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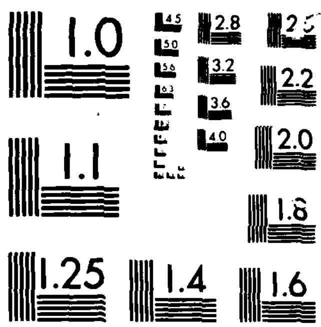

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AD-A167 421

MPL TECHNICAL MEMORANDUM 381

Vertical Directionality of Ambient Noise: 150-300 Hz

W. S. Hodgkiss and F. H. Fisher

Supported by
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MARINE PHYSICAL LABORATORY

of the Scripps Institution of Oceanography

San Diego, California 92152

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20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

Measurements of the vertical directionality of ambient noise have been made during CONTRACK VIII in the 150-300 Hz region with the 48 element NORDA VEKA array cut for 300 Hz and centered on fluctuations over time scales of a few minutes.

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Vertical Directionality of Ambient Noise: 150-300 Hz.

W.S. Hodgkiss and F.H. Fisher

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Abstract

Measurements of the vertical directionality of ambient noise have been made during CONTRACK VIII in the 150-300 Hz region with the 48 element NORDA VEKA array cut for 300 Hz and centered on the sound axis (750 m). There is pronounced anisotropy about the horizontal with significant fluctuations over time scales of a few minutes.

I. Introduction

Although a substantial literature exists on the general subject of ocean acoustic ambient noise, few experiments have been done which provided information on the vertical distribution of ambient noise at frequencies above 100 Hz. Those that have been done often have suffered from one or more of the following limitations: (1) common-mode noise, (2) upward looking only, (3) insufficient aperture, and (4) grating lobe and side lobe contamination.

In this report, we report on measurements of the vertical directionality of ambient noise during CONTRACK VIII at several frequencies between 150 and 300 Hz. Related literature includes [1-11]. As will be shown here, anisotropies in the vertical distribution of ambient noise are pronounced and fluctuate significantly over time scales of a few minutes.

II. Experiment Description and Data Analysis

The data were obtained with a 48 element, uniformly spaced (d = 2.4 m) array suspended in the vertical from FLIP and centered on the sound axis (z = 750 m). Essentially, the array was the NORDA VEKA 32 element array used in CONTRACK VI augmented and reconfigured for this experiment. FLIP was in a tight, three-point moor ~350 miles west of San Diego at 32°N, 124°W (see Figure 1). Measurements of array tilt could only be made when the hydrophones were powered down. Array tilt was 0.7° the only time it was measured. In this deployment, ~500 pounds of metal were attached to the bottom of the array to keep it as near vertical as possible. Considering the array aperture (112.8 m), the small tilt of the array did not degrade the data. A representative sound speed profile and corresponding ray trace diagrams are provided in Figure 2.

The data discussed here were taken on 18 October 1985 starting at 20:05 local time (tape 85010), 19 October 1985 starting at 02:16 local time (tape 85021), and 19 October 1985 starting at 14:20 local time (tape 85042). Eight data segments each of length 72 s were analyzed from each tape. With a sampling rate $f_s = 907.8$ Hz, each segment consisted of 65536 samples/channel.

Figure 3 displays the power spectra of Channel #01 (top hydrophone), Channel #16, Channel #32, and Channel #48 (bottom hydrophone) from the first segment of tape 85010. Similarly, Figures 4 and 5 are spectra from the first segments of tapes 85021 and 85042. They were derived from the incoherent addition of 15, 50% overlapped, 8192-point FFT's (111 mHz bin width). A Kaiser-Bessel window (α = 2.5) weighted the data prior to each FFT [12]. For this value of α, the highest sidelobe level is -57 dB. Proper calibration (dB re 1 μPa/$\sqrt{\text{Hz}}$) is obtained by adding 71 dB to the values reported in the spectra. The 90% confidence interval for these results is +2.0/-1.6 dB. Thus, the spectrum level at 200 Hz is 65 dB re 1 μPa/$\sqrt{\text{Hz}}$. 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 results in the next section were produced with a FFT beamformer [13]. 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 [12]. The cross-channel FFT's were 512-points in length where the (complex) data first were windowed with either a 48-point Kaiser-Bessel window ($\alpha = 1.5$) or rectangular window and then zero-padded out to the FFT length. Beam patterns are displayed in Figure 6 at f = 150, 200, 250, and 300 Hz. For the Kaiser-Bessel window and $\alpha = 1.5$, the first sidelobe is at -35 dB while for the rectangular window it is at -13 dB. Incoherent averages of 15 cross-channel FFT's are displayed as individual panels in each plot in the next section. The corresponding 90% confidence interval is +2.0/-1.6 dB. The plots have not been calibrated so must be interpreted on a relative basis. An important correction not yet made is to account for beam broadening going from broadside to endfire.

III. Discussion

Figures 7-12 report the time-evolving character of ambient noise vertical directionality over 9.6 minute intervals. The plots represent a (time) FFT bin width of 111 mHz centered every 25 Hz from 150 Hz through 300 Hz. Positive angles refer to downward looking beams. Figures 7, 9, and 11 are for a cross-channel (spatial) FFT with a Kaiser-Bessel ($\alpha = 1.5$) shading function and Figures 8, 10, and 12 correspond to use of a rectangular (uniform) shading function.

Three striking features are noteworthy. First, although the vertical structure is stable for a few minutes at a time, significant fluctuations occur over several minutes. Second, there is a noticeable asymmetry in the levels observed by the up-looking and down-looking beams with the down-looking beams being consistently 3-5 dB lower in level than the corresponding up-looking beams. Third, the ambient noise spatial structure appears to have an underlying boxcar character with a majority of the power contained within $\pm$15-20°. On top of this residual characteristic are substantial fluctuations often taking the form of horns at $\pm$10-14° with a significant notch in the $\pm$9-10° region. Notch depth is variable but reaches 5 dB in many instances. For these data, this notch is less significant in the up-looking beams than the down-looking beams.

IV. Summary

Measurements of the vertical directionality of ambient noise in the 150-300 Hz region have been reported. The 48 element NORDA VEKA array cut for 300 Hz and centered on the sound axis (750 m) was used to collect the data. Three features of the data are striking: (1) short term stability and long term fluctuations of the vertical structure, (2) asymmetry in the levels observed by the upward and downward looking beams, and (3) the existence of an underlying boxcar characteristic to the vertical structure on top of which are substantial fluctuations often taking the form of horns at ± 10-14° with a significant notch in the ± 9-10° region.

Acknowledgements

This work was supported by the Office of Naval Research under contract N00014-84-K-0097. 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 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.

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Figure Captions

Figure 1. Location of CONTRACK VIII experiment.

Figure 2. (a) Representative sound speed profile. (b) Corresponding ray trace diagrams.

Figure 3. Power Spectrum: 85010. FFT Bin Width = 111 mHz. Calibration: +71 dB//μPa/$\sqrt{}$Hz or +64 dB//μPa. (a) Channel #01, (b) Channel #16, (c) Channel #32, and (d) Channel #48.

Figure 4. Power Spectrum: 85021. FFT Bin Width = 111 mHz. Calibration: +71 dB//μPa/$\sqrt{}$Hz or +64 dB//μPa. (a) Channel #01, (b) Channel #16, (c) Channel #32, and (d) Channel #48.

Figure 5. Power Spectrum: 85042. FFT Bin Width = 111 mHz. Calibration: +71 dB//μPa/$\sqrt{}$Hz or +64 dB//μPa. (a) Channel #01, (b) Channel #16, (c) Channel #32, and (d) Channel #48.

Figure 6. Beam Patterns: NORDA VEKA Array. (a) f = 150 Hz, (b) f = 200 Hz, (c) f = 250 Hz, and (d) f = 300 Hz.

Figure 7. Ambient Noise Vertical Directionality: 85010. 18 October 1985, 20:05 Local. Kaiser-Bessel (α = 1.5) shading function. Positive angles refer to downward looking beams. (a) f = 150 Hz, (b) f = 175 Hz, (c) f = 200 Hz, (d) f = 225 Hz, (e) f = 250 Hz, (f) f = 275 Hz, and (g) f = 300 Hz.

Figure 8 Ambient Noise Vertical Directionality: 85010. 18 October 1985, 20:05 Local. Rectangular (uniform) shading function. Positive angles refer to downward looking beams. (a) f = 150 Hz, (b) f = 175 Hz, (c) f = 200 Hz, (d) f = 225 Hz, (e) f = 250 Hz, (f) f = 275 Hz, and (g) f = 300 Hz.

Figure 9. Ambient Noise Vertical Directionality: 85021. 19 October 1985, 02:16 Local. Kaiser-Bessel (α = 1.5) shading function. Positive angles refer to downward looking beams. (a) f = 150 Hz, (b) f = 175 Hz, (c) f = 200 Hz, (d) f = 225 Hz, (e) f = 250 Hz, (f) f = 275 Hz, and (g) f = 300 Hz.

Figure 10. Ambient Noise Vertical Directionality: 85021. 19 October 1985, 02:16 Local. Rectangular (uniform) shading function. Positive angles refer to downward looking beams. (a) $f = 150$ Hz, (b) $f = 175$ Hz, (c) $f = 200$ Hz, (d) $f = 225$ Hz, (e) $f = 250$ Hz, (f) $f = 275$ Hz, and (g) $f = 300$ Hz.

Figure 11. Ambient Noise Vertical Directionality: 85042. 19 October 1985, 14:20 Local. Kaiser-Bessel ($\alpha = 1.5$) shading function. Positive angles refer to downward looking beams. (a) $f = 150$ Hz, (b) $f = 175$ Hz, (c) $f = 200$ Hz, (d) $f = 225$ Hz, (e) $f = 250$ Hz, (f) $f = 275$ Hz, and (g) $f = 300$ Hz.

Figure 12. Ambient Noise Vertical Directionality: 85042. 19 October 1985, 14:20 Local. Rectangular (uniform) shading function. Positive angles refer to downward looking beams. (a) $f = 150$ Hz, (b) $f = 175$ Hz, (c) $f = 200$ Hz, (d) $f = 225$ Hz, (e) $f = 250$ Hz, (f) $f = 275$ Hz, and (g) $f = 300$ Hz.

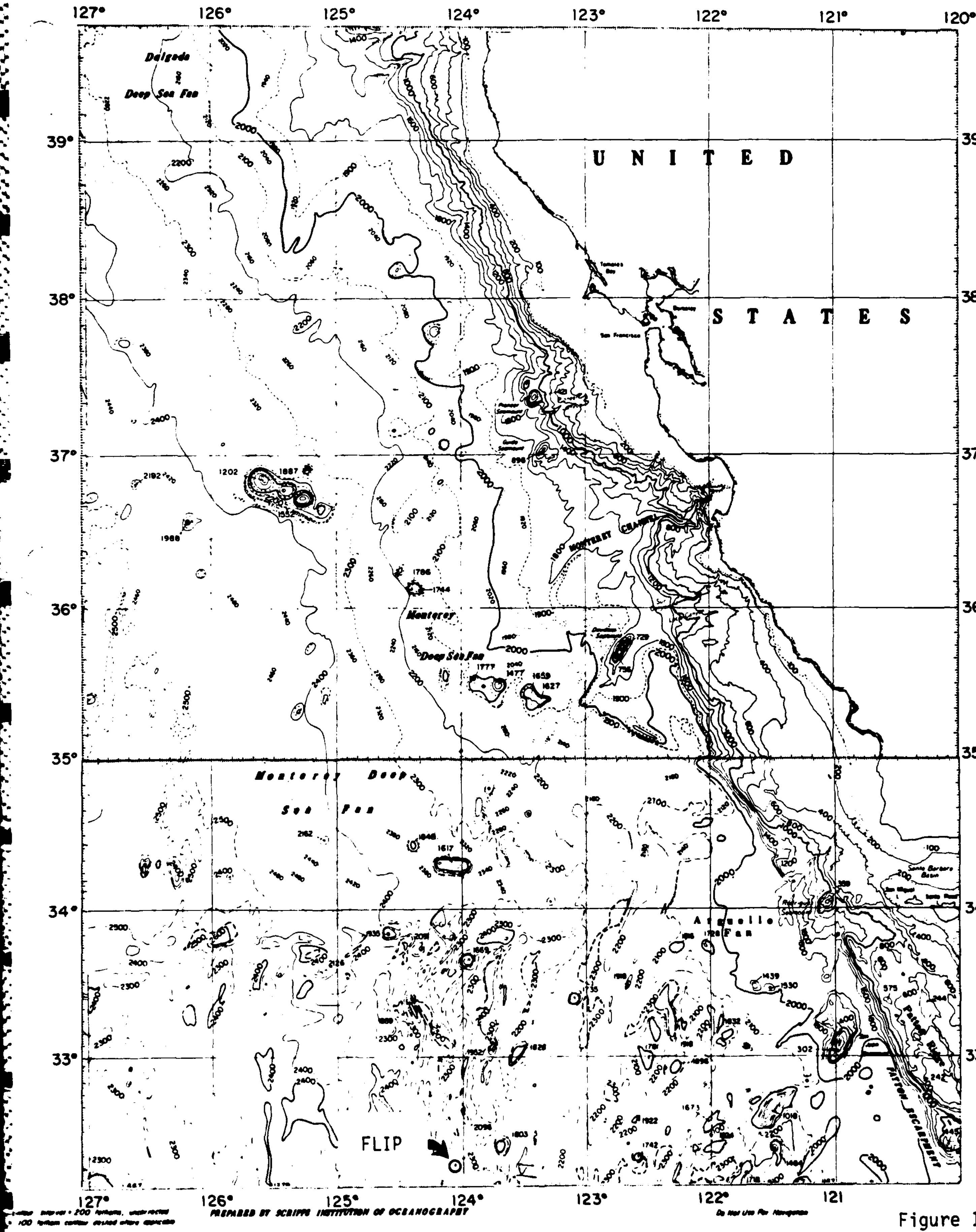
UNITED STATES
Monterey Deep Sea Fan
Monterey Deep Sea Fan
Delgada Deep Sea Fan
MONTEREY CHANNEL
Arguello Fan
FLIP
San Francisco
127°
126°
125°
124°
123°
122°
121°
120°
39°
38°
37°
36°
35°
34°
33°
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Figure 1.

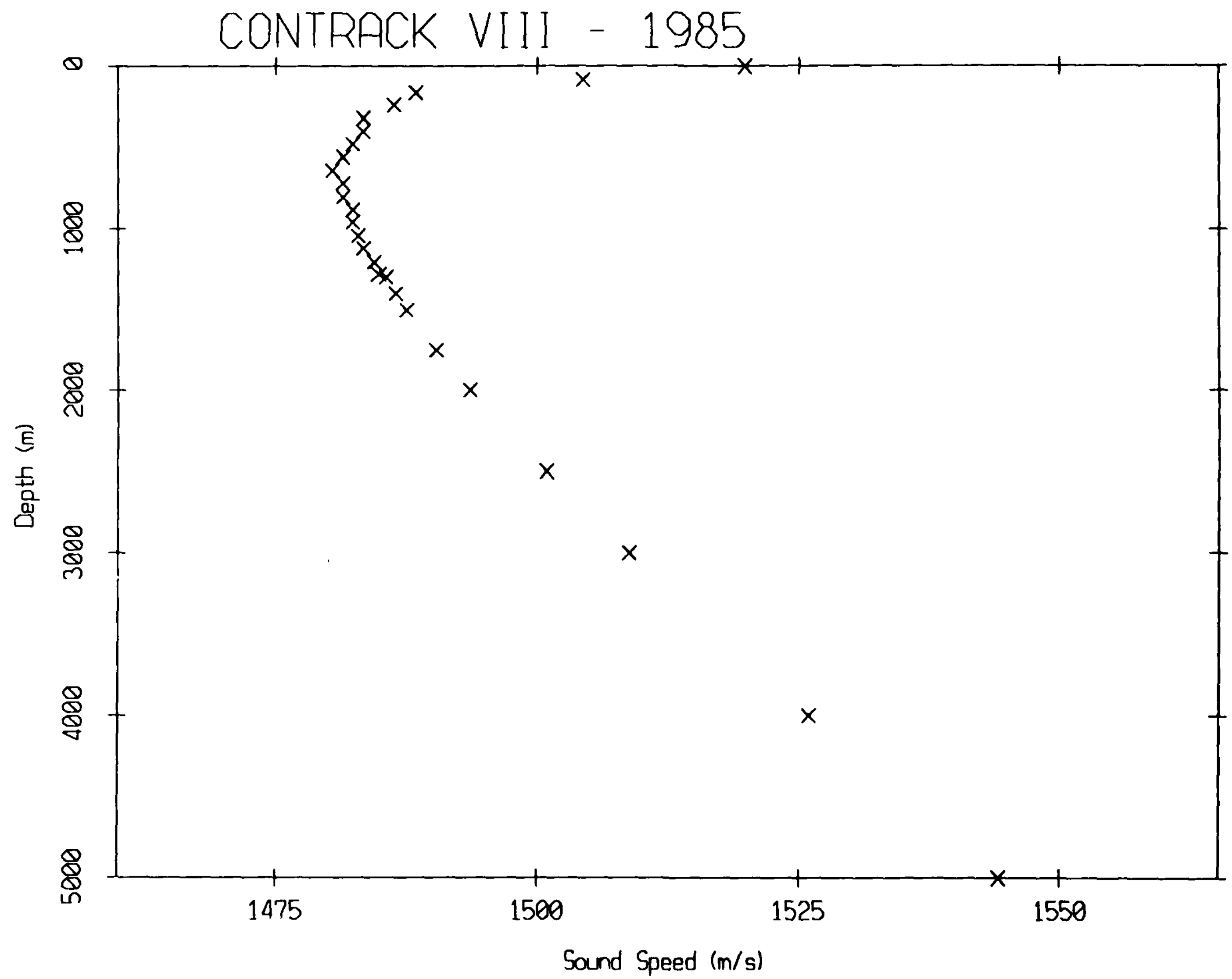

CONTRACK VIII - 1985
Depth (m)
0
1000
2000
3000
4000
5000
1475
1500
1525
1550
Sound Speed (m/s)

Figure 2(a).

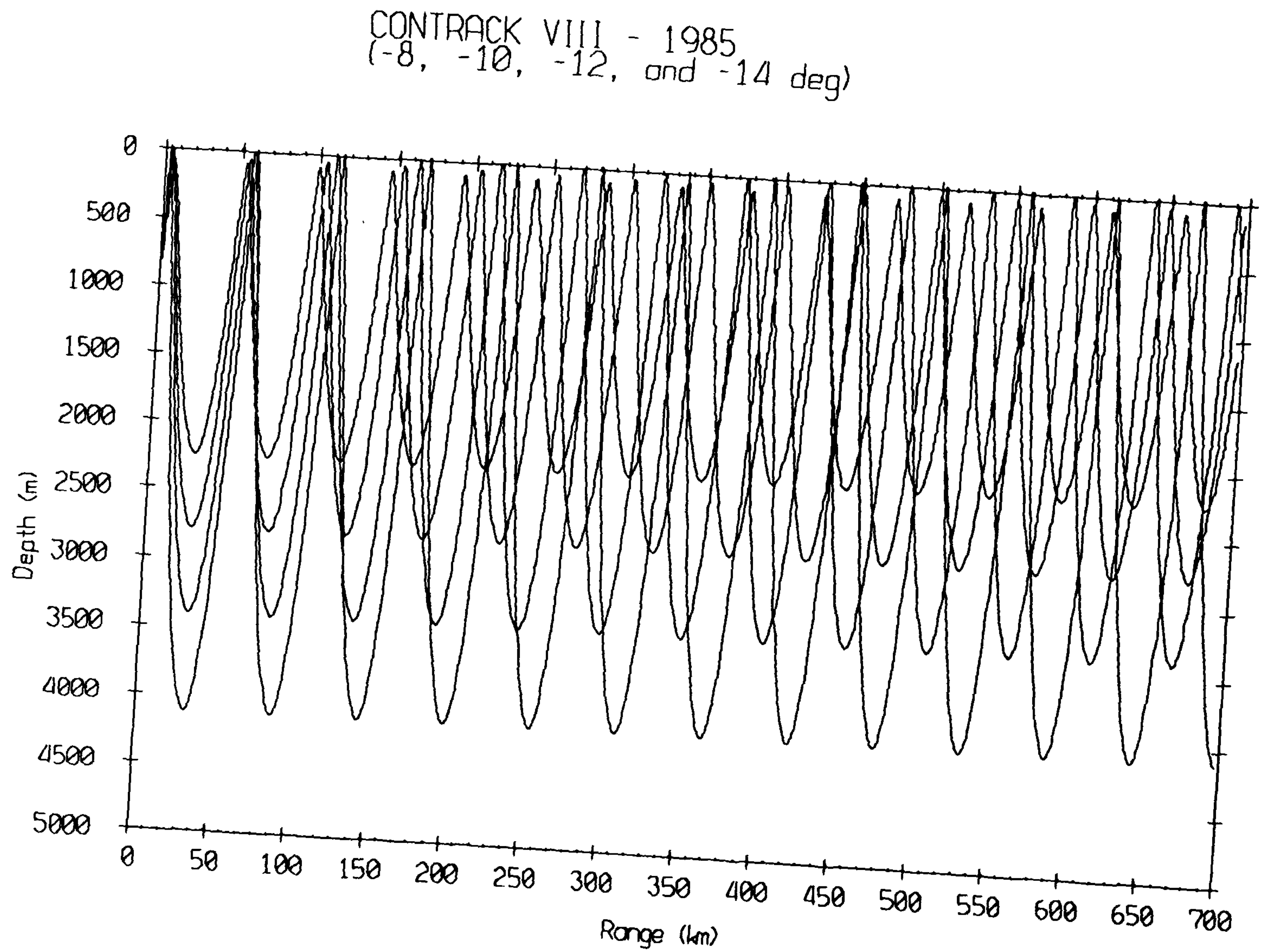

CONTRACK VIII - 1985
(-8, -10, -12, and -14 deg)
0
500
1000
1500
2000
2500
3000
3500
4000
4500
5000
Depth (m)
0
50
100
150
200
250
300
350
400
450
500
550
600
650
700
Range (km)

Figure 2(b).

