

AD 67473

UNDERWATER SYSTEMS, INC.

TECHNICAL PROGRESS REPORT NO. 21

SPECTRAL ANALYSIS OF HYDROACOUSTIC SIGNALS GENERATED BY
THE CHASE V, CHASE VII, NOL-VELA, AND ARCTIC EXPLOSIONS

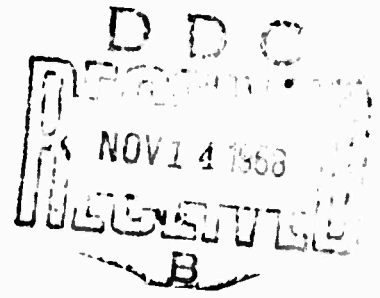
Prepared by:

Mr. David F. Young
Mr. Daniel D. Woolston
Mr. Maurice Blaik

Sponsored by:

ADVANCED RESEARCH PROJECTS AGENCY (ARPA)
OFFICE OF NAVAL RESEARCH (ONR)

Contract No. NOnr 4026(00)
Project Code No. 3810
ARPA Order No. 218



30 July 1968

World Building • 8121 Georgia Ave
SILVER SPRING, MD 20910
Telephone: 589-1188

This document has been approved
for public release and sale; its
distribution is unlimited

Reproduced by the
CLEARINGHOUSE
for Federal Scientific & Technical
Information Springfield Va. 22151

35

TECHNICAL PROGRESS REPORT NO. 21

SPECTRAL ANALYSIS OF HYDROACOUSTIC SIGNALS GENERATED BY
THE CHASE V, CHASE VII, NOL-VELA, AND ARCTIC EXPLOSIONS

Prepared by:

Mr. David F. Young
Mr. Daniel D. Woolston
Mr. Maurice Blaik

Sponsored by:

ADVANCED RESEARCH PROJECTS AGENCY (ARPA)
OFFICE OF NAVAL RESEARCH

Contract No. NONr 4026(00)
Project Code No. 3810
ARPA Order No. 218

30 July 1968

TABLE OF CONTENTS

	Page No.
INTRODUCTION	1
CHASE V Signal Analysis	4
CHASE VII Signal Analysis	6
NOL-VELA and SIR HORACE LAMB Series	8
Arctic Ocean Signal Analysis	10
Figures	12
References	30

SPECTRAL ANALYSIS OF HYDROACOUSTIC
SIGNALS GENERATED BY THE CHASE V,
CHASE VII, NOL-VELA, AND ARCTIC
EXPLOSIONS

Introduction

The purpose of this report is to present the results of narrow band analyses of the hydroacoustic signals generated by explosives in the following programs:

- (1) CHASE V
- (2) CHASE VII
- (3) NOL-VELA Underwater Explosive Series (including
SIR HORACE LAMB shots (February - March 1965)
- (4) Arctic Ocean Underwater Explosive Series

This will complete the narrow band analysis of the CHASE Series. CHASE II, III and IV data was presented in Reference (1). Our analysis of the NOL-VELA and Arctic Ocean data has not previously been presented.

The CHASE program is an operation where reserve fleet vessels are loaded with obsolete materials, such as explosives, towed to sea and subsequently scuttled. The program, as it applied to the ONR underwater explosion experiment, involved the deliberate detonation* of the CHASE hulls at predetermined

* The CHASE II hull, it will be remembered, was not intentionally detonated. Its accidental explosion, however, triggered interest which resulted in the planned experiment which followed.

depths and subsequent analysis of the hydroacoustic and seismic signals generated. Of the hulls in the planned explosive series only CHASE VI failed to explode, having drifted into and sunk in water too shallow for detonation, Reference (2).

The NOL-VELA Explosive Series of February-March 1965 was of interest to us at that time since large charge data was not available. It was intended to use the hydroacoustic data from that series for extrapolation to larger yields and to confirm that the spectral characteristics were independent of range. The availability of large charge data from the CHASE Series made it unnecessary to utilize extrapolation procedures. However, the analyses performed are included here for completeness. It was planned that, in addition to numerous smaller explosions, three 1000 pound detonations would take place. However, none of the 1000 pounders detonated. The remaining smaller charges were monitored close-in at the USNS GILLISS, the drop ship, by NOL personnel and at the SIR HORACE LAMB by personnel from the Columbia University Geophysical Field Station, Bermuda. Also, the SIR HORACE LAMB personnel detonated three 1000 pound charges for one of their own programs during the NOL-VELA Series. Spectra obtained for one of the 1000 pound SIR HORACE LAMB shots as received at the Tudor Hill Observatory in Bermuda and two of the smaller NOL-VELA shots as monitored at the UNSN GILLISS are presented in this report.

The Arctic Ocean explosive signals were obtained from two separate series of underwater detonations. One series was detonated by the U.S. Coast Guard Icebreaker NORTHWIND and monitored at Fletcher's Ice Island (T-3). The other series was detonated by T-3 personnel and monitored at Ice Station Arlis II. Copies of the recordings were made available to us by the Lamont Geophysical Laboratory. Some typical spectra are presented here.

CHASE V Signal Analysis

The pertinent on-site data for CHASE V, Reference (3), is as follows:

Shot Location: Latitude $39^{\circ} 28' N$

Longitude $125^{\circ} 48' W$

(Shot location accuracy unknown; however, best guess is $\pm 1/2$ n.m.)

Shot Instant: 24 May 1966

05:49:06.58 $\pm$ 00.00:00:25 Zulu (GMT)

Water Depth: 12,500 $\pm$ 100 feet

Shot Depth: 3,750 feet $\pm$ 250 feet

Yield: 1.0 $\pm$ 0.2 kilotons

The on-site signal was recorded at a distance of approximately 4.5 nautical miles from the detonation site. The broadband signal (pressure-time curve) is shown in Figure (1) and described in Reference (3). As expected, and as can be calculated, the shock wave portion of the pressure-time curve is modified (cut-off) by the surface reflected signal. A bubble pulse period of 0.575 seconds is apparent, corresponding to a frequency of 1.74 Hz. The narrow band analysis of this signal is shown in Figure (2). A harmonically related series of spectral maxima with a fundamental frequency of approximately 1.7 Hz, corresponding to the bubble pulse frequency, is clearly exhibited.

Figures (3) and (4) present spectra obtained for the CHASE V signal as received at the ship GRASS VALLEY by Naval Radiological Defense Laboratory personnel. The ship was located approximately 87 nautical miles from the detonation site. The spectra were obtained for hydrophone depths of 90 feet, Figure (3), and 40 feet, Figure (4). The bubble pulse frequency as measured from these records is again found to be approximately 1.7 Hz.

Narrow band spectra of the longer range hydroacoustic signal are shown in Figures (5) and (6). Figure (5) is the spectral analysis of the hydroacoustic signal as monitored by the MILS station at the PMR facility at Midway Island in the Pacific, a range of about 2600 nautical miles. This analysis clearly displays the spectral maxima spacing of approximately 1.7 Hz. Figure (6) presents the spectrum of the hydroacoustic signal obtained by the MILS station at New Zealand, a range of about 5600 nautical miles. Although the interpretation is more difficult, the 1.7 Hz maxima spacing is still evident.

The spectral analyses performed for the CHASE V experiment clearly demonstrate that bubble pulse frequency can be monitored at all ranges.

CHASE VII Signal Analysis

The CHASE VII event occurred on 29 July 1966 about 100 miles east of Kitty Hawk, North Carolina. Pertinent on-site data for the detonation, Reference (4), is given below:

Shot Depth: $\approx$ 3,000 feet

Water Depth: 7,500 feet

Yield: 400 tons

(Various failures during the experiment precluded accurate shot instant and shot location determinations. A discussion of the test and estimates of these parameters are given in Reference (4)).

The spectral analyses presented here for the CHASE VII event, Figures (7)-(10), were performed for signals received at Columbia University Geophysical Field Station in Bermuda, a distance of approximately 540 nautical miles from the detonation site. The analysis band for each spectrum is 0 - 12.5 Hz with a bandwidth of 1/8 Hz. The signal arrivals investigated are the following:

Figure (7) - Direct arrival.

Figures (8) and (9) - Reverberation immediately following direct arrival.

Figure (10) - Reverberation approximately 255 seconds after direct arrival.

Each of the spectra clearly exhibits the harmonics in the bubble pulse series. A bubble pulse frequency of 2.0 Hz is obtained.

It is observed that the direct arrival spectrum yields as clear a presentation of the bubble pulse series as does that of the reverberant arrival immediately following. This is in contrast to the findings of the analyses of the CHASE II, III, and IV events, Reference (1), where the reverberation yielded a significantly clearer spectrum than did the direct arrival. This is probably due to the fact that the CHASE VII direct signal does not exhibit the early discrete arrival pattern shown by those of the other events.

The reverberation about 255 seconds after the direct signal is the return from the U.S. east coast. Its spectrum differs from the other spectra presented in that the signal level is reduced at the low frequencies. This is the result of shallow water propagation effects, a discussion of which is given in Reference (1).

NOL-VELA and SIR HORACE LAMB Series

The US Naval Ordnance Laboratory (NOL) detonated a series of underwater charges during February and March 1965. The Columbia University Geophysical Field Station ship SIR HORACE LAMB also detonated several underwater charges during the same period.

Figure (11) shows the spectrum obtained from one of the large charges (1000 lbs) dropped from the SIR HORACE LAMB. The detonation depth was 8000 feet (nominal). Analysis was performed for the signal received at the Tudor Hill Observatory at Bermuda, a range of approximately 600 nautical miles. The measured bubble pulse frequency, 41 Hz, agrees with the predicted value based on the nominal depth figure. The relatively low amplitudes of the first and second harmonics may reflect in part the roll-off of the AM recording system used to obtain the shot data. It is observed that the position of the fundamental is shifted upward about 10 Hz from the value determined from the second, third, and fourth harmonics. This deviation is qualitatively consistent with the previous observation that the fundamental usually exhibits some shift. This is related to the strong negative going portion of the explosive signal which appears between the shock wave and first bubble pulse for deep low yield detonations, Reference (5).

