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SUMMARY OF ENVIRONMENTAL ACOUSTIC DATA PROCESSING

Annual Report under Contract N00014-70-A-0166, Task 0016
1 July 1973 - 30 June 1974

Glen E. Ellis

OFFICE OF NAVAL RESEARCH
Contract N00014-70-A-0166, Task 0016

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This report summarizes the tasks performed under Contract N00014-70-A-0166, Task 0016, during the period 1 July 1973 through 30 June 1974. Description of the modifications to the continuous wave, ambient noise, and explosive source processing systems is provided. The utilization of these analyses for a "quick look" and volume data processing associated with the BLAKE Test and the CHURCH ANCHOR and the SQUARE DEAL Exercises is described. Other short term analyses and technical support efforts are described.

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ABSTRACT

This report summarizes the tasks performed under Contract N00014-70-A-0166, Task 0016, during the period 1 July 1973 through 30 June 1974. Description of the modifications to the continuous wave, ambient noise, and explosive source processing systems is provided. The utilization of these analyses for a "quick look" and volume data processing associated with the BLAKE Test and the CHURCH ANCHOR and the SQUARE DEAL Exercises is described. Other short term analyses and technical support efforts are described.

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I. INTRODUCTION

The work described in this report was performed under Contract N00014-70-A-0166, Task 0016, during the period 1 July 1973 through 30 June 1974. The areas of work performed were data processing system development and modifications, environmental acoustic data processing and analysis, exercise planning, and technical support. Specifically, tasks in these areas were involved with the BLAKE Test and the CHURCH ANCHOR and the SQUARE DEAL Exercises.

II. DATA PROCESSING SYSTEMS

During this period of work, modifications were made to the explosive source (SUS) processing system to incorporate new features and automate the procedures to handle the large volume of data. The ambient noise/continuous wave processing systems (AN/CW) were redesigned and combined in the implementation.

A. SUS Processing System

Two updates were made to the software portion of the SUS processing system: (1) an algorithm to automatically determine signal length on a shot-to-shot basis and (2) procedures to address the false alarm rate.

The SUS signal duration is independently determined on each data channel (maximum of three) because varying propagation paths can exist between the source and receiving hydrophones. An adaptive filter based on the signal energy relative to the ambient noise energy is used to determine the received shot signal termination. Shot epoch is determined independently on each corresponding data channel.[1] Information from each detected SUS is used to update the filter parameters for each following event.

False alarms using the automation shot detector became a concern during the processing and analysis of the CHURCH ANCHOR SUS data. Although the processing system can require coincident detection on either two or three hydrophone data channels, a procedure to conduct a quality assurance during the postprocessing phase was required. One output of the SUS processor is the high resolution spectra of the SUS signal and ambient noise segment associated with that signal over the frequency band of 10 to 300 Hz.[1] These spectra are archived on digital tape during processing and can be used to identify the low signal-to-noise ratio (SNR) SUS signals. A criterion was derived to establish a confidence level on the detected SUS signal relative to the SNR. The methods will be reported in the technical report on the SUS diagnostic work.

B. Ambient Noise/Continuous Wave Processing System

The large scale environmental acoustic exercises have generated large volumes of ambient noise (AN) and continuous wave (cw) data. These data are recorded by analog systems from hydrophones distributed throughout the water columns.

The ambient noise/continuous wave processing system (AN/CW) is implemented with a modification of the hardware/software system that has been utilized and updated for the studies of active sonar signal processing. The hardware portion of the system consists of a CDC 3200 digital computer with associated peripherals, including a flexible analog-to-digital (A/D) and digital-to-analog (D/A) interface. The software utilized was based on the routines existing in the signal processing software library for the CDC 3200.

AN/CW Processor Description

The AN/CW processor is a hardware/software configuration designed to perform a narrowband analysis over a variable frequency range by handling large volumes of data. The system is divided into five tasks: A/D conversion, spectral estimation, band estimation, editing, and display. Parameters such as bandwidth, frequency range and resolution, and integration or averaging time can be readily adopted to suit different applications.

For the A/D task, the analog data recordings are time compressed in playback and are converted to digital format. The equipment configuration is shown in Fig. 1.[2] One hydrophone channel along with the corresponding timing and receiving system information is digitized on each processing run. Programmable amplifiers, controlled by the digital computer, are used to maximize the dynamic range utilization of the A/D converter. The sampling signal is phased locked to a reference on the data tape or on the time code carrier to minimize errors due to record/playback fluctuations.

During one A/D pass, the computer flags any sample whose amplitude exceeds the range of the A/D converter. The computer also determines the peak and average amplitude of the data for each minute. This information is used to determine the desired amplifier setting for the data in the following minute. Time synchronization checks are maintained by the computer throughout an A/D run.

