
UNCLASSIFIED N S HODGKISS ET AL. JAN 88 MPL-TM-307-A F/0 20/1
VERTICAL DIRECTIONALITY OF AMBIENT NOISE
AT 32° N AS A FUNCTION OF LONGITUDE

W. S. Hodgkiss and F. H. Fisher

MPL TECHNICAL MEMORANDUM 387-A

MPL-U-32/86

Approved for public release; distribution unlimited.

January 1988
Measurements have been made of the ambient noise field between 25 and 300 Hz with vertical arrays at 32° N (124° W, 136° W, and 150° W). Substantial differences in the vertical distribution of noise have been measured, especially at the higher frequencies which can be interpreted in the context of attenuation by seawater sound absorption of coastal shipping. Due to substantial differences in weather at the stations, these measurements also provide an opportunity to observe the effect of weather on the vertical distribution of ambient noise.
Vertical Directionality of Ambient Noise

at 32° N as a Function of Longitude

W.S. Hodgkiss and F.H. Fisher

Marine Physical Laboratory
Scripps Institution of Oceanography
San Diego, CA 92152

Abstract

Measurements have been made of the ambient noise field between 25 and 300 Hz with vertical arrays at 32° N (124° W, 136° W, and 150° W). Substantial differences in the vertical distribution of noise have been measured, especially at the higher frequencies which can be interpreted in the context of attenuation by seawater sound absorption of coastal shipping. Due to substantial differences in weather at the stations, these measurements also provide an opportunity to observe the effect of weather on the vertical distribution of ambient noise.
I. Introduction

Ambient ocean noise in the low and mid-frequency regions has received a great deal of attention over the last 25 years. Although not intended to be complete, the references provide an indication of the wide scope of this work. In the unclassified literature, major comprehensive bibliographies include [1-4], books [5-8], workshops [9-10], the analysis of experimental data sets [11-43], ship radiated noise characteristics [44-47], theoretical models [48-64], and the performance of array processors operating in an ambient noise environment [65-73]. A representative view into the classified literature can be obtained by reviewing past issues of the U.S. Navy Journal of Underwater Acoustics and the proceedings of the Navy Symposium on Underwater Acoustics.

Downslope conversion of coastal shipping noise has been discussed as being a major contributor to the low-angle noise distribution in the vertical plane (angles close to the horizontal) [33,38-40,42]. If this is so, then sound absorption in seawater should produce changes in the distribution of low-angle noise in the vertical plane as a function of range from coastal shipping.

A decrease in the noise energy per unit angle in the vertical offers improved array performance as a function of distance from coastal shipping. In the Pacific for these latitudes (32°N), the attenuation is about 0.005 dB/km at 300 Hz and decreases to 0.00125 dB/km at 150 Hz. At a range of 1500 nmi (2778 km), the attenuation would be 13.9 dB at 300 Hz and only 3.5 dB at 150 Hz. Therefore, if we had data on vertical noise distribution at short and long ranges from coastal shipping, we would expect to see substantial absolute differences at low angles between the 300 Hz data and much less for the 150 Hz data.

We have made such measurements - two at 32°N 124°W (approximately 350 nmi due west of San Diego), and one each at 32°N 136°W (approximately 1000 nmi west) and 32°N 150°W (approximately 1700 nmi west). Due to substantial differences in weather at the stations, these measurements also provide an opportunity to observe the effect of weather on the vertical distribution of ambient noise.

A summary of the analysis results is contained in this volume (MPL-TM-387-A). Companion volumes (MPL-TM-387-B,C,D,E) contain the complete analysis results for the four data tapes examined (Tapes #85010, 86060, 86247, and 86180, respectively).
II. Experiment Description and Data Analysis

The data were obtained with two uniformly spaced arrays suspended in the vertical from FLIP and centered on the sound axis (z = 750 m) - the 48 element NORDA VEKA array cut for 309 Hz (d = 2.4 m) and the 27 element MPL digital array cut for 217 Hz (d = 3.46 m). FLIP was in a tight, three-point moor at 32°N, 124°W for the October 1985 data taken with the NORDA VEKA array and drifting slowly at 32° 124°W, 32° 136°W, and 32° 150°W for the April/May 1986 data taken with the MPL digital array. Figure 1 shows the array deployment geometry superimposed on a representative sound velocity profile. The locations of the FLIP stations are indicated on the chart in Figure 2.

