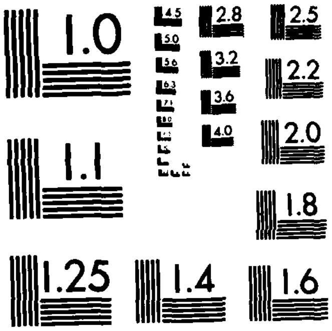
AD-A123 964 MEASUREMENTS OF ACOUSTIC AMBIENT NOISE IN SHALLOW WATER 1/1
DUE TO BREAKING SURF(U) NAVAL POSTGRADUATE SCHOOL
MONTEREY CA O B WILSON ET AL. DEC 82 NPS-61-83-006
UNCLASSIFIED F/G 20/1 NL

END
FILMED
DTIC



MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A

NPS61-83-006

NAVAL POSTGRADUATE SCHOOL

Monterey, California

MEASUREMENTS OF ACOUSTIC AMBIENT NOISE IN SHALLOW WATER DUE TO BREAKING SURF

O. B. Wilson, Jr.
Naval Postgraduate School
Stephen N. Wolf and Frank Ingenito
Naval Research Laboratory

December 1982

Approved for public release; distribution unlimited

Prepared for:
Chief of Naval Research, Arlington, VA 22237

NAVAL POSTGRADUATE SCHOOL
Monterey, California

Rear Admiral J. J. Ekelund Superintendent	David A. Schrady Provost

The work reported herein was supported in part by the Foundation Research Program of the Naval Postgraduate School with funds provided by the Chief of Naval Research.

Reproduction of all or part of this report is authorized.

This report was prepared by:

O.B Wilson, Jr.

O.B. WILSON, Jr.
Professor of Physics

Reviewed by:

J.N. DYER, Chairman Department of Physics	William M. Tolles WILLIAM M. TOLLES Dean of Research

Unclassified

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

REPORT DOCUMENTATION PAGE

READ INSTRUCTIONS BEFORE COMPLETING FORM

1. REPORT NUMBER
NPS-61-83-006

2. GOVT ACCESSION NO.
AD-A123 964

3. RECIPIENT'S CATALOG NUMBER

4. TITLE (and Subtitle)
Measurements of Acoustic Ambient Noise in Shallow Water Due to Breaking Surf

5. TYPE OF REPORT & PERIOD COVERED
Technical Report

6. PERFORMING ORG. REPORT NUMBER

7. AUTHOR(s)
O. B. Wilson, Jr., Stephen N. Wolf and Frank Ingenito

8. CONTRACT OR GRANT NUMBER(s)

9. PERFORMING ORGANIZATION NAME AND ADDRESS
Naval Postgraduate School
Monterey, California 93940

10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS
61152N: RR000-01-10
N0001482WR20043

11. CONTROLLING OFFICE NAME AND ADDRESS
Chief
Naval Research
Arlington, VA 22237

12. REPORT DATE
December 1982

13. NUMBER OF PAGES
30

14. MONITORING AGENCY NAME & ADDRESS(if different from Controlling Office)

15. SECURITY CLASS. (of this report)
Unclassified

15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)
Approved for public release; distribution unlimited

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Acoustic
Ambient noise
Monterey Bay
Shallow water
Surf

20. ABSTRACT (Continue on reverse side if necessary and identify by block number) Horizontal directionality of ambient noise was measured at ranges up to 15 km from the south-eastern shore of Monterey Bay, California. Water depths at the sites ranged from 8 to 175 m. A steerable cardioid receiving pattern was formed using signals telemetered from dipole and omnidirectional hydrophones suspended from tethered buoys. With no nearby shipping, whenever the maximum of the cardioid pattern was directed toward the beach, noise levels in the frequency range from 20 Hz to 700 Hz were greater (see reverse side)

DD FORM 1 JAN 73 1473 EDITION OF 1 NOV 65 IS OBSOLETE
S/N 0102-014-6601

Unclassified

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

Block 20. Abstract (cont'd)

than those obtained when the maximum was directed seaward. This difference or anisotropy (seaward vs. shoreward), which depends on range from the beach, on frequency and on surf intensity, was 10 dB at 300 Hz at the 9 km site during very heavy surf. Surf beat was clearly audible when the cardioid maximum was steered shoreward at ranges as great as 2 km. During heavy surf, the omnidirectional ambient noise levels also increased significantly in the same frequency range at which the anisotropy is evident. The anisotropy effects diminish both in magnitude and in frequency range with lower wave height but are still observable during light surf. We have concluded that intense breaking surf can contribute significantly to ambient noise in fairly deep continental shelf waters.

TABLE OF CONTENTS

A

INTRODUCTION

The contribution made by breaking surf to ambient noise in adjacent shallow water appears to have been studied very little. One of us (OBW) has heard anecdotal evidence from divers and from operators of acoustic sensors on submarines that surf beat is audible at significant ranges from shore. Saenger (1) in reporting his measurements of microseisms due to surf estimated that the transmission loss through the water column was so large that any noise generated thereby in the water would not contribute to the ambient noise field at significant ranges. Bardyshev, et al.(2) reported results of statistical studies of the noise as a function of range from a rocky coast in which there were significant departures from normal distributions of the pressure wave amplitudes in the noise at ranges out to 600 m from shore. He interpreted these as probably due to the pulses associated with the breaking waves and the impacts of rocks and pebbles on each other. Zakharov and Rzhevkin (3) in their discussion of the use of directional sensors for sound measurements in the sea refer to a conference presentation (4) and state that "this shows that noise produced in the surf zone of a sea coast induces a characteristic variation of the spectral composition of the noise." We have not yet had access to that conference report. So far as we have been able to determine, there are no other reports of measurements of ambient noise levels or directionality in shallow water which provide any evidence on the significance of the contribution surf generated acoustic noise to the levels in adjacent shallow water.

There are some problems of practical importance which depend on the predictability of ambient noise in shallow ocean areas. It was believed important that we make at least a preliminary measurement to determine whether surf generated noises ought to be included in ambient noise models.

This is a report of some measurements, made with limited resources and with limited objectives, to determine whether the ambient noise in shallow water might be influenced by the breaking of waves on the beach. The experiments were conducted on the eastern part of Monterey Bay, California, during May 1980 and March and April, 1981, using sonobuoys which have a steerable directional receiving pattern. These sensors provide a measure of the horizontal anisotropy of the ambient noise field. Sensors were located at various ranges from shore under a variety of surf and wind conditions. Some limited measurements of the ambient environmental conditions were made during the time that noise measurements were being conducted.

The following sections describe the ocean environment in which the experiments were conducted, the sensors used and the methods of data analysis. Some typical results are presented and some conclusions are drawn. This is primarily a field data report. Additional analysis of recorded data is in progress and will be reported later.

ENVIRONMENT AND SENSOR STATION GEOMETRY

The site was chosen because these beach areas are conveniently accessible and the surf is often quite strong. The southeastern shore of Monterey Bay is relatively uniform or straight for a distance of about 20 km, being approximately parallel to the North-South magnetic direction. In the neighborhood of the beach at Fort Ord, California, the isobathic contours are essentially parallel to the coast line out to a range of 15 km from shore where the depth is about 200 m (100 fathoms). Beyond this, the edge of the Monterey submarine canyon, the depth increases very rapidly and reaches over 1500 m within another four km. A reproduction of a chart for this area is shown in Figure 1. The locations of sonobuoy stations are presented in Table I.

The beaches at Fort Ord are characterized by Bascom (5) as steep. These beaches are exposed to the direct impact of swell from the northwesterly direction, which is the dominant arrival direction for waves from distant storms. The prevailing winds tend to also be from the westerly or northwesterly directions. The nature of the geometry of Monterey Bay also causes some focusing of the swell wave energy, so that the wave heights approaching the beach are about ten percent larger than those measured near the entrance to the Bay.

During the initial experiments in May 1980, a wave height pressure sensor was mounted on a bottom mounted platform located just beyond the surf zone. Spectral analysis of the signals from the pressure sensor showed a maximum at a wave period of eight to ten seconds during heavy surf conditions. Data from this sensor were not available for all tests, so that comparison of acoustic noise tests with wave height are made a using data (6) collected by the Coastal Processes Laboratory at the University of California, San Diego, at deep water wave sensors off the coast at Santa Cruz, California. Selected data from this source are presented in Table II. Visual estimates of wave height at the beach were made which corresponded well with the significant wave height at the deep water station. Photographic observation was also made at times. At Fort Ord, during heavy surf conditions, the waves break with a plunging type of surf. This results in large volumes of air being trapped under the breaking waves and intense pounding of the beach. The bottom near the beach is composed of coarse sand. The bottom at some distance from shore is characterized as mud. The slope at the beach does vary somewhat with position and time. At one time, in May 1980, during low tide, the slope was measured to be about 1:5. This result is believed to be typical for the spring season. Photographs of the waves breaking on the beach during moderately high surf conditions are presented in Fig. 2 and 3.