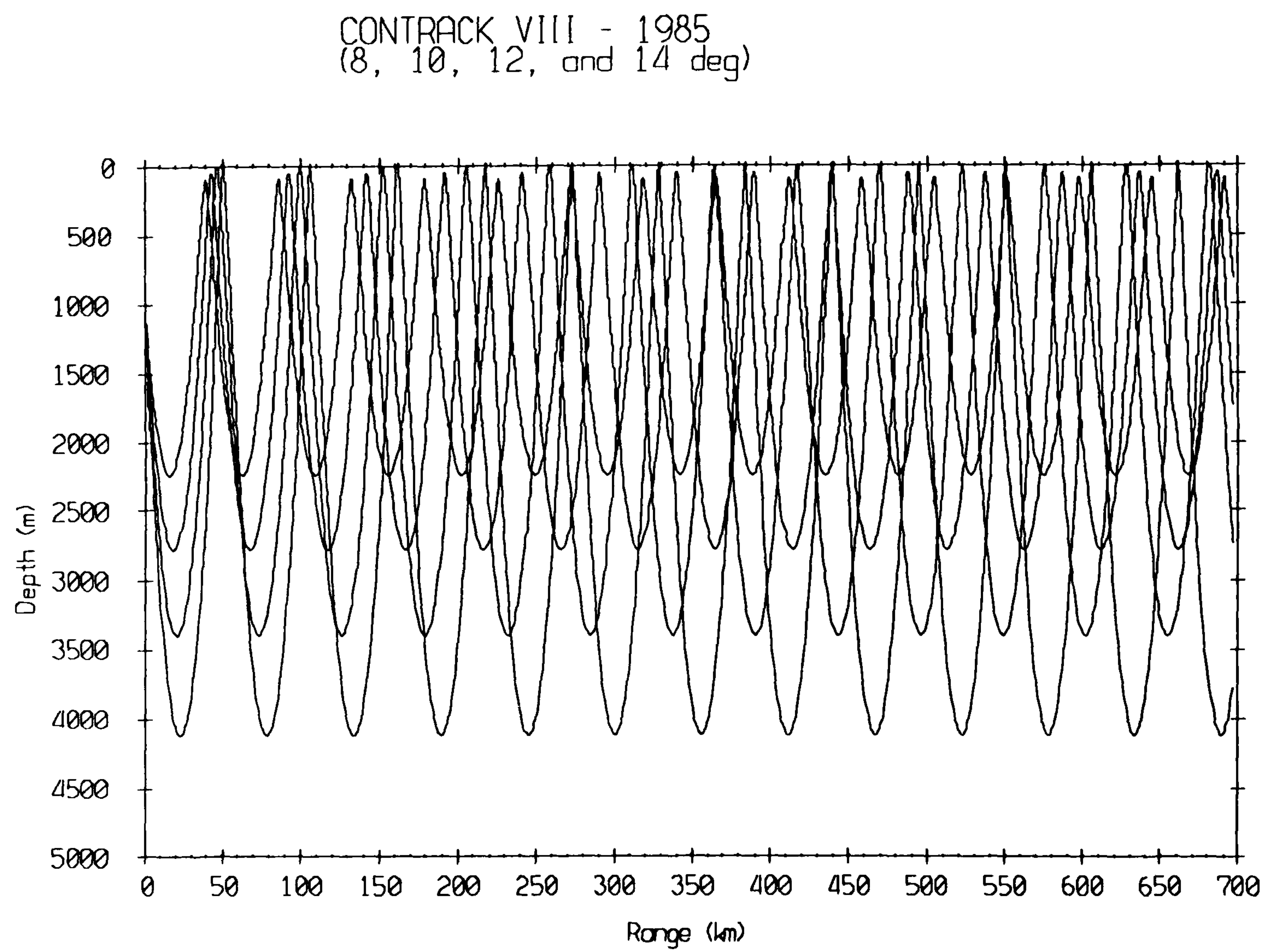
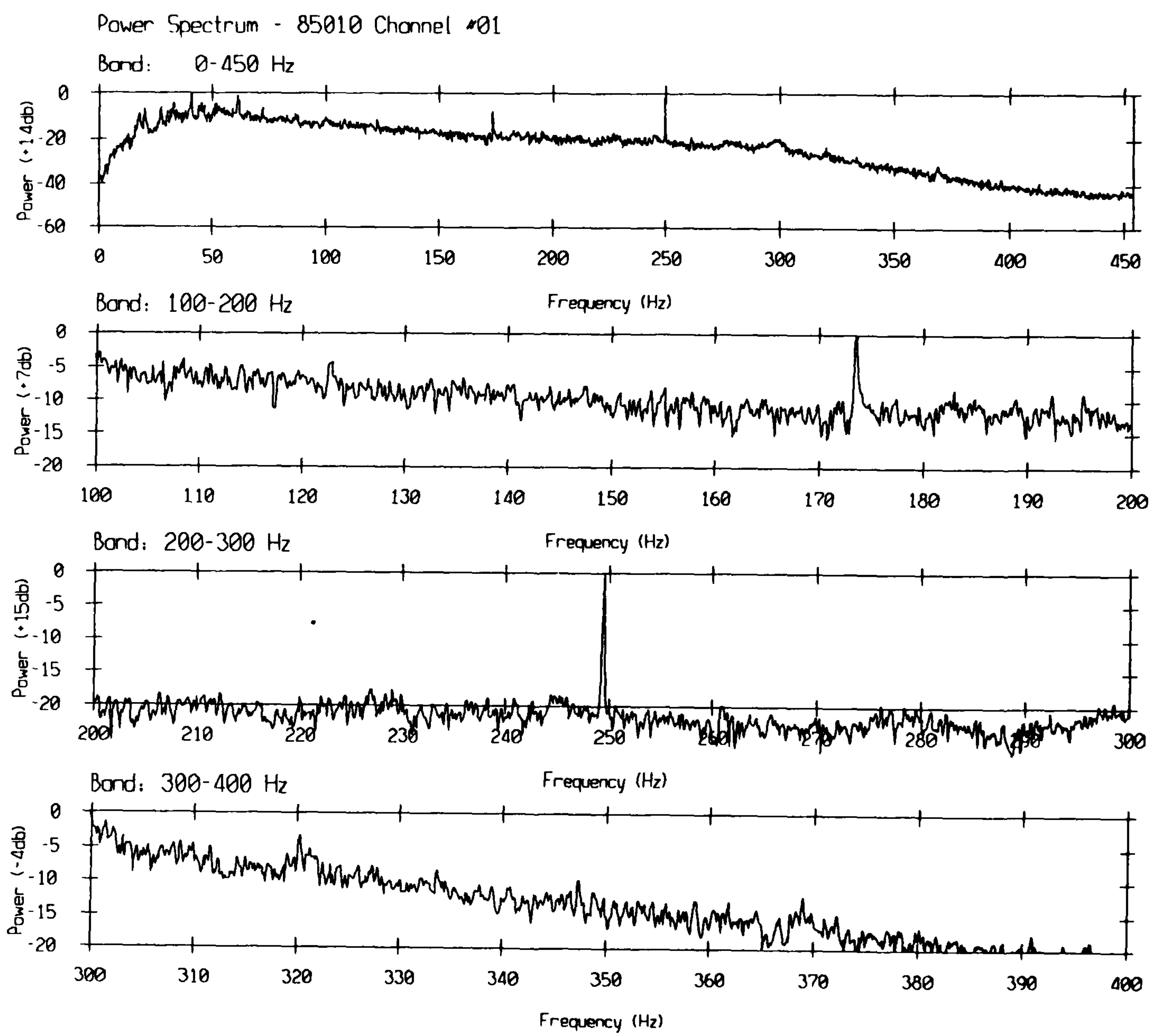

CONTRACK VIII - 1985
(8, 10, 12, and 14 deg)
0
500
1000
1500
2000
2500
3000
3500
4000
4500
5000
Depth (m)
0 50 100 150 200 250 300 350 400 450 500 550 600 650 700
Range (km)

Figure 2(b).



Power Spectrum - 85010 Channel #01
Band: 0-450 Hz
Power (+14db)
0
-20
-40
-60
0
50
100
150
200
250
300
350
400
450
Frequency (Hz)
Band: 100-200 Hz
Power (+7db)
0
-5
-10
-15
-20
100
110
120
130
140
150
160
170
180
190
200
Frequency (Hz)
Band: 200-300 Hz
Power (+15db)
0
-5
-10
-15
-20
200
210
220
230
240
250
300
Frequency (Hz)
Band: 300-400 Hz
Power (-4db)
0
-5
-10
-15
-20
300
310
320
330
340
350
360
370
380
390
400
Frequency (Hz)

Figure 3(a).

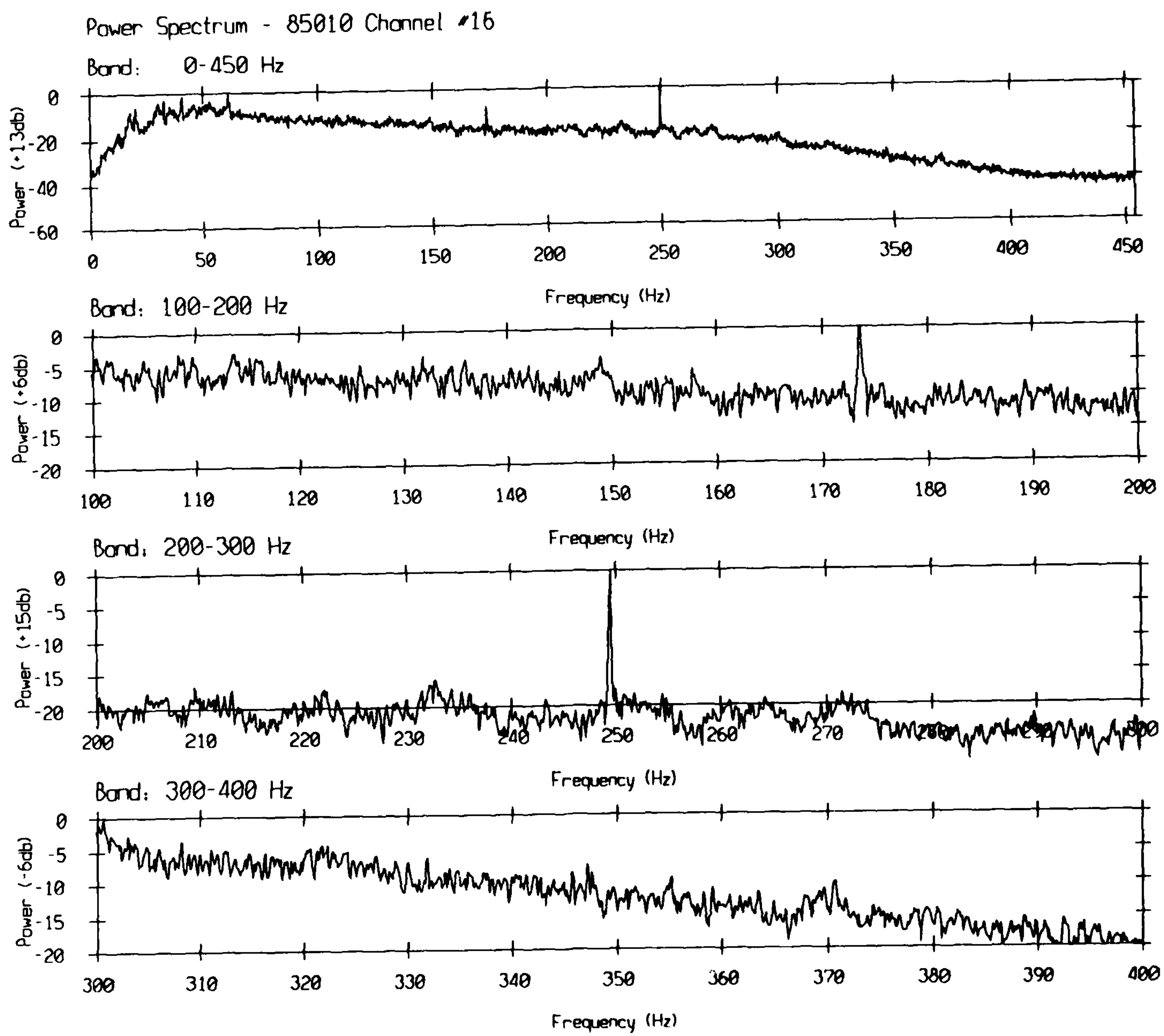
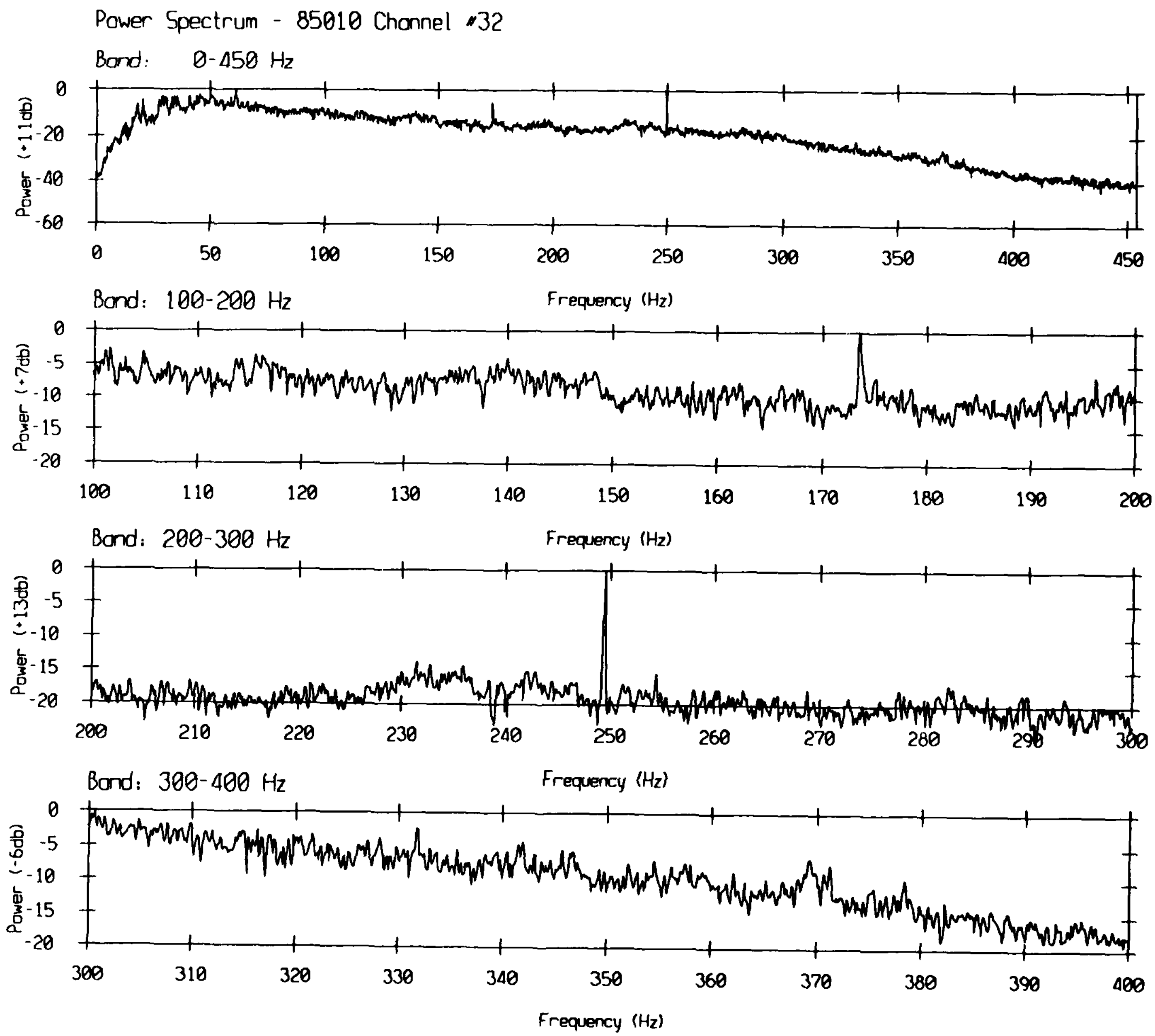

Power Spectrum - 85010 Channel #16
Band: 0-450 Hz
Power (+13db)
0
-20
-40
-60
0
50
100
150
200
250
300
350
400
450
Frequency (Hz)
Band: 100-200 Hz
Power (+6db)
0
-5
-10
-15
-20
100
110
120
130
140
150
160
170
180
190
200
Frequency (Hz)
Band: 200-300 Hz
Power (+15db)
0
-5
-10
-15
-20
200
210
220
230
240
250
260
270
Frequency (Hz)
Band: 300-400 Hz
Power (-6db)
0
-5
-10
-15
-20
300
310
320
330
340
350
360
370
380
390
400
Frequency (Hz)

Figure 3(b).



Power Spectrum - 85010 Channel #32
Band: 0-450 Hz
Power (+11db)
0
-20
-40
-60
0
50
100
150
200
250
300
350
400
450
Frequency (Hz)
Band: 100-200 Hz
Power (+7db)
0
-5
-10
-15
-20
100
110
120
130
140
150
160
170
180
190
200
Frequency (Hz)
Band: 200-300 Hz
Power (+13db)
0
-5
-10
-15
-20
200
210
220
230
240
250
260
270
280
290
300
Frequency (Hz)
Band: 300-400 Hz
Power (-6db)
0
-5
-10
-15
-20
300
310
320
330
340
350
360
370
380
390
400
Frequency (Hz)

Figure 3(c).