Spectra for two of the charges from the NOL trials mentioned above are presented in Figures (12) and (13). The signals analyzed were those monitored close-in by the USNS GILLISS, the ship from which the charges were dropped. Pertinent shot information is given below:

Figure (12) - NOL Shot No. 79; yield 55 lb; detonation depth (nominal) 7000 feet.

Figure (13) - NOL Shot No. 42; yield 1 lb; detonation depth (nominal) 1200 feet.

A significant upward shift in the position of the bubble pulse fundamental is observed for both records. It is also observed in each of the records that the second harmonic is split. Bubble pulse frequency determinations, therefore, were based on the positions of maxima above the second harmonic.

A bubble pulse frequency of 103 Hz is obtained for the spectrum of Figure (12). This is slightly higher than the predicted value, 97 Hz, indicating that detonation occurred at a depth somewhat greater than 7000 feet. The spectrum of Figure (13) yields a bubble pulse frequency of approximately 86 Hz which agrees with the predicted value.

Arctic Ocean Signal Analysis

Two different series of explosion tests in the Arctic Ocean were analyzed. These are the charge series dropped from the U.S. Coast Guard icebreaker NORTHWIND and received at Fletcher's Ice Island (T-3) in September 1965 and the charge series dropped from T-3 and received at drifting ice station Arlis II in September 1962.

A typical real time signal from one of the T-3 shots as received at Arlis II is shown in Figure (14). Frequency dispersion causes the signal to be divided into two major arrivals. The spectral analysis of the interval indicated is shown in Figure (15). Loss of low frequency energy is expected because of the response of the recording system. Loss of high frequency energy is expected because of scattering at the rough surface of the ice cover. The resulting spectrum reveals the superposition of the band-limited spectrum and the spectrum of the bubble oscillation for harmonics 2 through 11 with a bubble pulse frequency of approximately 12.3 Hz. This corresponds quite well with the expected value for this detonation of 5.5 pounds at a depth of 200 feet.

Figure (16) shows the real time signal recorded at T-3 for one of the NORTHWIND cruise detonations. As can be noted, the time duration is quite short, and only one of the two major arrivals is received. The spectral analysis is shown

in Figure (17). Major energy groupings give an apparent bubble pulse frequency of about 7 Hz which is in disagreement with the expected value of 3.8 Hz for this detonation of 44 pounds at a depth of 100 feet. This is the only case known to us where spectral analysis has failed to disclose the bubble pulse frequency. It is suggested that this is due to the short integration time available combined with spectral peaks controlled by mode effects. Mode effects are expected whenever water depths are several thousand feet or less and the frequencies of interest are several tens of Hz as in this case.

Another NORTHWIND shot analysis is shown in Figure (18). In this case, the combination of high pass (due to equipment response) and low pass (due to surface scattering losses in propagation) effects produce a usable band limited to the interval from about 15 Hz to 30 Hz. The three strongest spectral peaks are at approximately 18, 20, and 22 Hz. This set corresponds to the calculated harmonics 9 through 11 for the given charge weight of 1320 pounds at a depth of 200 feet.

Shock Wave Bubble Pulse
 Direct Surf.Ref Direct Surf.Ref. Bottom Ref. Bottom-Surf.Ref.



1 sec.

Figure 1
 Pressure-time history of QUAD-1
 detonation at a range of approximately
 4.5 n.m.

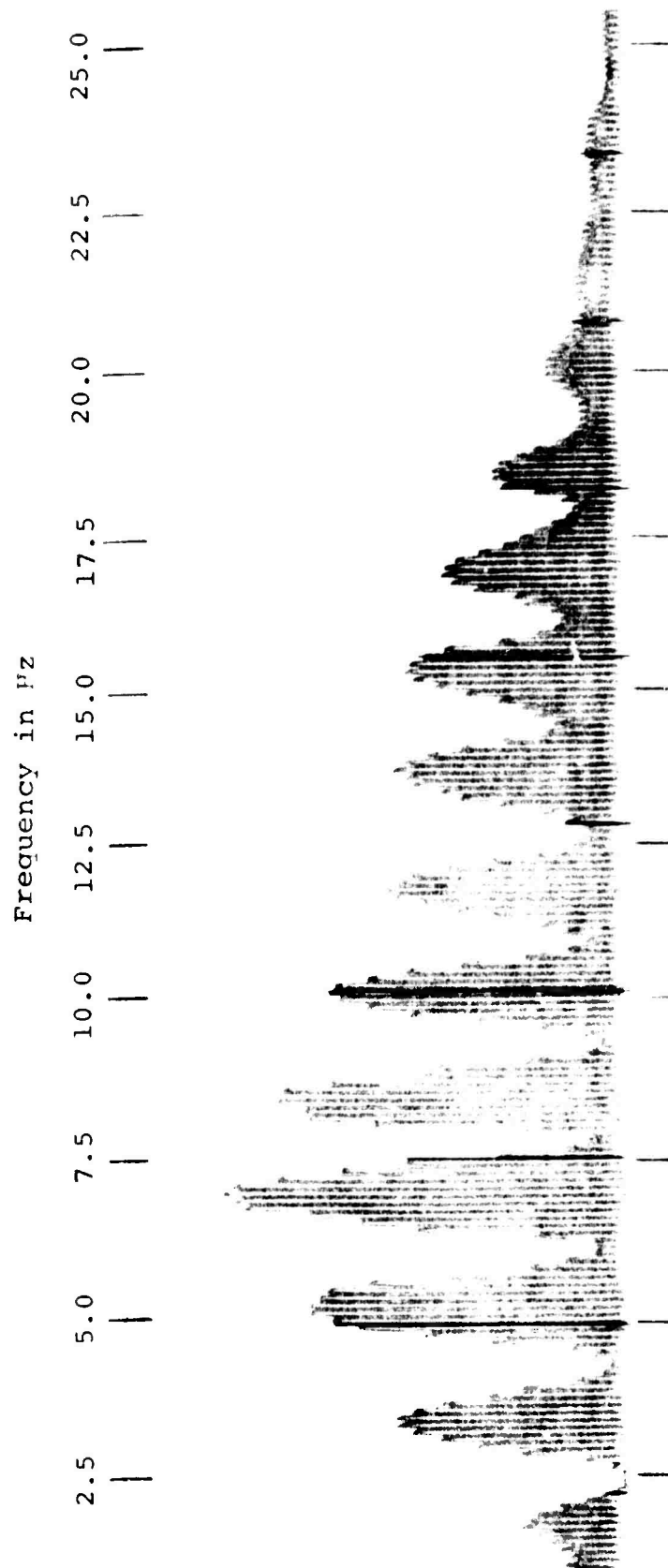


Figure (2)
Spectral analysis of hydroacoustic
signal generated by CHASE V detonation
as received at a range of approximate-
ly 4.5 n.m.

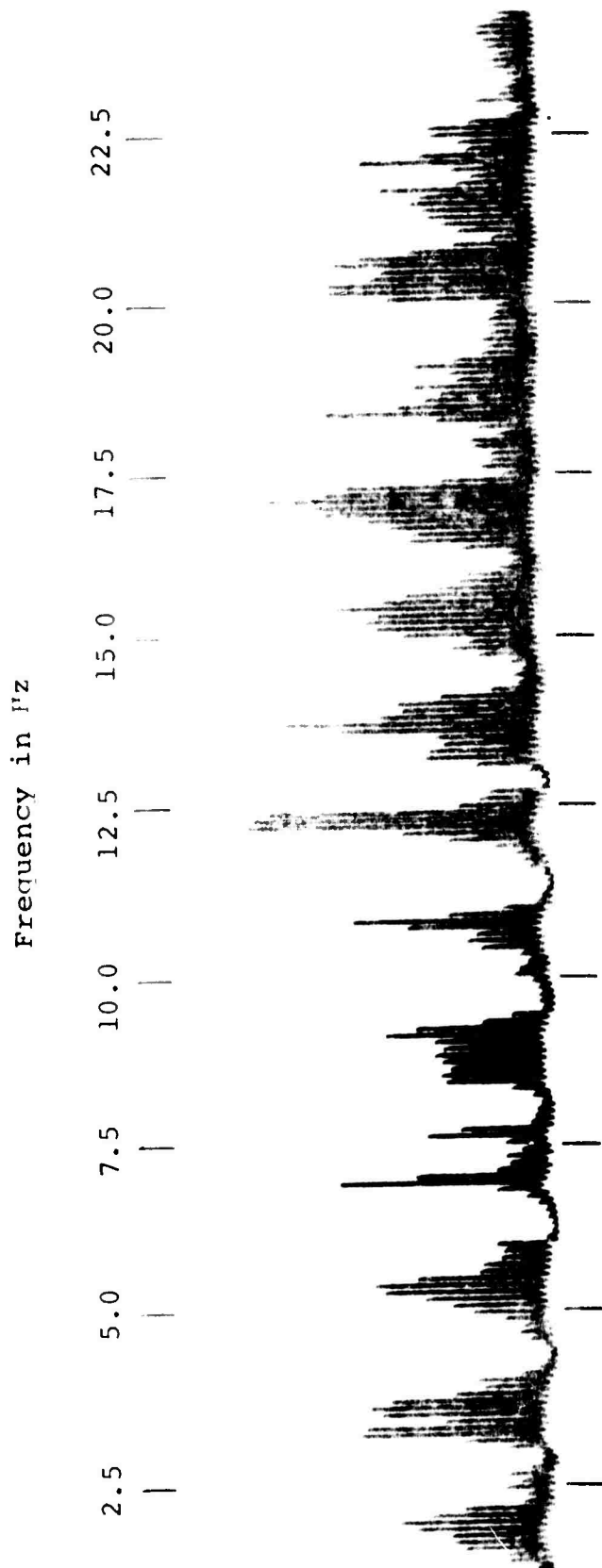


Figure (3)

Spectral analysis of hydroacoustic signal generated by CHASE V detonation as received at GRASS VALLEY. Direct signal. Hydrophone depth 90 feet; range 87 n.m. Bandwidth 1/8 Hz.