Temperature profiles were taken in the neighborhood of several of the buoy stations, using a mechanical bathythermograph. These readings indicated a mixed layer depth of about 20 m and a gentle negative gradient from that point to the bottom. Except at the stations nearest the shore, hydrophone depths were such that the hydrophone was below the mixed layer depth. Several sound speed profiles are shown in Fig. 4, which are believed to be typical for this area and season during heavy wind and surf conditions.

During the May 1980 experiment, wind speeds were obtained from anemometers aboard the RV ACANIA, the vessel used for deployment of the buoys, and mounted on a bluff above the Fort Ord beach. In the 1981 experiments, records from the U.S. Weather Service were employed. During heavy surf conditions wind speeds were often 25 to 35 knots. Sea states of 5 to 6 were estimated by the Captain of the RV ACANIA. These rough sea conditions also resulted in the absence of local fishing vessels, so that there were very few cases where shipping noise contaminated the ambient noise records.

ACOUSTIC SENSORS

The sonobuoys were modified versions of Navy-furnished directional lofar (DIFAR) sonobuoys, model AN/SSQ-53A, which have been used by the US Navy as underwater acoustic sensors in its fleet air operations for a number of years. This buoy has a radio frequency transmitter for relaying the signals from a hydrophone package which consists of an omnidirectional hydrophone, two horizontally disposed pressure gradient sensors, a magnetic compass and a data transmission system which permits the operator of the receiving equipment to resolve separately the omnidirectional sound pressure and the North-South and East-West components of the sound wave. In addition, the operator may also, by adjusting the phase shift in one of the sub-carriers in the signal, steer one of the cosine receiving patterns from the horizontal gradient sensors relative to the earth's horizontal magnetic field direction.

In these experiments, the rotatable cosine receiving pattern output was combined with the omnidirectional receiver output in a simple summing network so that the result, a cardioid receiving pattern was developed, which has a pattern function, ideally, of the following form:

$$H(\phi, \chi) = (1/2)(1 + \cos\phi \cos\chi) \qquad (1)$$

where ϕ is the azimuthal angle and χ the elevation angle above the horizontal. The reference angle from which ϕ is measured could be rotated at will, as indicated above. The technique was verified by tracking the noise from the deployment vessel as it maneuvered near the buoy.

Although the theoretical directivity index for a cardioid pattern is only 4.8 dB, the depth of the null was measured on one of our buoys to be at least 15 dB below that of the maximum lobe of the pattern using a source of simple harmonic waves.

The operating frequency range for these sonobuoys is from about 10 Hz to about 2500 Hz. Their response is not uniform, since a low frequency roll-off (at about -6dB per octave) in sensitivity below about one kHz is designed into the system. The hydrophone depths were set to 28 m before launch. In order to avoid hydrophone bottoming in the water more shallow than 28 m, bouys deployed at such locations were modified to reduce the hydrophone depth. Hydrophone depths are shown in the data tables. Buoy drift during their normal operating life of four hours was prevented by tethering the buoys to an anchored float. Tests of anchored and nearby free-floating bouys confirmed that anchoring did not introduce spurious noise.

The interpretation of the output from the cardioid receiving pattern as a function of its orientation in a non-isotropic noise field is important to the experiment, particularly since this pattern has a fairly small directivity ratio, namely 3 to 1, which corresponds to a Directivity Index of 4.8 dB. For this reason, some elementary calculations were carried out of the difference in level to be expected in the cardioid sensor output when the major lobe of the pattern is oriented first toward and then away from a line array of sources. The sources of sound along the shore are assumed to be represented by a uniform but incoherent line of elemental sources which radiate into a half space of uniform depth, h. The sensor is located at a range r_o from the line of sources and is assumed to have a directional sensitivity in the azimuthal plane of

$$H(\phi) = (1+\cos\phi). \qquad (2)$$

Here, the major lobe is directed toward the source.

If a cosine obliquity factor is assumed and if energy losses into the boundary and in the medium are neglected, the mean squared pressure to be expected at the location of the directional sensor should be:

$$\overline{p^2} = \int_{-\infty}^{\infty} \rho_o c_o \, S \, \frac{\cos\phi \, H^2(\phi)}{\pi h} \, dx, \qquad (3)$$

where dx is the differential element of length along the source line, $\rho_o c_o$ is the specific acoustic impedance of the fluid S is radiated power per unit of length and $H(\phi)$ is given by Eq. 2.

For the cardioid receiving pattern oriented toward the source line, the result is

$$\overline{p^2} = \frac{\rho_o c_o S}{2\pi h} \left[\frac{3\pi}{4} + 2 \right] \tag{4}$$

When the major lobe of the cardioid is oriented away from the line of sources, the sign in H(ϕ) reverses and the result for the mean squared pressure becomes:

$$\overline{p^2} = \frac{\rho_o c_o S}{2\pi h} \left[\frac{3\pi}{4} - 2 \right] \tag{5}$$

The ratio of the values in Eq. (4) and (5) is about 12.2, which corresponds to a difference in level of about 10.9 dB.

Thus, although the cardioid directivity index is not large, there should be expected a significant difference in perceived noise pressure levels for various orientations of the pattern in the field of a line source.

ANALYSIS EQUIPMENT

Spectral analysis of the signals was carried out using a Hewlett-Packard 3825A spectrum analyzer. This device performs a 256 point sampling and Fast Fourier Transform. The control of the spectrum analyzer was provided by a Hewlett-Packard 9825 calculator and spectral data were plotted on an associated plotter. In most areas, the spectra presented are averages of 128 individual spectra which represents an average over about one minute of signal sampling for the 0 to 2500 Hz band width case. The spectra shown in this report have not been corrected for system response.

EXPERIMENTAL PROCEDURES

Normally, after the buoy stations were deployed and the research vessel had departed the area, spectral data from the cardioid beam outputs were made, using various orientations. Tape recordings were made of the sonobuoy receiver outputs, sometimes from as many as four buoys simultaneously. Due to limited demultiplexing capability, the horizontal directionality of the signals from only one sonobuoy could be studied at one time. Some spectral analyses were made by reproduction of the recorded signals. Reasonable agreement was obtained between spectra made directly from the receiver and those made from magnetic tape recordings.

During the May 1980 experiment, the bottom mounted platform located beyond the surf zone also was equipped with an omnidirectional hydrophone, a vertically oriented geophone and a moving coil acoustic projector (Type J-11 projector from the Underwater Sound Reference Division of the Naval Research Laboratory). All these instruments were connected electrically by cables to the shore station. All receiving and processing equipment was located on a bluff above the beach at Fort Ord. During the May 1980 experiments, tethered sonobuoy stations were located at nominal distances of 300, 1000, 2000 and 4000 meters from shore. Some 1980 data were also recorded from free floating sonobuoys, deployed at various ranges, some as far as 10 km from shore.

In the spring, 1981 experiments, tethered buoy stations were located at similar positions along approximately the same line perpendicular to the beach as used in 1980. One station was operable for a limited time at a range of about 15 km from shore. Radio frequency propagation conditions prevented observations at ranges from shore greater than 15 km. For the 1981 experiments, all receiving and processing equipment were located on the roof of Spanagel Hall on the Naval Postgraduate School campus.

RESULTS

There are three kinds of evidence found in our data which tend to show that noise contributions are made by the surf processes. One is the variability in the sound pressure level in the near-shore region with time(i.e. surf beat); the second is the horizontal directionality of the noise, as shown by the change in level with the orientation of the cardioid directional receiving pattern and the third is the spatial dependence of the omnidirectional spectrum level of the noise with range from shore at the same frequencies at which the horizontal anisotropy is observed. In addition, the temporal variation in sound pressure spectrum level near the surf zone is largest in the same frequency band at which the horizontal anisotropy is most noticeable far from the beach. Further, the above effects were found to be greatest when the surf was high, and least under low surf conditions.

The evidence that the noise level in the water near the surf zone changes with time are indicated in Fig. 5, which shows the spectra made using exponential time averaging during the times that the surf beat was intense and compares this with spectra made several minutes later, during a quiet period, again using exponential time averaging. This mode of averaging weights each new spectrum 1/4 and previously averaged spectra 3/4. New spectra are formed about one per second. The hydrophone from which these data were taken was was mounted on the instrument package just beyond the surf zone. It shows clearly that there is a significant change in the very local ambient noise level with time. Because of limited visibility of the beach area, the association of these surf beats could often, but not always, be made with the visual observation of breaking waves at the beach near the instrument site. The background spectrum undoubtedly contains some energy from the surf. The comparison is shown to illustrate the typical differences observed in the case of a nearby plunging wave.