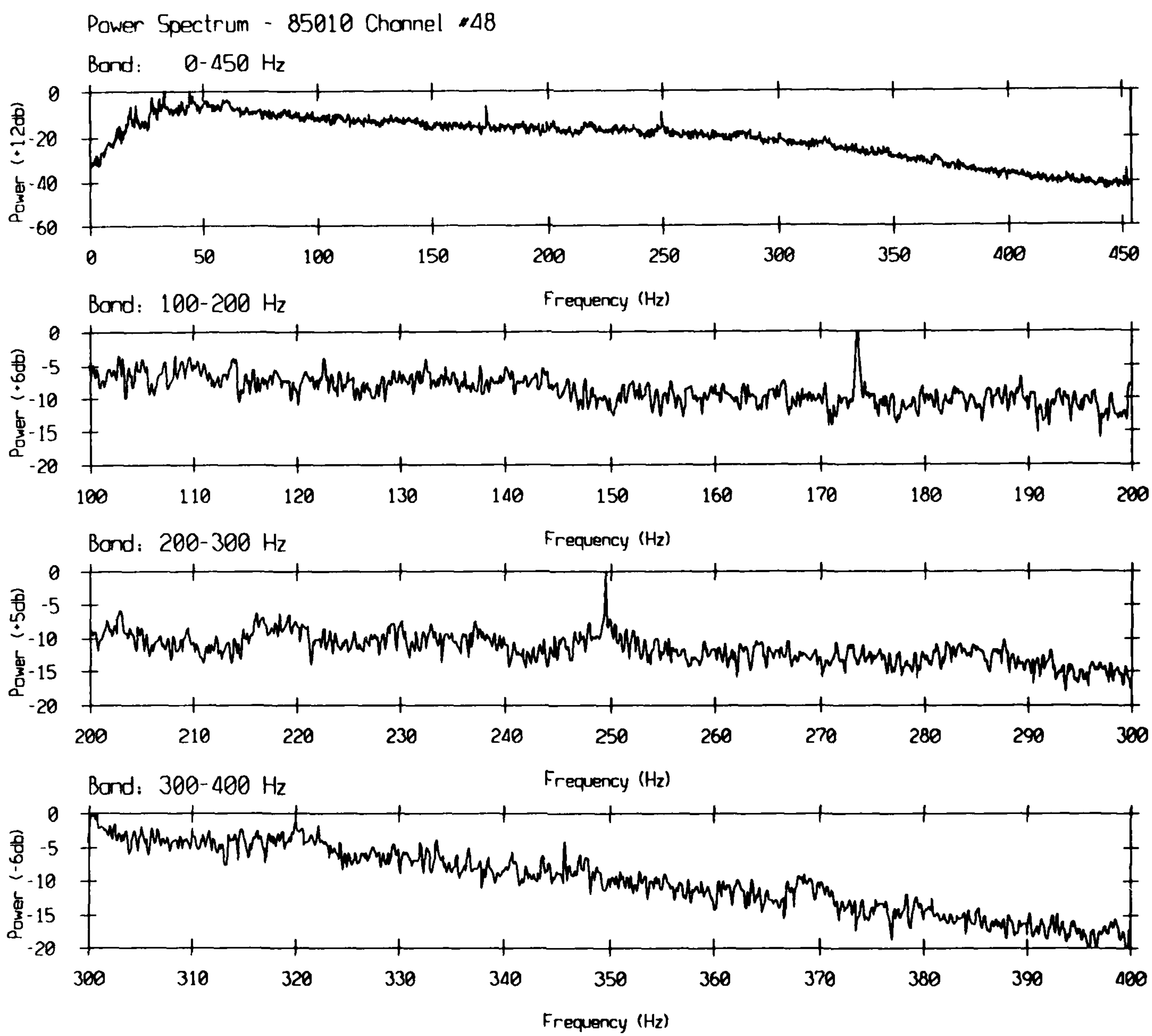
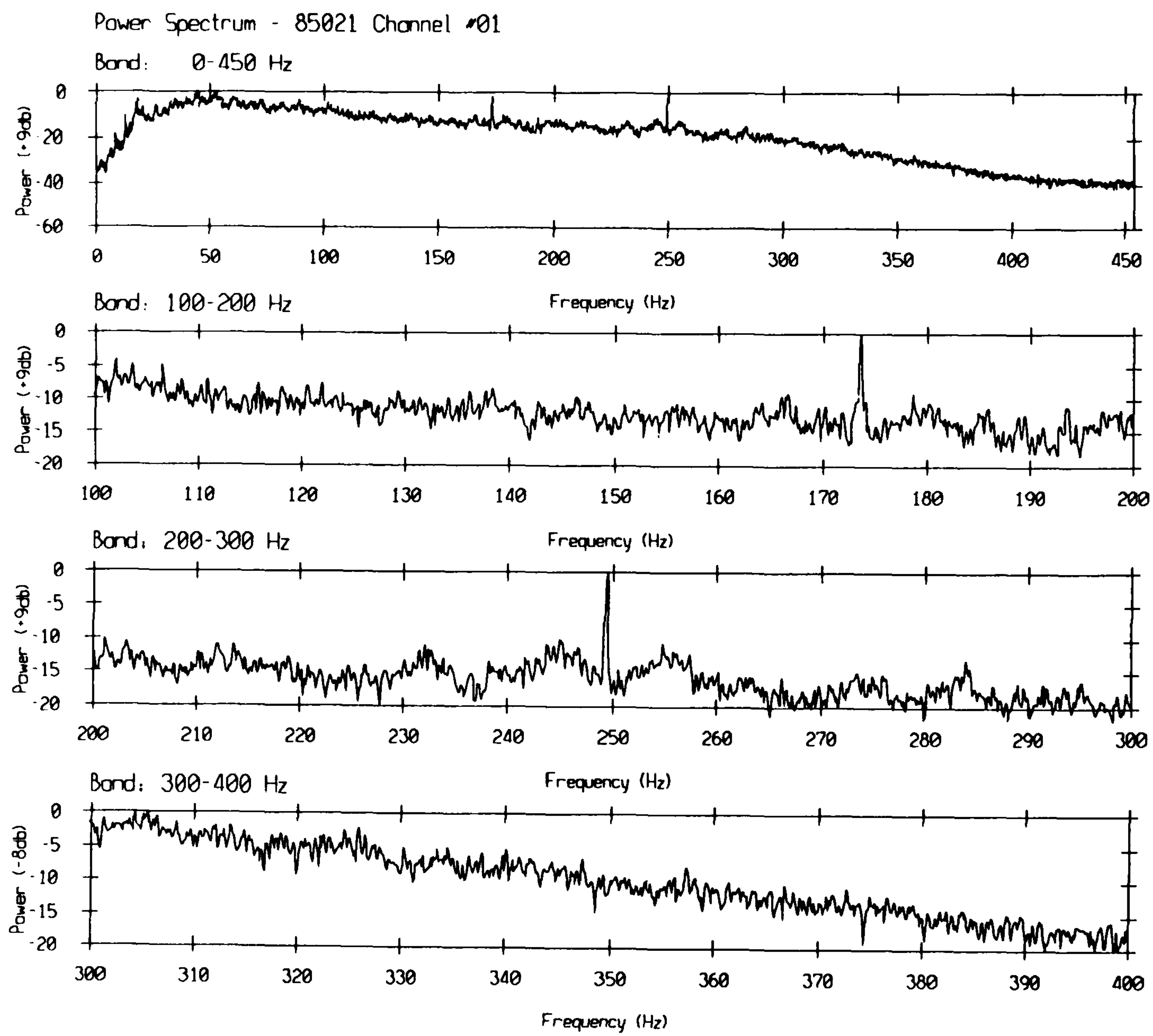
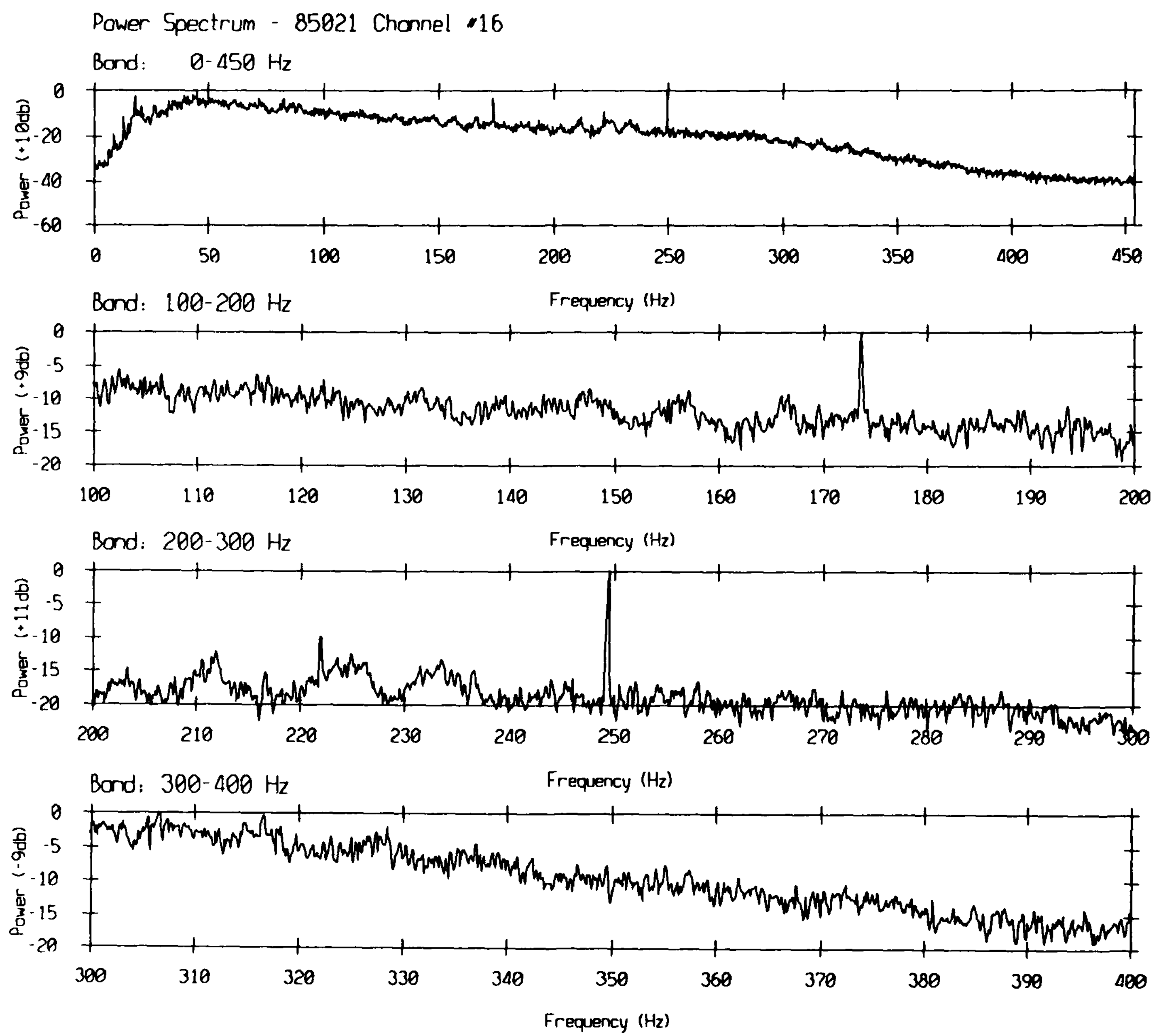

Power Spectrum - 85010 Channel #48
Band: 0-450 Hz
Power (+12db)
0
-20
-40
-60
0
50
100
150
200
250
300
350
400
450
Frequency (Hz)
Band: 100-200 Hz
Power (+6db)
0
-5
-10
-15
-20
100
110
120
130
140
150
160
170
180
190
200
Frequency (Hz)
Band: 200-300 Hz
Power (+5db)
0
-5
-10
-15
-20
200
210
220
230
240
250
260
270
280
290
300
Frequency (Hz)
Band: 300-400 Hz
Power (-6db)
0
-5
-10
-15
-20
300
310
320
330
340
350
360
370
380
390
400
Frequency (Hz)

Figure 3(d).



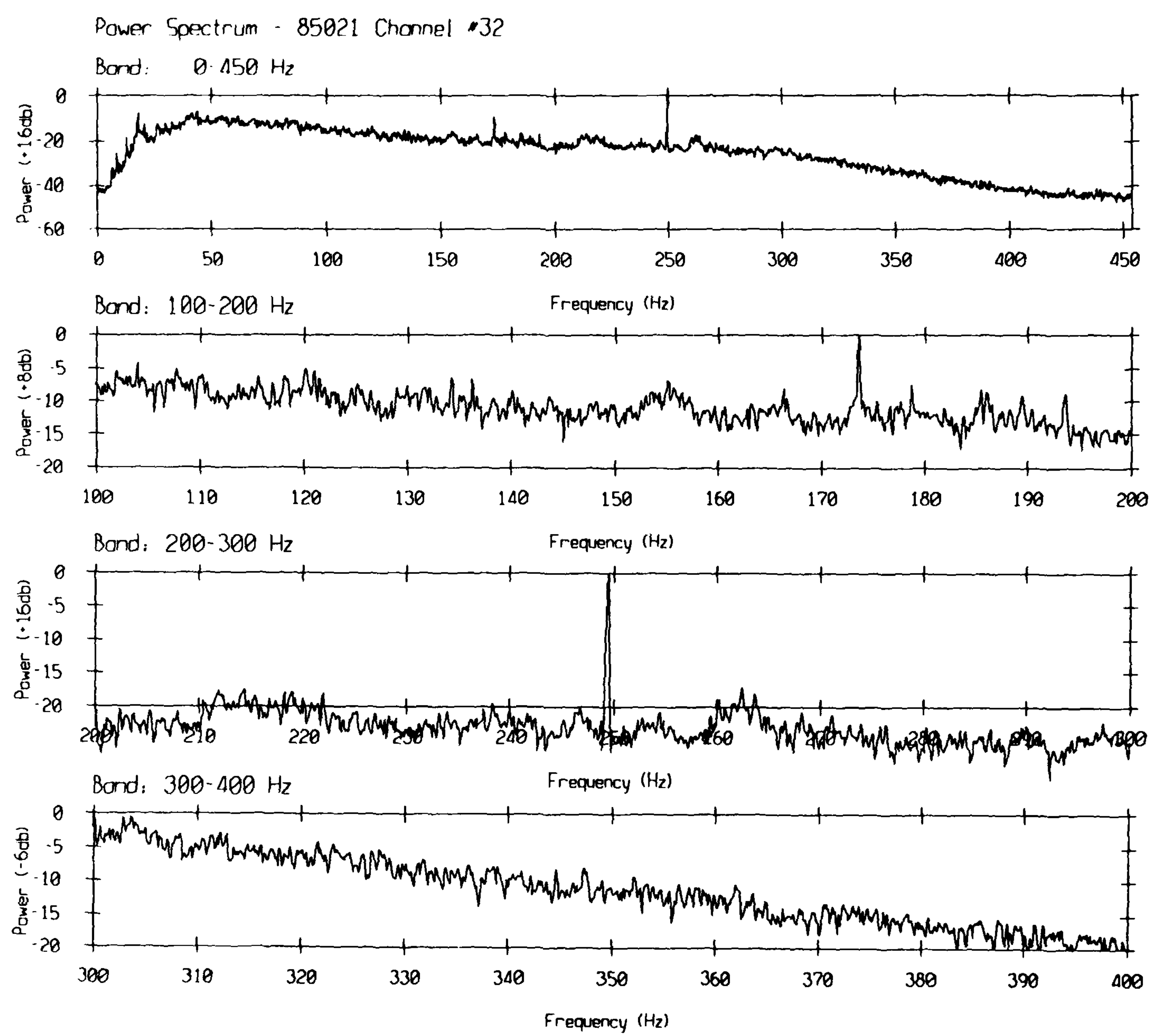
Power Spectrum - 85021 Channel #01
Band: 0-450 Hz
Power (+9db)
0
-20
-40
-60
0
50
100
150
200
250
300
350
400
450
Frequency (Hz)
Band: 100-200 Hz
Power (+9db)
0
-5
-10
-15
-20
100
110
120
130
140
150
160
170
180
190
200
Frequency (Hz)
Band: 200-300 Hz
Power (+9db)
0
-5
-10
-15
-20
200
210
220
230
240
250
260
270
280
290
300
Frequency (Hz)
Band: 300-400 Hz
Power (-8db)
0
-5
-10
-15
-20
300
310
320
330
340
350
360
370
380
390
400
Frequency (Hz)

Figure 4(a).



Power Spectrum - 85021 Channel #16
Band: 0-450 Hz
Power (+10db)
0
-20
-40
-60
0
50
100
150
200
250
300
350
400
450
Frequency (Hz)
Band: 100-200 Hz
Power (+9db)
0
-5
-10
-15
-20
100
110
120
130
140
150
160
170
180
190
200
Frequency (Hz)
Band: 200-300 Hz
Power (+11db)
0
-5
-10
-15
-20
200
210
220
230
240
250
260
270
280
290
300
Frequency (Hz)
Band: 300-400 Hz
Power (-9db)
0
-5
-10
-15
-20
300
310
320
330
340
350
360
370
380
390
400
Frequency (Hz)

Figure 4(b).



Power Spectrum - 85021 Channel #32
Band: 0-450 Hz
Power (+16db)
0
-20
-40
-60
0
50
100
150
200
250
300
350
400
450
Frequency (Hz)
Band: 100-200 Hz
Power (+8db)
0
-5
-10
-15
-20
100
110
120
130
140
150
160
170
180
190
200
Frequency (Hz)
Band: 200-300 Hz
Power (+16db)
0
-5
-10
-15
-20
210
220
240
Frequency (Hz)
Band: 300-400 Hz
Power (-6db)
0
-5
-10
-15
-20
300
310
320
330
340
350
360
370
380
390
400
Frequency (Hz)

Figure 4(c).

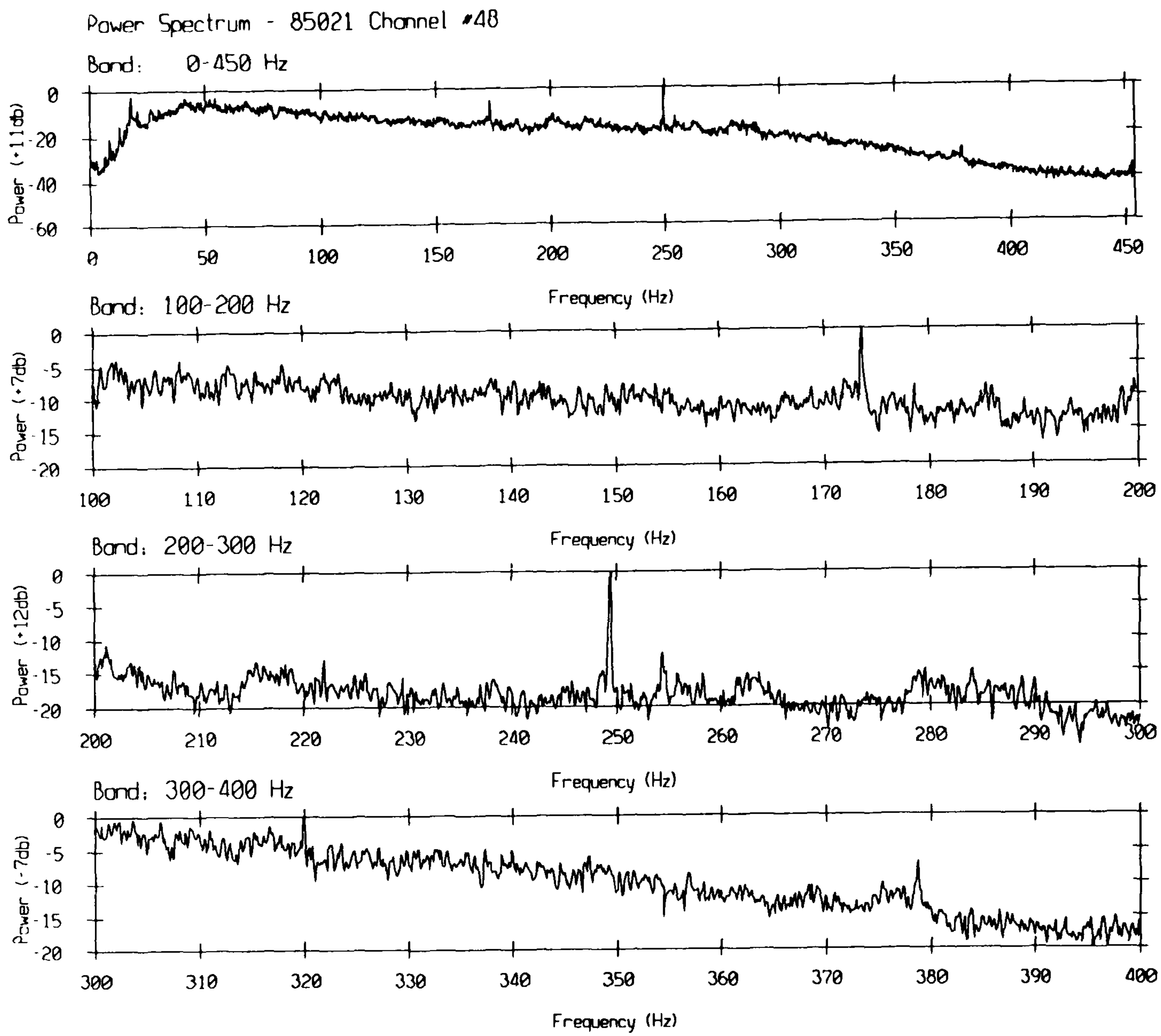

Power Spectrum - 85021 Channel #48
Band: 0-450 Hz
Power (+11db)
0
-20
-40
-60
0
50
100
150
200
250
300
350
400
450
Frequency (Hz)
Band: 100-200 Hz
Power (+7db)
0
-5
-10
-15
-20
100
110
120
130
140
150
160
170
180
190
200
Frequency (Hz)
Band: 200-300 Hz
Power (+12db)
0
-5
-10
-15
-20
200
210
220
230
240
250
260
270
280
290
300
Frequency (Hz)
Band: 300-400 Hz
Power (-7db)
0
-5
-10
-15
-20
300
310
320
330
340
350
360
370
380
390
400
Frequency (Hz)

Figure 4(d).