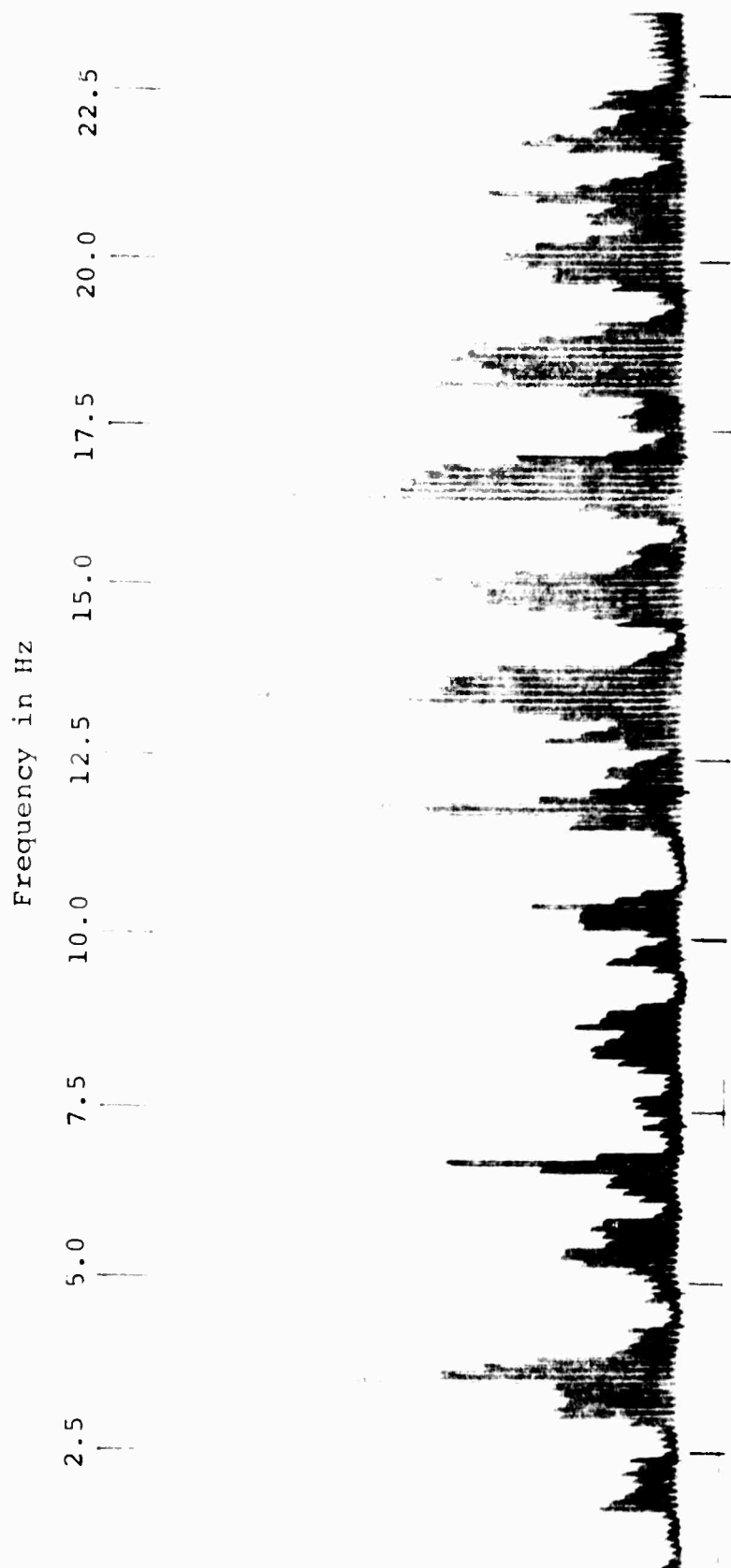


Figure (4)

Spectral analysis of hydroacoustic signal generated by CHASE V detonation as received at GRASS VALLEY. Direct signal. Hydrophone depth 40 feet; range 87 n.m. Bandwidth 1/8 Hz.

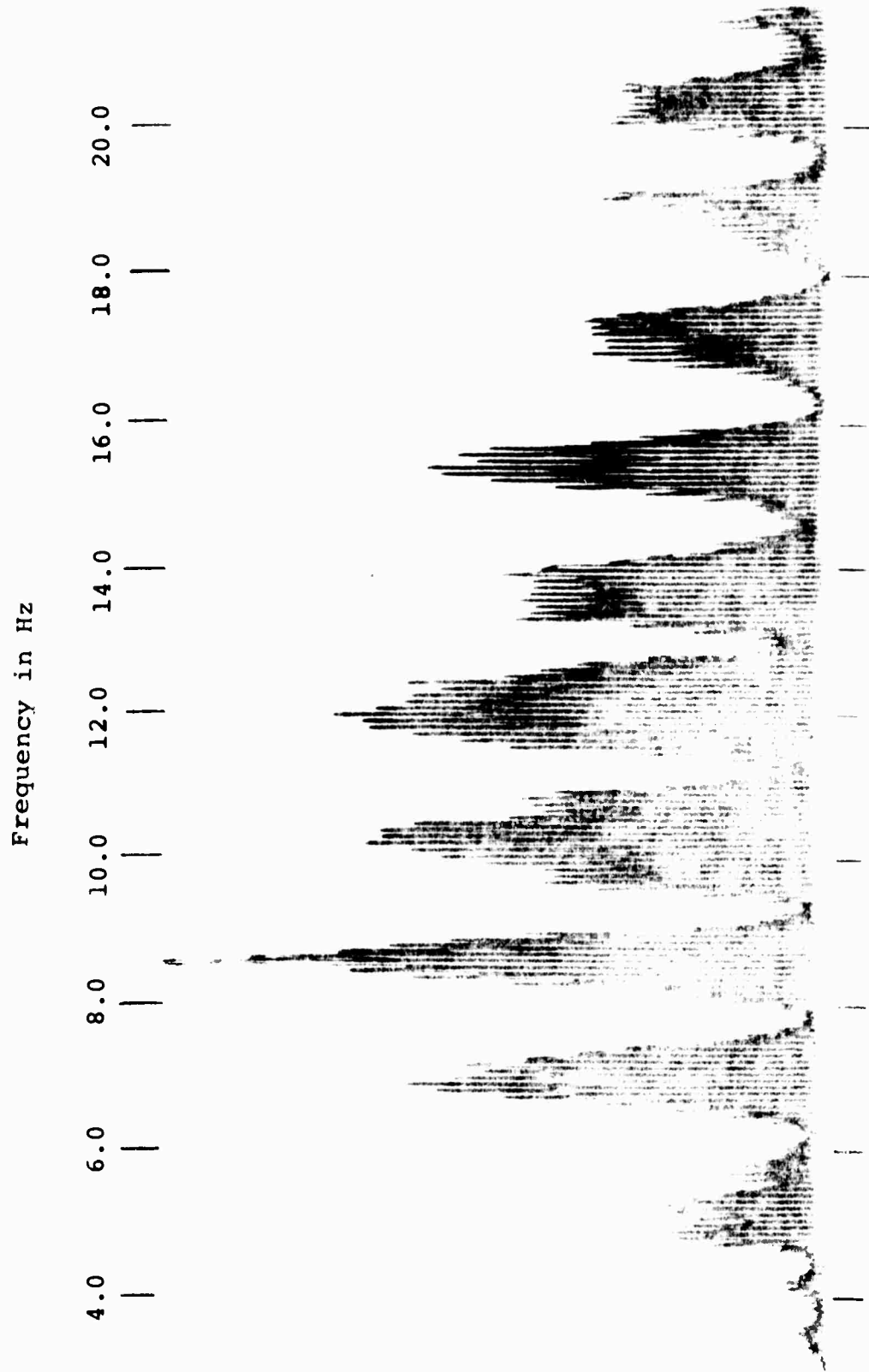


Figure (5)

Spectral analysis of hydroacoustic signal generated by CHASE V detonation as received at Midway Island. Reversion following direct signal. Range ≈ 2600 n.m. Bandwidth $1/5$ Hz.