Fig. 6 shows a comparison of spectra made from the output of the cardioid beam-former with the maximum of the pattern pointed toward the shore, East, and with the maximum pointed seaward, West, using signals from a sonobuoy at a range of one km from the beach. The levels near 100 Hz looking shoreward are larger by about 10 dB than those looking seaward. The differences are clearly smaller at the frequencies near 500 Hz. These graphs represent averages of 128 spectra, which involves averaging over a time period of a little more than one minute.

Fig. 7 shows spectra made at about the same time from signals received from the buoy at 2 km from shore. Again, the levels near 100 to 150 Hz are higher but by about 8 or 9 dB when the cardioid maximum is directed shoreward than when directed seaward. Near

500 Hz there is no discernable anisotropy.

Fig. 8 presents results from analysis of signals received from the station at 4 km. The maximum difference in level is about 8 db in the neighborhood of 100 to 150 Hz, but is discernable from 50 Hz to about 400 Hz. Records made from a free floating buoy located about 10 km from the beach gave similar results, with a maximum difference between the shorewardly and seawardly directed cardioids of about 6 or 7 db between 100 and 150 Hz.

At range 1 km, when the maximum of the cardioid receiving pattern was pointed to the east, surf beat was audible and observable on the spectrum analyzer in the frequency range in which east-dominant anisotropy was observed. The surf beat was strongly reduced or eliminated when the maximum of the cardioid was pointed to the west. Although strong anisotropy was also observed at greater ranges from the beach, the surf beat was not observed at these ranges. The apparent reason for this effect is that at longer ranges a longer surf zone falls within the ±3dB azimuth angles (±65°) of the cardioid pattern. As can be seen in Figures 2 and 3, over short sections of beach the surf activity is highly variable; over long sections of beach the average activity is more nearly stationary.

There was no obvious significant ship noise present during the time that these particular spectra were made. Occasionally at other times, lines at 50 or at 60 Hz could be observed when the cardioid maximum was pointed seaward. It is believed that these were generated by distant shipping.

The next several figures show spectra made in the Spring of 1981, again during heavy surf conditions. In each of these, it is seen that the horizontal anisotropy is even more pronounced than in the 1980 results and the spectral shape at the low frequencies is different. Fig. 9 shows data from the cardioid output when the maximum is steered toward and away from shore for a buoy located about 4.4 km from shore. The maximum difference in level is about 10 dB at around 500 Hz. Observable differences extend from about 20 Hz to around 800 Hz. The next, Fig. 10, gives the spectra with the cardioid pattern oriented up and down shore, that is, North and South. The components at the highest frequencies are due to biological sources, believed to be Dolphins.

Corresponding results for the station at 8.5 km are presented in Figures 11 and 12. There is a maximum anisotropy of about 10 dB in levels with the shorewardly directed levels being larger. The results for the North and South orientations of the cardioid indicate that the levels are perhaps a maximum of 2 dB larger for the northerly directed beam.

Fig. 13 gives the spectra made at about the same time from the outputs of the omnidirectional hydrophones on the buoys located at three different ranges from shore during these heavy surf conditions in March 1981. These spectra have not been corrected for system response. It is apparent that the change in level with range from shore occurs only at the same low frequencies, 20 to 700 or 800 Hz, at which the anisotropy in the horizontal directionality of the noise occurs.

Finally, the results for stations at 3.2 km and 1.7 km from the beach during low surf conditions are shown in Figures 14 and 15. The effect of steering the pattern toward or away from shore is still evident at around 250 Hz. At the high frequencies, the noise appears to come more from the open sea, which might be expected. The analysis range for the spectra in Fig. 15 is 500 Hz. The line components are believed to be due to noises from the underwater discharge of coolant pumps at an electrical power plant several miles up the coast from the Fort Ord Beach. The reduction in anisotropy during low surf conditions is further evidence that the strong noise components at low frequencies coming from the east are generated by action of surf.

It was not possible to monitor surf heights at the beach during all of the experiments. However, we do have data provided by a group at Scripps Institution of Oceanography from their records (6) from wave sensors on the west coast. Records for deep water waves in the northern part of Monterey Bay (off Santa Cruz) indicate that the wave energies differed by factor of about seven from the heavy surf conditions to the light surf conditions (see Table II).

It should be noted that the deep water waves were somewhat larger on 27 March 1981 than on 23 May 1980, which should have led to heavier surf conditions.

CONCLUSIONS

To summarize, we have observed anisotropy in the horizontal directionality of the low frequency ambient noise in the shallow waters of Monterey Bay. The dependence of this anisotropy on range from shore and the decrease in noise level with range from shore in the same frequencies at which the anisotropy occurs and the large reduction in these effects during low surf conditions lead us to conclude that the breaking of waves does contribute significantly to the shallow water ambient noise.

There are still a number of unanswered questions. For example, we do not yet know how far from shore these effects may be observable. These effects were observed in Monterey Bay to water depths of almost 100 fathoms and ranges from shore of about 15 km, ranges which were imposed by limitations radio data link to the shore recording station. Also, the basic mechanisms for the generation of of the sound at the surf zone and for the propagation of the sound from the surf zone to the deeper water are not yet clearly delineated.

ACKNOWLEDGMENTS

This work was supported by funds from the Naval Postgraduate School Research Foundation and from the Naval Sea Systems Command. We are also grateful to various activities and persons who provided assistance. The Department of the Army provided space for our instrumentation at Fort Ord during the May 1980 experiments. Mr. Mike Scherschel of the Naval Weapons Support Center, Crane, Indiana, assisted by loaning us electronic demultiplexing equipment for use with the Difar buoys. Mr. Harvey Inman, of the Naval Avionics Center, Indianapolis, assisted in obtaining a supply of refurbished Difar sonobuoys. We are also grateful to the Department of Oceanography of NPS for the use of the RV ACANIA and their fine crew and for the loan of some important instrumentation. The hard work of our research support technicians, Bob Smith, Bill Smith, Kim McCoy and Lyn May is gratefully acknowledged.

TABLE I
SONOBUOY STATION DATA

Station Number	Latitude North	Longitude West	Range from beach (km)	Water Depth (m)
	1980 Stations			
1	Not determined	Not determined	0.5	13
2	Not determined	Not determined	1	25
3	Not determined	Not determined	2	34
4	Not determined	Not determined	4	60
	1981 Stations prior to 16 April 1981			
D	36°40.70	121°52.00'	4.4	64
E	36°40.38	121°50.95'	2.8	48
F	36°41.70	121°54.48'	8.5	90
	1981 Stations on and after 16 April 1981			
D	36°41.00	121°51.06'	3.2	59
E	36°40.72	121°50.04'	1.7	35

TABLE II
DEEP WATER WAVE MEASUREMENTS IN NORTHERN MONTEREY BAY (Ref 6)
(Santa Cruz Buoy at 36°53.4'N, 122°04.3'W in 70 m water)

Date	Local Time	Significant Wave Height (cm)	Wave Energy (cm^2)
23 May 1980	2209	247	3818
27 March 1981	2115	255	4049
02 April 1981	2117	289	5235
16 April 1981	1513	111	775