The NORDA VEKA array data discussed here were taken on 18 October 1985 starting at 20:05 PDT (Tape #85010, position 32° 124°W, wind speed 6 kts). Twenty-one data segments each of length 72 s were analyzed (25.2 min total). With a sampling rate $f_s = 907.8$ Hz, each segment consisted of 65536 samples/channel.

Figures 5-6 display the power spectra of Channels #1, 16, 32, and 48 from the first segment of the NORDA VEKA array data (Channel #1 corresponds to the hydrophone at the top of the array). They were derived from the incoherent addition of 15, 50% overlapped, 8192-point FFT's (111 mHz bin width). A Kaiser-Bessel window ($\alpha = 2.5$) weighted the data prior to each FFT. For this value of $\alpha$, the highest sidelobe level is -57 dB [74]. The values reported in these figures are properly calibrated (dB re 1 $\mu$Pa/$\sqrt{Hz}$). The 90% confidence interval for these results is ±2.0/-1.8 dB. The very prominent line at slightly less than 250 Hz was projected from a support ship as part of the experiment. The line at 174 Hz was generated on board FLIP.

The MPL digital array data discussed here were taken on 27 April 1986 starting at 06:34 PDT (Tape #86080, position 32° 124°W, wind speed 22 kts), 9 May 1986 starting at 13:38 PDT (Tape #86247, position 32° 136°W, wind speed 17 kts), and 5 May 1986 starting at 10:09 PDT (Tape #86180, position 32° 150°W, wind speed 10 kts). Twenty data segments each of length 55.7 s were analyzed (18.6 min total) from each tape. With a sampling rate of $f_s = 1176$ Hz, each segment consisted of 65536 samples/channel.
Figures 9-10, 13-14, and 17-18 display the power spectra of Channels #1, 10, 20, and 27 from the first segment of each of the MPL digital array data tapes (Channel #1 corresponds to the hydrophone at the top of the array). They were derived from the incoherent addition of 15, 50% overlapped, 8192-point FFT's (144 mHz bin width). A Kaiser-Bessel window (α = 2.5) weighted the data prior to each FFT. The values reported in these figures are properly calibrated (dB re 1 μPa/√Hz). The 90% confidence interval for these results is +2.0/-1.6 dB.

The results in the next section were produced with a FFT beamformer [75]. The along-channel FFT's were 50% overlapped and 8192-points in length. A Kaiser-Bessel window (α = 2.5) weighted the data prior to each FFT. The cross-channel FFT's were 512-points in length where the (complex) data first was windowed with a 48-point (NORDA VEKA array data) or a 27-point (MPL digital array data) Kaiser-Bessel window (α = 1.5) and then zero-padded out to the FFT length. For this value of α, the first sidelobe is -35 dB [74]. Figures 3-4 display the beam patterns of both arrays at several frequencies.
III. Discussion

Figures 7-8, 11-12, 15-16, and 19-20 report the time-evolving character of ambient noise vertical directionality at three stations due west of San Diego. Tape M5010 is from the NORDA VEKA array at 124°W. Tapes 06060, 86247, and 86180 are from the MPL digital array at 124°W, 136°W, and 150°W, respectively. The waterfall plots represent a (time) FFT bin width of 111 mHz (NORDA VEKA array) and 144 mHz (MPL digital array) centered every 25 Hz from 25 Hz through 300 Hz. Multi-panel plots of the same results are included for $f = 75$ Hz, $f = 150$ Hz, and $f = 300$ Hz. Positive angles refer to downward looking beams. The plots have been calibrated to report ambient noise power spectral density per Hz per degree of vertical angle (dB re 1 $\mu$Pa/√HzDeg).