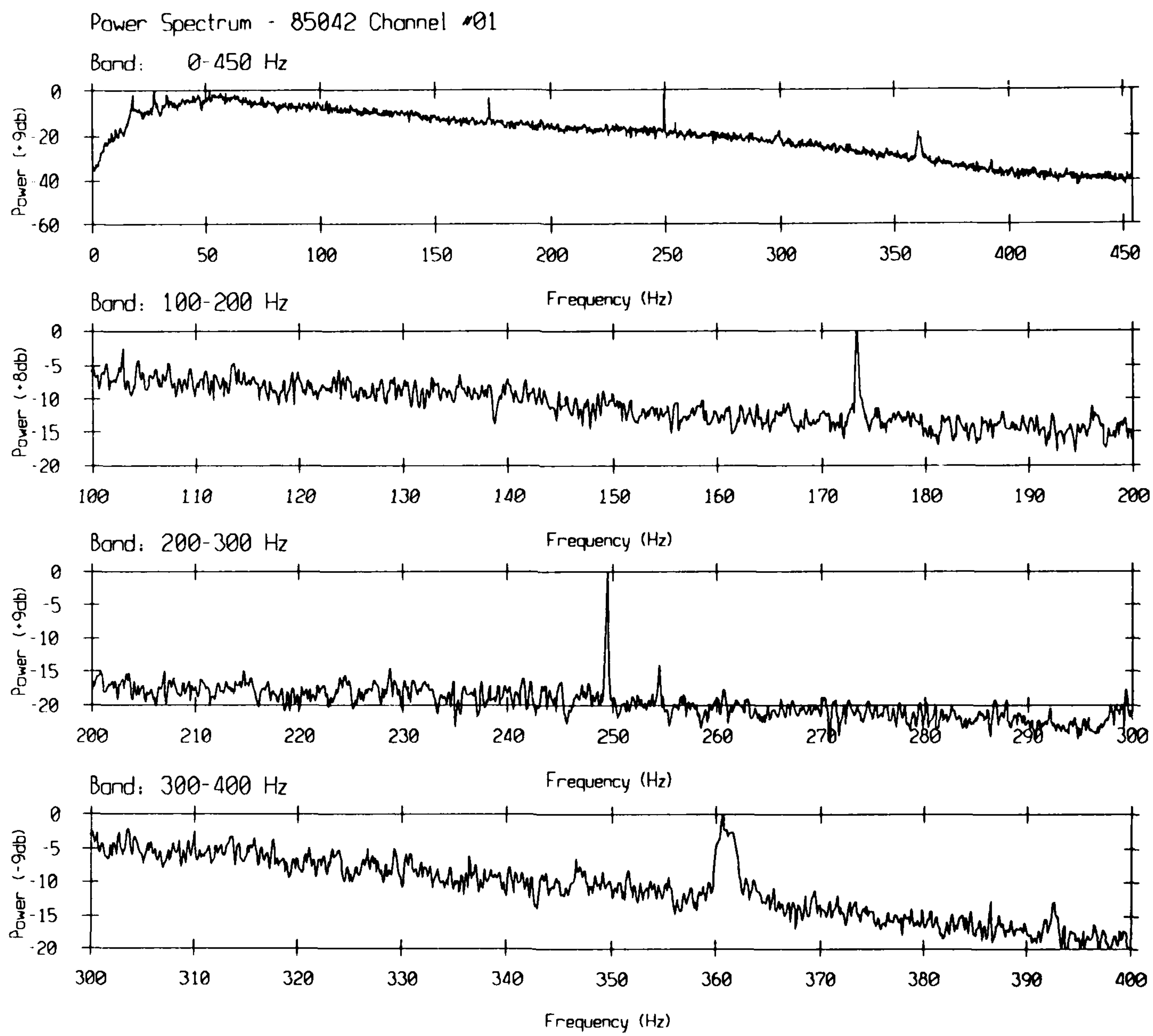
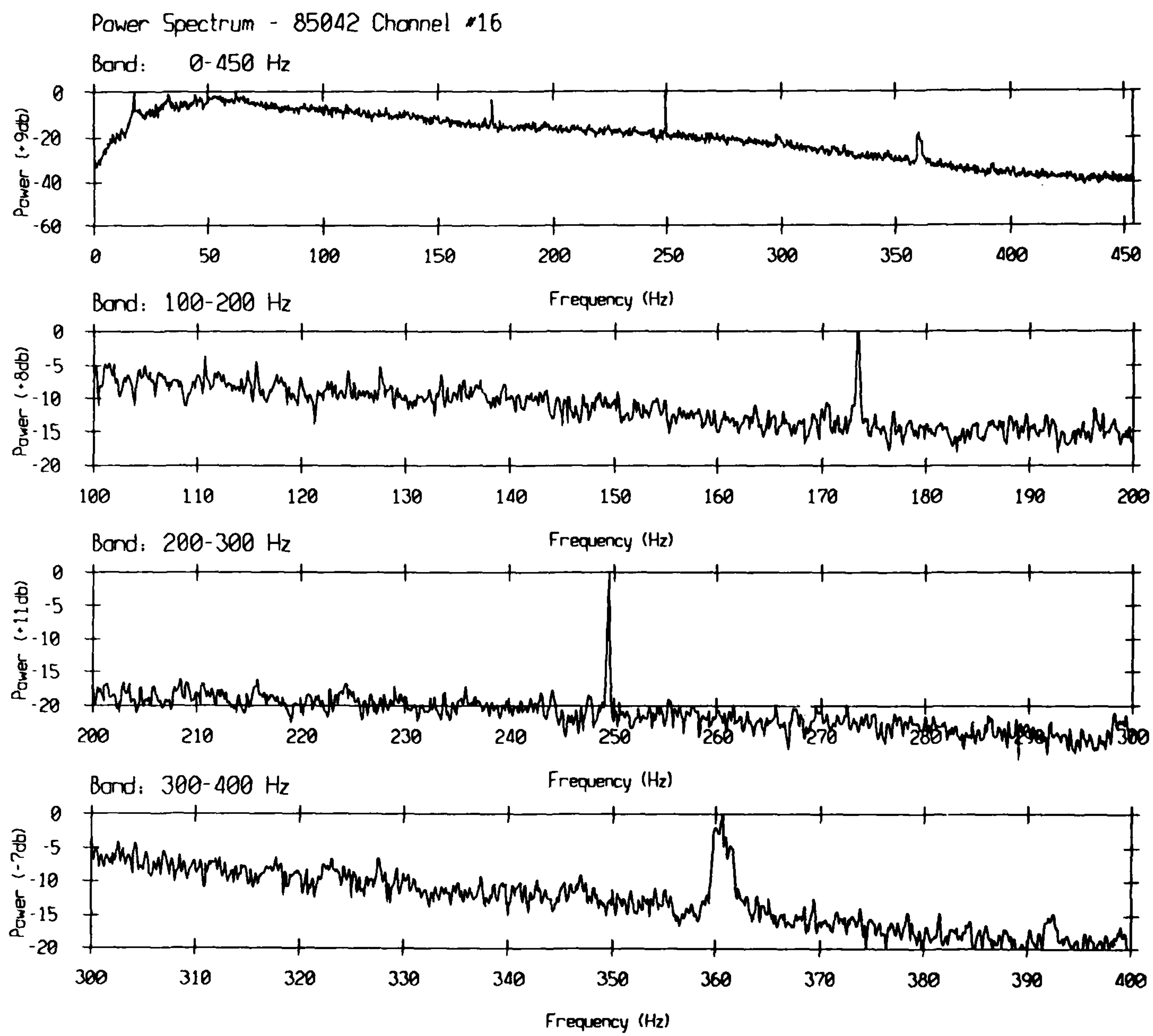
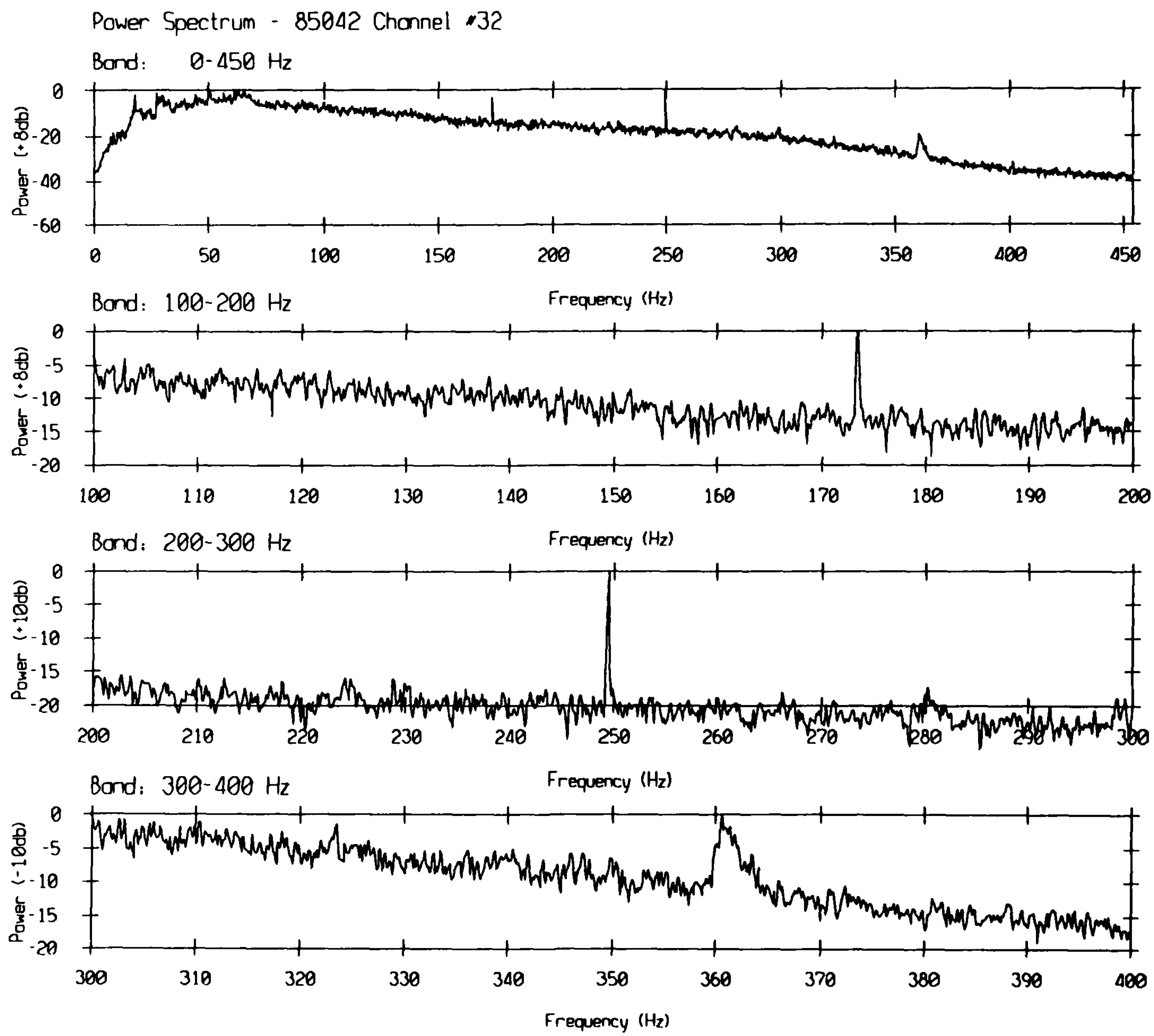

Power Spectrum - 85042 Channel #01
Band: 0-450 Hz
Power (+9db)
0
-20
-40
-60
0
50
100
150
200
250
300
350
400
450
Frequency (Hz)
Band: 100-200 Hz
Power (+8db)
0
-5
-10
-15
-20
100
110
120
130
140
150
160
170
180
190
200
Frequency (Hz)
Band: 200-300 Hz
Power (+9db)
0
-5
-10
-15
-20
200
210
220
230
240
250
260
270
280
290
300
Frequency (Hz)
Band: 300-400 Hz
Power (-9db)
0
-5
-10
-15
-20
300
310
320
330
340
350
360
370
380
390
400
Frequency (Hz)

Figure 5(a).



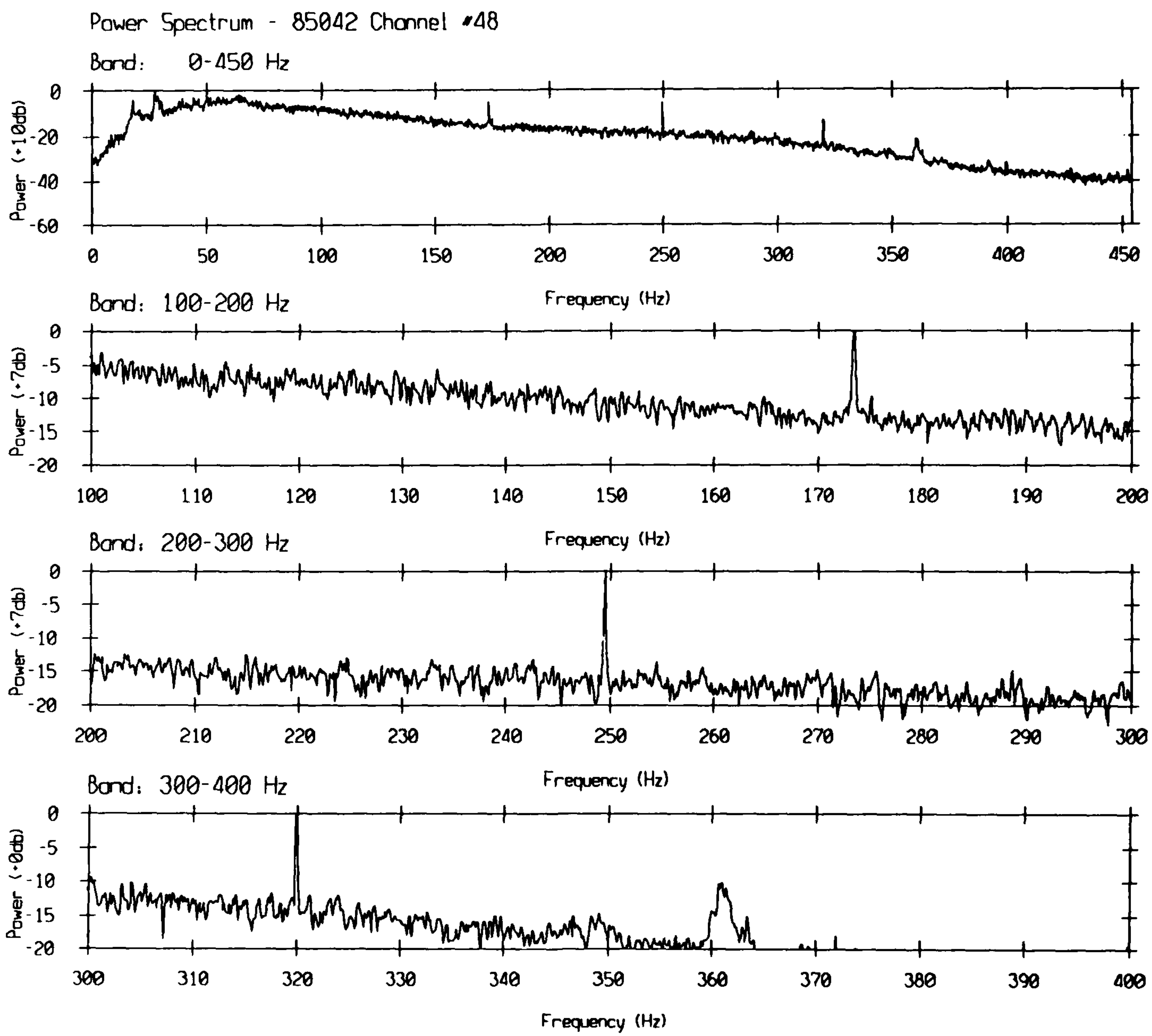
Power Spectrum - 85042 Channel #16
Band: 0-450 Hz
Power (+9db)
0
-20
-40
-60
0
50
100
150
200
250
300
350
400
450
Frequency (Hz)
Band: 100-200 Hz
Power (+8db)
0
-5
-10
-15
-20
100
110
120
130
140
150
160
170
180
190
200
Frequency (Hz)
Band: 200-300 Hz
Power (+11db)
0
-5
-10
-15
-20
200
210
220
230
240
250
260
270
280
290
300
Frequency (Hz)
Band: 300-400 Hz
Power (-7db)
0
-5
-10
-15
-20
300
310
320
330
340
350
360
370
380
390
400
Frequency (Hz)

Figure 5(b).



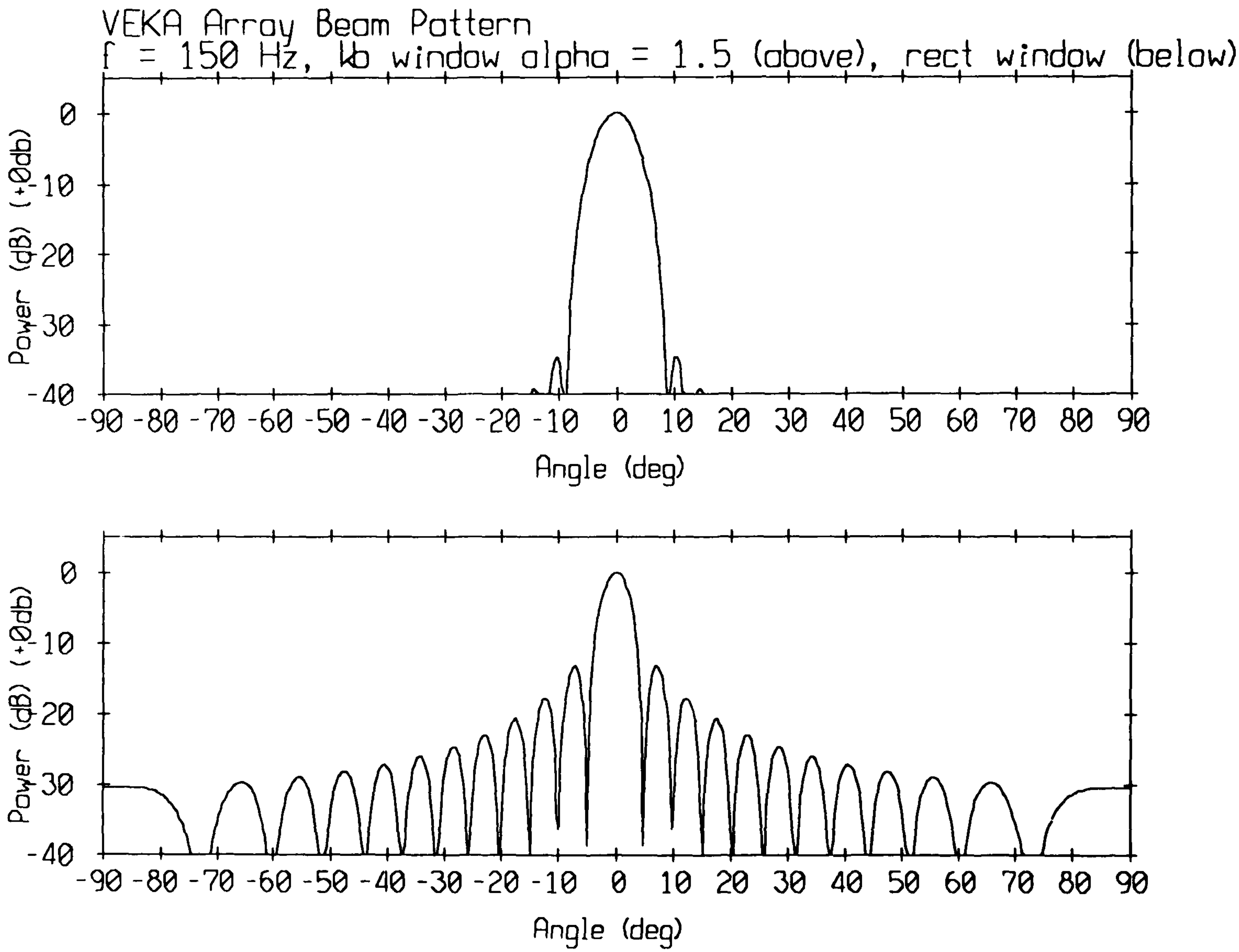
Power Spectrum - 85042 Channel #32
Band: 0-450 Hz
Power (+8db)
0
-20
-40
-60
0
50
100
150
200
250
300
350
400
450
Frequency (Hz)
Band: 100-200 Hz
Power (+8db)
0
-5
-10
-15
-20
100
110
120
130
140
150
160
170
180
190
200
Frequency (Hz)
Band: 200-300 Hz
Power (+10db)
0
-5
-10
-15
-20
200
210
220
230
240
250
260
270
280
290
300
Frequency (Hz)
Band: 300-400 Hz
Power (-10db)
0
-5
-10
-15
-20
300
310
320
330
340
350
360
370
380
390
400
Frequency (Hz)

Figure 5(c).



Power Spectrum - 85042 Channel #48
Band: 0-450 Hz
Power (•10db)
0
-20
-40
-60
0
50
100
150
200
250
300
350
400
450
Frequency (Hz)
Band: 100-200 Hz
Power (•7db)
0
-5
-10
-15
-20
100
110
120
130
140
150
160
170
180
190
200
Frequency (Hz)
Band: 200-300 Hz
Power (•7db)
0
-5
-10
-15
-20
200
210
220
230
240
250
260
270
280
290
300
Frequency (Hz)
Band: 300-400 Hz
Power (•0db)
0
-5
-10
-15
-20
300
310
320
330
340
350
360
370
380
390
400
Frequency (Hz)

Figure 5(d).



