606-76-C-0011
Amount of Contract: $440,000
Beginning 15 July 1975
Ending 30 September 1976

Prepared for

AIR FORCE TECHNICAL APPLICATIONS CENTER
Alexandria, Virginia 22314

Sponsored by

ADVANCED RESEARCH PROJECTS AGENCY
Nuclear Monitoring Research Office
ARPA Program Code No. 6F10
ARPA Order No. 2551

10 July 1976

Acknowledgment: This research was supported by the Advanced Research Projects Agency, Nuclear Monitoring Research Office, under Project VELA-UNIFORM, and accomplished under the technical direction of the Air Force Technical Applications Center under Contract Number F08606-76-C-0011.

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This fourth quarterly report summarizes progress under the VELA Network and Automatic Processing Research Program, Contract Number F08606-76-C-0011, during the period 10 April 1976 to 10 July 1976. Work in the following areas is summarized: - -

- Array and network evaluation,
- Signal detection methods, ——— > next page

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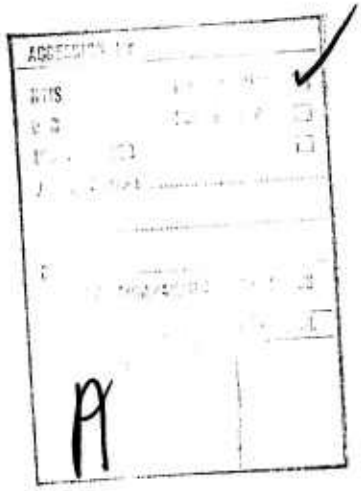
- Signal estimation techniques, and
- Discrimination.



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SECTION I

INTRODUCTION AND SUMMARY

This fourth quarterly report summarizes the progress made during the period 10 April 1976 to 10 July 1976 in the VELA Network Evaluation and Automatic Processing Research program being carried out by Texas Instruments Incorporated at the Seismic Data Analysis Center (SDAC) in Alexandria, Virginia. The four program tasks are:

- Array and network evaluation
- Signal detection methods
- Signal estimation techniques
- Discrimination.

Analysis of both short-period (SP) and long-period (LP) data from the Seismic Research Observatories (SRO's) has continued. Several hundred records have been processed and analyzed from five stations: Albuquerque, New Mexico (ANMO); Mashhad, Iran (MAIO); Guam (GUMO); Wellington (South Karuri) New Zealand (SNZO); and Mundaring (Narrogin), Western Australia (NWAO). The detection thresholds at these stations are being determined along with an evaluation of the automatic SP signal detector at each station. Modifications were completed to the general analysis package software to handle Iranian Long Period Array (ILPA) field tape formats, and approximately 70 events have been processed since the data arrived at the SDAC in the latter part of May. Efforts for transferring ILPA data to files on the mass storage device were directed at experimenting with data language procedures required for the transfer.

In the task area of automatic signal detectors, the detector performance for two signal detection algorithms was investigated for events from three regions in Eurasia. The detectors were applied to 181 events from January and February 1976 to evaluate winter detection performance. The performance of the detectors is being compared using an algorithm which allows comparison at a constant false alarm rate. Detection probabilities (versus m_b) for a number of cases were estimated with the maximum likelihood method.

Software development for the study to examine the effects of cascading various signal enhancement techniques now includes matched filtering, Wiener filtering, and a three component adaptive filter. For the matched filter, a synthetic signal has been obtained which displays a narrower range of correlation coefficients with test signals than those using an observed reference event. A rapidly adapting three component adaptive filter has been developed, and is now being tested to see whether it offers substantial improvement over the original version.

Testing of the dispersion relation filter has been completed, and a technical report describing the results is in preparation. Using a time-variant Wiener filter, the dispersion filter was found to enhance the estimation of signals from waveforms with 0 to 10 dB RMS signal-to-noise ratio. Noise rejection can be as much as 10 dB. This filter is effective as a signal estimator, and not as a detector.