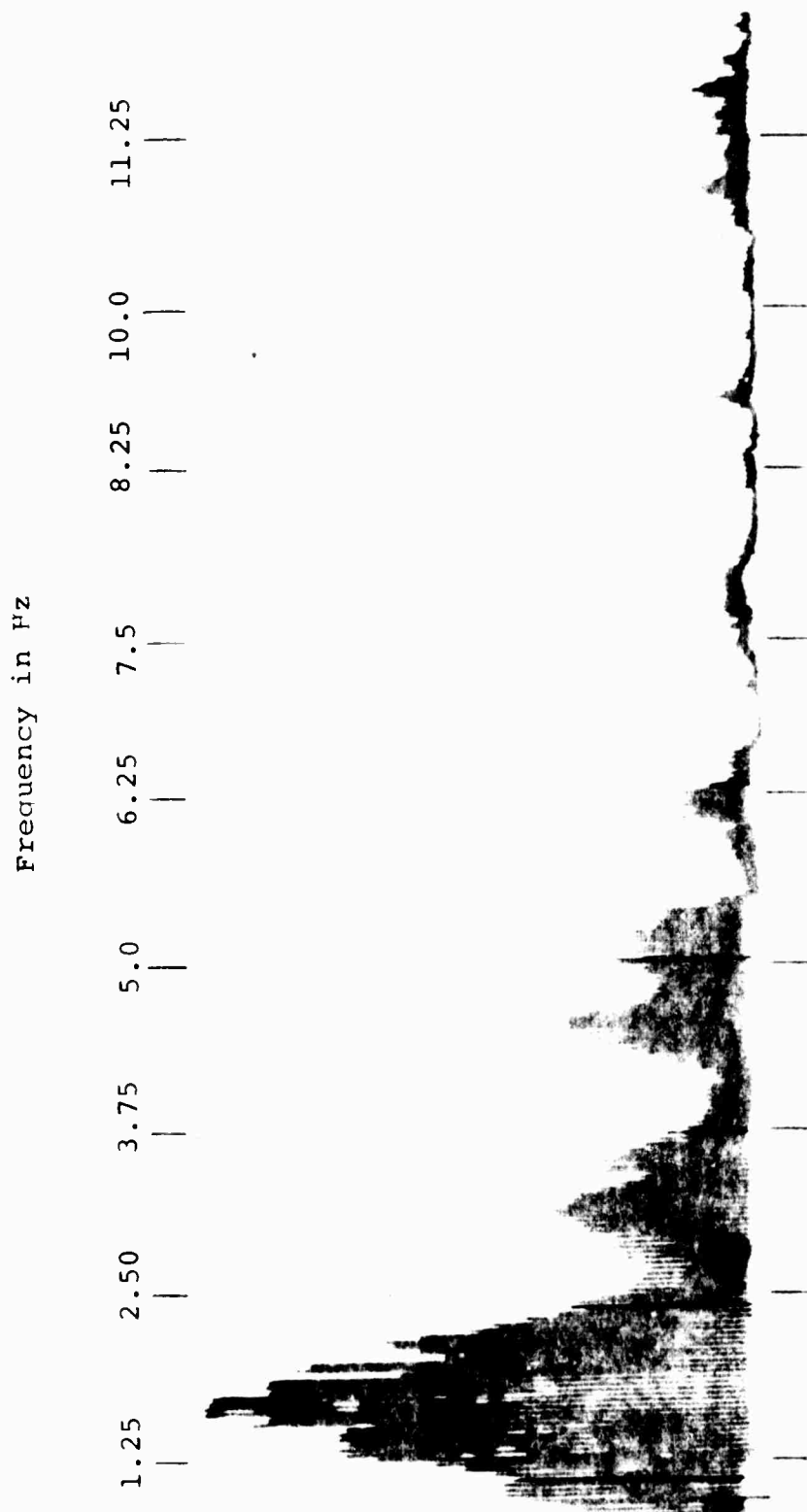


Figure (6)

Spectral analysis of hydroacoustic signal generated by CHASE V detonation as received at New Zealand. Reverberation following direct signal. Range ≈ 5600 n.m. Bandwidth $1/8$ Hz.

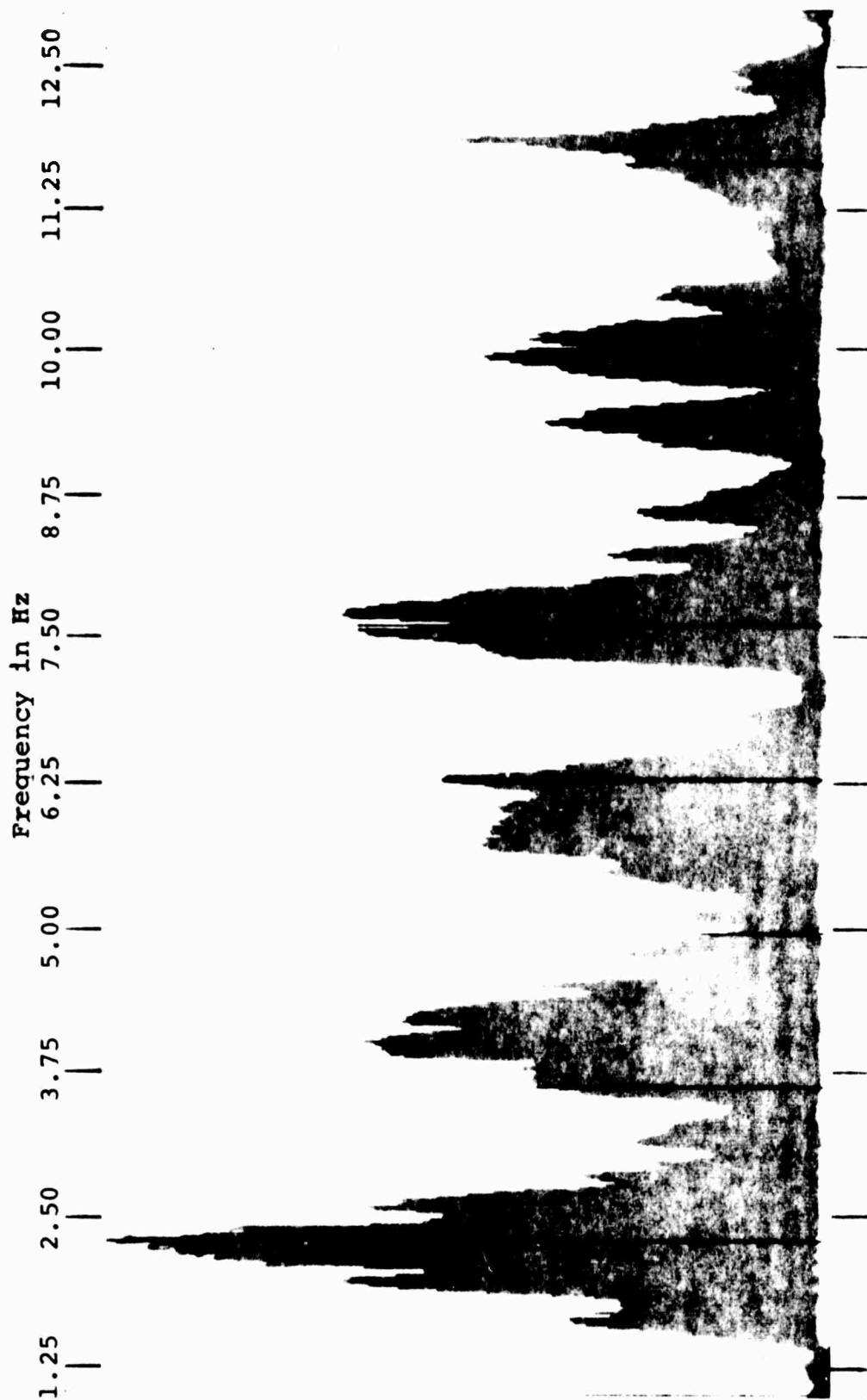


Figure (7)

Spectral analysis of hydroacoustic signal generated by CHASE VII detonation as received at Columbia University Geophysical Field Station in Bermuda. Direct signal. Range 540 n.m. Bandwidth 1/8 Hz.

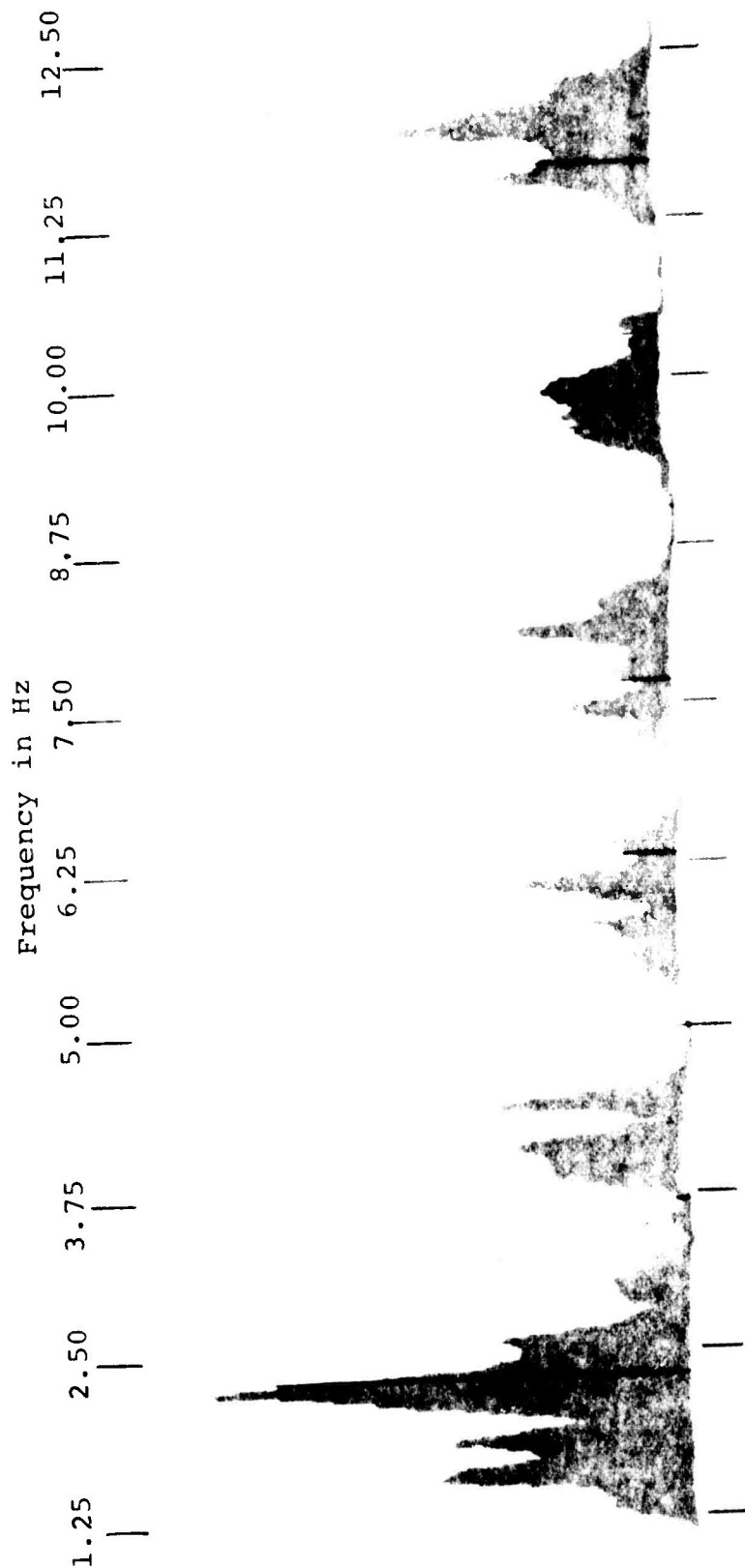


Figure (8)

Spectral analysis of hydroacoustic signal generated by CHASE VII detonation as received at Columbia University Geophysical Field Station in Bermuda. Reverberation immediately following direct signal. Range 540 n.m. Bandwidth 1/8 Hz.