VEKA Array Beam Pattern
f = 150 Hz, kb window alpha = 1.5 (above), rect window (below)
Power (dB) (+0db)
0
-10
-20
-30
-40
-90 -80 -70 -60 -50 -40 -30 -20 -10 0 10 20 30 40 50 60 70 80 90
Angle (deg)
Power (dB) (+0db)
0
-10
-20
-30
-40
-90 -80 -70 -60 -50 -40 -30 -20 -10 0 10 20 30 40 50 60 70 80 90
Angle (deg)

Figure 6(a).

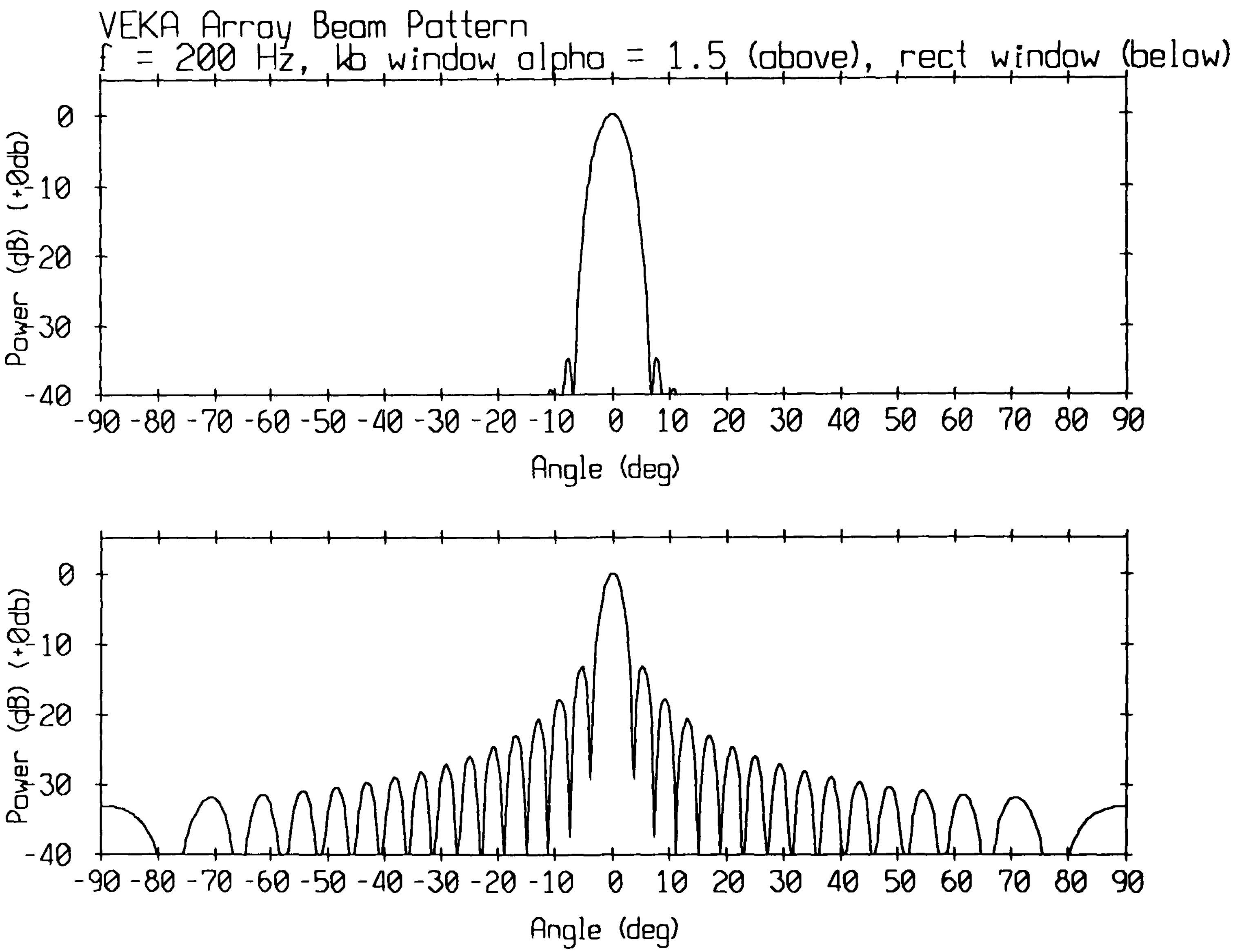

VEKA Array Beam Pattern
f = 200 Hz, kb window alpha = 1.5 (above), rect window (below)
0
-10
-20
-30
-40
Power (dB) (+0db)
-90 -80 -70 -60 -50 -40 -30 -20 -10 0 10 20 30 40 50 60 70 80 90
Angle (deg)
0
-10
-20
-30
-40
Power (dB) (+0db)
-90 -80 -70 -60 -50 -40 -30 -20 -10 0 10 20 30 40 50 60 70 80 90
Angle (deg)

Figure 6(b).

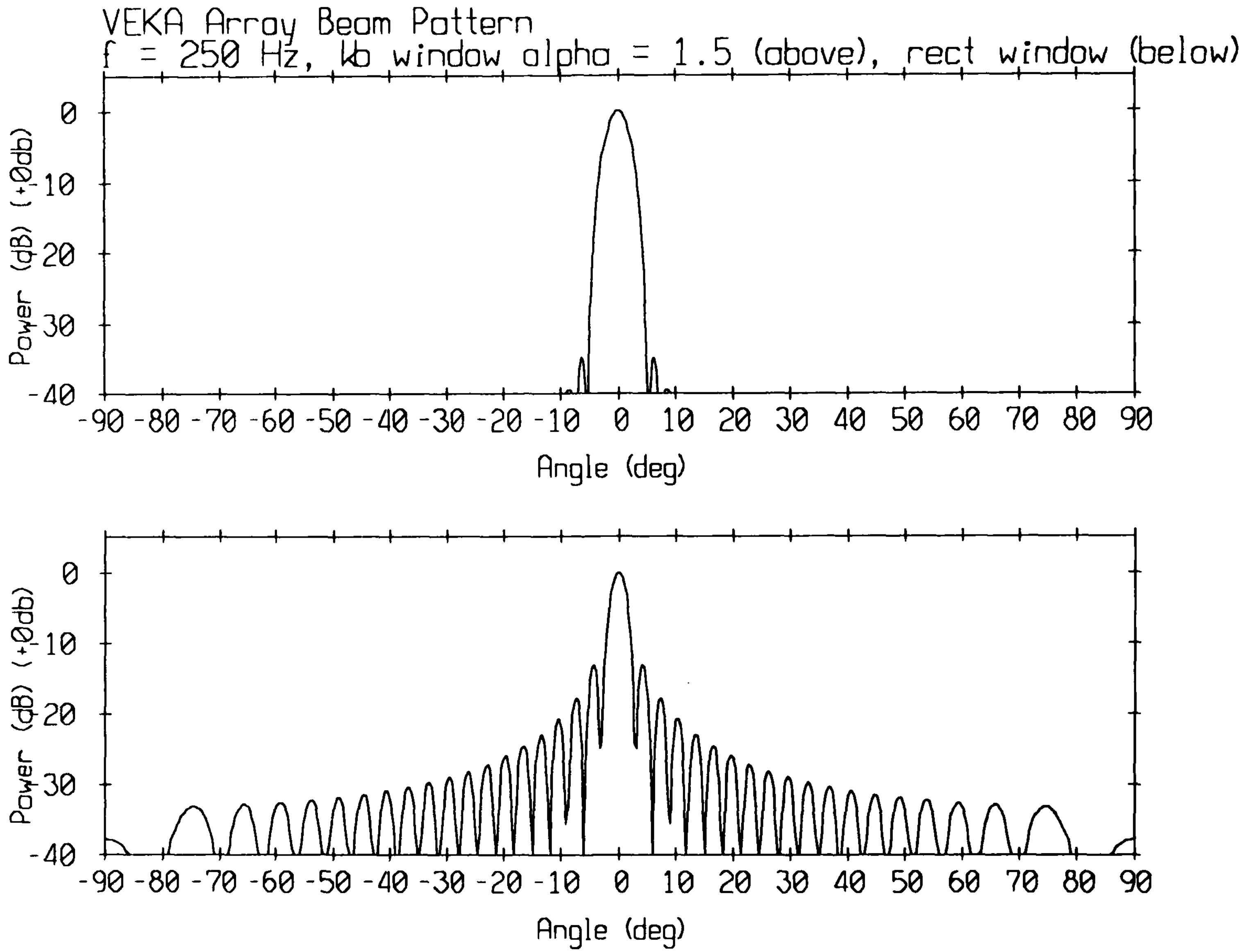

VEKA Array Beam Pattern
f = 250 Hz, kb window alpha = 1.5 (above), rect window (below)
Power (dB) (+0db)
0
10
20
30
-40
-90 -80 -70 -60 -50 -40 -30 -20 -10 0 10 20 30 40 50 60 70 80 90
Angle (deg)
Power (dB) (+0db)
0
10
20
30
-40
-90 -80 -70 -60 -50 -40 -30 -20 -10 0 10 20 30 40 50 60 70 80 90
Angle (deg)

Figure 6(c).

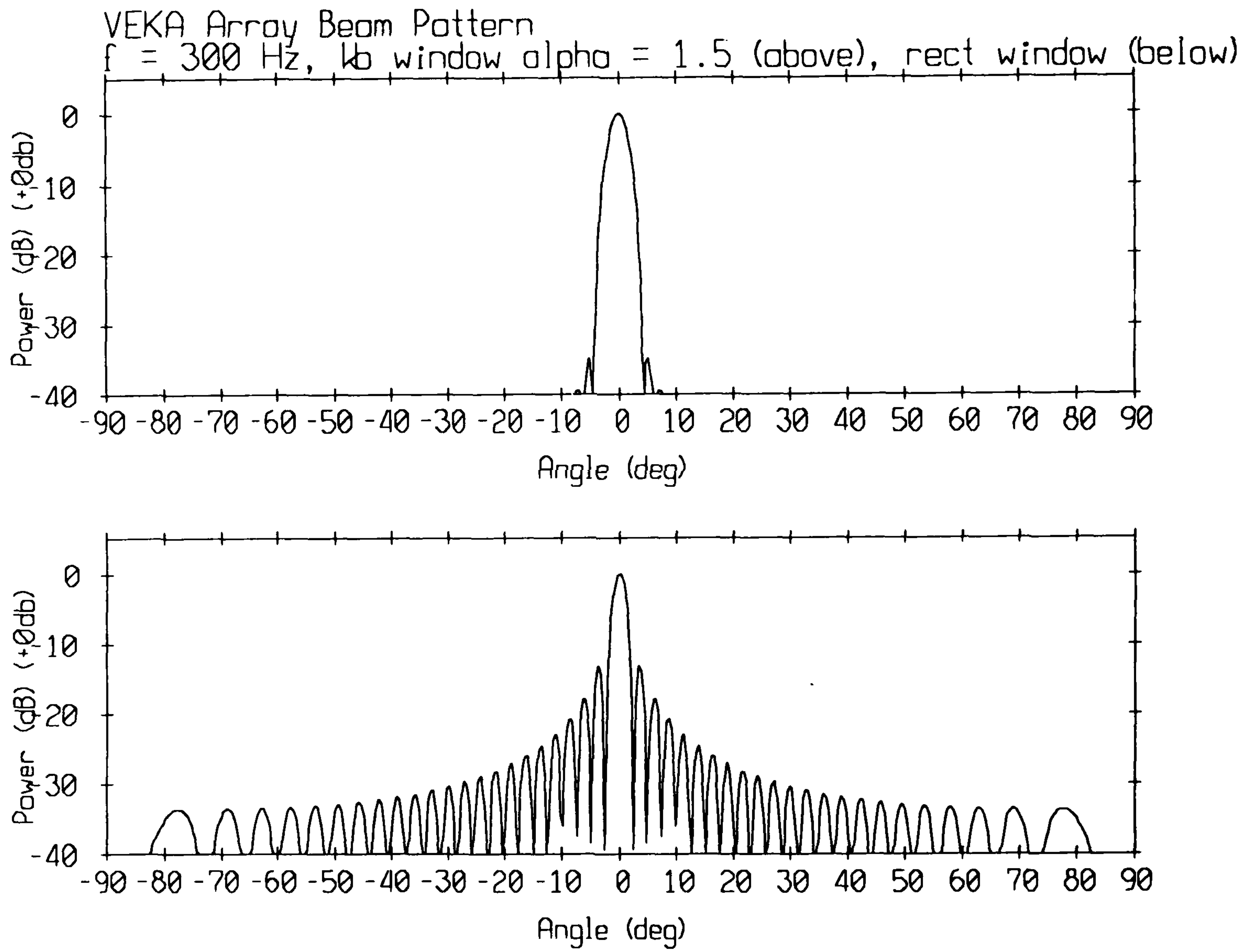

VEKA Array Beam Pattern
f = 300 Hz, kb window alpha = 1.5 (above), rect window (below)
Power (dB) (+0db)
0
10
20
30
-40
-90 -80 -70 -60 -50 -40 -30 -20 -10 0 10 20 30 40 50 60 70 80 90
Angle (deg)
Power (dB) (+0db)
0
10
20
30
-40
-90 -80 -70 -60 -50 -40 -30 -20 -10 0 10 20 30 40 50 60 70 80 90
Angle (deg)

Figure 6(d).

Array Response - 85010 Bin #5451

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

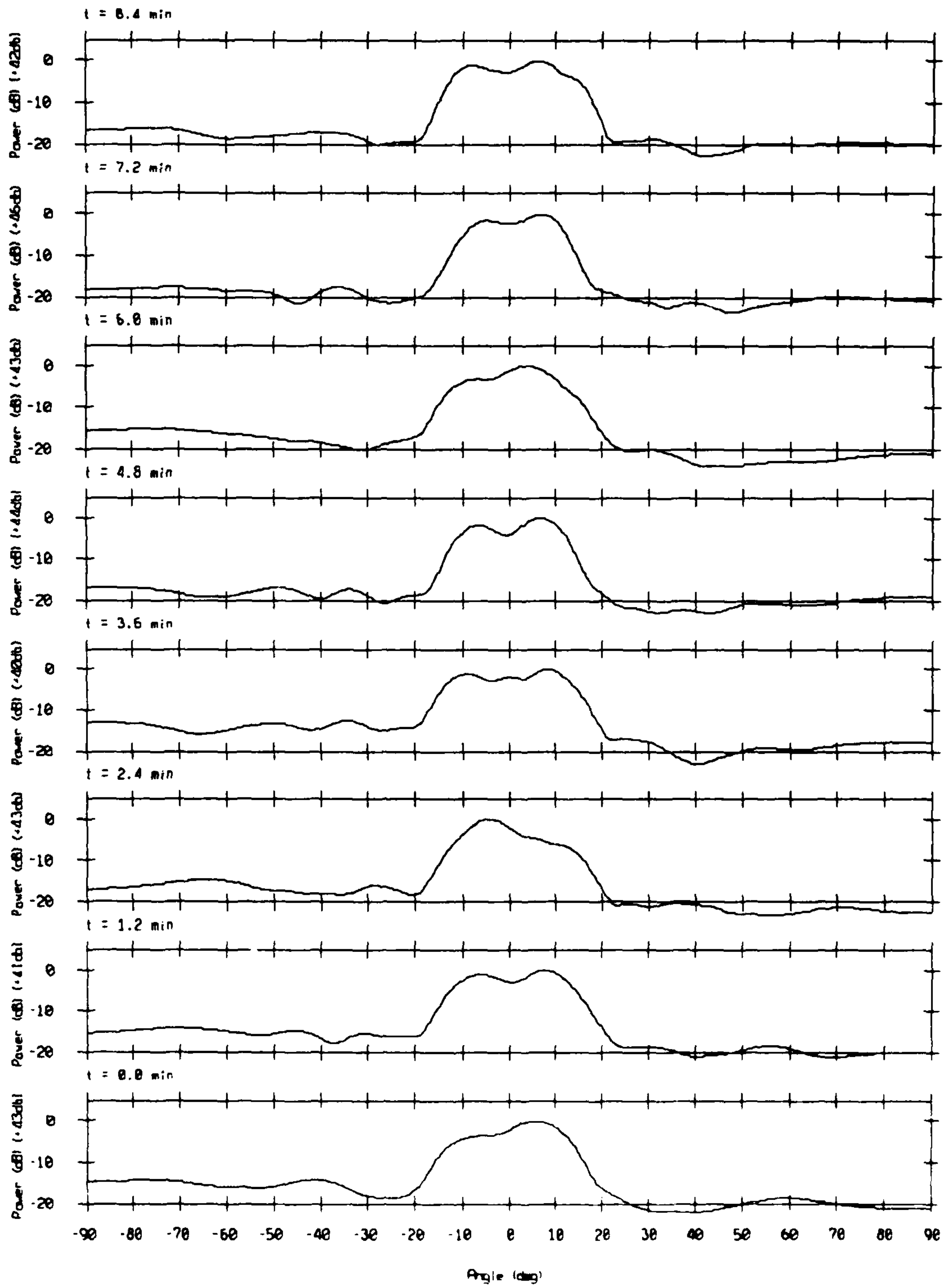


Figure 7(a).

Array Response - 85010 Bin #5676

f = 175 Hz, KB window (alpha = 1.5)