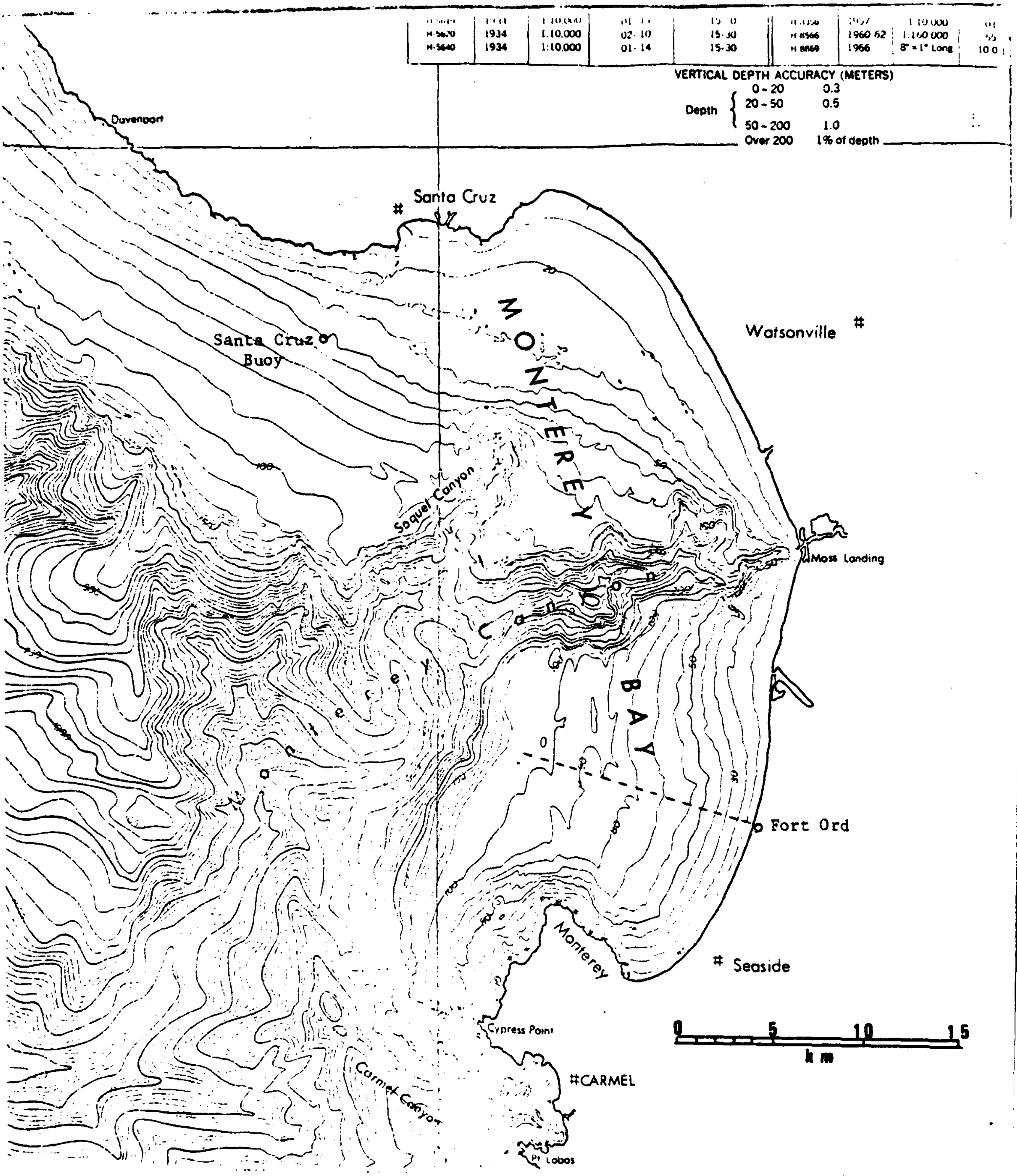


Figure 1. Taken from a bathymetric chart of Monterey Bay, California. The dotted line shows the approximate line of positions along which sonobuoys were deployed. Depths of the bathymetric contours are in meters.

Figure 2. Photograph of surf breaking on beach near test sites at Fort Ord, California, view along beach looking toward the north.

Figure 3. Photograph of surf breaking on beach at Fort Ord, California illustrating the plunging character of the surf.

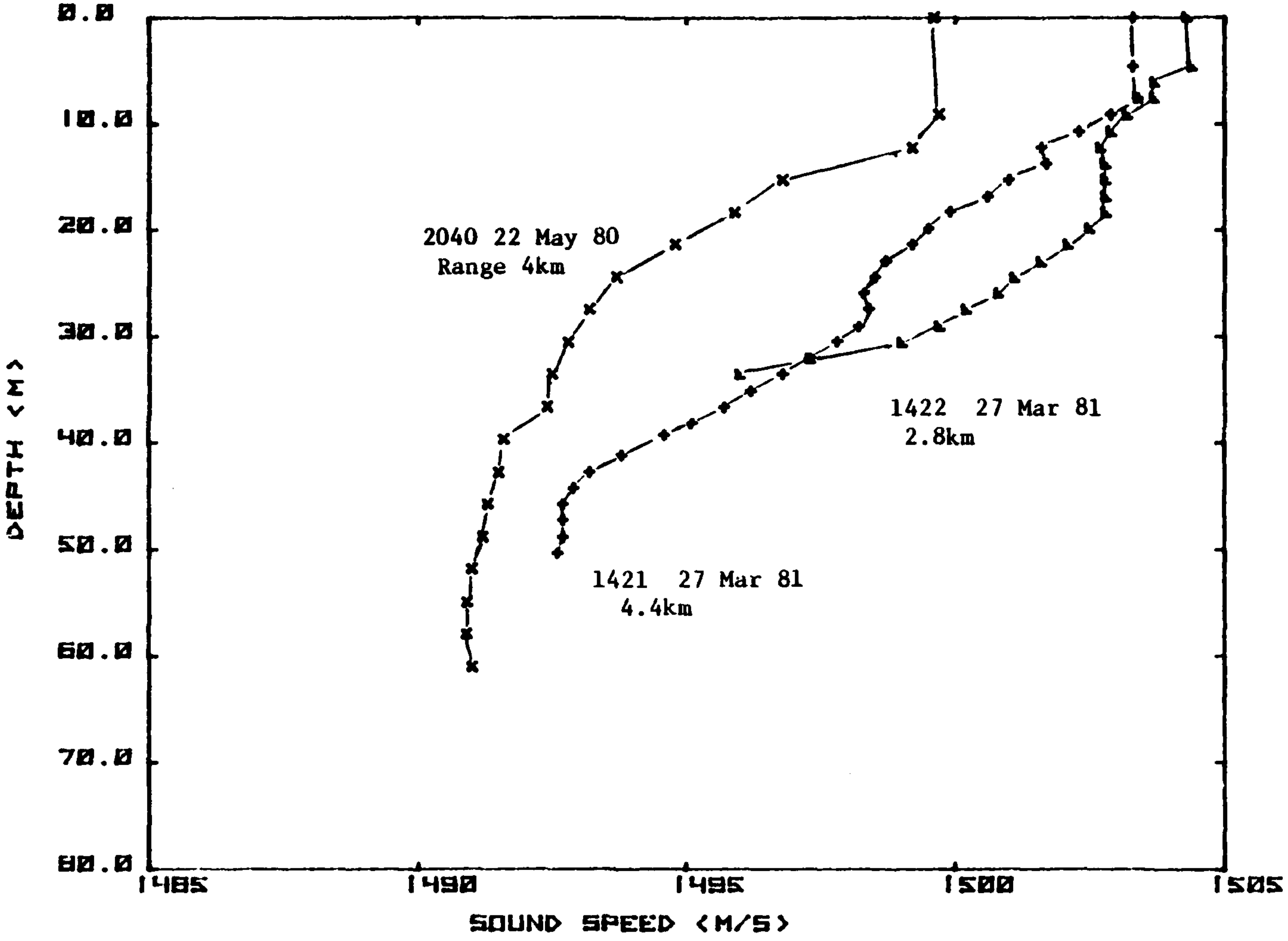


Figure 4. Typical sound speed profiles in the neighborhood of sonobuoy stations between 3 and 4km from shore. Water depth is about 60m.

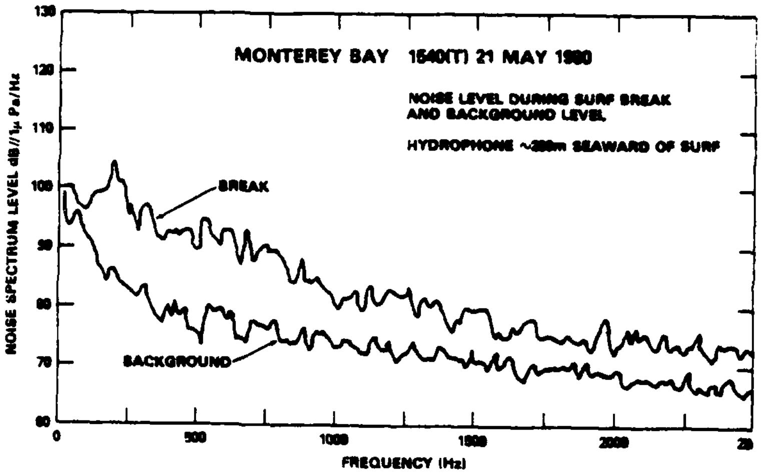


Figure 5. Spectra from a bottom mounted hydrophone located just seaward from surf zone illustrating temporal changes in levels with the breaking of waves.

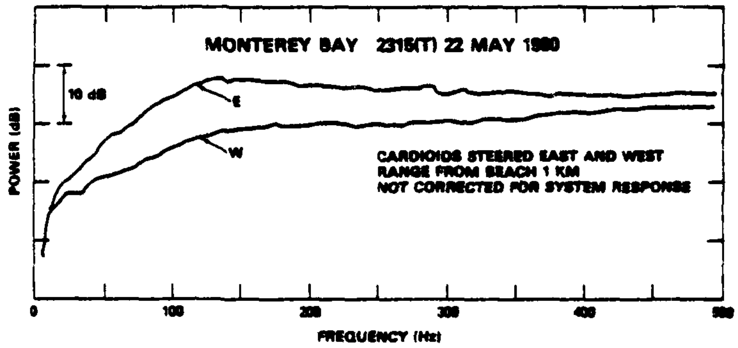


Figure 6. Spectra of output from cardioid beam former when oriented shoreward (E) and seaward (W). Range 1 km. 22 May 1980. Not corrected for system response.