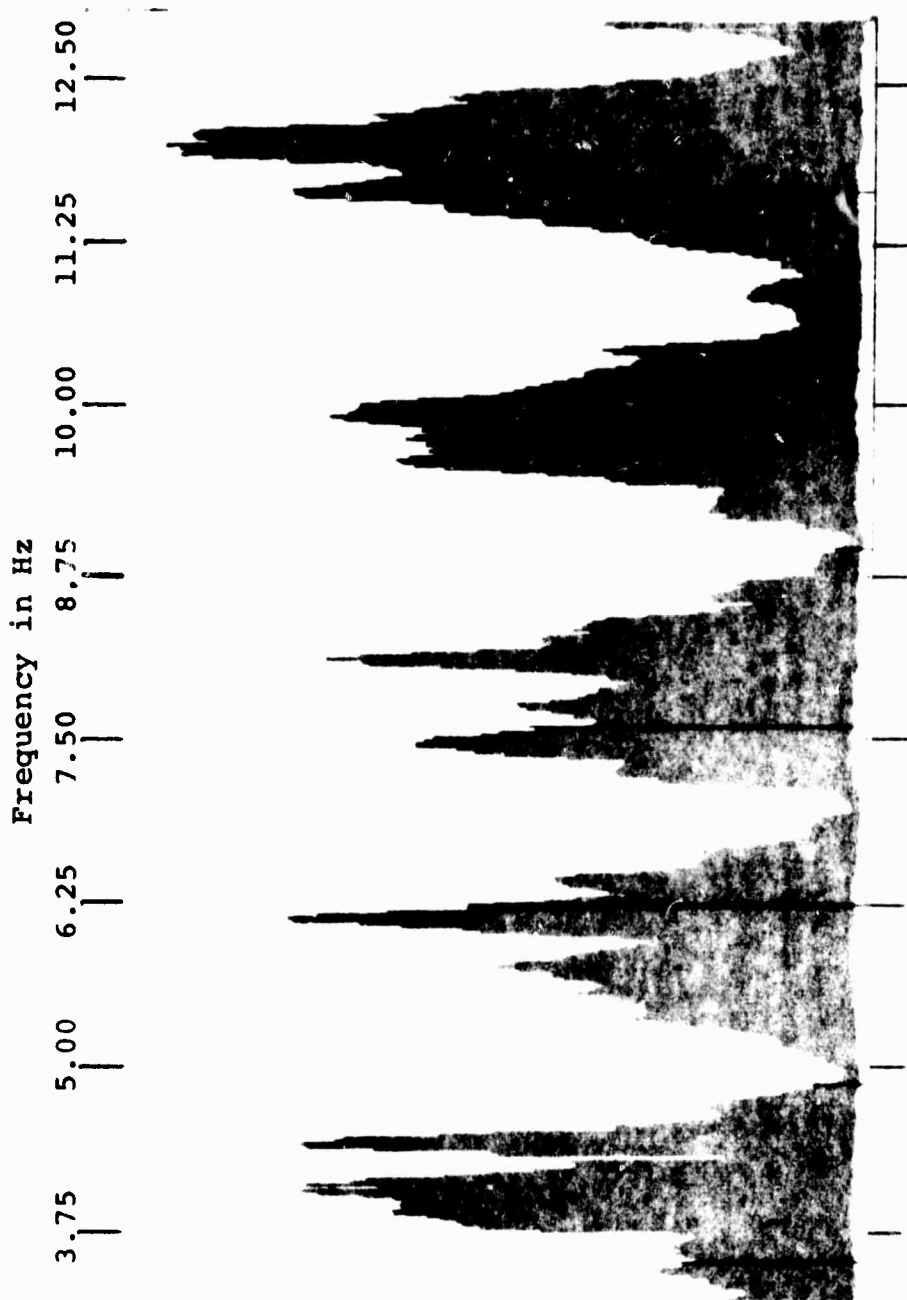


Figure (9)

Spectral analysis of hydroacoustic signal generated by CHASE VII detonation as received at Columbia University Geophysical Field Station in Bermuda. Reverberation immediately following direct signal. Range 540 n.m. Bandwidth $1/8$ Hz.

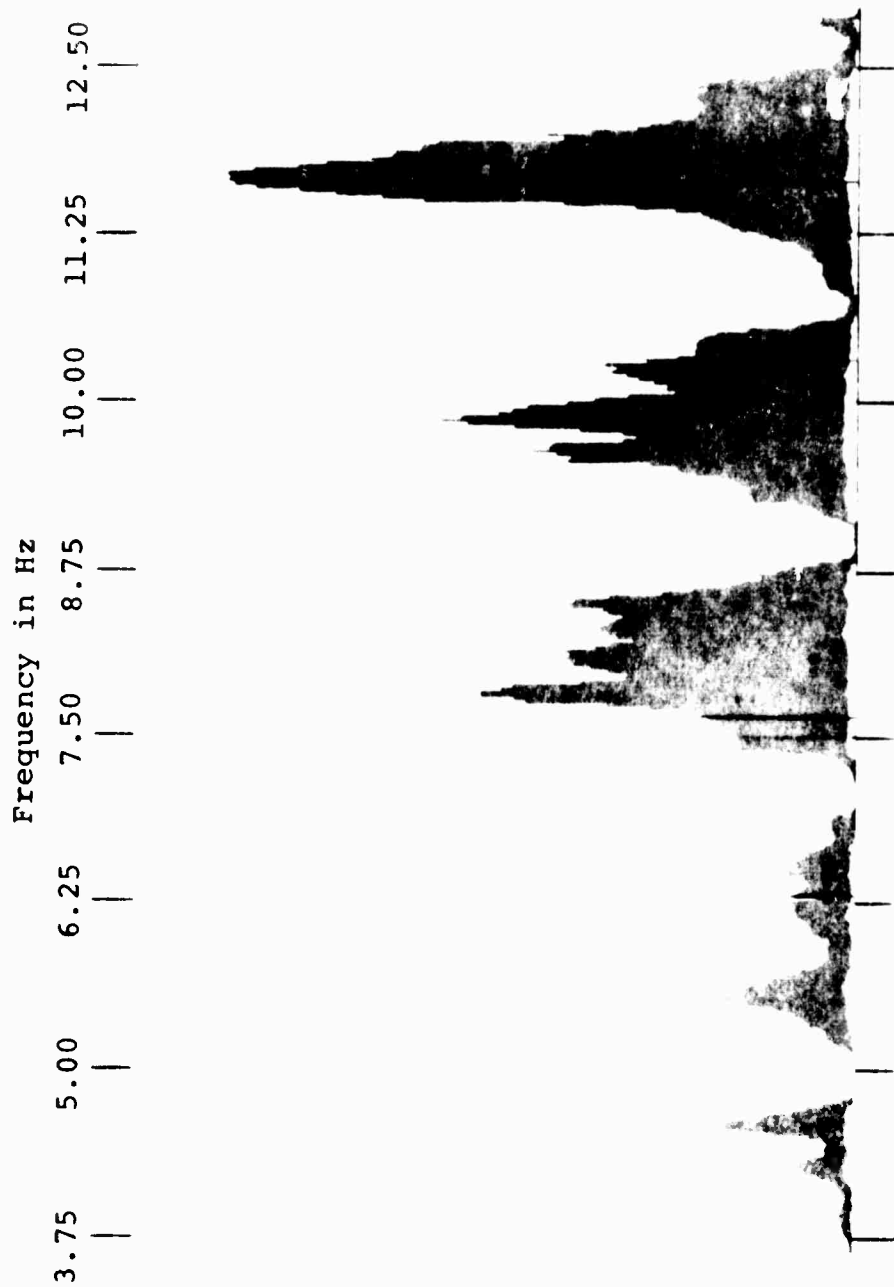


Figure (10)

Spectral analysis of hydroacoustic signal generated by CHASE VII detonation as received at Columbia University Geophysical Field Station in Bermuda. Reverberation about 255 seconds after direct signal. Range 540 n.m. Bandwidth 1/8 Hz.