The interactive discrimination package, the short-period earthquake explosion discriminator (SPEED), was successfully presented in a formal demonstration using earthquake and presumed explosion data. After the demonstration, the program was expanded to include the interactive capability to pick corner frequencies and measure long-period amplitude, and to apply an absorption correction to the spectrum. Final analysis of the data base for the technical report is now being completed.

For the higher mode study, data from the Nevada Test Site were examined for the presence of higher mode surface waves at periods less than 10 seconds. The data for these waveforms was found to be too sparse to attempt any depth resolution. Attention was then switched to Eurasian events for examination of higher modes of this period range, and again the data was too sparse. Efforts are now being directed toward uses of higher mode energy for discrimination purposes rather than depth estimation.

SECTION II

ARRAY AND NETWORK EVALUATION

A. ILPA AND SRO EVALUATION

1. Current Status

During the last quarter, efforts have been directed toward processing and analyzing a set of events for each of the five available SRO stations (ANMO, MAIO, GUMO, SNZO, and NWAO). Approximately 200 to 300 events have been analyzed for each station, with the corresponding short-period data examined when it was available. Short-period and long-period noise samples have also been examined. At the present time, the signal processing is complete with the noise sample processing being continued.

For the ILPA evaluation, the edit program was created by altering the Alaskan Long Period Array (ALPA) edit program to handle the seven elements and new tape format of ILPA. At the present time, this program only handles long-period data. The program has been debugged and tested. Seventy events have been edited, beamformed, filtered, and plotted.

2. Future Plans

During the next quarter, the SRO data will be analyzed to determine the detection and discrimination capabilities of the operational stations. A report on this evaluation will be written during the next quarter.

For the ILPA evaluation, we will continue to build the data base. Routine processing of events will be carried out during July and the first half of August. The available data will be quality checked during this

period to determine the frequency and severity of instrument and recording malfunctions. Finally, a report on the ILPA evaluation will be written.

B. ILPA DATA TRANSFER

1. Current Status

During the last quarter we became familiar with ARPANET related program and data structures needed to satisfy the task requirements. CCA personnel were consulted to ascertain which Data Language transfer procedure would be operationally feasible for ILPA files. As the UPDATE statement was found to be most satisfactory, an ILPA long-period port specification was written to support that approach. The front end driver and long-period routine for the ILPA Satellite Tape re-format program was designed, implemented, and debugged. This program was used to generate a re-formatted test tape containing a long-period file. This test tape data was transferred via Geotech's file transfer program and the long-period port to a sample long-period file in the mass store, and it was verified that the procedure was successful by retrieving the data at an ARPANET terminal.

2. Future Plans

The ILPA Satellite Tape re-format program will be completed by writing routines to generate short-period and coarse status files compatible with respective input port specifications. These files will follow the long-period file on the given output tape. Then these three files will be transferred in a test mode to the mass store via the file transfer program using the Data Computer. The transfer will be verified by retrieving the data for inspection. Finally, the operational procedure by which an analyst may transfer actual ILPA tapes to the mass store will be defined and demonstrated.

C. AUTOMATIC SIGNAL DETECTOR EVALUATION

1. Current Status

Major accomplishments for work on the optimum automatic signal detector evaluation include the following:

- A regional detection study was conducted for three areas; South Eurasia, Central Eurasia, and Kurile-Kamchatka. A total of 181 events were processed with the Fisher detector and the conventional power detector. The results have been obtained and compiled, and are being estimated with the maximum likelihood method to form detection probability curves.
- The conventional power detector was also applied to the same event ensemble using the single central site (Site 1) data only. The results were also edited and estimated to obtain the Gaussian probability parameters.

2. Future Plans

We will attempt to incorporate the maximum likelihood method for detection probability with a false alarm probability. Then the final report will be prepared.

SECTION III

SIGNAL DETECTION METHODS
ADAPTIVE BEAMFORMING DETECTOR

1. Current Status

Major accomplishments for the adaptive beamforming (ABF) detector task for the last quarter can be summarized as follows:

- Simulation studies were conducted by burying a scaled signal in noise. The signal-to-noise ratios for the input signal were varied in the single-sensor data from which the adaptive beaming was performed. The ABF beamforming output signal-to-noise gains relative to beamsteering were obtained as a function of input signal-to-noise ratios.
- In an attempt to use the ABF detector for off-line processing the filter update was stopped at a specific time to examine the ABF noise suppression at different times. A number of tests with different adaptive filter lengths were performed.
- A total of 96 events in the Kurile-Kamchatka region were processed with the ABF processor. Beamforming was performed for those whose signals were not visible in the single-sensor data. The results were also used to check against the automatic detector detection performance.