A number of observations can be made by comparing the waterfall and multi-panel plots from the three stations. Under calm weather conditions (Tapes M5010 and 86180), the vertical distribution of ambient noise clearly is concentrated within approximately ±15° of the horizontal. Under poor weather conditions (Tape 06060), high wind speed has the effect of filling in the higher vertical angles while leaving the level within the low-angular region unchanged. Under intermediate weather conditions (Tape 86247), a transition between these two characteristics occurs which is frequency dependent (in the case of Tape 86247, the transition occurs in the the 125-150 Hz region). This frequency-dependent transition characteristic is consistent with single hydrophone measurements reported in the literature (e.g. see [24] where ambient noise levels above 100 Hz were very sensitive to wind speed while ambient noise levels below 100 Hz showed no wind speed dependence at all).

In the low-angular region at the higher frequencies, significant differences can be seen in the vertical distribution of ambient noise as a function of distance from the coast. There is a clear decrease in absolute level with distance. Furthermore, a concave character to the angular distribution of ambient noise centered on the horizontal begins to appear. Both of these observations are consistent with the hypothesis that downslope conversion of coastal shipping noise constitutes a major portion of the low-angle energy and that this kind of noise is diminished by sound absorption as a function of distance from the coast.
IV. Summary

Downslope conversion of coastal shipping noise has been discussed as being a major contributor to the low-angle noise distribution in the vertical plane (angles close to the horizontal). The results reported here on the vertical directionality of ambient noise as a function of longitude are consistent with this hypothesis. Sound absorption in seawater appears to diminish the low-angle energy as a function of distance from the coast with the effect being more pronounced at higher frequencies than at lower frequencies.

Due to substantial differences in weather at the stations, these measurements also provided an opportunity to observe the effect of weather on the vertical distribution of ambient noise. Under calm weather conditions, the vertical distribution of ambient noise clearly is concentrated within approximately ±15° of the horizontal. Under poor weather conditions, high wind speed has the effect of filling in the higher vertical angles while leaving the level within the low-angular region unchanged. Under intermediate weather conditions, a frequency-dependent transition between these two characteristics occurs which is consistent with single hydrophone measurements of wind speed dependence.
Acknowledgements

This work was supported by the Office of Naval Research under contract N00014-84-K-0097 and the Naval Air Systems Command under contract N00014-87-C-0127. The NORDA VEKA array was augmented by Neptune Ocean Engineering under the supervision of Dr. Tom Tunnell of NORDA. Dr. Tunnell was in charge of the NORDA and Neptune Ocean Engineering personnel which included Cecil Watkins and Andrew Monks of NORDA and Dr. Norman Gholson and Tony Jarrell of Neptune. Subcontracts from MPL to NORDA and Neptune Ocean Engineering were let in order to collect the data discussed here. Dr. Fred Fisher was chief scientist for CONTRACK VIII and IX and Dr. Bill Hodkgiss was in charge of data analysis. We wish to thank Mr. Dewitt Efird, the Officer-in-Charge of FLIP and his crew for their excellent cooperation.
References


Figure Captions

Figure 1. Array Deployment Geometry and Representative Sound Velocity Profile.

Figure 2. FLIP Stations for October 1985 and April/May 1986 Experiments.

Figure 3. Beam Patterns: NORDA VEKA Array. (a) Kaiser-Bessel ($\alpha = 1.5$) shading function and (b) Rectangular shading function.

Figure 4. Beam Patterns: MPL Digital Array. (a) Kaiser-Bessel ($\alpha = 1.5$) shading function and (b) Rectangular shading function.

Figure 5. Power Spectra: Tape #85010. FFT Bin Width = 111 mHz. Calibration: dB/µPa/√Hz. Channels #1, 16, 32, and 48.

Figure 6. Power Spectra: Tape #85010. FFT Bin Width = 111 mHz. Calibration: dB/µPa/√Hz. (a) Channel #1, (b) Channel #16, (c) Channel #32, and (d) Channel #48.

Figure 7. Ambient Noise Vertical Directionality: Tape #85010. 32°N 124°W. Wind speed 6 kts. 18 October 1985, 20:05 PDT. Kaiser-Bessel ($\alpha = 1.5$) shading function. Positive angles refer to downward looking beams. Calibration: dB/µPa/√HzDeg. (a) $f = 25$ Hz, (b) $f = 50$ Hz, (c) $f = 75$ Hz, (d) $f = 100$ Hz, (e) $f = 125$ Hz, (f) $f = 150$ Hz, (g) $f = 175$ Hz, (h) $f = 200$ Hz, (i) $f = 225$ Hz, (j) $f = 250$ Hz, (k) $f = 275$ Hz, and (l) $f = 300$ Hz.