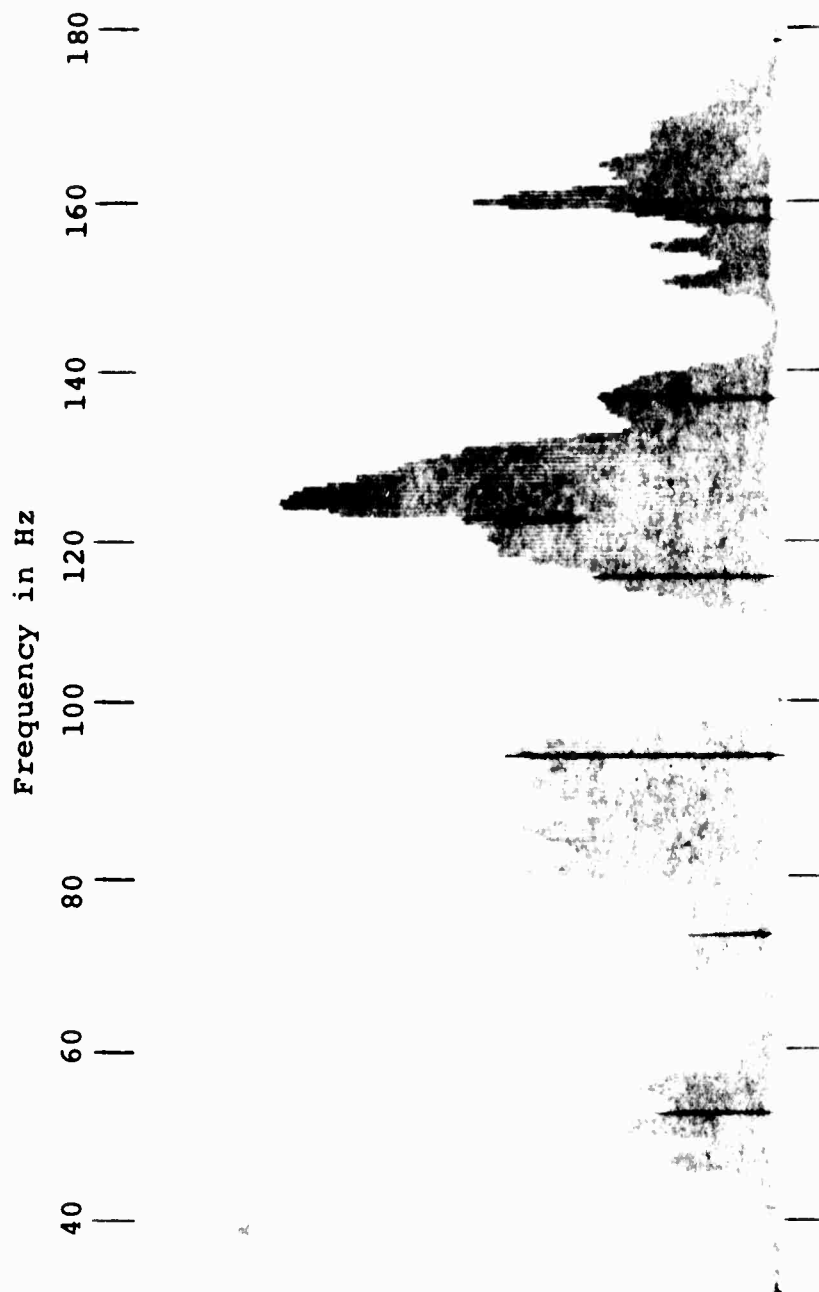


Figure (11)

Spectral analysis of hydroacoustic signal generated by a 1000 pound charge in SIR HORACE LAMB series as received at the Tudor Hill Observatory at Bermuda. Direct signal. Detonation depth 8000 feet; range ≈ 600 n.m. Bandwidth 2.5 Hz.

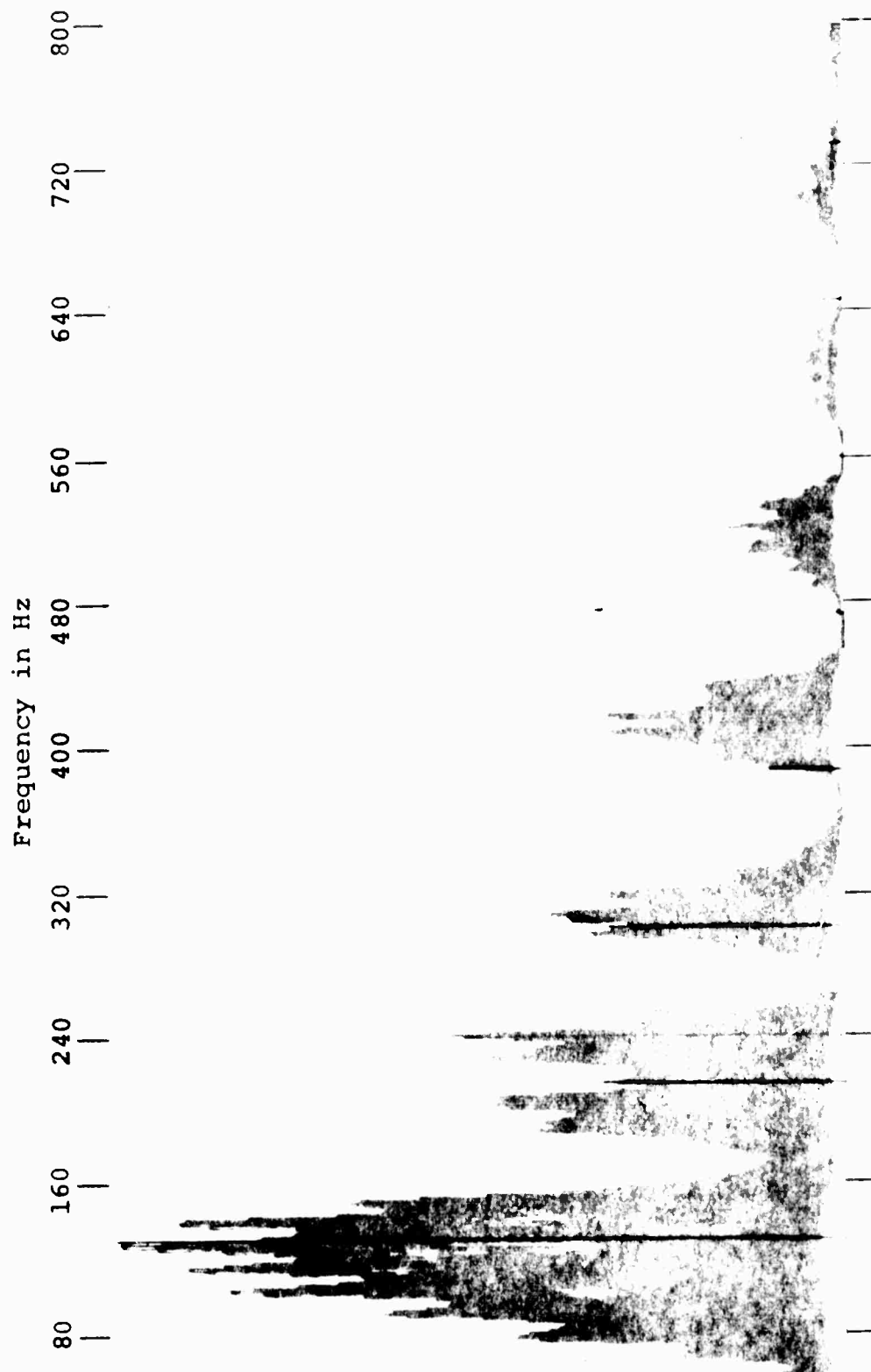


Figure (12)

Spectral analysis of hydroacoustic signal generated by a 55 pound charge in NOL series as received at USNS GILLISS at very short range. Detonation depth 7000 feet. Bandwidth 8 Hz.

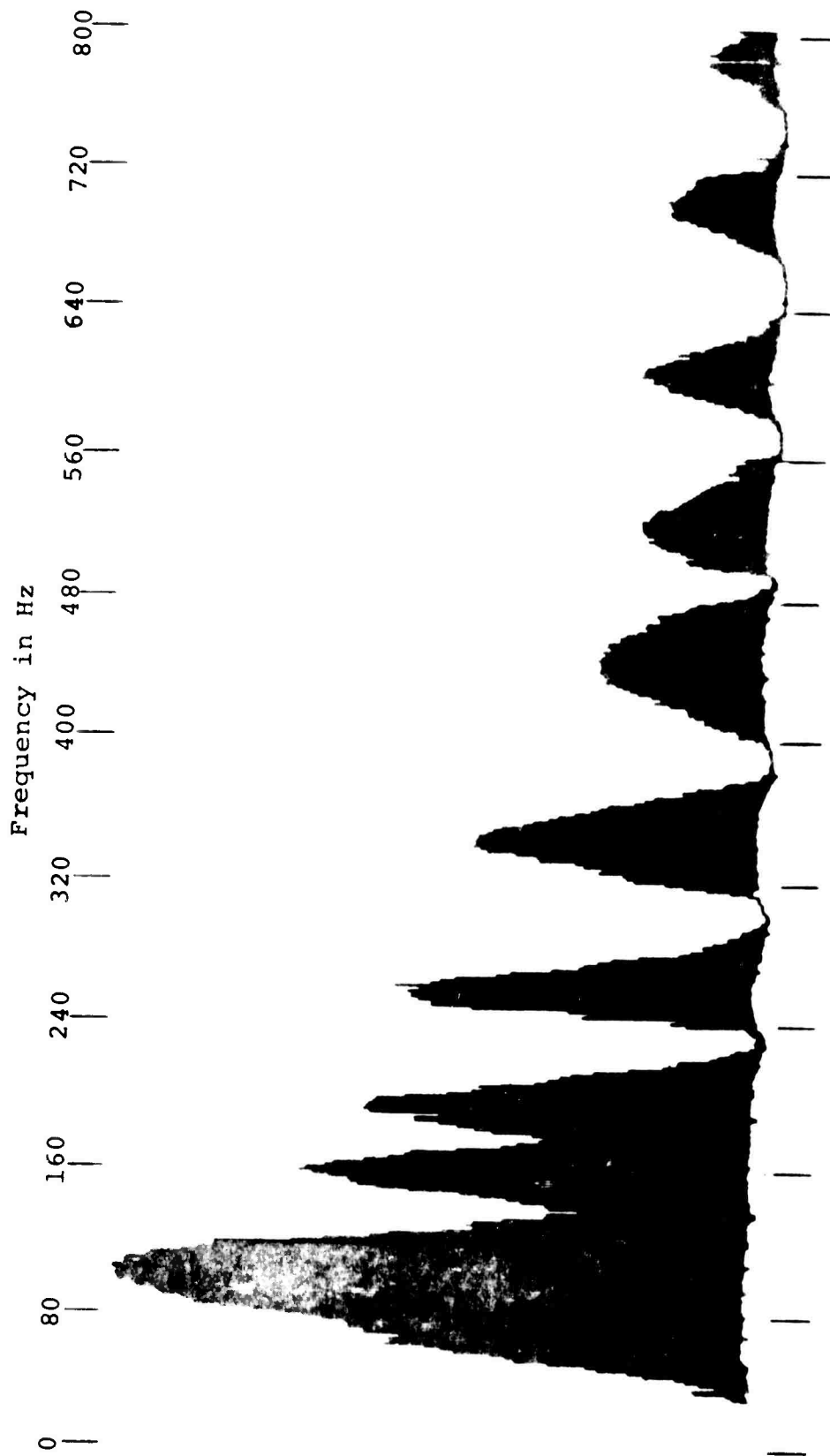


Figure (13)

Spectral analysis of hydroacoustic signal generated by a 1 pound charge in NOL series as received at USNS GILLISS at very short range. Detonation depth 1200 feet. Bandwidth 8 Hz.

