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LARGE-ARRAY SIGNAL AND NOISE ANALYSIS

Quarterly Report No. 7

1 January 1968 through 31 March 1968

Frank H. Binder, Program Manager

TEXAS INSTRUMENTS INCORPORATED
Science Services Division
P.O. Box 5621
Dallas, Texas 75222

Contract No. AF 33(657)-16678

Prepared for

AIR FORCE TECHNICAL APPLICATIONS CENTER
Washington, D.C. 20333

Attn: VSC

Sponsored by

ADVANCED RESEARCH PROJECTS AGENCY
ARPA Order No. 599
AFTAC Project No. VT/6707

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TEXAS INSTRUMENTS
INCORPORATED
SCIENCE SERVICES DIVISION

24 April 1968

Air Force Technical Applications Center
VELA Seismological Center
Headquarters, USAF
Washington, D.C. 20333

Attention: Captain Carroll F. Lam

Subject: Seventh Quarterly Report Covering Period January 1, 1968 Through March 31, 1968

AFTAC Project No.:	VT/6707
Project Title:	Large Array Signal and Noise Analysis
ARPA Order No.:	599
Name of Contractor:	Texas Instruments Incorporated
Date of Contract:	16 May 1966
Amount of Contract:	$1,083,696
Contract Number:	AF33(657)-16678
Contract Expiration Date:	25 June 1968
Name and Phone No. of Program Manager:	Frank H. Binder Area Code 214, 238-3473

Gentlemen:

Below is set forth the work progress against the major tasks remaining under the contract.

PUBLICATION OF SPECIAL REPORTS DEALING WITH WORK PREVIOUSLY COMPLETED

The following special reports dealing with previously completed work were published during the past quarter.

LASA Special Report No. 4 - SPACE AND TIME VARIABILITY OF SHORT-PERIOD LASA NOISE

LASA Special Report No. 10 - EQUALIZATION STUDIES

LASA Special Report No. 11 - RESOLUTION OF EVENTS

LASA Special Report No. 15 - TRAVELTIME ANALYSIS FOR LASA

LASA Special Report No. 17 - CORRELATION BETWEEN STORMS AT SEA AND LASA LONG-PERIOD NOISE

The following reports are in different stages of publication.

LASA Special Report No. 16 - ITERATIVE TECHNIQUES FOR THE SOLUTION OF FREQUENCY-DOMAIN FILTER SETS

LASA Special Report No. 18 - SUMMER K-LINE SPECTRA

LASA Special Report No. 19 - NOISE SUPPRESSION BY LONG-PERIOD INFINITE VELOCITY PROCESSORS

SHORT PERIOD NOISE ANALYSIS

K-line spectra obtained from two 7-minute summer noise samples have been analyzed. Details of this analysis will be presented in a special report. (LASA Special Scientific Report No. 18, SUMMER K-LINE SPECTRA.)

The purpose of this work was to make a brief comparison between the character of summer noise at LASA and that of winter noise samples previously studied. (LASA Special Scientific Report No. 6, ANALYSIS OF SUB-ARRAY WAVENUMBER SPECTRA.) Except at the microseism peak, the summer noise appears to be quite similar to the winter noise at LASA. As a result it appears that any short-period processing results (gains) can probably be extrapolated across seasons.

To test the hypothesis that longer noise samples might provide better K-line spectra a few spectra were computed from a 21-minute, April 29, 1968 noise sample. These were compared with similar spectra computed from a 7-minute portion of the same sample. The two sets of spectra are quite similar, and it appears that 7-minute samples are sufficient for calculating K-line spectra.

Short-period seismic records at LASA typically exhibit brief bursts of apparently local high frequency energy. Playbacks where such energy appears are being examined in an effort to determine its source. This work is presently incomplete.

LONG PERIOD NOISE STUDIES

As reported previously, at frequencies near the 7-sec microseism peak power spectra from the horizontal seismometers are generally 5-10 db higher than those from similarly located vertical seismometers at LASA. It was questioned whether theoretical considerations would explain this behavior if the mode of propagation was Rayleigh waves. To test this, the theoretical horizontal and vertical displacement spectra resulting from a distant vertical stress source and the LASA crustal structure were computed. This was done for the fundamental Rayleigh mode which is the only Rayleigh mode which can exist at the frequencies of interest. The results indicate that expected differences in the horizontal and vertical Rayleigh mode amplitudes are not nearly enough to explain the observed differences. This seemingly implies that the excess horizontal energy results from Love wave propagation.

Analysis of long-period noise samples through the use of Markoff power spectra, conventional wavenumber spectra, and multiple coherences has been sufficiently definitive that calculation of high-resolution wavenumber spectra on these noise samples is not likely to yield any new information. Previous plans to calculate such spectra, therefore, have been abandoned.

Analysis of the five 80-minute summer noise samples, the long noise sample, and the simultaneous microbarograph-seismic records has been delayed by unexpected difficulty with the computer programs. These difficulties have been resolved and analysis will begin immediately.

LONG PERIOD SIGNAL ANALYSIS AND DISSECTION

A previous report has mentioned a study of ambient noise rejection while preserving high velocity (P or S phases) signal energy. This work included design and evaluation of multichannel filter systems using (1) vertical components and doing velocity filtering, (2) horizontal components for noise prediction. As a logical conclusion of this work a multichannel filter using all of the A and B ring horizontal and vertical components (with the exception of one anomalous horizontal trace) has been designed and evaluated. These results and their interpretation will be reported in Special Scientific Report No. 19, now in preparation.