Figure 8. Ambient Noise Vertical Directionality: Tape #85010. 32°N 124°W. Wind speed 6 kts. 18 October 1985, 20:05 PDT. Kaiser-Bessel ($\alpha = 1.5$) shading function. Positive angles refer to downward looking beams. Calibration: dB/µPa/√HzDeg. (a) $f = 75$ Hz, (b) $f = 150$ Hz, and (c) $f = 300$ Hz.

Figure 9. Power Spectra: Tape #86060. FFT Bin Width = 111 mHz. Calibration: dB/µPa/√Hz. Channels #1, 10, 20, and 27.
Figure 10. Power Spectra: Tape #86060. FFT Bin Width = 144 mHz. Calibration:
$\text{dB} / \mu \text{Pa} / \sqrt{\text{Hz}}$. (a) Channel #1, (b) Channel #10, (c) Channel #20, and (d) Channel #27.

Figure 11. Ambient Noise Vertical Directionality: Tape #86060. 32°N 124°W. Wind speed 22 kts. 27 April 1986, 06:34 PDT. Kaiser-Bessel ($\alpha = 1.5$) shading function. Positive angles refer to downward looking beams. Calibration: $\text{dB} / \mu \text{Pa} / \sqrt{\text{HzDeg}}$. (a) $f = 25$ Hz, (b) $f = 50$ Hz, (c) $f = 75$ Hz, (d) $f = 100$ Hz, (e) $f = 125$ Hz, (f) $f = 150$ Hz, (g) $f = 175$ Hz, (h) $f = 200$ Hz, (i) $f = 225$ Hz, (j) $f = 250$ Hz, (k) $f = 275$ Hz, and (l) $f = 300$ Hz.

Figure 12. Ambient Noise Vertical Directionality: Tape #86060. 32°N 124°W. Wind speed 22 kts. 9 May 1986, 13:38 PDT. Kaiser-Bessel ($\alpha = 1.5$) shading function. Positive angles refer to downward looking beams. Calibration: $\text{dB} / \mu \text{Pa} / \sqrt{\text{HzDeg}}$. (a) $f = 75$ Hz, (b) $f = 150$ Hz, and (c) $f = 300$ Hz.

Figure 13. Power Spectra: Tape #86247. FFT Bin Width = 144 mHz. Calibration:
$\text{dB} / \mu \text{Pa} / \sqrt{\text{Hz}}$. Channels #1, 10, 20, and 27.

Figure 14. Power Spectra: Tape #86247. FFT Bin Width = 144 mHz. Calibration:
$\text{dB} / \mu \text{Pa} / \sqrt{\text{Hz}}$. (a) Channel #1, (b) Channel #10, (c) Channel #20, and (d) Channel #27.

Figure 15. Ambient Noise Vertical Directionality: Tape #86247. 32°N 136°W. Wind speed 17 kts. 9 May 1986, 13:38 PDT. Kaiser-Bessel ($\alpha = 1.5$) shading function. Positive angles refer to downward looking beams. Calibration: $\text{dB} / \mu \text{Pa} / \sqrt{\text{HzDeg}}$. (a) $f = 25$ Hz, (b) $f = 50$ Hz, (c) $f = 75$ Hz, (d) $f = 100$ Hz, (e) $f = 125$ Hz, (f) $f = 150$ Hz, (g) $f = 175$ Hz, (h) $f = 200$ Hz, (i) $f = 225$ Hz, (j) $f = 250$ Hz, (k) $f = 275$ Hz, and (l) $f = 300$ Hz.

