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VERTICAL DIRECTIONALITY OF AMBIENT NOISE AT 32° N AS A FUNCTION OF LONGITUDE

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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

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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 \((z = 750 \text{ m})\) - the 48 element NORDA VEKA array cut for 309 Hz \((d = 2.4 \text{ m})\) and the 27 element MPL digital array cut for 217 Hz \((d = 3.46 \text{ m})\). FLIP was in a tight, three-point moor at \(32^\circ \text{N}, 124^\circ \text{W}\) for the October 1985 data taken with the NORDA VEKA array and drifting slowly at \(32^\circ 124^\circ \text{W}, 32^\circ 136^\circ \text{W},\) and \(32^\circ 150^\circ \text{W}\) 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 \(32^\circ 124^\circ \text{W}\), wind speed 6 kts). Twenty-one data segments each of length 72 s were analyzed (25.2 min total). With a sampling rate \(f_s = 907.8 \text{ Hz}\), each segment consisted of 65536 samples/channel.

Figures 5-6 display the power spectra of Channels #4, 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 \(-57 \text{ dB}\) [74]. The values reported in these figures are properly calibrated (dB re 1 \(\mu\text{Pa}/\sqrt{\text{Hz}}\)). The 90\% confidence interval for these results is \(+2.0/-1.6 \text{ dB}\). 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 \(32^\circ 124^\circ \text{W}\), wind speed 22 kts), 9 May 1986 starting at 13:38 PDT (Tape \#86247, position \(32^\circ 136^\circ \text{W}\), wind speed 17 kts), and 5 May 1986 starting at 10:09 PDT (Tape \#86180, position \(32^\circ 150^\circ \text{W}\), 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 \(f_s = 1176 \text{ Hz}\), 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 ($\alpha = 2.5$) weighted the data prior to each FFT. 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/-1.6 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 ($\alpha = 2.5$) 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 ($\alpha = 1.5$) and then zero-padded out to the FFT length. For this value of $\alpha$, 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 #85010 is from the NORDA VEKA array at 124°W. Tapes #86060, 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 μPa/√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 #85010 and #86180), the vertical distribution of ambient noise clearly is concentrated within approximately ±15° of the horizontal. Under poor weather conditions (Tape #86060), 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 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 $\pm 15^\circ$ 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 Hodgkiss 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


NSTL, MS (1985).


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:
  dB/μPa/√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 (α = 1.5) shading function. Positive angles refer to downward looking beams. Calibration: dB/μPa/√Hz/Deg. (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 (α = 1.5) shading function. Positive angles refer to downward looking beams. Calibration: dB/μPa/√Hz/Deg. (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:
  dB/μPa/√Hz. Channels #1, 10, 20, and 27.

Figure 14. Power Spectra: Tape #86247. FFT Bin Width = 144 mHz. Calibration:
  dB/μPa/√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 (α = 1.5) shading function. Positive angles refer to downward looking beams. Calibration: dB/μPa/√Hz/Deg. (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 (α = 1.5) shading function. Positive angles refer to downward looking beams. Calibration: dB/μPa/√Hz/Deg. (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:
dB/μPa/√Hz. Channels #1, 10, 20, and 27.

Figure 18. Power Spectra: Tape #86180. FFT Bin Width = 144 mHz. Calibration:
dB/μPa/√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 (α = 1.5) shading function. Positive angles refer to downward looking beams. Calibration: dB/μPa/√Hz Deg. (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 (α = 1.5) shading function. Positive angles refer to downward looking beams. Calibration: dB/μPa/√Hz Deg. (a) f = 75 Hz, (b) f = 150 Hz, and (c) f = 300 Hz.
Hawaii to California

Figure 2.
VIKA Array Beam Pattern: 4π window (alpha = 1.5)

Figure 3(a).
VIKA Array Beam Pattern: rect window
HT Array Beam Pattern: Rh window (alpha = 1.5)
Figure 4(b).
Figure 5.
Figure 6(b).
Figure 6(c).
Array Response - 85010 8m #2323
f = 25 Hz, KB window (alpha = 1.5)
Array Response: $50 \text{ Hz}$, $K_B$ window, $\alpha = 1.5$

Figure 7.5.
Array Response - 85010 Bin #4774

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

$\theta = 125$ Hz, KB window (alpha = 1.5)

Figure 7(e).
Array Response - 85012 Bin #5451
f = 150 Hz, K8 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)