Due to a lack of adequate noise samples in time proximity to events in our library, it was planned to imbed representative events in a 400-minute noise sample for studying the extraction of Rayleigh wave signals from ambient noise. Actually, a shorter noise sample will provide adequate noise statistics for the filter design. The events will be imbedded, therefore, in one of our 80-minute noise samples. This work along with the design of multichannel filters for the separation of interfering Rayleigh wave signals will begin in April.

The problem of extracting the Rayleigh phase of an event from the Rayleigh phase of an interfering event is complicated by the marked dissimilarities between long-period seismometer outputs for events recorded at LASA. One possible approach to this problem has been investigated. First a beam is formed in the direction of the interfering event. Then short one-channel adaptive prediction filters are designed to predict each of the individual traces (which have been time shifted to make the interfering event align with the interfering event in the beamsteer) from the beamsteer). The shortness of the filters permits a high rate of adaptation. Ideally this allows the filters to adapt to differences between the interfering event in the beamsteer and the individual traces and to successfully predict off the interfering event. On the other hand, the target event is a small portion of the individual traces, for low SNR, and is further suppressed in the beamsteer. It should have little effect, therefore, on the adaptive filter weights, and the target event should remain undistorted in the prediction error traces. The prediction error traces, then, are expected to contain undistorted target event and suppressed interfering event. To further suppress the interfering event the prediction error traces are then beamed in the direction of the target event.

To test this technique an event from California was added to a Greenland Sea event. The events were scaled to make the peak value of the interfering Greenland Sea event about five times that of the target California event. It is to be noted that this composite is a simple one in two respects:

1) the events are well separated azimuthally,

2) these two events exhibit less trace to trace dissimilarity than do most recorded teleseisms.

The AO, D, and E ring vertical seismometers were used in the mode described above. Three-point filters were designed. The rate of adaptation was the maximum permitted by the stability considerations as described by Widrow. This stability constraint is conservative, however, and for data such as ours the filters are never operating on the verge of instability. One adaptive pass was made through the data. Experience has shown that the results of subsequent passes do not differ significantly from those of the first pass.

The target California event is reproduced in the final beamsteer resonably well but with an amplitude reduction of about 6 db. The early portions of the interfering event are suppressed by about 30 db. In the later part of this event, where trace to trace dissimilarities are more evident, noise suppression degrades markedly. In an effort to improve the ability of the filters to handle all portions of the interfering event, the experiment will be repeated using the AO, C, and D ring sensors and one-point filters. The reduced filter length permits a threefold increase in the rate of adaptation.

For purposes of comparison, it is noted that simple beamsteer of this composite results in a SNR improvement of about 12 db.

HIGH RESOLUTION WAVENUMBER SPECTRA RESEARCH

Wavenumber spectra research with emphasis on the high resolution technique has been divided into two areas:

- Location statistics
- Short period event processing

The objectives of each of these areas and the palnned route to them is delineated below.

A. LOCATION STATISTICS

This area of study is being conducted to determine how locating events using wavenumber spectra is related to the signal-to-noise ratio of the data being processed. Initially, this task was undertaken analytically but soon became untractable. The problem was then divided into two experiments designed to determine the location ability for particular array geometries as a function of signal-to-noise ratio. By using both the high-resolution and probabilistic F-K techniques, a comparison of the two is possible.

The two experiments are obtained by treating correlated and uncorrelated noise fields separately. This separation results from the increased computational difficulty in treating correlated noise compared with treating uncorrelated noise. Both the data generation and the processing techniques require matrix rather than vector arithmetic when the noise field is correlated.

The uncorrelated noise field experiment is completed and the results have been tabulated. This experiment utilized a synthetic signal set consisting of the transform of a uniform plane wave signal traversing the LASA A, B, C, and D ring subarrays at infinite velocity. To this signal transform one hundred noise sets, consisting of random numbers generated by a normal (mean = zero, variance = one) random number generator, were added to the signal set. The signal-to-noise ratio was controlled by uniform scaling of the amplitudes of the signal transform set. This data was then processed by both the probabilistic technique and by the high resolution technique. At each signal-to-noise ratio the mean and variance of each wavenumber point were computed for both techniques. These statistics demonstrated that the probabilistic processor and the high resolution techniques are essentially equivalent for the array geometry and uncorrelated noise model used.

For correlated noise fields, a program has been written which generates the power spectral matrix for combinations of disk, annulus, and multiple plane wave noise models. These matrices will be used in both the coherent noise statistics experiment and in coherent noise processing of sub-array data. The program needed for the coherent noise experiment is being written and should be operating before the end of April. Analysis of the output of this program will result in a statistical comparison of conventional, high resolution, and probabilistic wavenumber spectra techniques.

B. SHORT PERIOD EVENT PROCESSING

Processing of the six available events has commenced. This processing will generate conventional, high resolution, and probabilistic wave-number spectra generated at several frequencies covering the signal bandwidth. During the processing, the various parameters such as transform gate length, reference sensor stacking, and frequency stacking will be investigated to determine desirable ranges for each. All programs needed for this processing are currently operational on S/360. Processing should be completed and the analysis of the results well underway by the end of the second quarter.

The program simulating the current LASA teleseismic event detection is operational and four of the events have been processed and detected. The remaining two events will be processed during April.

Very truly yours,

TEXAS INSTRUMENTS INCORPORATED

Frank H Binder

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13. ABSTRACT

~~This~~ The report is a summary of results obtained on Contract AF 33(657)-16678, LASA Evaluation, during the period January 1, 1968 through March 31, 1968.

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