Figure 16. Ambient Noise Vertical Directionality: Tape #86247. 32°N 136°W. Wind speed 17 kts. 9 May 1986, 13:38 PDT. Kaiser-Bessel ($\alpha = 1.5$) shading function. Positive angles refer to downward looking beams. Calibration: $\text{dB} / \mu \text{Pa} / \sqrt{\text{HzDeg}}$. (a) $f = 75$ Hz, (b) $f = 150$ Hz, and (c) $f = 300$ Hz.
Figure 17. Power Spectra: Tape #86180. FFT Bin Width = 144 mHz. Calibration:

$\text{dB}/\mu\text{Pa}/\sqrt{\text{Hz}}$. Channels #1, 10, 20, and 27.

Figure 18. Power Spectra: Tape #86180. FFT Bin Width = 144 mHz. Calibration:

$\text{dB}/\mu\text{Pa}/\sqrt{\text{Hz}}$. (a) Channel #1, (b) Channel #10, (c) Channel #20, and (d) Channel #27.

Figure 19. Ambient Noise Vertical Directionality: Tape #86180. 32° N 150° W. Wind speed 10 kts. 5 May 1986, 10:09 PDT. Kaiser-Bessel ($\alpha = 1.5$) shading function. Positive angles refer to downward looking beams. Calibration: $\text{dB}/\mu\text{Pa}/\sqrt{\text{HzDeg}}$. (a) $f = 25$ Hz, (b) $f = 50$ Hz, (c) $f = 75$ Hz, (d) $f = 100$ Hz, (e) $f = 125$ Hz, (f) $f = 150$ Hz, (g) $f = 175$ Hz, (h) $f = 200$ Hz, (i) $f = 225$ Hz, (j) $f = 250$ Hz, (k) $f = 275$ Hz, and (l) $f = 300$ Hz.

Figure 20. Ambient Noise Vertical Directionality: Tape #86180. 32° N 150° W. Wind speed 10 kts. 5 May 1986, 10:09 PDT. Kaiser-Bessel ($\alpha = 1.5$) shading function. Positive angles refer to downward looking beams. Calibration: $\text{dB}/\mu\text{Pa}/\sqrt{\text{HzDeg}}$. (a) $f = 75$ Hz, (b) $f = 150$ Hz, and (c) $f = 300$ Hz.
Figure 2.

Hawaii to California

- San Francisco
- San Diego
- Hawaiian Islands
V/H11 array beam pattern: 16 window (alpha = 1.5)
VLIKA Array Beam Pattern: rect window

Figure 3(b).
HF Array Beam Pattern: Kn window (alpha = 1.5)

Figure 4(a).
MP1 Array Beam Pattern: rect window

\( f = 50 \text{ Hz} \quad f = 100 \text{ Hz} \quad f = 150 \text{ Hz} \quad f = 200 \text{ Hz} \quad f = 250 \text{ Hz} \quad f = 300 \text{ Hz} \)

Figure 4(b).
Power Spectrum - 85010.1

Channel #1

Channel #16

Channel #32

Channel #48

Figure 5.
Figure 6(a). Power Spectrum - 85010.1 Channel #1

Band: 0-450 Hz

Band: 200-300 Hz

Band: 300-400 Hz
Figure 6(b).
Figure 6(d).
Array Response - 85010.8m #2323
f = 25 Hz, KB window (alpha = 1.5)
Array Response - 85010.8m #4548
f = 50 Hz, KB window (alpha = 1.5)

Figure 7(b).
Array Response - 85010 Bin #4774

f = 75 Hz, K6 window (alpha = 1.5)
Array Response - 85010 Bin #4999
\( f = 100 \) Hz, KB window (alpha = 1.5)
Array Response - 85010 Bin #5225

$\lambda = 125$ Hz, KB window (alpha = 1.5)
Array Response - 85012 B in #5451
f = 150 Hz, <B window (alpha = 1.5)
Array Response - 85010 Bin #5676
f = 1.75 Hz, K3 window (alpha = 1.5)
Array Response - 85010 Bin #5902
f = 200 Hz, KB window (alpha = 1.5)
Array Response - 85010 Bin #6127
f = 225 Hz, KB window (alpha = 1.5)
Array Response - 85010 Bin #6354
f = 250 Hz, KB window (alpha = 1.5)
Array Response - Bin 6579
f = 275 Hz, KB window (alpha = 1.5)
Array Response - 85010 Bin #6804
\( f = 300 \text{ Hz, KB window (alpha} = 1.5) \)