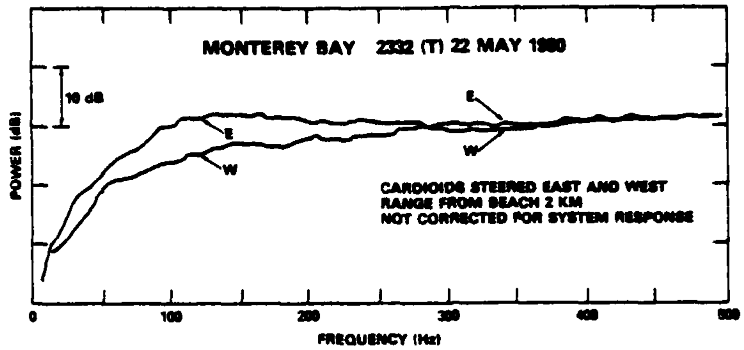


Figure 7. Spectra of output from cardioid beam former when oriented shoreward (E) and seaward (W). Range 2 km. 22 May 1980. Not corrected for system response.

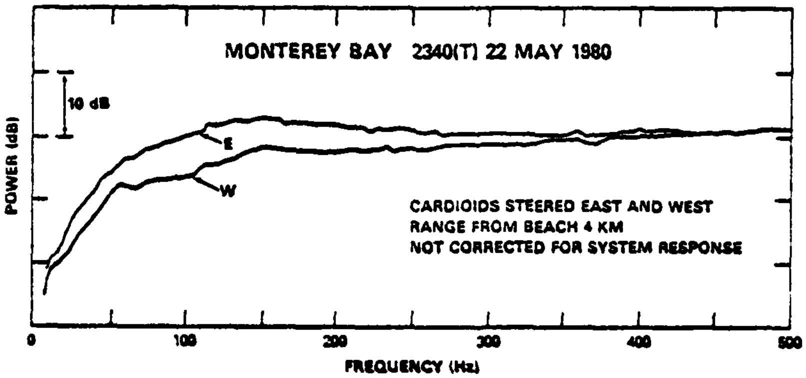


Figure 8. Spectra of output from cardioid beam former when oriented shoreward (E) and seaward (W) during heavy surf conditions. Range 4 km. 22 May 1980. Not corrected for system response.

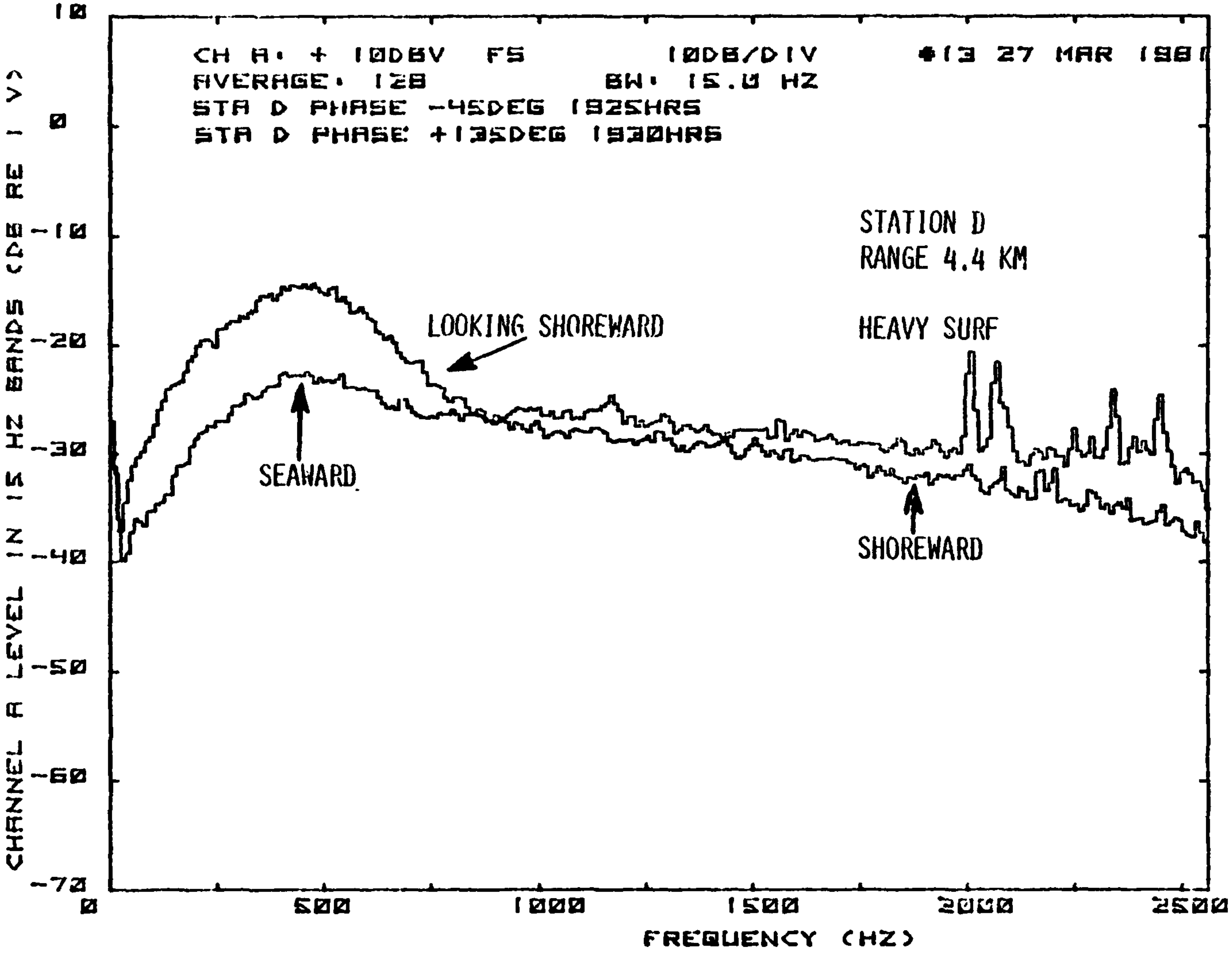
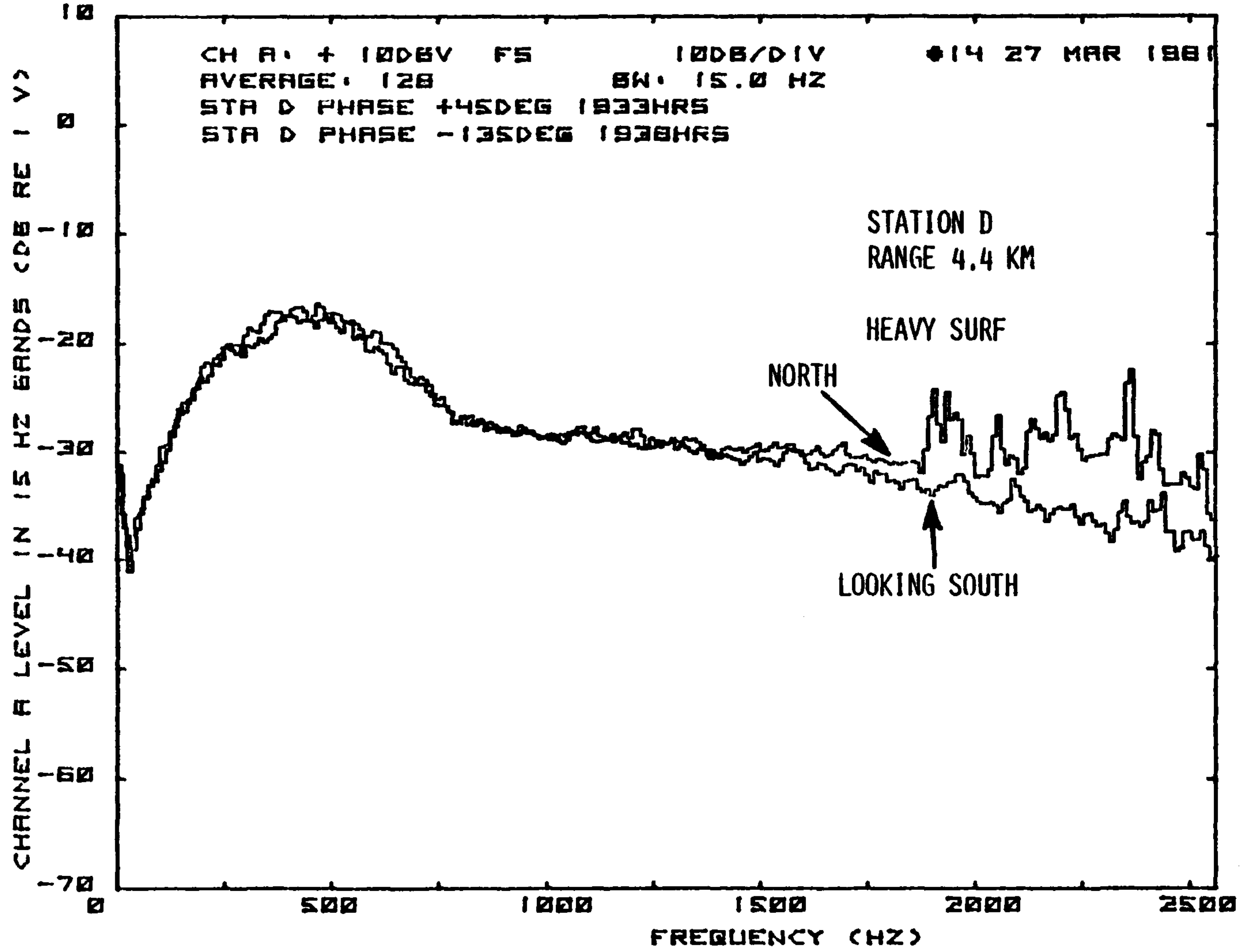