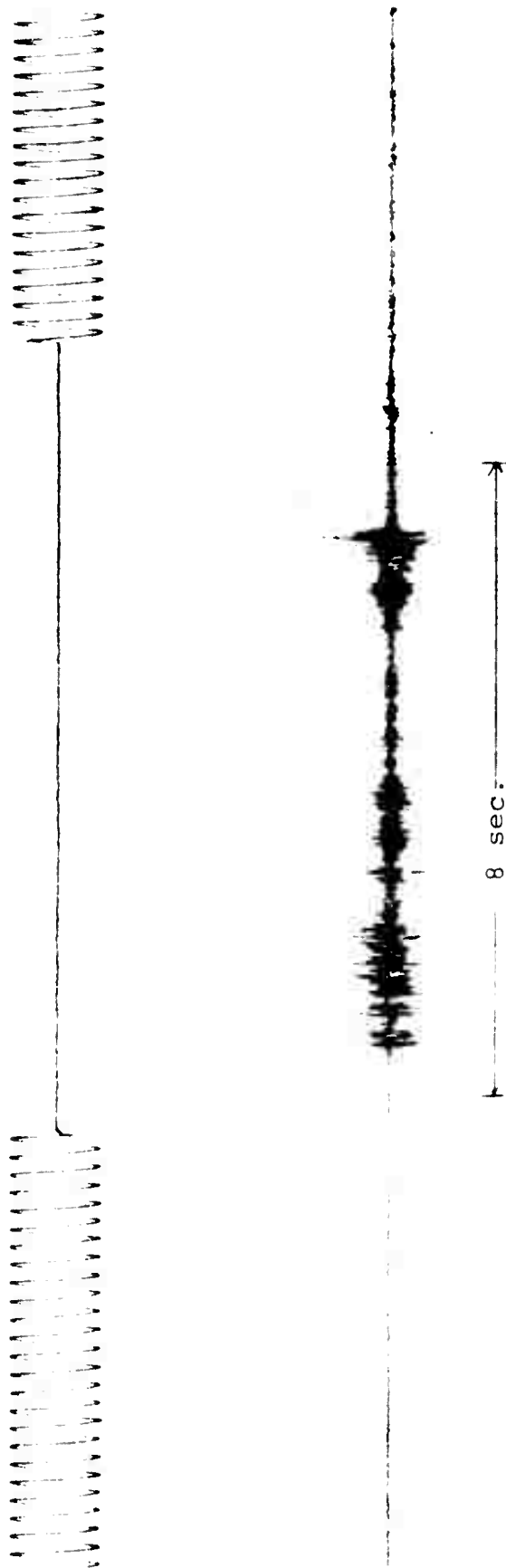


Figure (14)

Hydroacoustic time signature at 150 foot hydrophone for 5 pound TNT charge at a depth of 200 feet and range of 2,000 kilofeet. This Arctic Ocean propagation path is over uniform water depths of about 10 kilofeet.

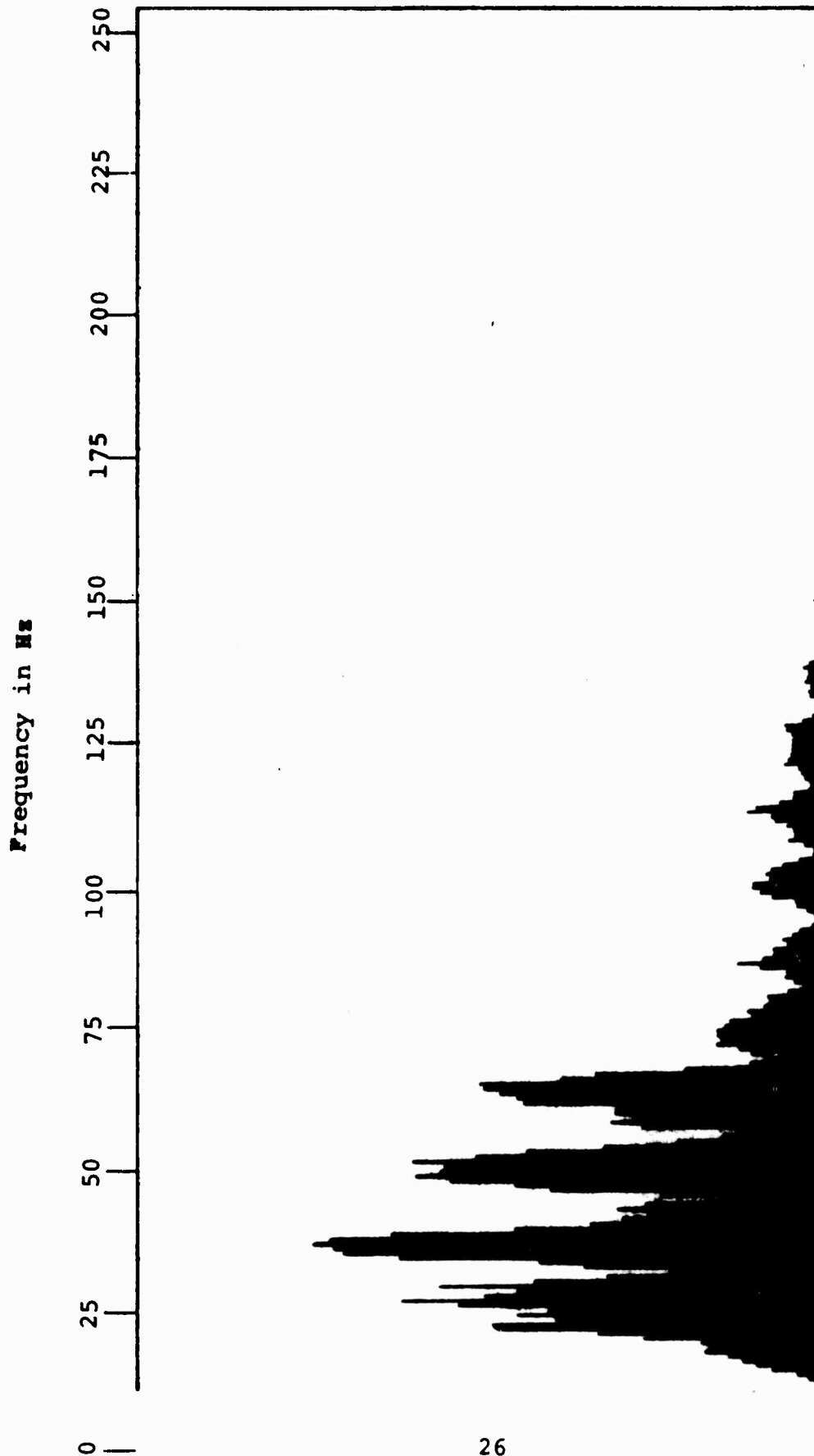


Figure (15)

Spectrum analysis of time interval indicated in Figure (14) by stop and start of sine wave (approximately 10 seconds duration). Note the clear indication of bubble spectrum harmonics 2 through 11. Bandwidth 1.25 Hz.

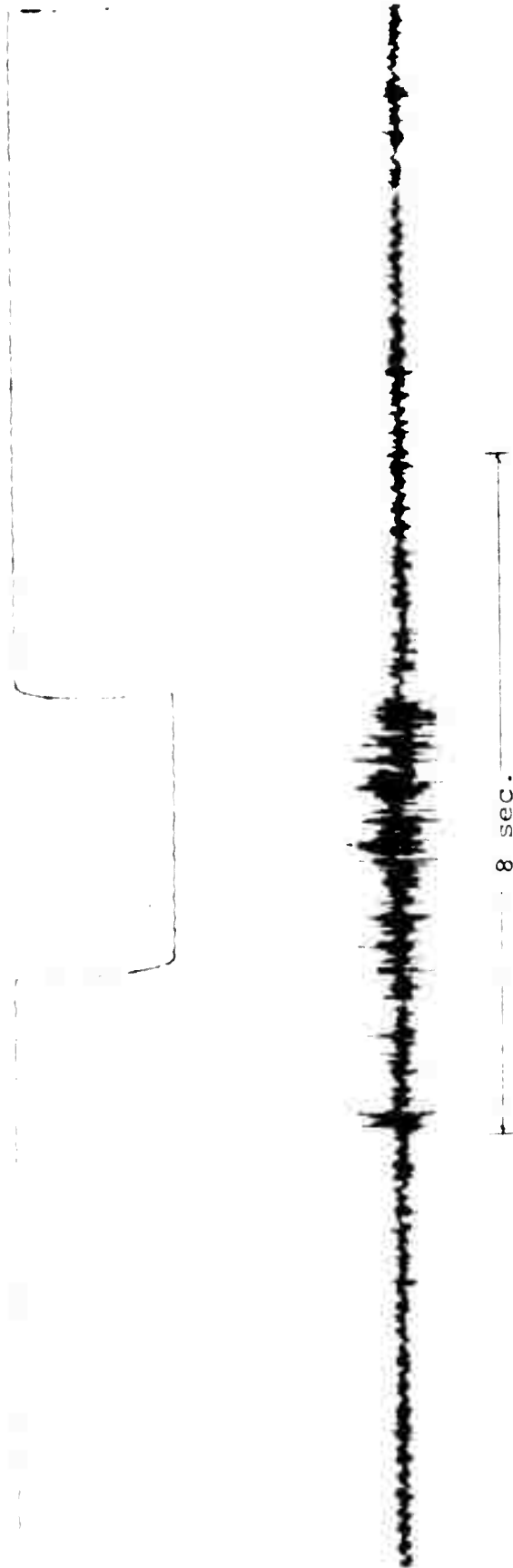


Figure (16)

Hydroacoustic time signature for 44 pound TNT charge at a depth of 100 feet and a range of about 1,540 miles.