Figure 7(1).
Array Response - 85010 Bin #4774

f = 75 Hz, KB window (alpha = 1.5)

Figure 3(a).
Array Response - 85010 Bin #4774

f = 75 Hz, KB window (alpha = 1.5)
Array Response - 85010 Bin #4774

f = 75 Hz, KB window (alpha = 1.5)
Array Response - 85010 Bin #5451

\( f = 150 \text{ Hz}, \text{ KB window (alpha } = 1.5) \)
Array Response - 85010 Bin #5451

$f = 150$ Hz, KB window (alpha = 1.5)
Array Response - 85010 Bin #5451

\( f = 150 \) Hz, KB window (alpha = 1.5)
Array Response - 85010 Bin #6804

f = 300 Hz, KB window (alpha = 1.5)

Figure 3(c).
Array Response - 85010 Bin #6504

f = 300 Hz, KB window (alpha = 1.5)
Array Response - 85010 Bin #6804

f = 300 Hz, KB window (alpha = 1.5)
Power spectrum - 86050 1 Channel #20

Figure 10(c).
Array Response - 86960 Bin #4271
$f = 25$ Hz, KB window (alpha = 1.5)
Array Response - 86060 Bin #4445
f = 50 Hz, KB window (alpha = 1.5)
Array Response - 86060 Bin #4519
f = 75 Hz, KB window (alpha = 1.5)
Array Response - 86060 Bin #4793
f = 100 Hz, KB window (alpha = 1.5)
Array Response - 86060 Bin #4967
f = 125 Hz, KB window (alpha = 1.5)
Array Response - 86060 Bin #5141
f = 150 Hz, KB window (alpha = 1.5)

Figure 11(f).
Array Response - 86060 Bin #5316
f = 175 Hz, KB window (alpha = 1.5)

Figure 11(a)
Array Response - 86060 Bin #5490

f = 200 Hz, KB window (alpha = 1.5)
Array Response - 86060 Bin #5664
f = 225 Hz, KB window (alpha = 1.5)
Array Response - 86060 Bin #5832
\[ f = 250 \text{ Hz}, \ KB \text{ window (alpha} = 1.5) \]
Array Response - 86060 Bin #6012
\(f = 275\) Hz, KB window (alpha = 1.5)
Array Response - 86060 Bin #6186
f = 300 Hz, KB window (alpha = 1.5)
Array Response - 86060 Bin #4619

f = 75 Hz, KB window (alpha = 1.5)

[Graph showing array response with frequency and power levels plotted against time]
Array Response - 86060 Bin #4619

f = 75 Hz, KB window (alpha = 1.5)
Array Response - 85060 Bin #5141

\( f = 150 \text{ Hz, KB window (alpha = 1.5)} \)

Figure 12(b).
Array Response - 86060 Bin #5141
f = 150 Hz, KB window (alpha = 1.5)
Array Response - 86060 Bin #5141

f = 150 Hz, KB window (alpha = 1.5)
Array Response - 86060 Bin #6186
f = 300 Hz, KB window (alpha = 1.5)

Figure 12(c)
Array Response - 86060 Bin #6186

f = 300 Hz, KB window (alpha = 1.5)
Array Response - 86060 Bin #6186

f = 300 Hz, KB window (alpha = 1.5)
Figure 13.
Figure 14(a).
Array Response - 86247 Bin #4271
f = 25 Hz, KB window (alpha = 1.5)
Array Response - 86247 B in #4445

f = 50 Hz, KB window (alpha = 1.5)

Figure 15(b).
Array Response - 86247 Bin #4619
f = 75 Hz, KB window (Glastra = 1.5)
Array Response - 86247 Bin #4793
f = 100 Hz, KB window (aavg = 1.5)
Array Response - 86247 Bin #4967

f = 125 Hz, KB window (alpha = 1.5)
Array Response - 86247 Bin #5141
f = 150 Hz, KB window (alpha = 1.5)
Array Response - Bin #5316
f = 175 Hz, KB window (alpha = 1.5)

Figure 15(q).
Array Response - 86247 Bin #5490

f = 200 Hz, KB window (alpha = 1.5)