The second task of the processor is to compute and calibrate a narrowband spectra from contiguous time increments throughout the data period analyzed. Currently, an 8192 point FFT is used to provide a frequency resolution of 0.07 Hz for the frequency range of 10 to 300 Hz.

The ambient noise spectra can be both time averaged over a selected period and output as narrowband and/or octave band time series. Various statistical algorithms are available to furnish the information required to perform an acoustical analysis of the data.

The cw analysis is achieved by using the calibrated narrowband spectra to estimate the signal power in a given frequency band. The spectra are first averaged for a specified period. From these averages, two types of band estimates are obtained. For each cw signal, a narrowband (2 Hz wide) centered about the source frequency is searched for its spectral peak line. The power in a narrower band (0.22 Hz) centered about this peak is then determined. Peak tracking is used to compensate for any Doppler shift and variation in source frequency that might occur.

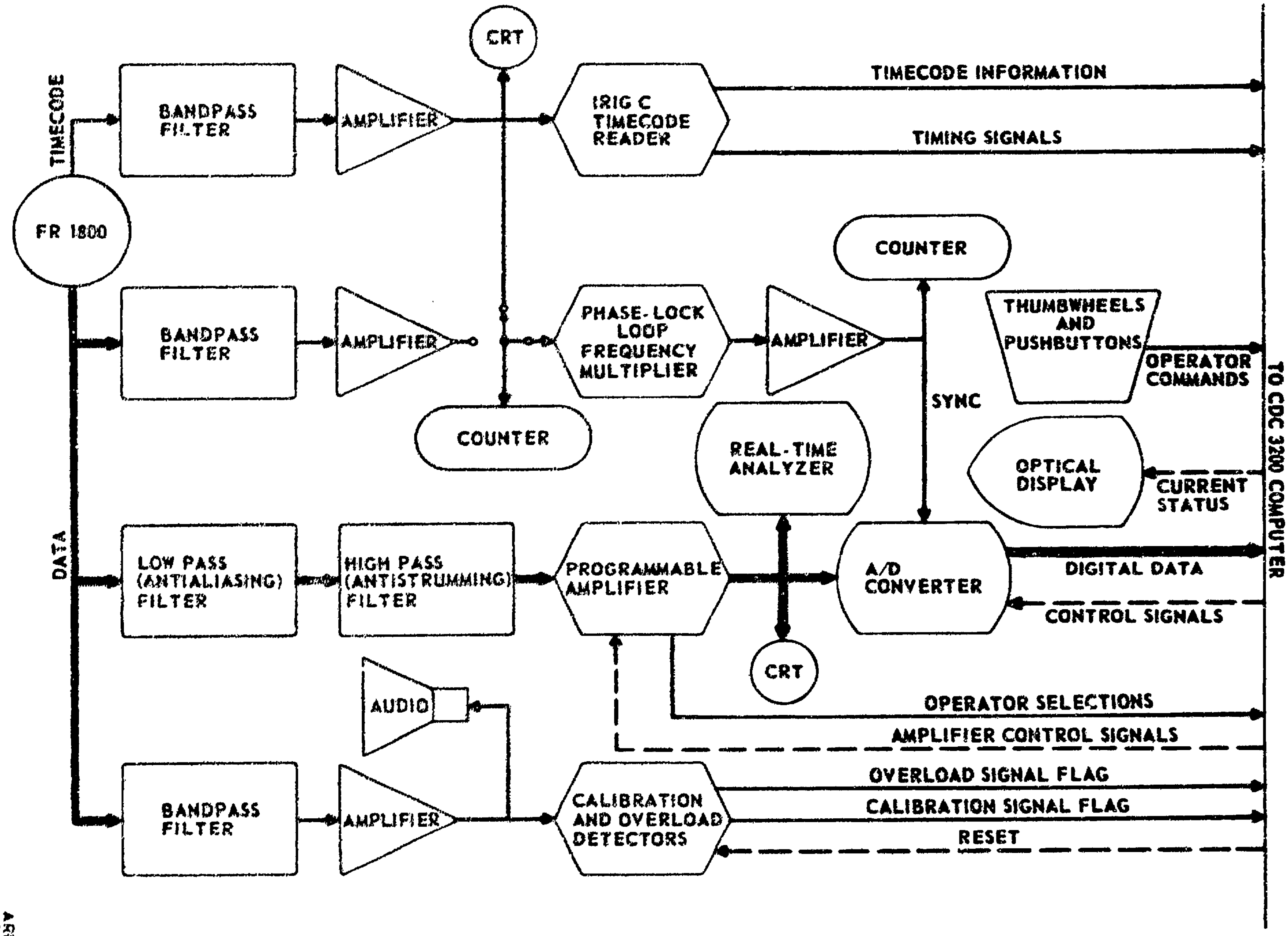

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FIGURE 1
ANALOG EQUIPMENT CONFIGURATION

The third task performed by the AN/CW processor automatically edits the reduced data for artifacts and contamination from the following sources:

1. environmental effects such as biological and seismic noise,
2. exercise effects such as conflicting sources (SUS), source level fluctuations, source timing, and shipping noise, and
3. receiver and recording system effects.