2. Future Plans

The results will be edited and estimated to form a detection probability for ABF detectors in the Kurile-Kamchatka region. The ABF

detector performance for the Eurasia region will be studied. In addition, attempts to better understand (or improve) the algorithm are being made. Work on the final report will be initiated.

SECTION IV
SIGNAL ESTIMATION TECHNIQUES

A. CASCADING STUDIES

1. Current Status

It has been found difficult to obtain a theoretically justifiable form for the signal-noise correlation term in the Wiener filter, although an ad hoc term has been developed which gives a gain of about 2 dB over the filter without this correlation. This gain is about equal to the variations in signal-to-noise ratio obtained by locating the test signal at different times in the noise sample.

A synthetic signal has been obtained which displays a narrower range of correlation coefficients with test signals than does an observed reference event. This implies that matched detection with this synthetic event should take place at a lower threshold than when an observed event is used.

A rapidly adapting three component adaptive filter has been developed. At this time it is not clear whether it offers any improvement over the original version.

2. Future Plans

A theoretical investigation of the optimum shape for the three component adaptive filter window in angle will be undertaken, using a Monte Carlo technique. A final report will also be prepared.

B. DISPERSION RELATION FILTER

1. Current Status

During the last quarter, work was essentially completed on this task. We continued to test a time-variant Wiener filter (TVWF) with scaled synthetic and real signals buried in noise. It was found that the filter enhances the estimation of signals from waveforms with 0-10 dB RMS signal-to-noise ratio. Noise rejection can be as much as 10 dB, depending on the 'instantaneous' signal bandwidth along the waveform's dispersion curve. The filter's performance is limited by the presence of non-stationary noise, the filter's inherent property to generate false signal estimates from pure noise, the 'instantaneous' signal bandwidth, and by the reliability and resolution of the spectral analysis methods. The filter output strongly depends on the user's signal spectrum specification. The filter is effective as a signal estimator and not as a detector.

2. Future Plans

The technical report for this task will be written during the next quarter.

SECTION V
DISCRIMINATION

A. PDP-15 DISCRIMINATION PACKAGE

1. Current Status

The programming and testing of the short-period earthquake-explosion discrimination program was completed. The program now displays log-amplitude versus log-frequency spectrum with interactive capability of picking corner frequencies and measuring long-period amplitude and roll-off above the corner frequencies. For complex spectra it is possible to pick up to four corner frequencies. Provision is made for applying an absorption correction to the spectrum and correcting for reflected echos.

The data preparation program is now being finalized. It has been split into four programs for more efficient analyst interaction via batch processing. One of the programs now corrects waveforms for absorption. The analyst can select up to four waveform outputs; seismic response, acceleration, velocity, or displacement ground motion.

2. Future Plans

A data base will be formed to make a preliminary evaluation of the short-period earthquake-explosion discrimination capability. The events selected are between m_b 4.4 and 6.1. These include 15 presumed explosions and two announced Peaceful Nuclear Explosions (PNE's), 10 simple earthquakes, and 10 complex earthquakes.

The formal documentation of the short-period earthquake-explosion discrimination program will be completed. The data preparation programs are being documented via notes on the listings.

B. HIGHER MODE STUDIES

1. Current Status

During the last quarter, seismograms recorded at Eurasian stations from Eurasian events were examined for the presence of higher modes. No higher mode energy was found. Therefore, attention was directed toward uses other than depth determination for the higher modes detected from North American events to date. Theoretical spectra suggest that the ratio of short-period higher mode to fundamental mode Love wave energy may be indicative of the source region seismic velocity.

2.

The possibility of using higher mode energy to investigate structure will be explored on both a theoretical and experimental basis.