Figure 15(h)
Array Response - Bin #5664
f = 225 Hz, KB window (alpha = 1.5)
Array Response - 86247 Bin #5832
f = 250 Hz, KB window (alpha = 1.5)

Figure 15(j).
Array Response - 86247 Bin #6012
f = 275 Hz, KB window (alpha = 1.5)

Figure 15(k).
Array Response - 86247 Bin #6186
f = 300 Hz, KB window (alpha = 1.5)
Array Response - 86247 Bin 4019

f = 75 Hz, KB window (alpha = 1.5)

Figure 16(a).
Frequency Response - 56247 Bin #4619
f = 75 Hz, K5 window (alpha = 1.5)
Array Response - 86247 8:1 - #4619
f = 75 Hz. <3 window (a.b.n = 1.5)
VERTICAL DIRECTIONALITY OF AMBIENT NOISE AT 32 DEG N AS A FUNCTION OF LON

Scripps Institution of Oceanography
La Jolla CA Marine Physic.

W S Hodgkiess et al. Jan 98 MPL-TM-387-A

F/G 20/1
Array Response - 86247 Bin #5141
$\gamma = 150$ Hz, KB window ($\alpha = 1.5$)

Figure 16(b).
Array Response - 86247 Bin #5141

f = 150 Hz, KB window (alpha = 1.5)
Array Response - 86247 Bin #5141

\( f = 150 \text{ Hz}, \text{ KB window (alpha = 1.5)} \)
Array Response - 86247 Bin #6186
f = 300 Hz, KB window (alpha = 1.5)

Figure 16(c).
Array Response - 86247 Bin #6186

f = 300 Hz, KB window (alpha = 1.5)
Array Response - 86247 Bin #6186

f = 300 Hz, KB window (alpha = 1.5)
Figure 17.
Power Spectrum - Channel 10
Band: 0-600 Hz

Band: 100-200 Hz

Band: 200-300 Hz

Band: 300-400 Hz

Figure 18(b).
Array Response - 86180 Bin #4271
f = 25 Hz, KB window (alpha = 1.5)
Array Response - 86180 Bin #4619
f = 75 Hz, KB window (alpha = 1.3)

Figure 19(c).
Array Response - 86180 Bin #4793

\( f = 100 \text{ Hz}, \text{ KB window (alpha = 1.5)} \)

Figure 19(d).
Array Response - Bin #4967
\( f = 125 \text{ Hz}, \) KB window (alpha = 1.5)
Array Response - 86180 Bin #5141
f = 150 Hz, KB window (alpha = 1.5)
Array Response - 86180 Bin #5316
f = 175 Hz, KB window (alpha = 1.5)

Figure 19(a).
Array Response - 86180 Bin #5490
f = 200 Hz, KB window (alpha = 1.5)
Array Response - 86180 Bin #5664
f = 225 Hz, KB window (alpha = 1.5)
Array Response - 86180 Bin #5832
f = 250 Hz, KB window (alpha = 1.5)
Array Response - 86180 Bin #6012

f = 275 Hz, KB window (alpha = 1.5)
Array Response - 86180 Bin #6186
f = 300 Hz, KB window (alpha = 1.5)
Array Response - 86180 Bin 4619

f = 75 Hz, KB window (alpha = 1.5)
Array Response - 86180 Bin #4619
\[ f = 75 \text{ Hz}, \text{ KB window (cipro = 1.5)} \]
Array Response - 86180 Bin #4619

f = 75 Hz, KB window (alpha = 1.5)
Array Response - 86180 Bin #5141
f = 150 Hz, KB window (alpha = 1.5)
Array Response - Bin #5141

f = 150 Hz, KB window (alpha = 1.5)
Array Response - 86180 Bin #5141

$\omega = 150$ Hz, KB window ($\alpha = 1.5$)
Array Response - 86180 Bin #6186

\( f = 300 \) Hz, KB window (alpha = 1.5)

Figure 20(c).
Array Response - 86180 Bin #6186
f = 300 Hz, KB window (alpha = 1.5)
Array Response - 86180 Bin 96136

f = 300 Hz, K5 window (alpha = 1.5)
END
DATE
FILMED
DTIC
July 88