The techniques and algorithms used in the editing phase are software implemented with the exception of some SUS detection accomplished during the A/D phase. These algorithms consist of calibrations, data quality indicators, information from exercise operations, and adaptive filters for octave and narrowband noise estimators, peak tracking, and correction of receiver system artifacts.

The data display consists of graphics and tabulations specified and required in the final analysis performed. Figure 2 summarizes the AN/CW processor.

Processor Outputs

The following outputs of the AN/CW processor are available for analysis:

1. ambient noise spectra in narrow and/or octave bands,
2. cw signal power, noise power, and signal-to-noise or signal excess estimates in narrow frequency bands, and
3. propagation loss (PL), noise power estimates, and signal-to-noise or signal excess estimates versus range and/or time.

Examples of PL and signal excess (S+N)/N in the deep ocean are shown in Figs. 3 and 4. These plots show the PL along the same track for an inbound source and then for an outbound source. The figures illustrate the repeatability of the PL as a function of range. Equally interesting is that they show rather large variations in the noise

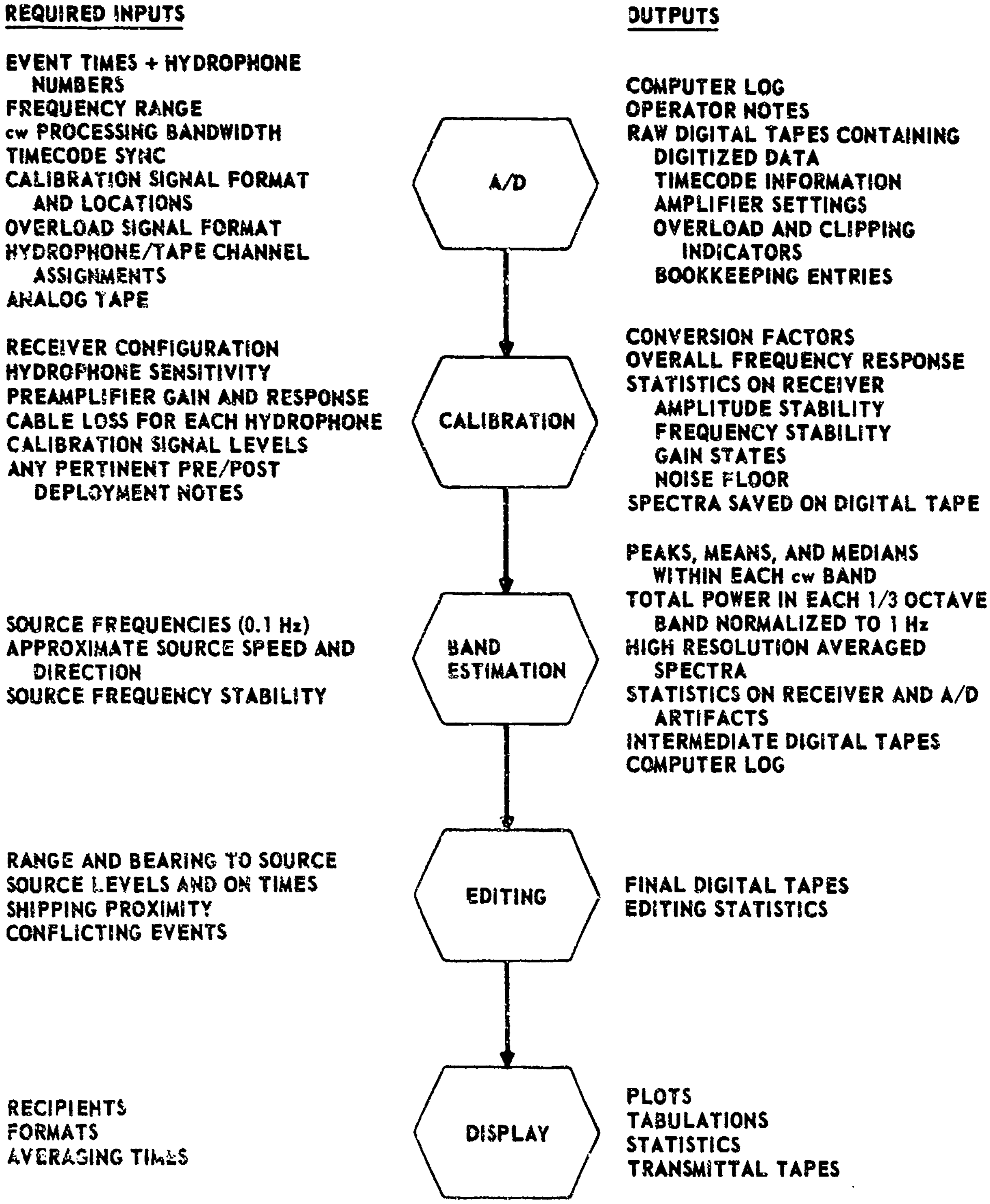

FIGURE 2
ARL/UT AN/CW PROCESSOR FUNCTIONS

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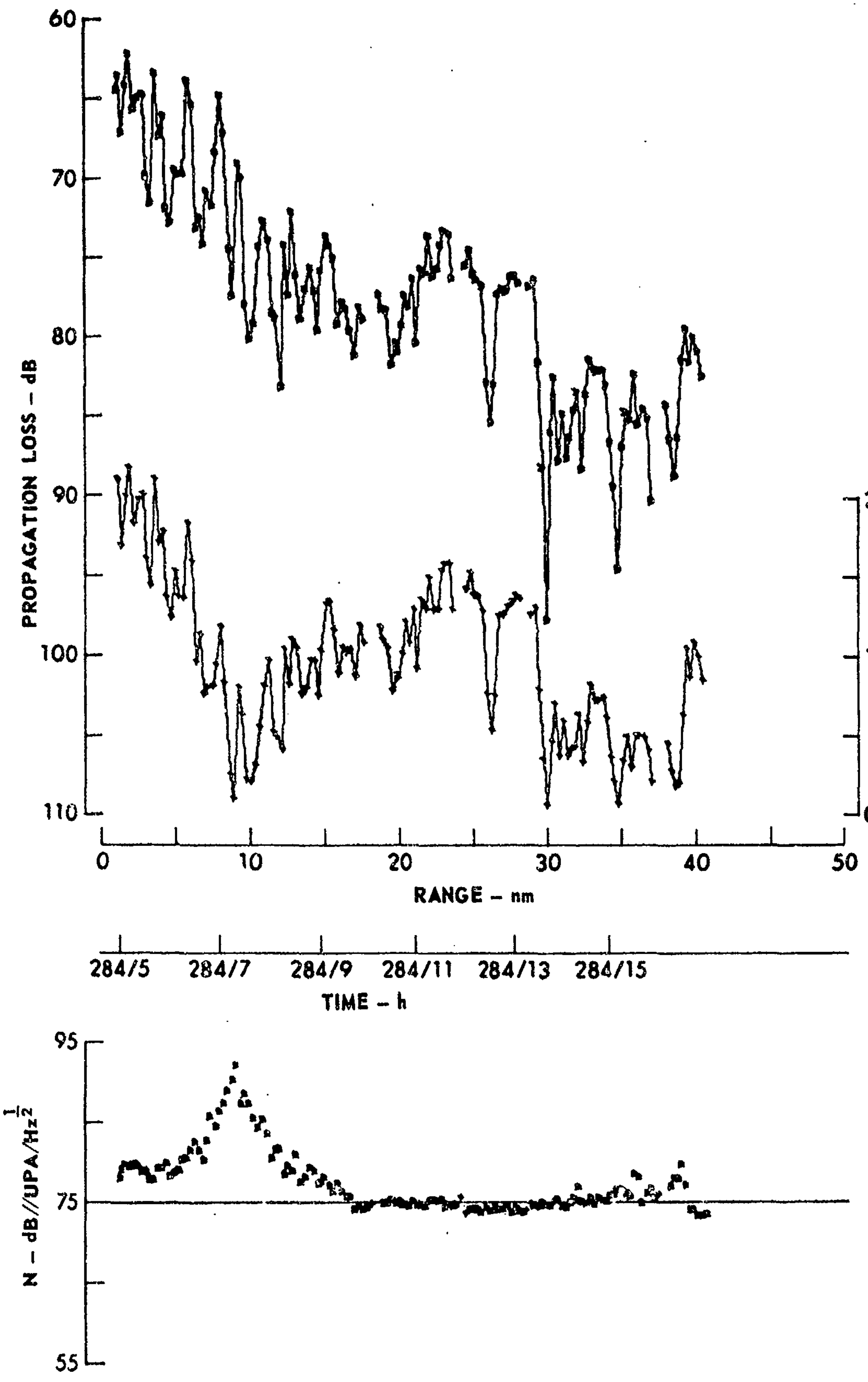