Figure 9. Spectra of cardioid beam output when oriented shoreward (E) and seaward (W) during heavy surf conditions. Range 4.4 km. 27 March 1981. Not corrected for system response.

Figure 10. Spectra of cardioid beam output when oriented up shore (N) and down shore (S) during heavy surf conditions. Range 4.4 km. 27 March 1981. Not corrected for system response.



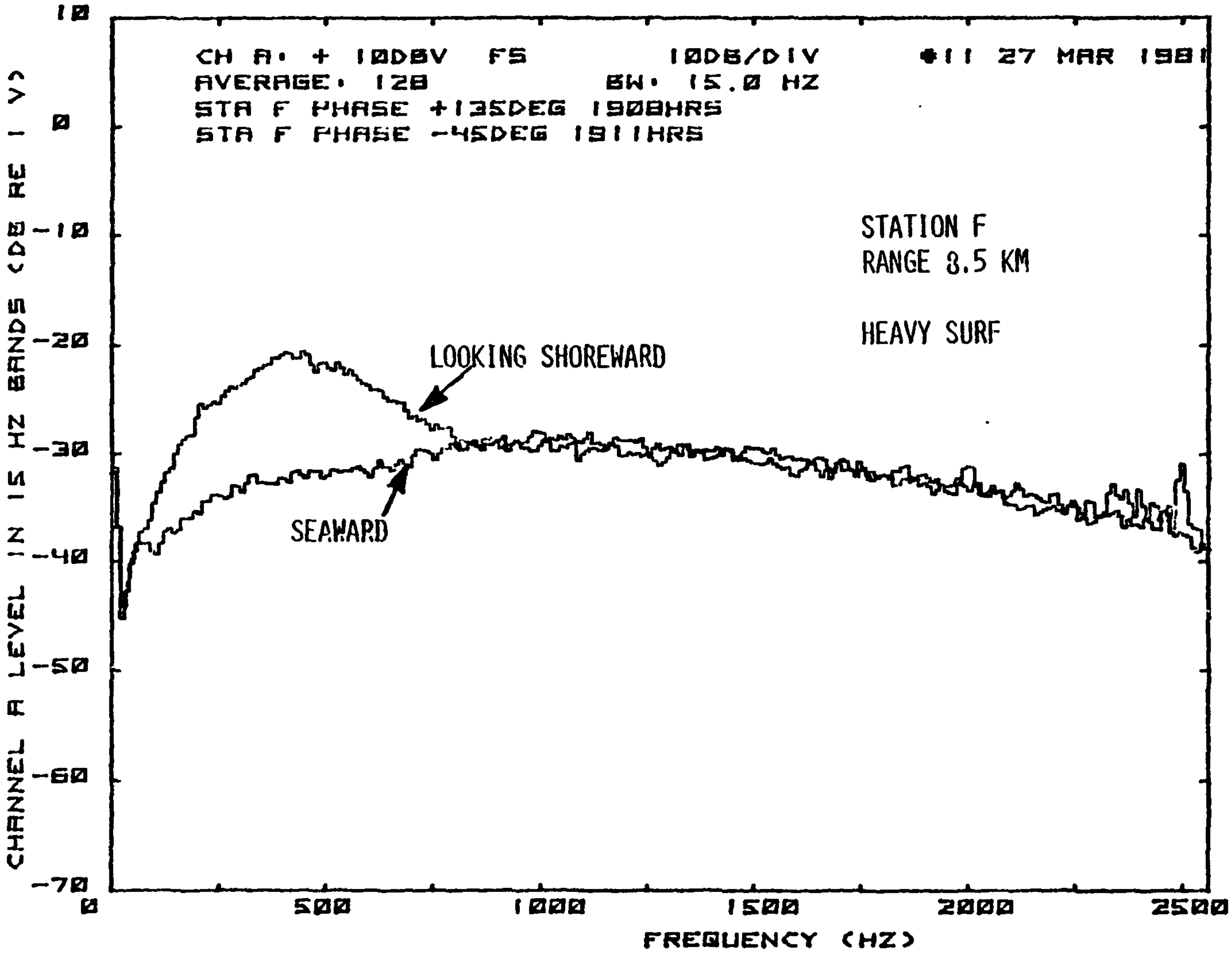
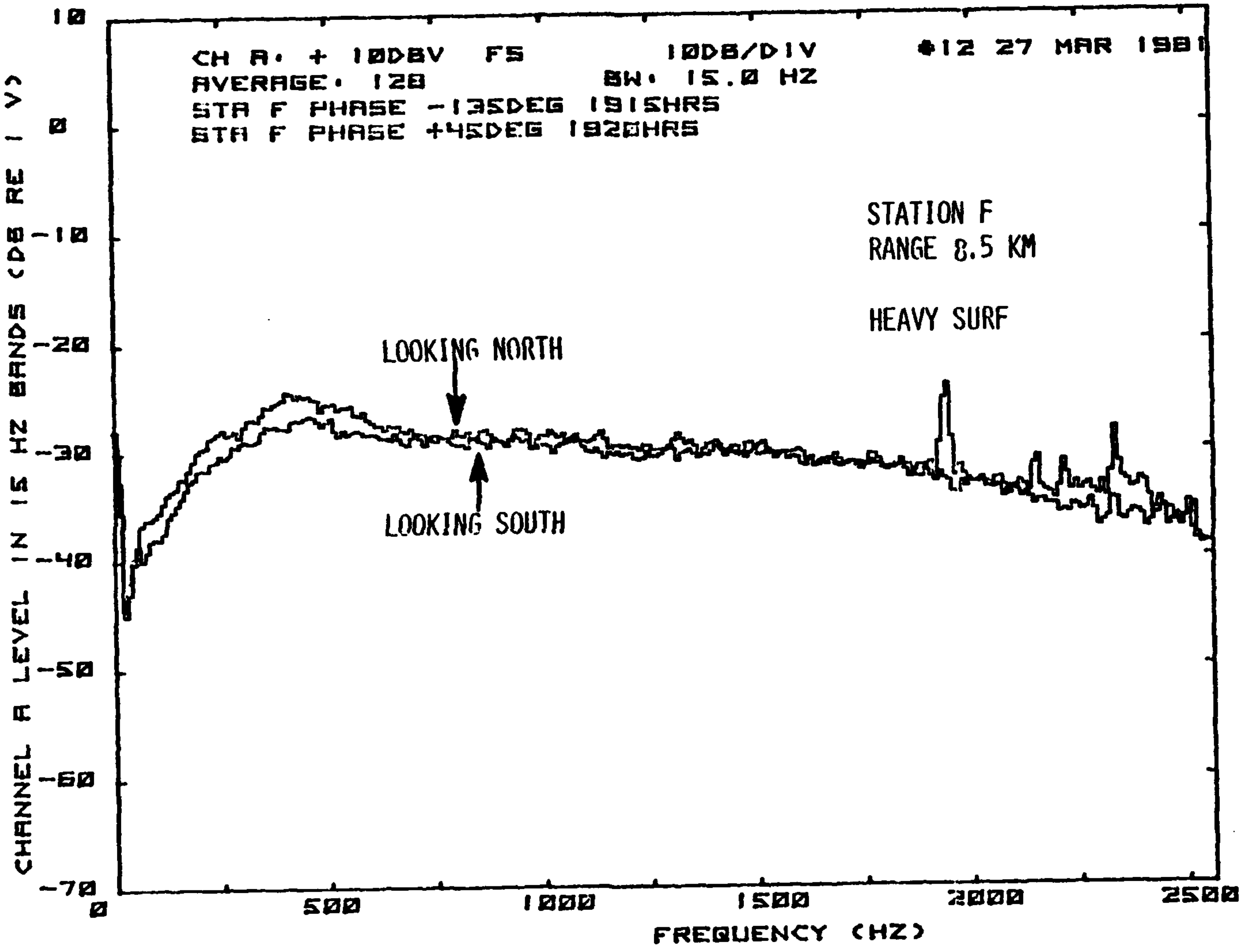


Figure 11. Spectra of cardioid beam output when oriented shoreward (E) and seaward (W) during heavy surf conditions. Range 8.5 km. 27 March 1981. Not corrected for system response

Figure 12. Spectra of cardioid beam output when oriented up shore (N) and down shore (S) during heavy surf conditions. Range 8.5 km. 27 March 1981. Not corrected for system response.