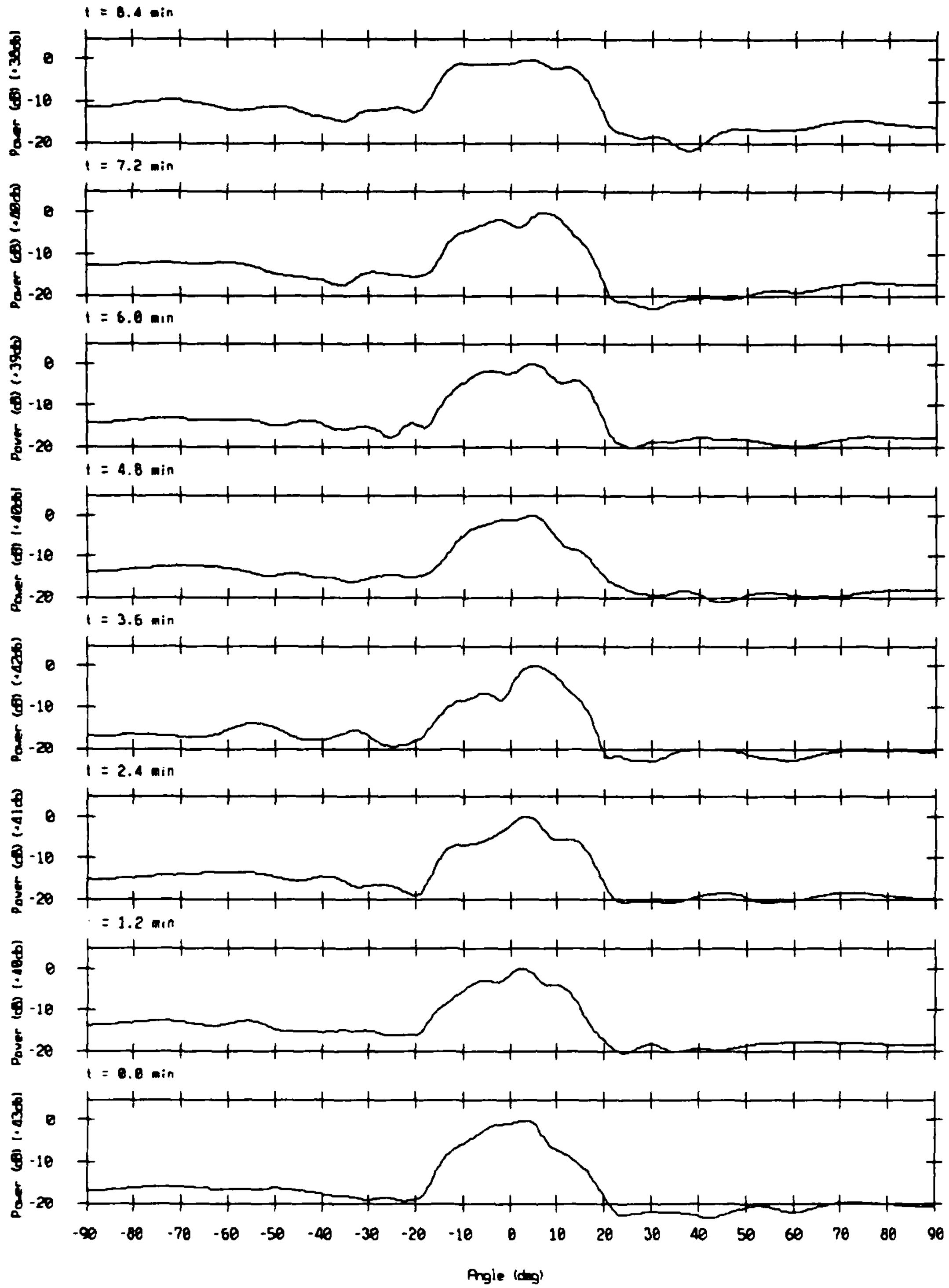
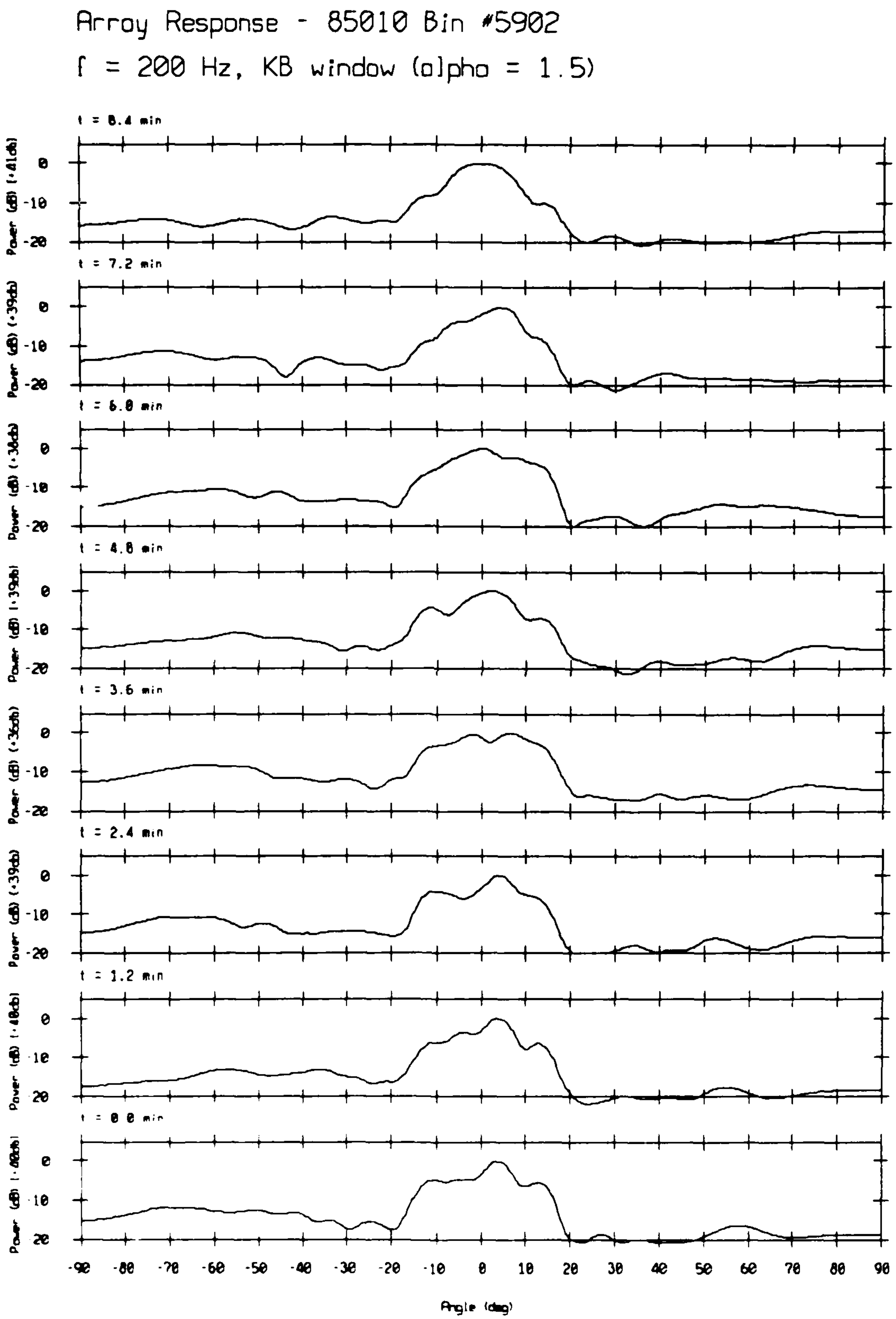
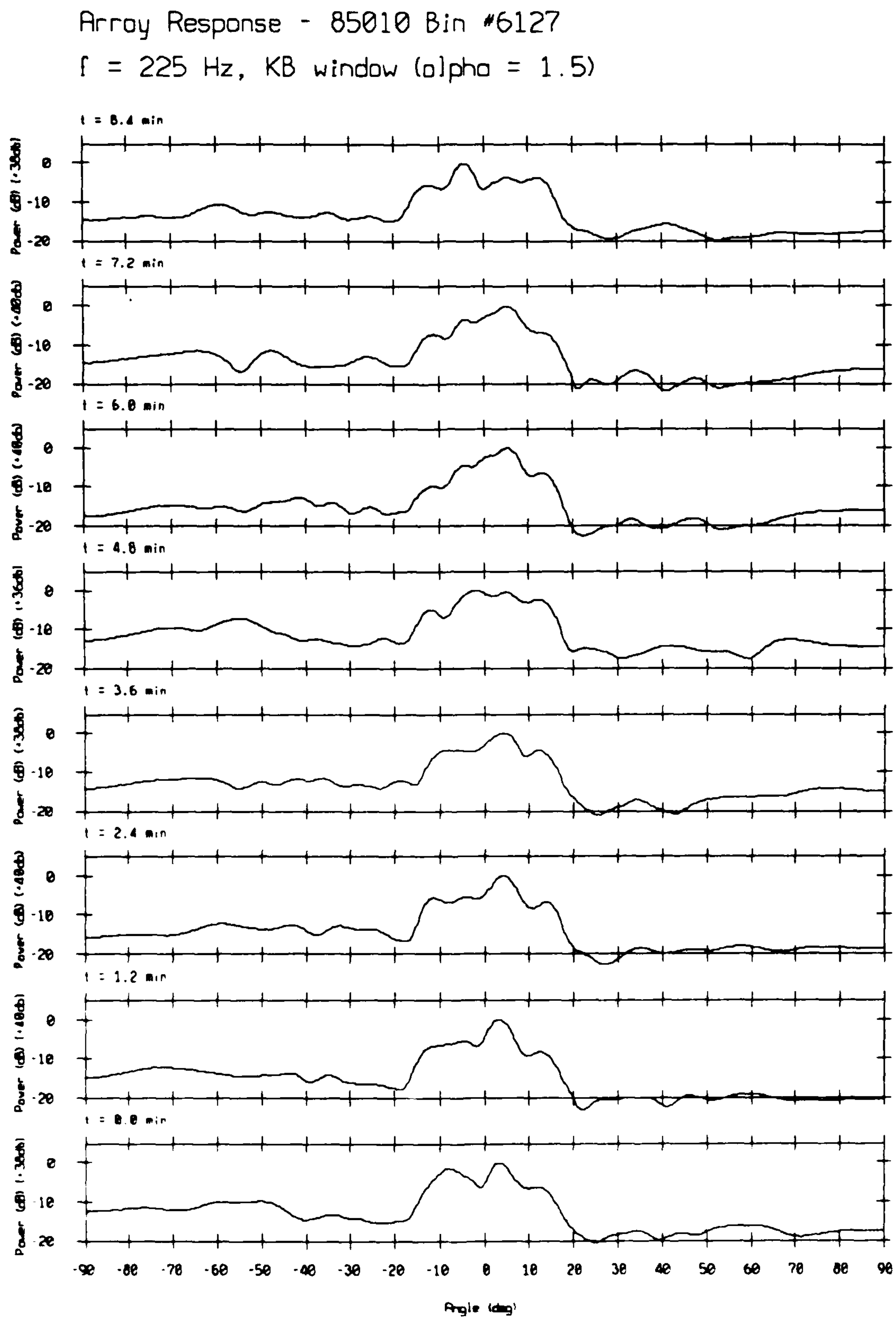


Figure 7(b).



Array Response - 85010 Bin #5902
f = 200 Hz, KB window (alpha = 1.5)
t = 8.4 min
t = 7.2 min
t = 6.0 min
t = 4.8 min
t = 3.6 min
t = 2.4 min
t = 1.2 min
t = 0.0 min
Power (dB)
0
-10
-20
-90 -80 -70 -60 -50 -40 -30 -20 -10 0 10 20 30 40 50 60 70 80 90
Angle (deg)

Figure 7(c).



Array Response - 85010 Bin #6127
f = 225 Hz, KB window (alpha = 1.5)
t = 8.4 min
t = 7.2 min
t = 6.0 min
t = 4.8 min
t = 3.6 min
t = 2.4 min
t = 1.2 min
t = 0.0 min
Power (dB) (+30db)
Power (dB) (+40db)
0
-10
-20
-90 -80 -70 -60 -50 -40 -30 -20 -10 0 10 20 30 40 50 60 70 80 90
Angle (deg)

Figure 7(d).

Array Response - 85010 Bin #6354

f = 250 Hz, KB window (alpha = 1.5)

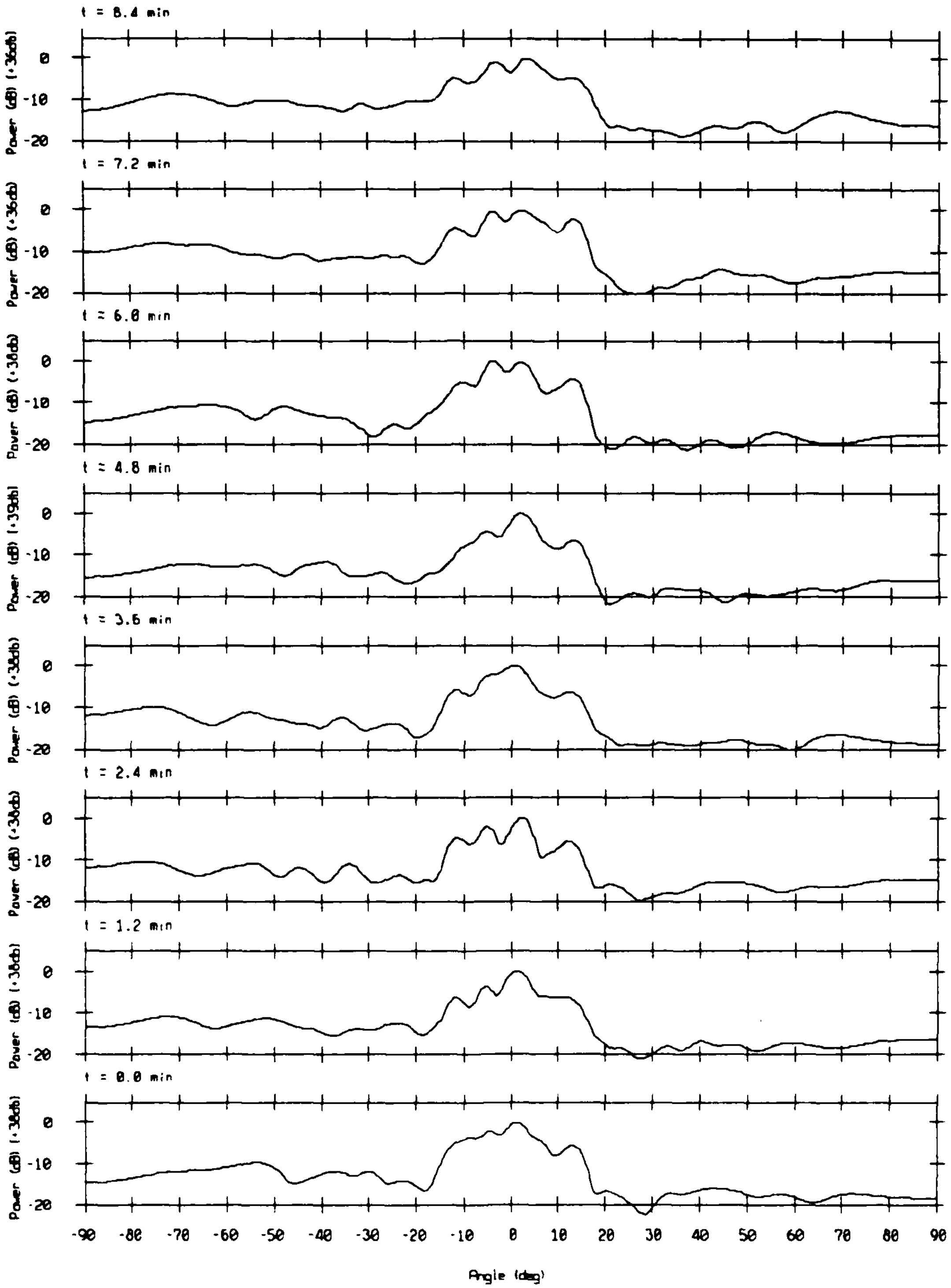


Figure 7(e).

Array Response - 85010 Bin #6579

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

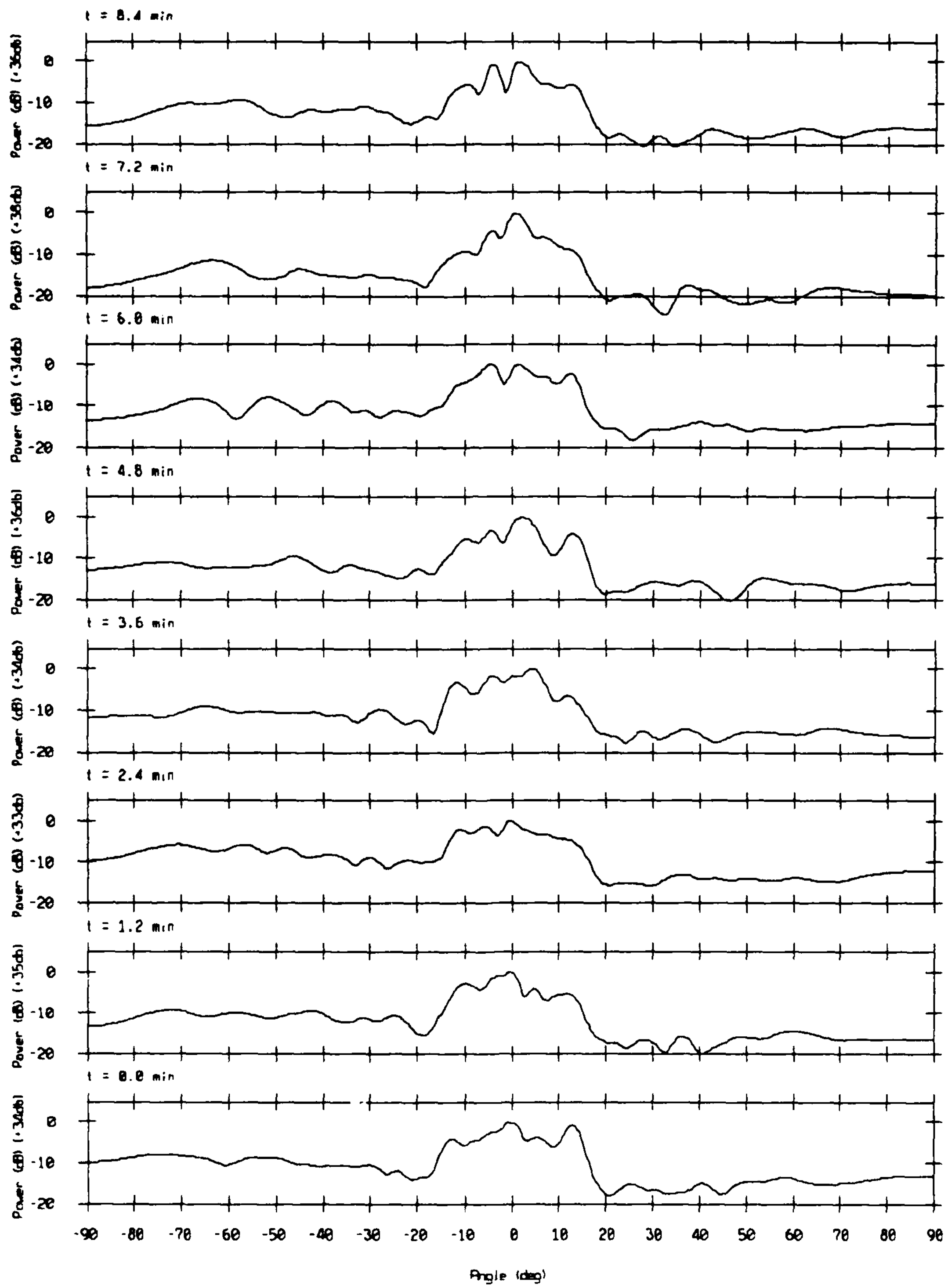


Figure 7(f).

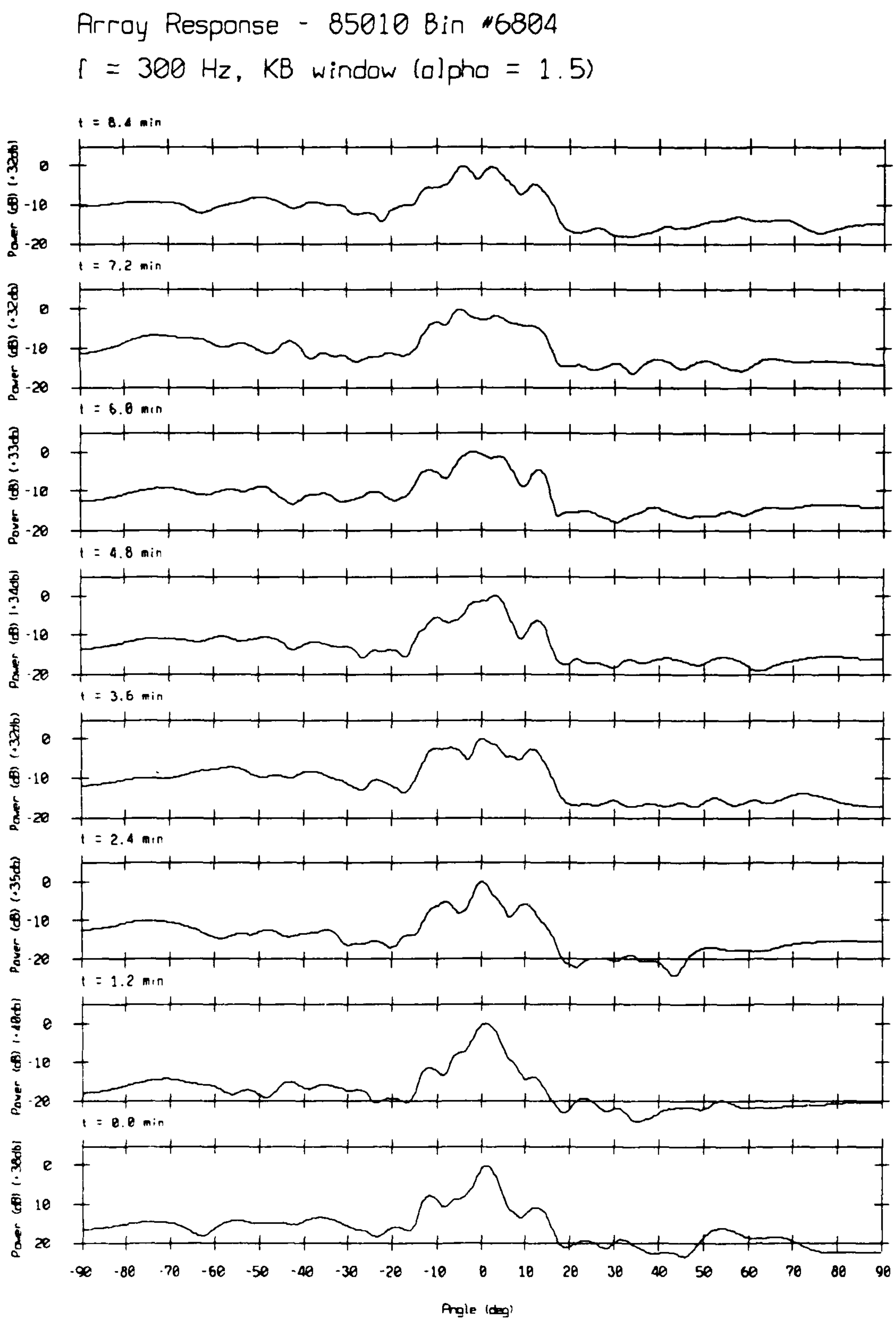

Array Response - 85010 Bin #6804
f = 300 Hz, KB window (alpha = 1.5)
t = 8.4 min
t = 7.2 min
t = 6.0 min
t = 4.8 min
t = 3.6 min
t = 2.4 min
t = 1.2 min
t = 0.0 min
Power (dB) (+32db)
Power (dB) (+32db)
Power (dB) (+33db)
Power (dB) (+34db)
Power (dB) (+32db)
Power (dB) (+35db)
Power (dB) (+40db)
Power (dB) (+38db)
0
-10
-20
-90
-80
-70
-60
-50
-40
-30
-20
-10
0
10
20
30
40
50
60
70
80
90
Angle (deg)

Figure 7(g).