FIGURE 3
cw PROPAGATION LOSS
ACODAC SYSTEM 1 HYDROPHONE 6 5328 m BOTTOM
CHAIN TRACK G-F SOURCE J15-3 70 Hz 91 m 157 dB

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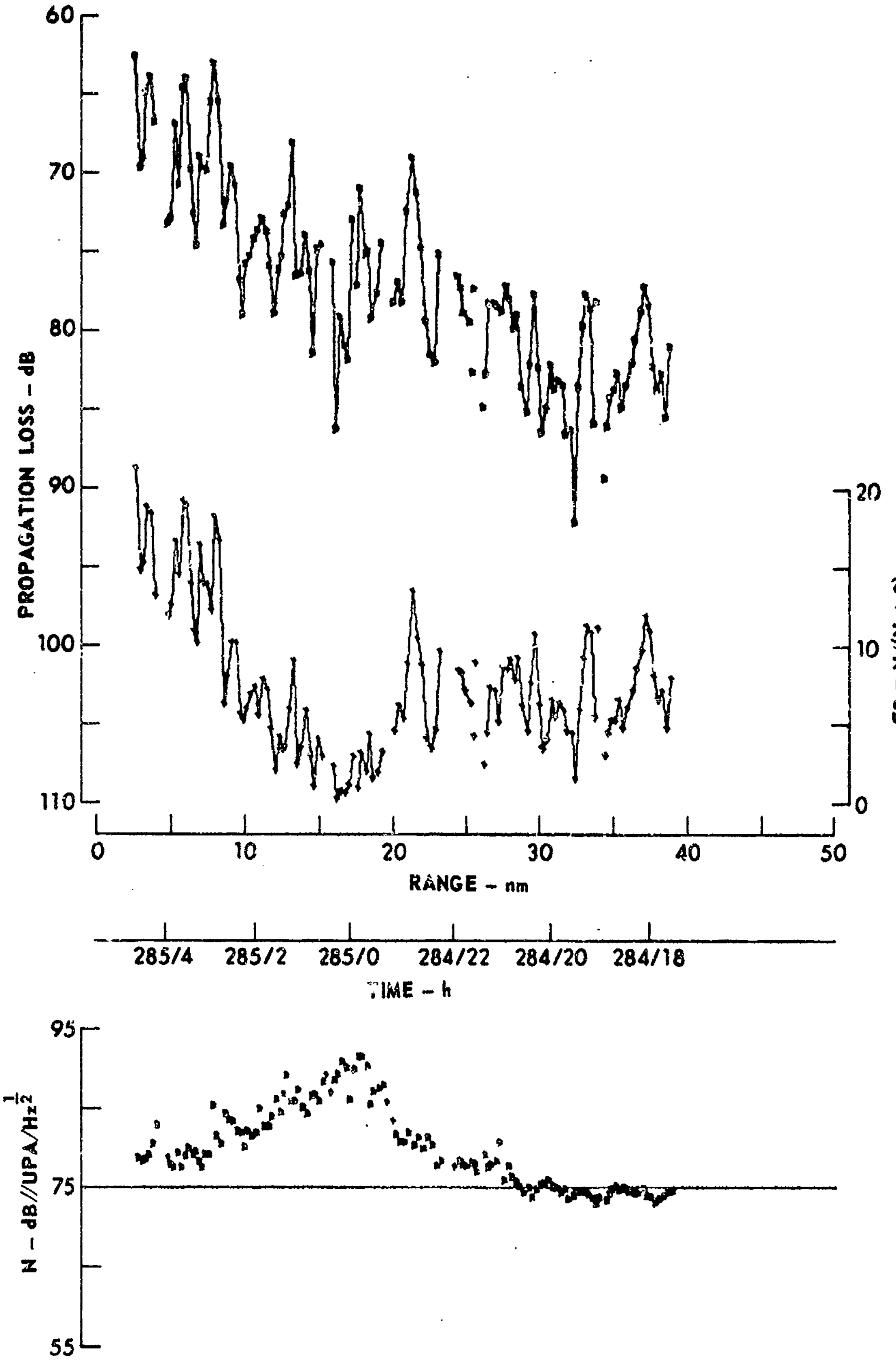

FIGURE 4
cw PROPAGATION LOSS

ACODAC SYSTEM 1 HYDROPHONE 6 5328 m BOTTOM
CHAIN TRACK F-G SOURCE J15-3 70 Hz 91 m 156 dB

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background. Such noise variations are difficult to interpret when viewed through a narrowband processor. ARL has found that a valuable aid in interpretation is a time versus frequency plot of the total available spectrum. For example, the noise increase in Fig. 3 is identified as a moving broadband source in the three-dimensional plot shown in Fig. 5. Another view of Fig. 5 is Fig. 6, which is a better illustration of the quantitative rise in the noise level.