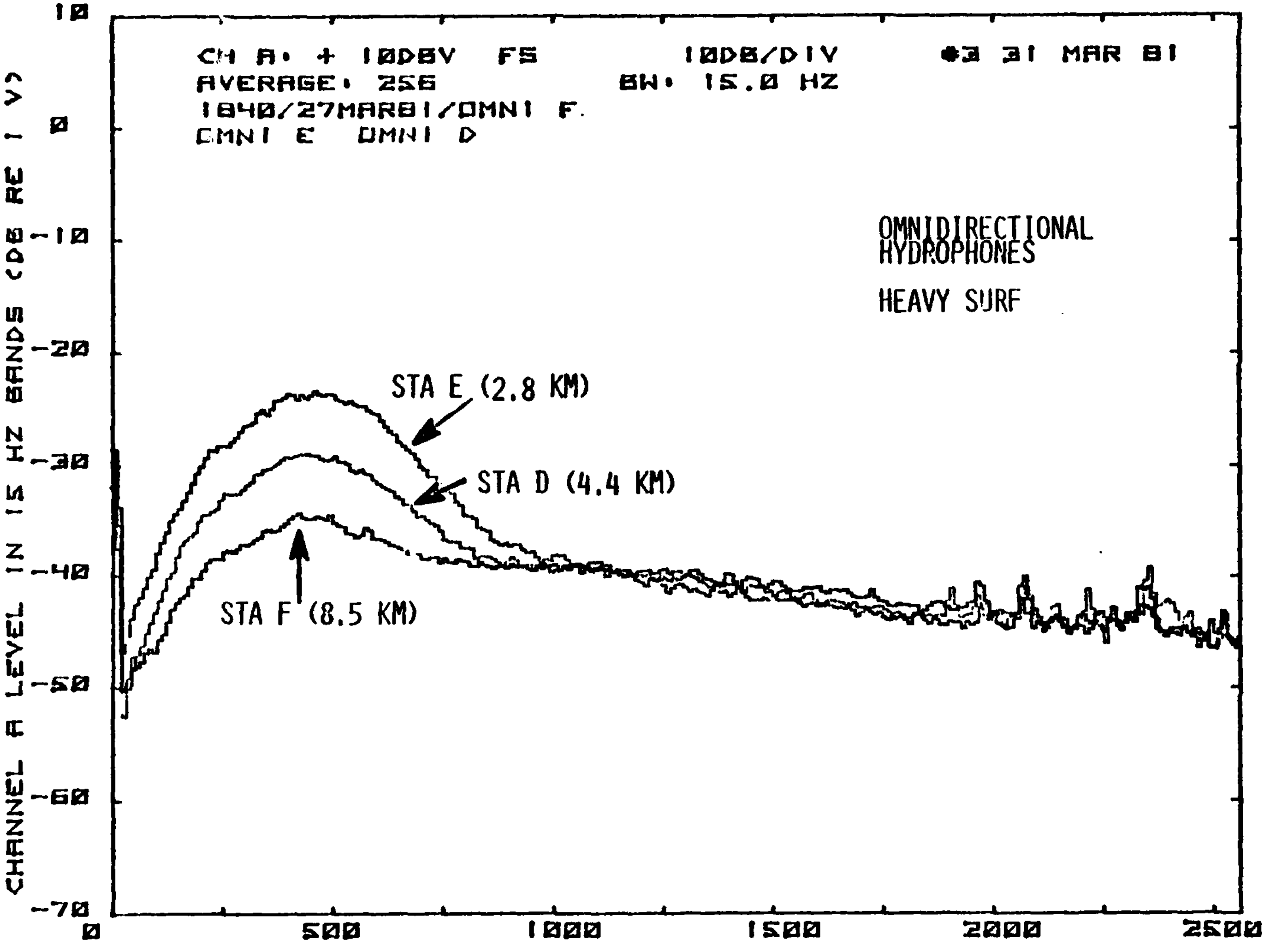
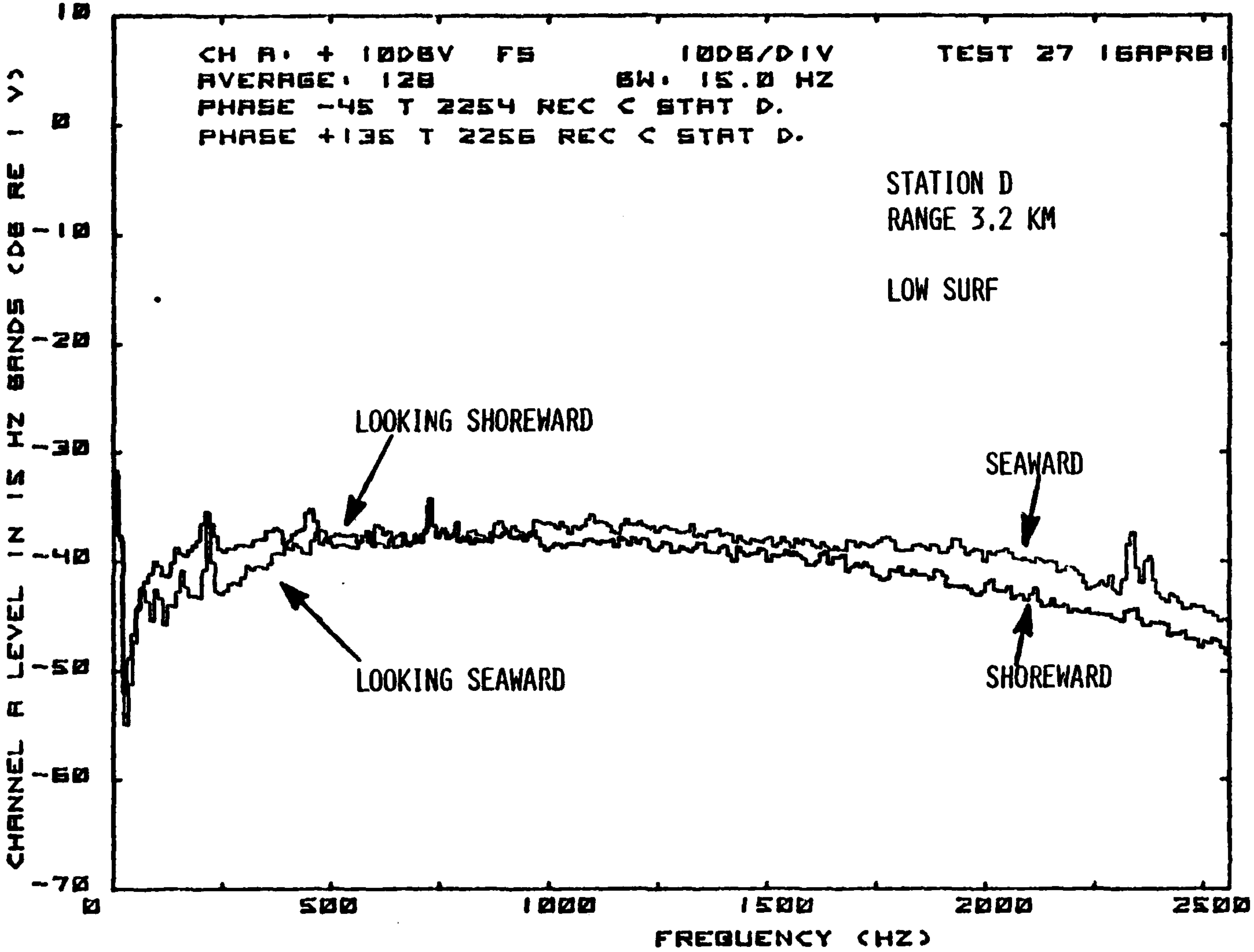


Figure 13. Spectra of omnidirectional hydrophone output at ranges of 2.8, 4.4 and 8.5 km from shore during heavy surf conditions. 31 March 1981. No correction for system response.