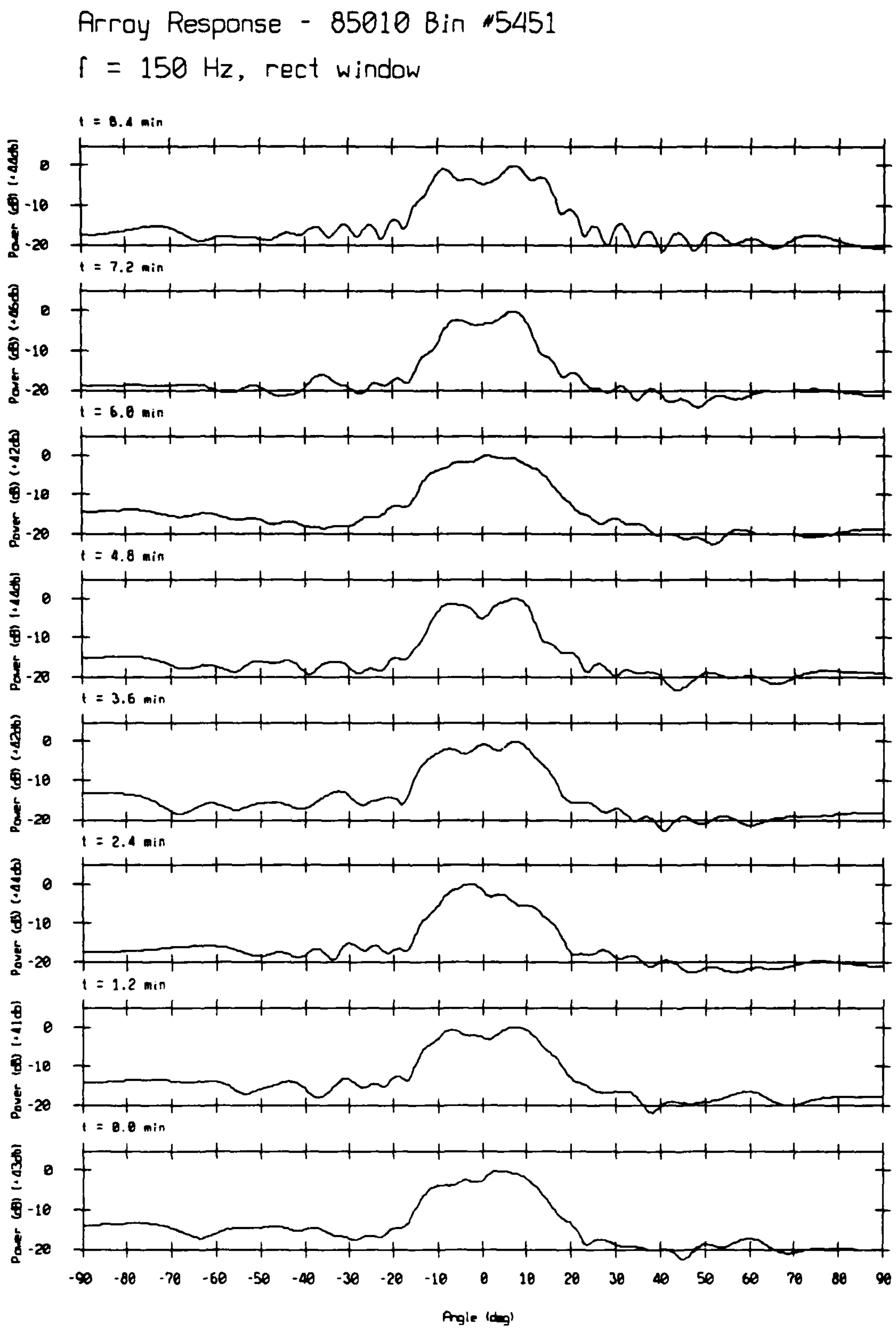

Array Response - 85010 Bin #5451
f = 150 Hz, rect window
t = 8.4 min
t = 7.2 min
t = 6.0 min
t = 4.8 min
t = 3.6 min
t = 2.4 min
t = 1.2 min
t = 0.0 min
Power (dB)
0
-10
-20
-90 -80 -70 -60 -50 -40 -30 -20 -10 0 10 20 30 40 50 60 70 80 90
Angle (deg)

Figure 8(a).

Array Response - 85010 Bin #5676

f = 175 Hz, rect window

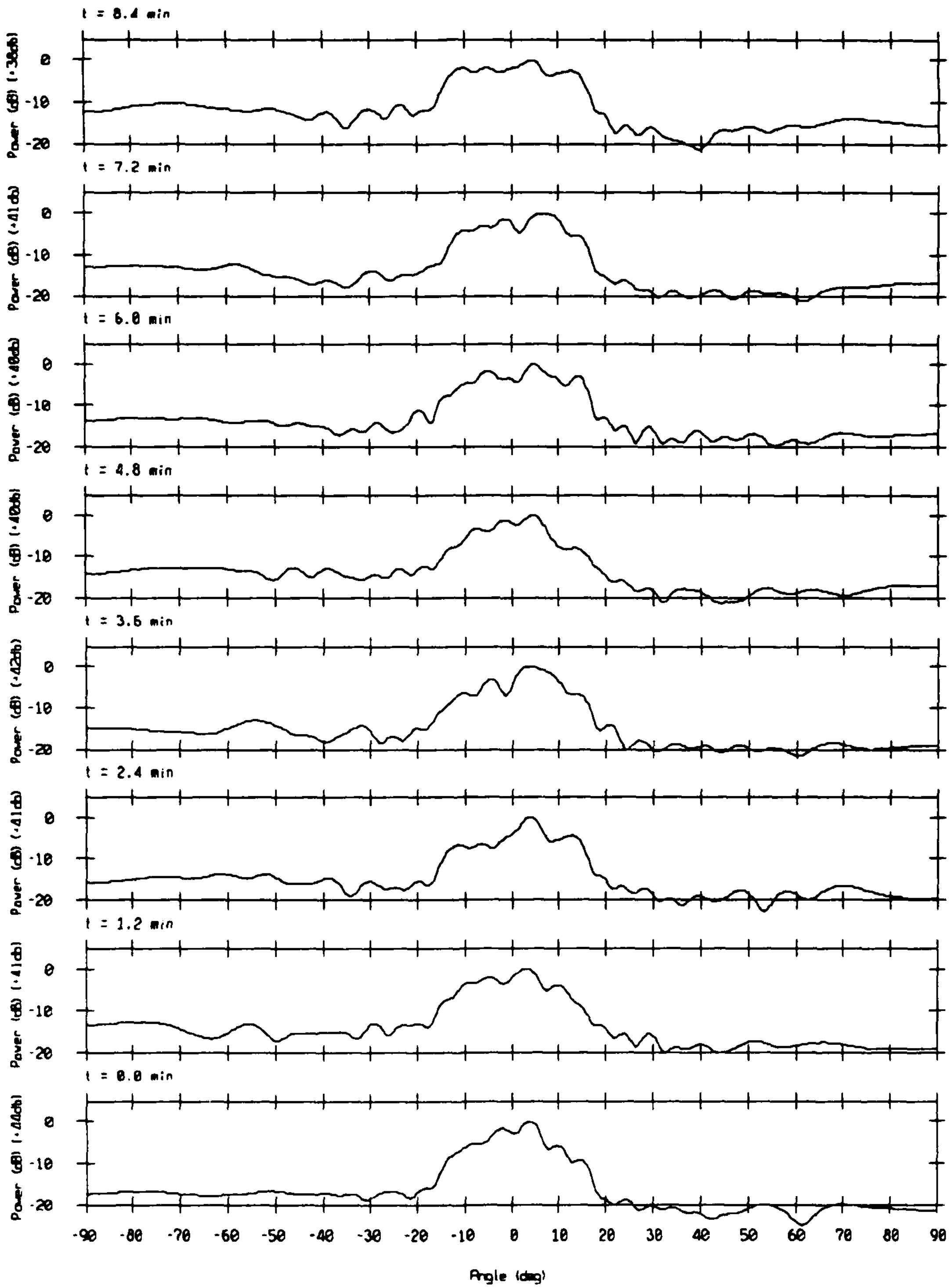
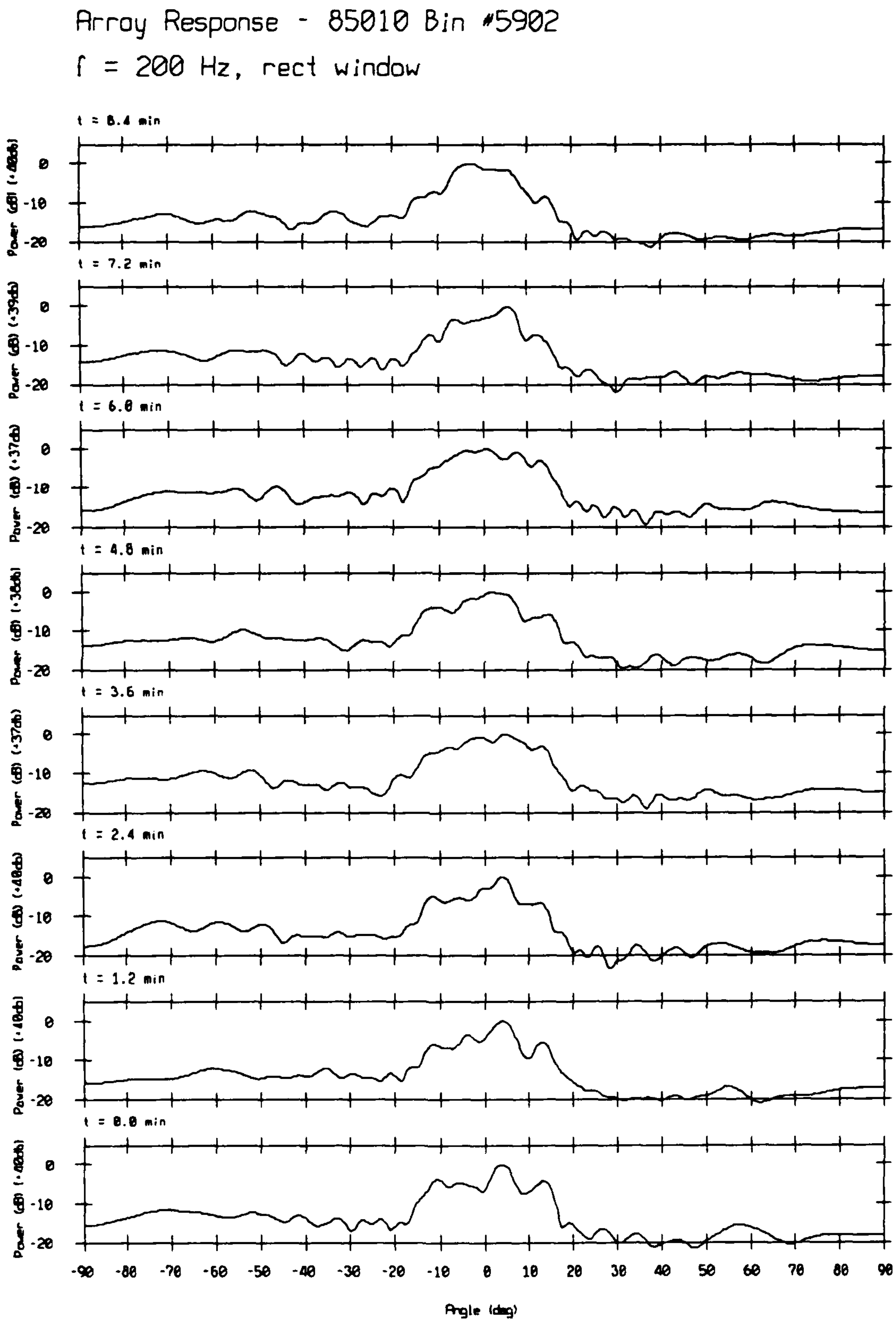
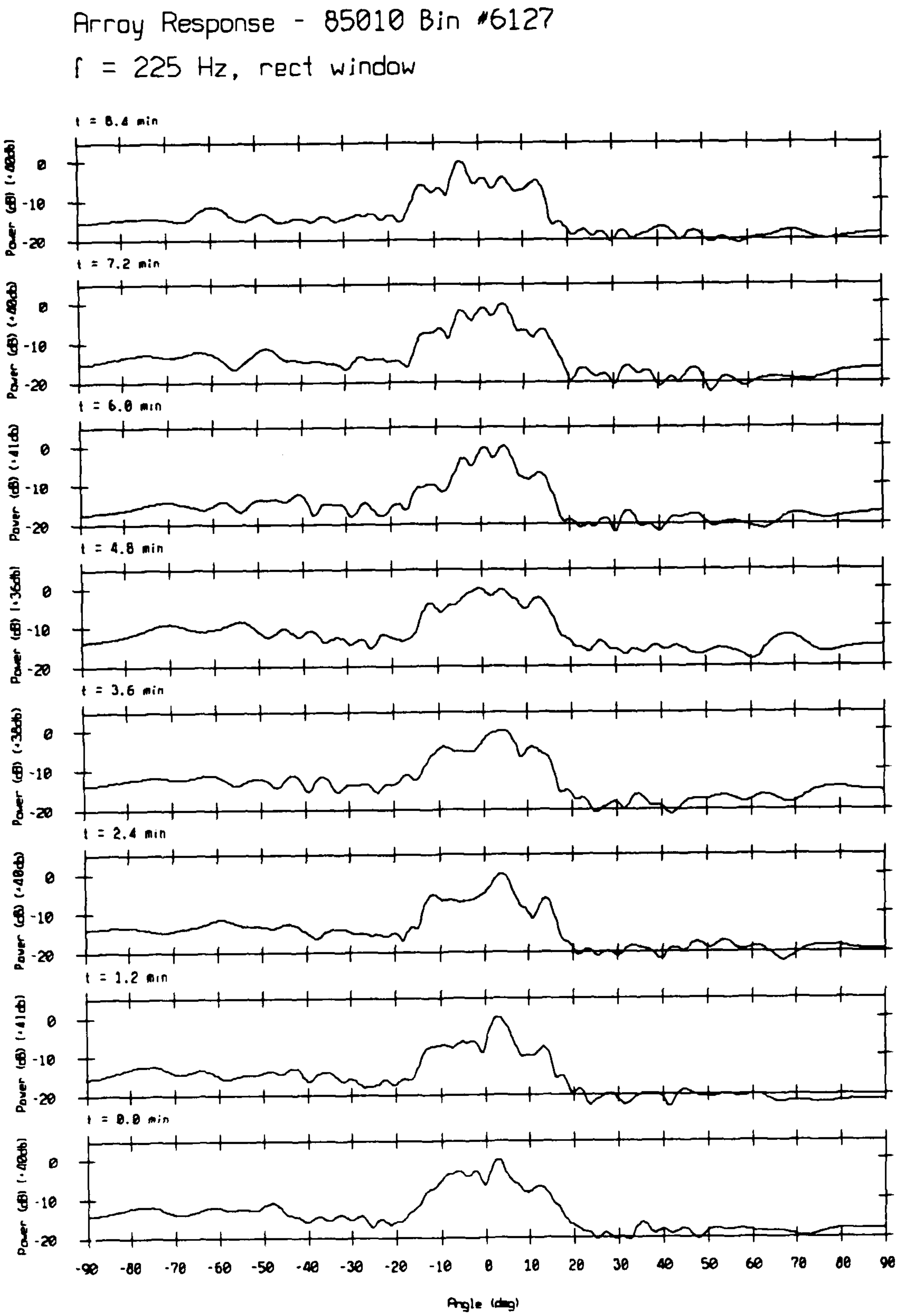


Figure 8(b).



Array Response - 85010 Bin #5902
f = 200 Hz, rect window
t = 8.4 min
Power (dB) (+40db)
t = 7.2 min
Power (dB) (+39db)
t = 6.0 min
Power (dB) (+37db)
t = 4.8 min
Power (dB) (+38db)
t = 3.6 min
Power (dB) (+37db)
t = 2.4 min
Power (dB) (+40db)
t = 1.2 min
Power (dB) (+40db)
t = 0.0 min
Power (dB) (+40db)
0
-10
-20
-90 -80 -70 -60 -50 -40 -30 -20 -10 0 10 20 30 40 50 60 70 80 90
Angle (deg)

Figure 8(c).



Arroy Response - 85010 Bin #6127
f = 225 Hz, rect window
t = 8.4 min
t = 7.2 min
t = 6.0 min
t = 4.8 min
t = 3.6 min
t = 2.4 min
t = 1.2 min
t = 0.0 min
Power (dB)
0
-10
-20
-90 -80 -70 -60 -50 -40 -30 -20 -10 0 10 20 30 40 50 60 70 80 90
Angle (deg)

Figure 8(d).

Array Response - 85010 Bin #6354

f = 250 Hz, rect window

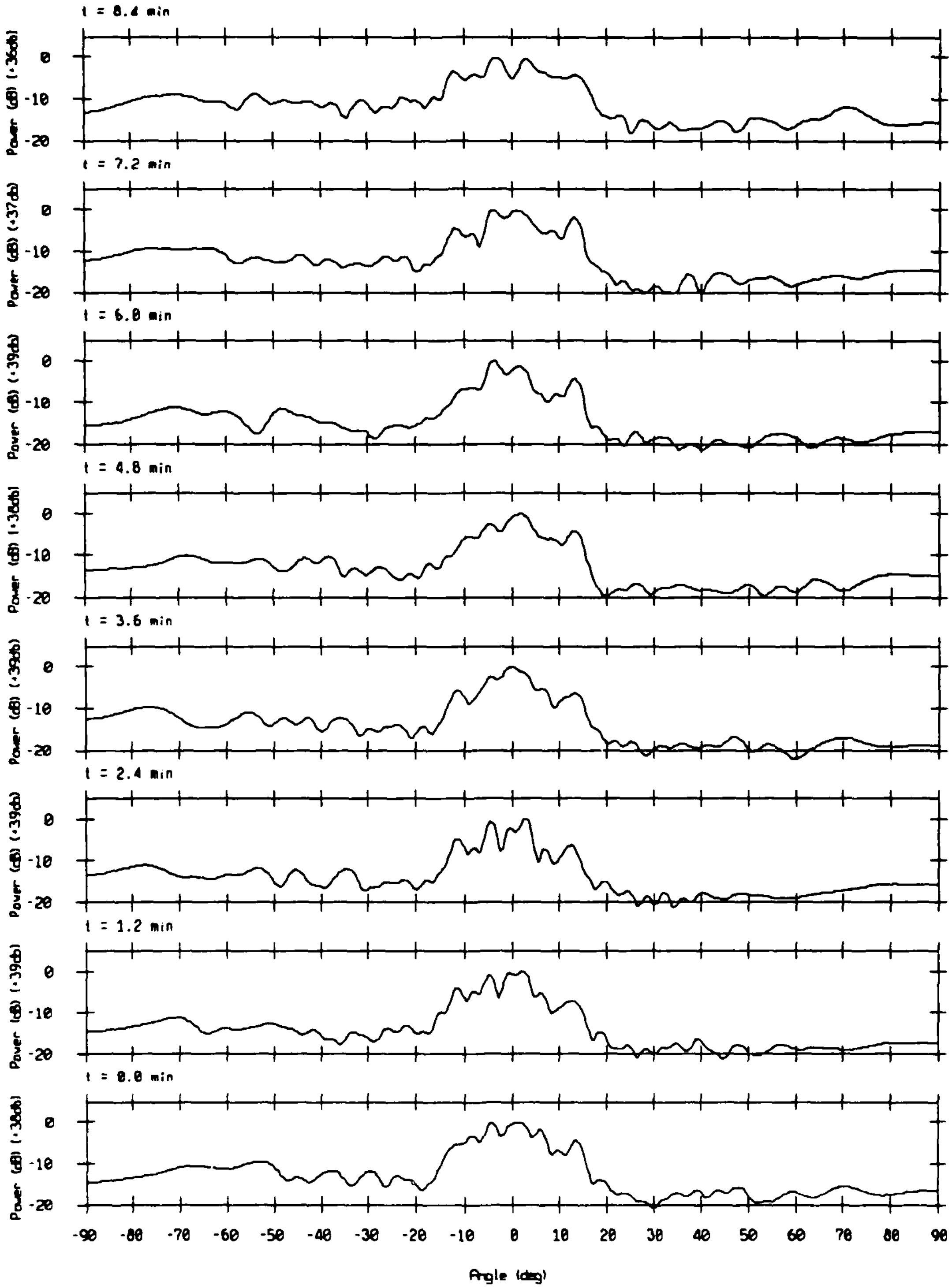


Figure 8(e).