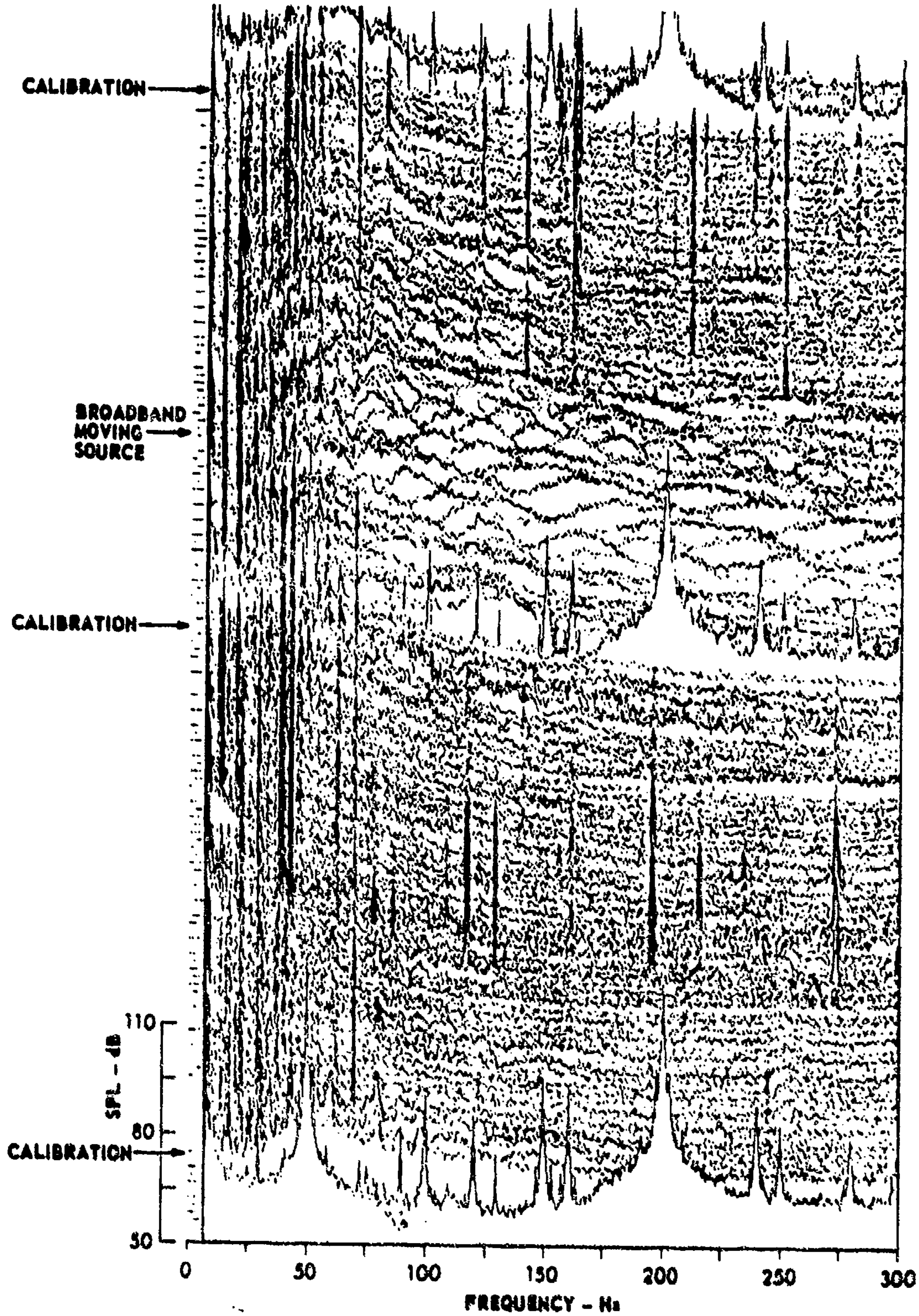

FIGURE 5
NARROWBAND SPECTRA
5328 m BOTTOM
J-15 F TO G VIBROSEIS G TO E

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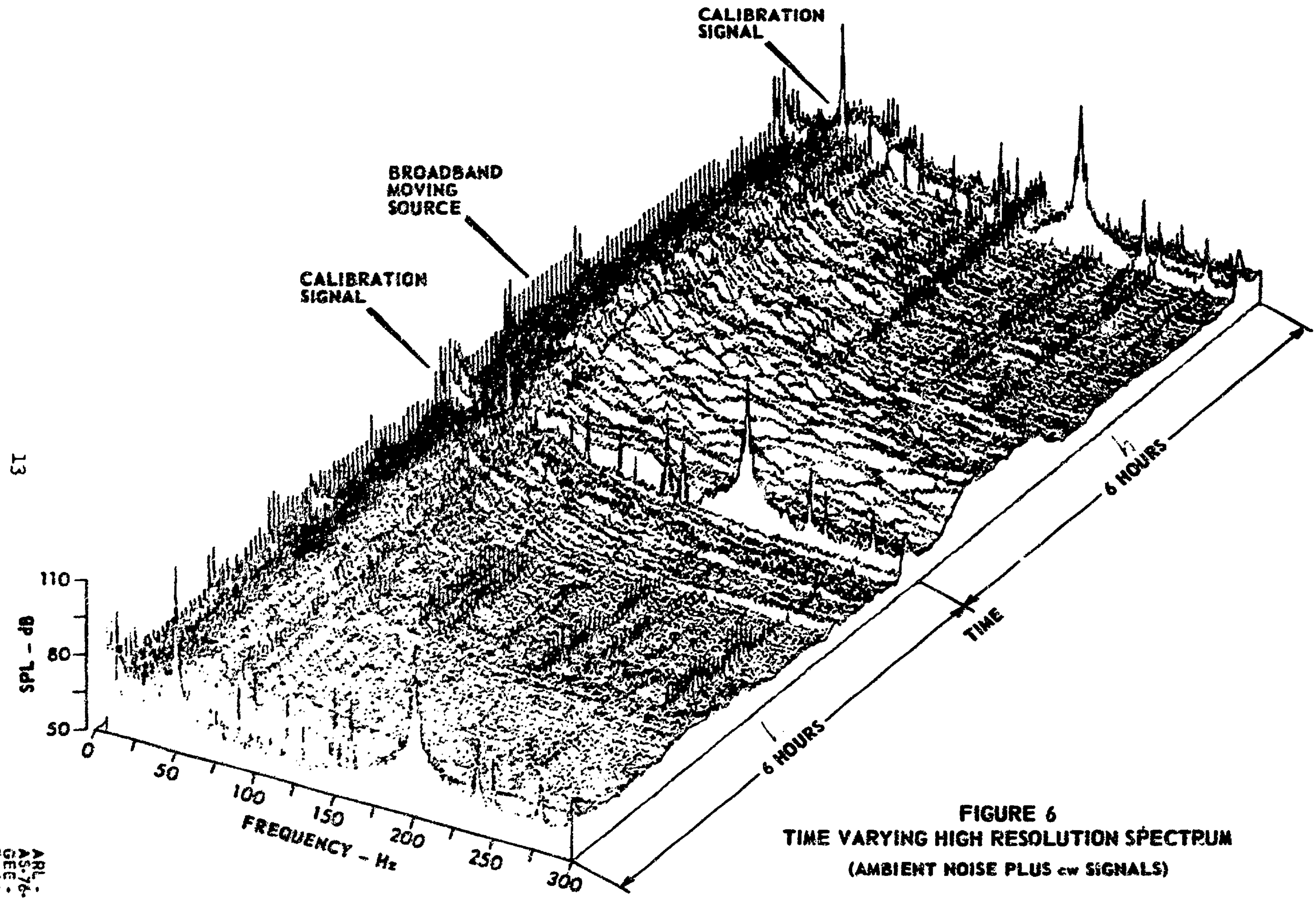

FIGURE 6
TIME VARYING HIGH RESOLUTION SPECTRUM
(AMBIENT NOISE PLUS cw SIGNALS)

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III. DATA PROCESSING

The data processing of the environmental acoustic data consisted of data quality assessments, "quick look or response" analyses, and volume data processing of ambient noise, cw, and SUS data for the BLAKE Test, the CHURCH ANCHOR Exercise, and the SQUARE DEAL Exercise.

A. Data Processing Planning

Applied Research Laboratories, The University of Texas at Austin (ARL/UT) participated in the preparation of the CHURCH ANCHOR and the SQUARE DEAL Exercise Data Analysis Plans. Procedures, requirements, and schedules for the data processing together with the interactions and data flow between other exercise participants were developed and documented in a plan to achieve the exercise goals. Technical representatives from ARL/UT attended numerous meetings during this preparation phase. The response of ARL/UT to the data processing task outlined in these plans was via memoranda to the manager of the Long Range Acoustic Propagation Project (LRAPP).

B. "Quick Look" Analyses

"Quick look" analyses were conducted on both CHURCH ANCHOR and SQUARE DEAL environmental acoustic data. These types of analyses were performed to determine the suitability of the data for further processing. These results along with the processing recommendations were furnished to the LRAPP manager and the appropriate exercise technical director via technical memoranda.