Figure 7(j).
Array Response - 85010 Bin #6579

f = 275 Hz, KB window (alpha = 1.5)
Array Response - 85010 Bin #6804
\( f = 300 \text{ Hz}, \text{ KB window (alpha = 1.5)} \)
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 (alpfa = 1.5)
Array Response - 85010 Bin #5451

$f = 150$ Hz, KB window ($\alpha = 1.5$)

Figure 3(b).
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 #6804

$\omega = 300$ Hz, KB window (alpha = 1.5)

Figure 3(c).
Array Response - 85010 Bin #6804

\[ f = 300 \text{ Hz, KB window (alpha = 1.5)} \]
Array Response - 85010 Bin #6804
f = 300 Hz, KB window (alpha = 1.5)
Figure 10(a).
Figure 10(c).
Array Response - 86060 Bin #2271
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)
Array Response - 86060 Bin #5490
f = 200 Hz, KB window (alpha = 1.5)

Figure 11(h).
Array Response - 86060 Bin #5664
f = 225 Hz, KB window (alpha = 1.5)
Array Response - 86060 Bin #5832

f = 250 Hz, KB window (alpha = 1.5)
Array Response - 86060 Bin #6012
f = 275 Hz, KB window (alpha = 1.5)

Figure 12: X
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)
Array Response - 86060 Bin #4619

f = 75 Hz, KB window (alpha = 1.5)
Array Response - 86060 Bin #5141

f = 150 Hz, KB window (alpha = 1.5)

Figure 12(b).
Array Response - 86060 Bin #5141

f = 150 Hz, KB window (alpha = 1.5)
Array Response - 86068 Bin #5141

f = 150 Hz, KB window (alpha = 0.5)
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)
Array Response - 86060 Bin #6186

f = 300 Hz, KB window (alpha = 1.5)
Figure 14(c).
Array Response - 86247 Bin #4271
f = 25 Hz, KB window (alpha = 1.5)
Array Response - 86247.8m #4445

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

Figure 15(b).
Figure 15(c).

Array Response - 86247 Bin #4619
f = 75 Hz, KB window (cutoff = 1.5)
Array Response - 86247 Bin #4793
f = 100 Hz, KB window (alpha = 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)

Figure 15(f).
Array Response - 86247 Bin #5316
f = 175 Hz, KB window (alpha = 1.5)
Array Response - 86247 Bin #5490
f = 200 Hz, KB window (alpha = 1.5)
Array Response - 86247 Bin #5664
f = 225 Hz, KB window (alpha = 1.5)
Array Response - 86247 Bin #5832
f = 250 Hz, KB window (alpha = 1.5)
Array Response - 86247 Bin #6012

f = 275 Hz, KB window (alpha = 1.5)

Figure 15(k).
Array Response - 86247 Bin 46136
f = 300 Hz, KB window (alpha = 1.5)
Array Response - 86247 Bin 4619
f = 75 Hz, KB window (alpha = 1.5)

Figure 16(a).
Hanny Response - 86247 Bin #4619

f = 75 Hz, K8 window (alpha = 1.5)
Array Response - 85247 B1: #4619

f = 75 Hz, <3 window (a thru = 1.5)
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MICROCOPY RESOLUTION TEST CHART
Array Response - 66247 Bin #5141

$\omega = 150$ 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 Hz, 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
$\Gamma = 300$ Hz, KB window ($\alpha = 1.5$)
Array Response - 86247 Bin #6186

\( f = 300 \text{ Hz, KB window (alpha = 1.5)} \)
Power Spectrum - 86180.1 Channel 1

Band: 0-600 Hz

Band: 100-200 Hz

Band: 200-300 Hz

Band: 300-400 Hz

Figure 18(a).
Array Response - 86180 Bin #4271

f = 25 Hz, KB window (alpha = 1.5)
Array Response - 86180 Bin #4445
f = 50 Hz, KB-window (alpha = 1.5)
Array Response - 86180 Bin #4619
f = 75 Hz, KB window (alpha = 1.5)

Figure 19(c).
Array Response - 86180 Bin #4793
f = 100 Hz, KB window (alpha = 1.5)

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

Figure 20(a).
Array Response - 86180 Bin #4619
f = 75 Hz, 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 - 86180 Bin #5141
\[ f = 150 \text{ Hz}, \text{ KB window (alpha = 1.5)} \]
Array Response - 86180 Bin #5141

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

\[ f = 300 \text{ Hz}, \text{ KB window (alpha = 1.5)} \]

Figure 20(c).
Array Response - 86180 Bin #6186
f = 300 Hz. KB window (alpha = 1.5)
Array Response - 86180 Bin *6136
f = 300 Hz, K3 window (alpha = 1.5)
END
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