Figure 14. Spectra of cardioid beam output during low surf conditions when oriented shoreward (E) and seaward (W). Range 3.2 km. 16 April 1981. Not corrected for system response.



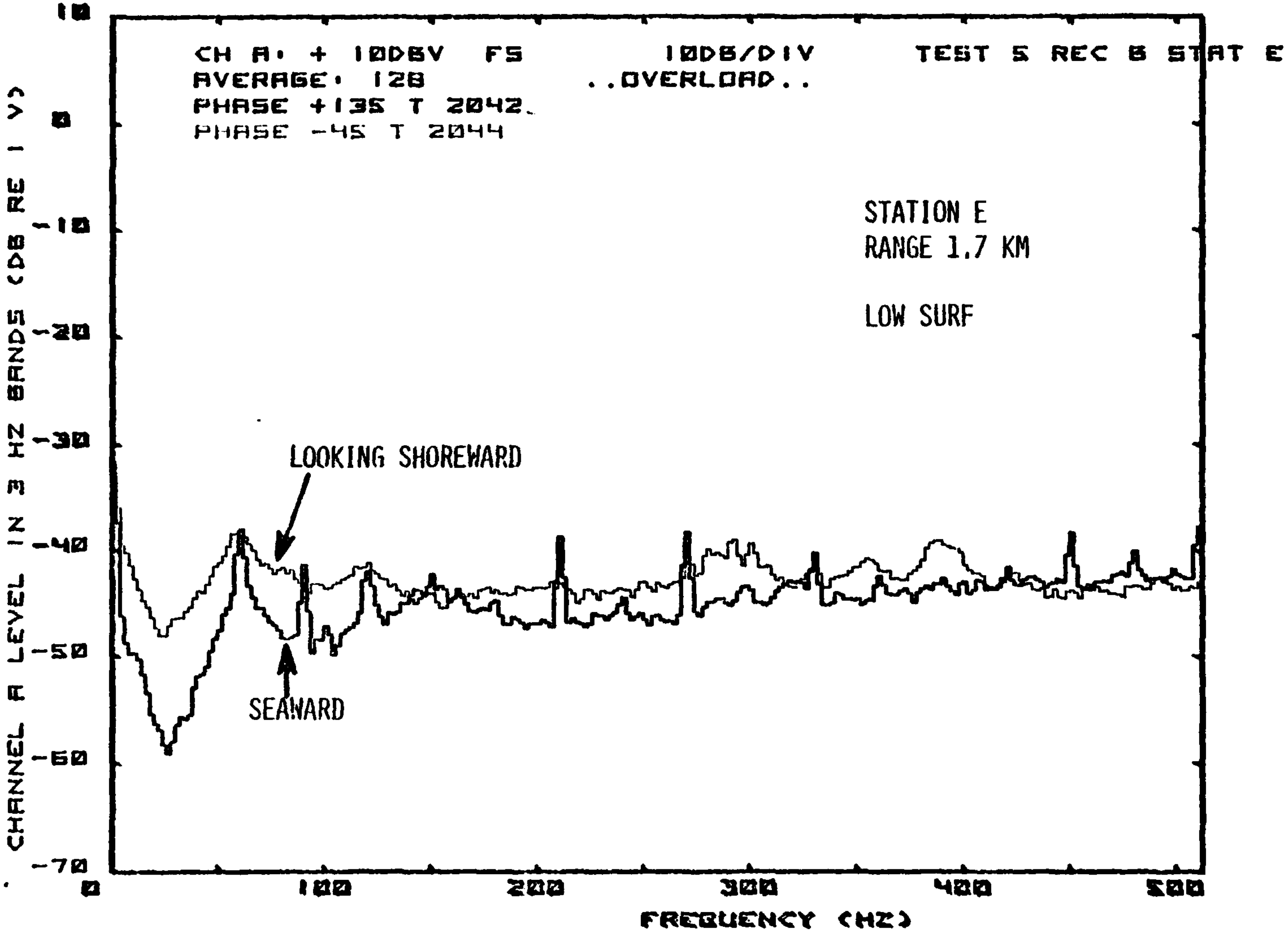


Figure 15. Spectra of cardioid beam output during low surf conditions when oriented shoreward (E) and se[illegible]rd [illegible]). Range 1.7 km. 16 April 1981. Not corrected for system res[illegible].

References

1. R. A. Saenger, "An estimate of the offshore ambient noise spectrum produced by a pounding surf," Paper Q11, November 1961 meeting of the Acoustical Society of America.

2. V. I. Bardyshev, N. G. Kozehelapova, and V. I. Kryshnii, "Study of underwater noise distributions in inland sea and coastal regions," Sov. Phys. Acous. 19 No. 2, 95-96, Sept-Oct 1973.

3. L. N. Zakharov and S. N. Rzhevkin, "Phase Gradient Measurements in Sound Fields," Sov.Phys.Acous. 20, 242-245, Nov-Dec 1974.

4. L. N. Zakharov, and V. A. Kirshov, "Undersea Noise in a Coastal Region," Eighth All-Union Acoustics Conference, Moscow (1973). In Russian.

5. W. Bascom, Waves and Beaches, Anchor Books (1964).

6. Coastal Data Information Program Reports, The Nearshore Research Group, Institute of Marine Resources. Scripps Institution of Oceanography, University of California, LaJolla, CA 92093

INITIAL DISTRIBUTION LIST

Chief of Naval Research 1
Attn: 425 CA
Arlington, Virginia 22217

Chief of Naval Research 1
Attn: 425 UA
Arlington, Virginia 22217

Chief of Technical Information 1
Attn: DTIC-DDR
Alexandria, VA 22314

Naval Postgraduate School 2
Attn: Library
Monterey, CA 93940

Naval Postgraduate School 1
Attn: Office of Research Administration
Monterey, CA 93940

Naval Postgraduate School 1
Attn: LCDR Cal Dunlap, Code 58
Monterey, CA 93940

Naval Postgraduate School 1
Attn: Professor Ed Thornton, Code 58
Monterey, CA 93940

Naval Research Laboratory 2
Attn: Dr. Stephen N. Wolf, Code 5120
Washington, DC 20375

Naval Research Laboratory 2
Attn: Dr. Frank Ingenito, Code 5120
Washington, DC 20375

Naval Research Laboratory 1
Attn: Dr. John Munson, Code 5100
Washington, DC 20375

Naval Research Laboratory 1
Attn: Dr. Orest I. Diachok, Code 5160
Washington, DC 20375

Naval Postgraduate School 1
Attn: Professor Ed Thornton, Code 58
Monterey, CA 93940

Naval Research Laboratory 1
Attn: Dr. W. B. Moseley, Code 5120
Washington, DC 20375

Naval Research Laboratory 1
Attn: Dr. A. I. Eller, Code 5109
Washington, DC 20375

Naval Research Laboratory 1
Attn: Mr. Burt Hurdle, Code 5101
Washington, DC 20375

Dr. Warren W. Denner 1
Science Applications, Inc.
2999 Monterey-Salinas Highway
Monterey, CA 93940

Naval Ocean Research and Development Center 1
Attn: Dr. R. B. Wagstaff
NSTL Station, MS 39539

Naval Underwater Systems Center 1
Attn: Mr. R. Alfred Saenger, Code 3122
New London, CT 06320

Naval Ocean Systems Center 1
Attn: Dr. John Northrop, Code 5311
San Diego, CA 92152

Marine Physical Laboratory 1
Scripps Institution of Oceanography
Attn: Dr. Victor C. Anderson
University of California
San Diego, CA 92152

Naval Weapons Support Center 1
Attn: Mr. Mike Scherschel, Code 3061
Crane, IN 47522

Mr. Robert J. Urick 1
11701 Berwick Road
Silver Spring, MD 20904

Naval Air Development Center 1
Attn: Mr. James Howard, Code 303
Warminster, PA 18974

TetraTech Services, Inc. 1
Attn: Dr. Don Ross, Vice-President
3559 Kenyon Street
San Diego, CA 92110

Science Applications, Inc. 1
Attn: Dr. James H. Wilson
21133 Victory Blvd, Suite 216
Canoga Park, CA 91303

Dr. Nai-chyuan Yen 9 Cross Drive Waterford, CT 06385	1
Easams Limited Attn: Ms. L. M. Kerks, Librarian Lyon Way, Frimley Road Camberly GU16 5EX, Surrey England	1
Naval Sea Systems Command Att. Code 63R Washington, DC 20360	1
Naval Postgraduate School Attn: Prof. O. B. Wilson, Code 61W1 Monterey, CA 93940	14