A "quick look" analysis similar to the preliminary ACODAC analysis[3] was performed in support of the chief scientist for the BLAKE test.

The primary acoustic source of interest was the SUS charges (explosive sources). One objective of the data analysis was to provide information for the investigation of ACODAC cable strumming. The results of this study were provided in an ARL technical memorandum.[4]

C. Volume Data Processing

A large volume of acoustic data was processed for the CHURCH ANCHOR Exercise. The data were recorded on analog tape from the ACODAC and FLIP receivers. The data types included ambient noise, cw, and SUS. The outputs of the data processing, as outlined in the CHURCH ANCHOR Data Analysis Plan, were ambient noise levels, propagation loss, and signal-to-noise ratios throughout the water column. The volume of data processed in hydrophone days (HD) and hydrophone shots (HS) was:

Sensor	Noise (HD)	cw (HD)	SUS (HS)
ACODAC	17	13	21,291
FLIP	--	--	1,935

For the SQUARE DEAL Exercise, a limited volume of SUS data was processed for analysis for the SQUARE DEAL Exercise Synopsis Report issued by the exercise technical director.

IV. ANALYSIS AND REPORTING

A. CHURCH ANCHOR Exercise

ARL/UT participated with staff members from Texas Instruments, Inc., (TI) in the analysis and documentation of the ambient noise and cw data. Technical reports were issued by TI. The analysis of the SUS data was performed by ARL/UT and will be documented in technical report form. ARL/UT also assisted the chief scientist in the preparation of the Environmental Acoustic Summary Report.

B. SQUARE DEAL Exercise

A summary of the preliminary findings from the limited amount of the processed SUS data for the SQUARE DEAL Exercise Synopsis Report was submitted to the technical director.

C. SUS Diagnostic Plan

ARL/UT participated in the planning of the SUS diagnostic plan that addresses the consistency aspects of SUS data processing within the organizations participating in the LRAPP data processing program. The efforts outlined in the plan have been initiated by using a selected data set from a SQUARE DEAL Exercise ACODAC. ARL/UT is coordinating the data processing and will assist Underwater Systems, Inc., in the analysis and interpretation of the results. A technical report will provide the documentation for these results.

D. High Resolution cw Study

ARL/UT participated in a LRAPP sponsored meeting concerning high resolution cw data processing. The emphasis of the meeting was to coordinate the processor parameters used by the various participants in the data analysis of the environmental acoustics collected during the LRAPP sponsored exercises. As a result of this meeting, ARL/UT was requested to perform a high resolution frequency analysis on related data sets to determine the presence of observable sidebands in cw signals generated by a moving source and received at ranges of up to 200 nm in the deep ocean. Theoretical predictions, as well as observations at relatively short ranges, and steep grazing angles show that a sound wave which is forward scattered from the ocean surface has its frequency components smeared by surface wave motions. The results of this analysis will be forwarded to the LRAPP manager in a technical memorandum.

E. High Resolution Travel Time Measurements of SUS Signals

During the CHURCH ANCHOR and SQUARE DEAL Exercises, the positions of the receivers at deployment and of source ships during their runs were determined from satellite fixes. There was some concern over the possibility of large errors (on the order of several nautical miles) in source-to-receiver ranges because of ineffective interpolation along the source track. The signal travel times are available as a byproduct of the ARL SUS processing; these times were examined for possible discrepancies between the acoustic information and the navigation data. Once the pattern of the acoustic data was explained, the accuracy of the navigation data was seen to be better than 0.1 nm. However, the travel time measurements are interesting in themselves. They were seen to reflect the sound velocity structure of the medium and also to give some indication of the variability of propagation loss to be expected. The results of this study were provided to the LRAPP manager in memorandum form.

F. SUS Processing Quality Control Study

The errors associated with the analysis of signals from explosive sources have been analyzed and reported. The effects of analog reproduction and subsequent digital conversion of the data on the estimation of propagation loss were considered. In addition, the techniques of spectral analysis as applied to these impulsive type data were addressed. The work was documented in an ARL technical memorandum.[5]

In summary, it was found that the digitizing processing can be repeated on a day-to-day basis to the extent that the energy in frequency bands for either shots or noise has standard deviations of 1 to 2%. The times at which the automatic SUS processor detected a shot showed no fluctuations other than those to be expected from the temporal resolution imposed by the sampling rate. The standard deviations due to repeated processing of transmission loss for a given frequency band is of the order of 0.1 to 0.2 dB.

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RAFF7412; 74-482	Scheu, J. E.	SQUARE DEAL SHIPPING DENSITIES (U)	Raff Associates, Inc.	750401	ADC003198; NS; ND	U
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