Frequency in Hz

0 3.75 7.50 11.25 15.00 18.75 22.50 26.25 30.00 33.75 37.50



Figure (17)

Spectrum analysis of time interval indicated in Figure (16) (approximately 3.2 seconds between steps in upper trace). Bandwidth 5/8 Hz.

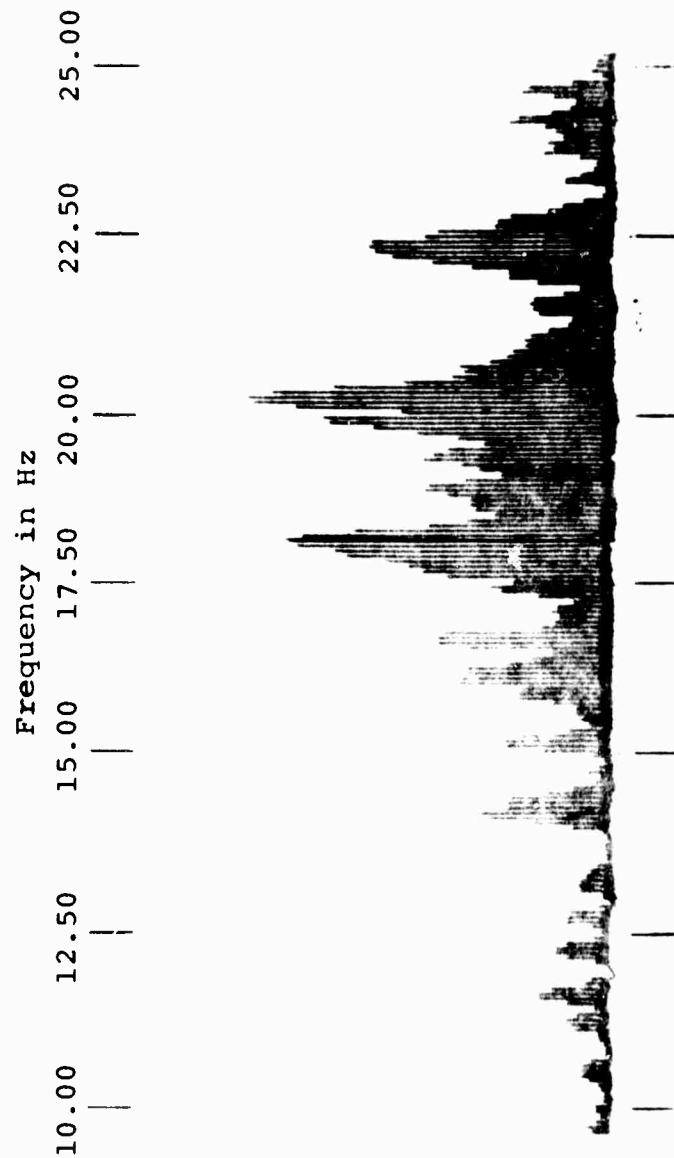


Figure (18)

Spectral analysis of hydroacoustic signal received at T-3 from a 1350 pound charge dropped by NORTHWIND in shallow water (1150 feet). Direct signal. Detonation depth 200 feet; range 1660 n.m. Bandwidth 1/4 Hz.

References

1. _____, Spectral Analysis of Hydroacoustic Signals Generated by the CHASE Explosions, Technical Progress Report No. 9, Underwater Systems, Inc. Contract No. NOnr 4026(00), December 23, 1965.
2. Woolston, D.D., Hecht, R.J., Wheaton, W.L. - CHASE VI, Technical Progress Report No. 18, Underwater Systems, Inc., Contract No. NOnr 4026(00), December 22, 1967.
3. _____, CHASE V Source Data, Technical Progress Report No. 11, Underwater Systems, Inc., Contract No. NOnr 4026(00), June 10, 1966.
4. Weinstein, M.S. - CHASE VII Source Data, Technical Progress Report No. 12, Underwater Systems, Inc., Contract No. NOnr 4026(00), August 10, 1966.
5. Weinstein, M.S. - Maxima and Minima in the Spectrum of an Underwater Explosion, Technical Progress Report No. 6 (Part I), Underwater Systems, Inc. Contract No. NOnr 4026(00), February 26, 1965.

DOCUMENT CONTROL DATA - R&D

(Security classification of title, body of abstract and indexing annotation must be entered when the overall report is classified)

1. ORIGINATING ACTIVITY (Corporate author) Underwater Systems, Inc. 8121 Georgia Avenue, World Bldg. Silver Spring, Maryland 20910		2a. REPORT SECURITY CLASSIFICATION UNCLASSIFIED	
		2b. GROUP	
3. REPORT TITLE SPECTRAL ANALYSIS OF HYDROACOUSTIC SIGNALS GENERATED BY THE CHASE V, CHASE VII, NOL-VELA, AND ARCTIC EXPLOSIONS			
4. DESCRIPTIVE NOTES (Type of report and inclusive dates) Technical Progress Report No. 21			
5. AUTHOR(S) (Last name, first name, initial) Young, David F. Woolston, Daniel D. Blak, Maurice			
6. REPORT DATE 30 July 1968	7a. TOTAL NO. OF PAGES 30	7b. NO. OF REFS 5	
8a. CONTRACT OR GRANT NO. NOnr 4026(00)	8b. ORIGINATOR'S REPORT NUMBER(S) N/A		
a. PROJECT NO. 3810			
c. ARPA Order No. 218	8d. OTHER REPORT NO(S) (Any other numbers that may be assigned this report)		
d. ONR Research Proj. RR-004-08-01	N/A		
10. AVAILABILITY/LIMITATION NOTICES Qualified requesters may obtain copies of this report from DDC.			
11. SUPPLEMENTARY NOTES N/A		12. SPONSORING MILITARY ACTIVITY Office of Naval Research (Code 418) Washington, DC 20360	
13. ABSTRACT Results of narrow band spectral analyses of hydroacoustic signals generated by underwater explosions in several programs are presented. Analyses were performed for explosion data obtained at ranges varying from several kiloyards to thousands of miles.			

14.

KEY WORDS

Spectral analysis
Underwater explosion
Hydroacoustic signals

LINK A

LINK B

LINK C

ROLE

WT

ROLE

WT

ROLE

WT

INSTRUCTIONS

1. ORIGINATING ACTIVITY: Enter the name and address of the contractor, subcontractor, grantee, Department of Defense activity or other organization (corporate author) issuing the report.

2a. REPORT SECURITY CLASSIFICATION: Enter the overall security classification of the report. Indicate whether "Restricted Data" is included. Marking is to be in accordance with appropriate security regulations.

2b. GROUP: Automatic downgrading is specified in DoD Directive 5200.10 and Armed Forces Industrial Manual. Enter the group number. Also, when applicable, show that optional markings have been used for Group 3 and Group 4 as authorized.

3. REPORT TITLE: Enter the complete report title in all capital letters. Titles in all cases should be unclassified. If a meaningful title cannot be selected without classification, show title classification in all capitals in parenthesis immediately following the title.

4. DESCRIPTIVE NOTES: If appropriate, enter the type of report, e.g., interim, progress, summary, annual, or final. Give the inclusive dates when a specific reporting period is covered.

5. AUTHOR(S): Enter the name(s) of author(s) as shown on or in the report. Enter last name, first name, middle initial. If military, show rank and branch of service. The name of the principal author is an absolute minimum requirement.

6. REPORT DATE: Enter the date of the report as day, month, year, or month, year. If more than one date appears on the report, use date of publication.

7a. TOTAL NUMBER OF PAGES: The total page count should follow normal pagination procedures, i.e., enter the number of pages containing information.

7b. NUMBER OF REFERENCES: Enter the total number of references cited in the report.

8a. CONTRACT OR GRANT NUMBER: If appropriate, enter the applicable number of the contract or grant under which the report was written.

8b, 8c, & 8d. PROJECT NUMBER: Enter the appropriate military department identification, such as project number, subject number, system number, task number, etc.

9a. ORIGINATOR'S REPORT NUMBER(S): Enter the official report number by which the document will be identified and controlled by the originating activity. This number must be unique to this report.

9b. OTHER REPORT NUMBER(S): If the report has been assigned any other report numbers (either by the originator or by the sponsor), also enter this number(s).

10. AVAILABILITY/LIMITATION NOTICES: Enter any limitations on further dissemination of the report, other than those

imposed by security classification, using standard statements such as:

- (1) "Qualified requesters may obtain copies of this report from DDC."
- (2) "Foreign announcement and dissemination of this report by DDC is not authorized."
- (3) "U. S. Government agencies may obtain copies of this report directly from DDC. Other qualified DDC users shall request through _____."
- (4) "U. S. military agencies may obtain copies of this report directly from DDC. Other qualified users shall request through _____."
- (5) "All distribution of this report is controlled. Qualified DDC users shall request through _____."

If the report has been furnished to the Office of Technical Services, Department of Commerce, for sale to the public, indicate this fact and enter the price, if known.

11. SUPPLEMENTARY NOTES: Use for additional explanatory notes.

12. SPONSORING MILITARY ACTIVITY: Enter the name of the departmental project office or laboratory sponsoring (paying for) the research and development. Include address.

13. ABSTRACT: Enter an abstract giving a brief and factual summary of the document indicative of the report, even though it may also appear elsewhere in the body of the technical report. If additional space is required, a continuation sheet shall be attached.

It is highly desirable that the abstract of classified reports be unclassified. Each paragraph of the abstract shall end with an indication of the military security classification of the information in the paragraph, represented as (TS), (S), (C), or (U).

There is no limitation on the length of the abstract. However, the suggested length is from 150 to 225 words.

14. KEY WORDS: Key words are technically meaningful terms or short phrases that characterize a report and may be used as index entries for cataloging the report. Key words must be selected so that no security classification is required. Identifiers, such as equipment model designation, trade name, military project code name, geographic location, may be used as key words but will be followed by an indication of technical context. The assignment of links, roles, and weights is optional.