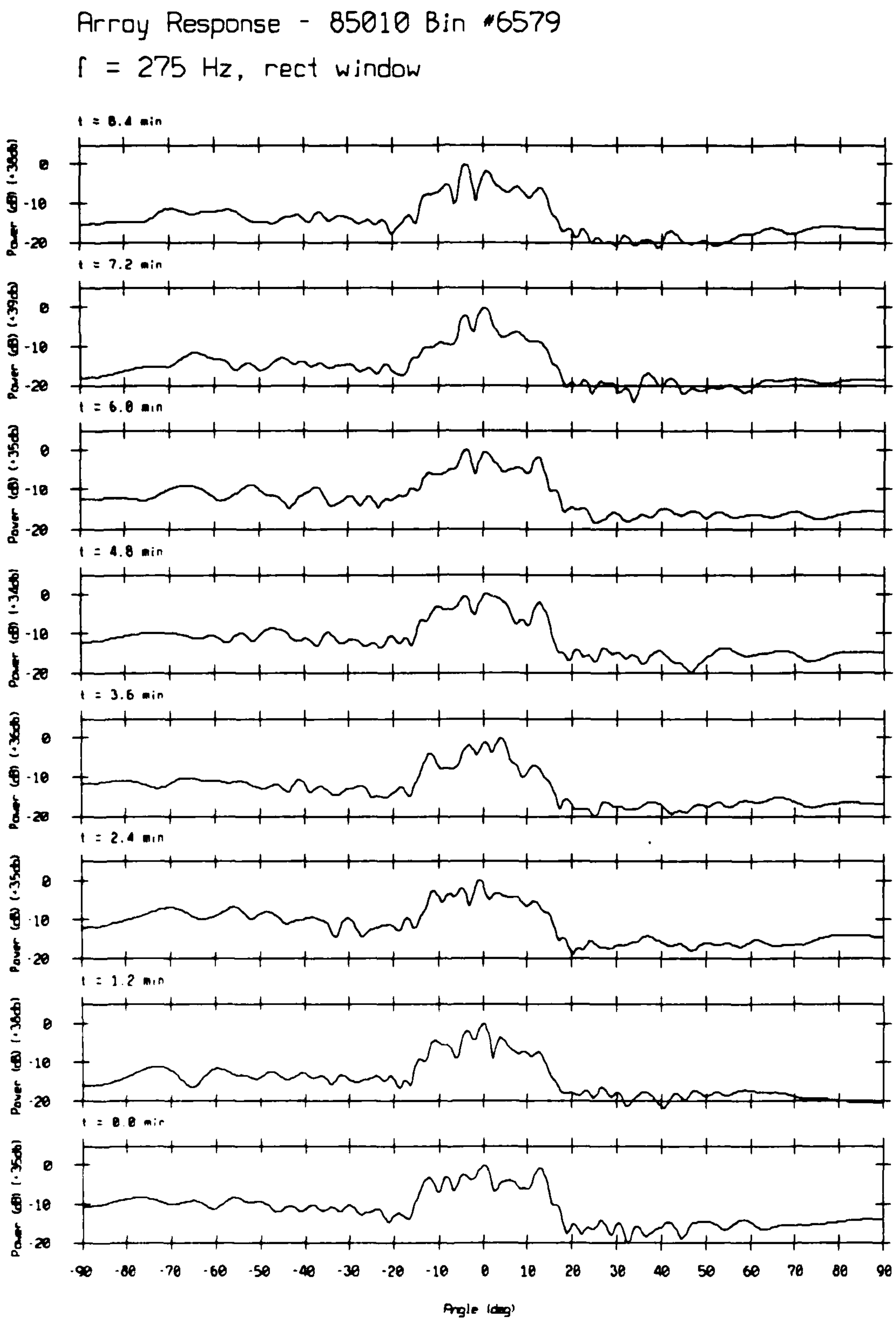

Array Response - 85010 Bin #6579
f = 275 Hz, rect window
t = 8.4 min
Power (dB) (+38db)
t = 7.2 min
Power (dB) (+39db)
t = 6.0 min
Power (dB) (+35db)
t = 4.8 min
Power (dB) (+34db)
t = 3.6 min
Power (dB) (+36db)
t = 2.4 min
Power (dB) (+35db)
t = 1.2 min
Power (dB) (+36db)
t = 0.0 min
Power (dB) (+35db)
0
-10
-20
-90 -80 -70 -60 -50 -40 -30 -20 -10 0 10 20 30 40 50 60 70 80 90
Angle (deg)

Figure 8(f).

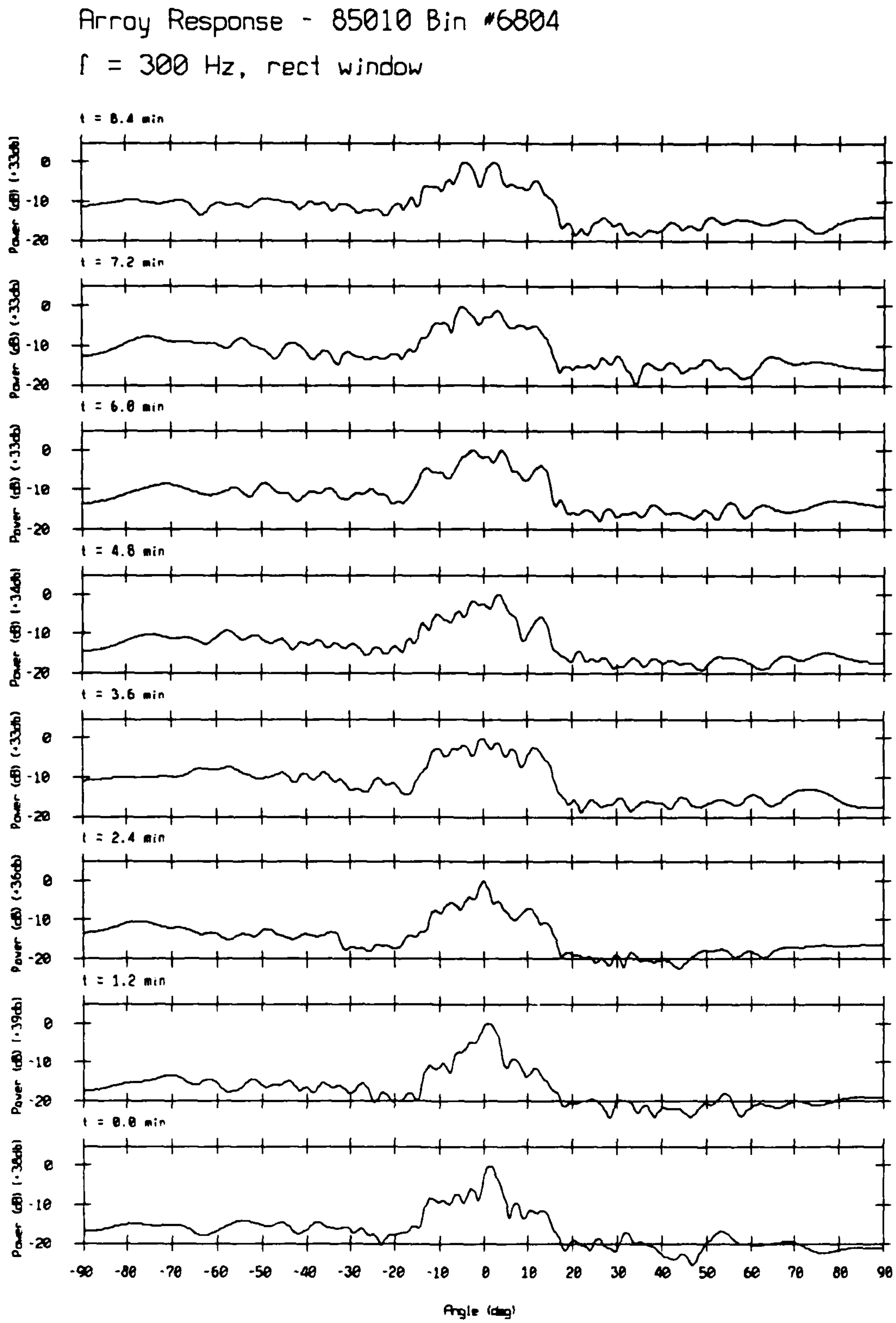

Array Response - 85010 Bin #6804
f = 300 Hz, rect window
t = 8.4 min
t = 7.2 min
t = 6.0 min
t = 4.8 min
t = 3.6 min
t = 2.4 min
t = 1.2 min
t = 0.0 min
Power (dB) (+33db)
Power (dB) (+33db)
Power (dB) (+33db)
Power (dB) (+34db)
Power (dB) (+33db)
Power (dB) (+36db)
Power (dB) (+39db)
Power (dB) (+38db)
0
-10
-20
-90 -80 -70 -60 -50 -40 -30 -20 -10 0 10 20 30 40 50 60 70 80 90
Angle (deg)

Figure 8(g).

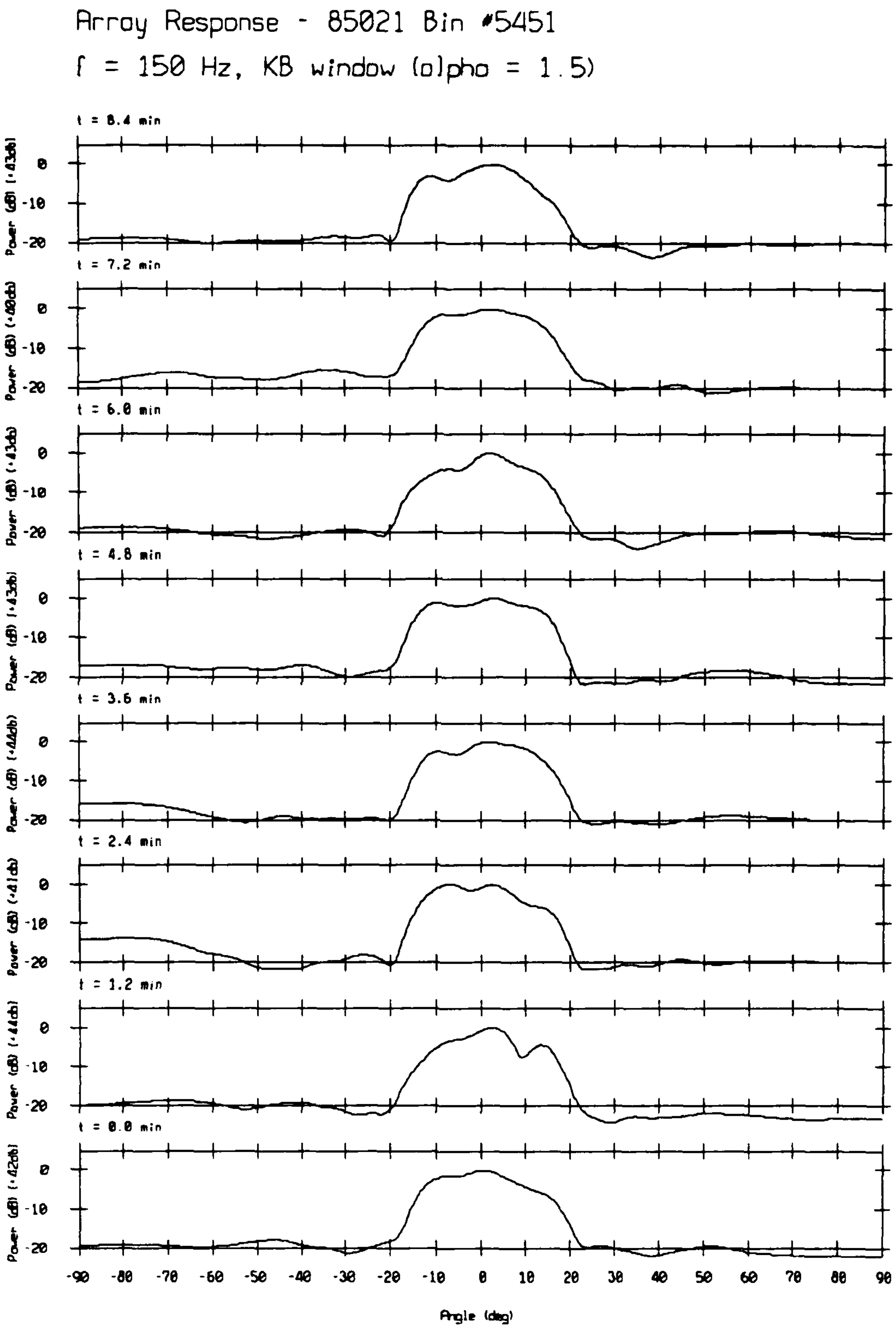
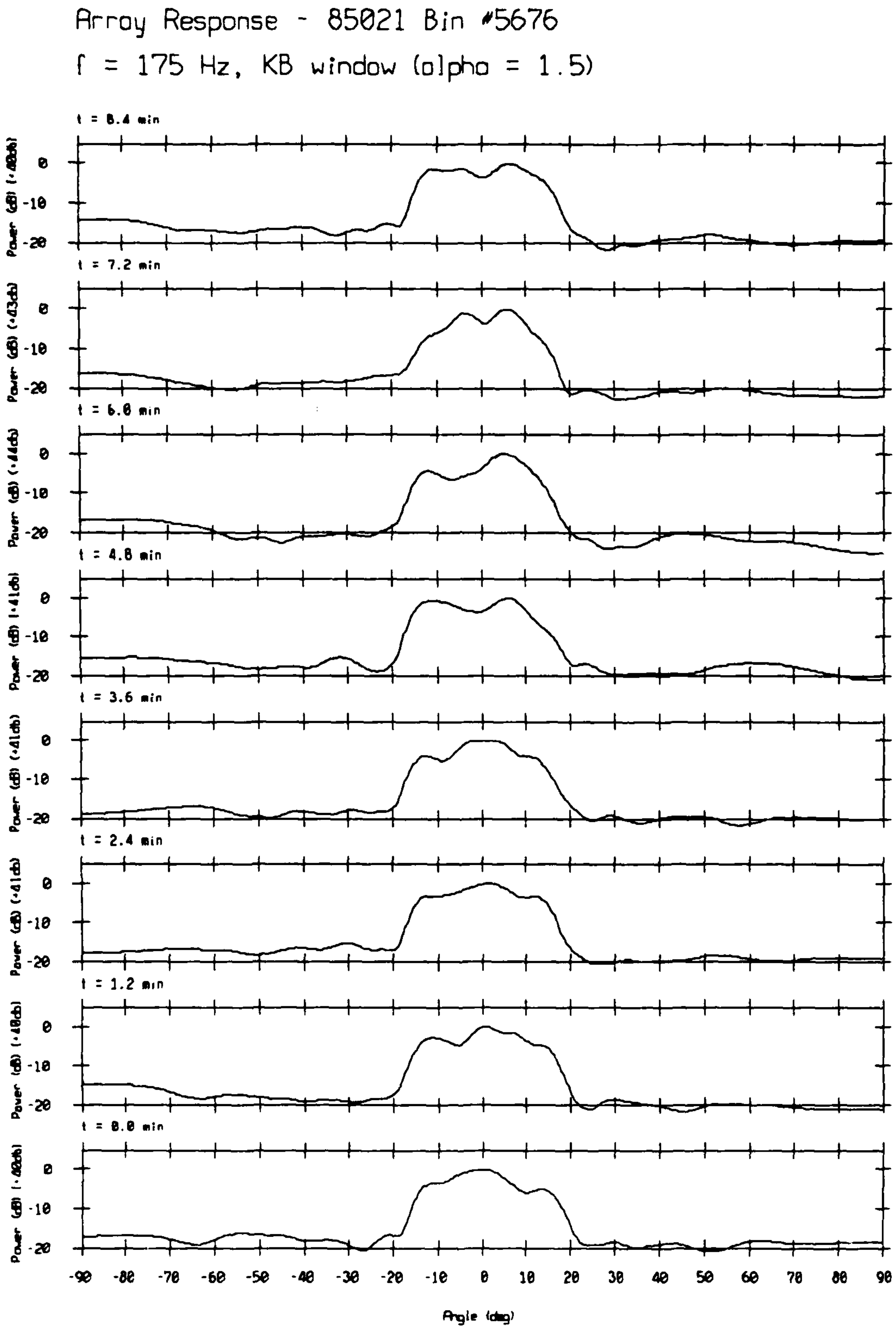

Array Response - 85021 Bin #5451
f = 150 Hz, KB window (alpha = 1.5)
t = 8.4 min
t = 7.2 min
t = 6.0 min
t = 4.8 min
t = 3.6 min
t = 2.4 min
t = 1.2 min
t = 0.0 min
Power (dB)
0
-10
-20
-90 -80 -70 -60 -50 -40 -30 -20 -10 0 10 20 30 40 50 60 70 80 90
Angle (deg)

Figure 9(a).



Array Response - 85021 Bin #5676
f = 175 Hz, KB window (alpha = 1.5)
t = 8.4 min
Power (dB) (+40db)
t = 7.2 min
Power (dB) (+43db)
t = 6.0 min
Power (dB) (+44db)
t = 4.8 min
Power (dB) (+41db)
t = 3.6 min
Power (dB) (+41db)
t = 2.4 min
Power (dB) (+41db)
t = 1.2 min
Power (dB) (+40db)
t = 0.0 min
Power (dB) (+40db)
0
-10
-20
-90 -80 -70 -60 -50 -40 -30 -20 -10 0 10 20 30 40 50 60 70 80 90
Angle (deg)

Figure 9(b).

Array Response - 85021 Bin #5902

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

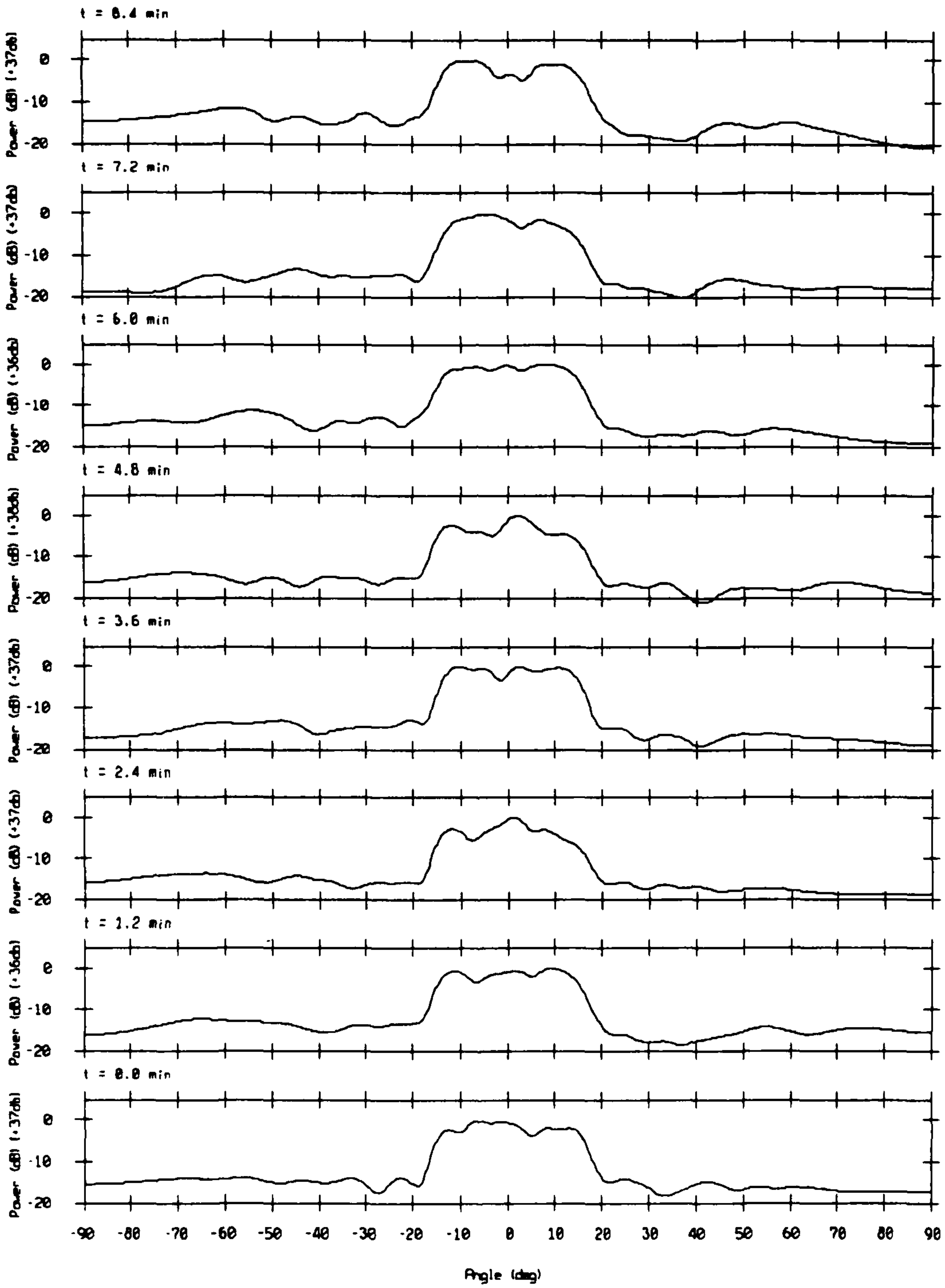
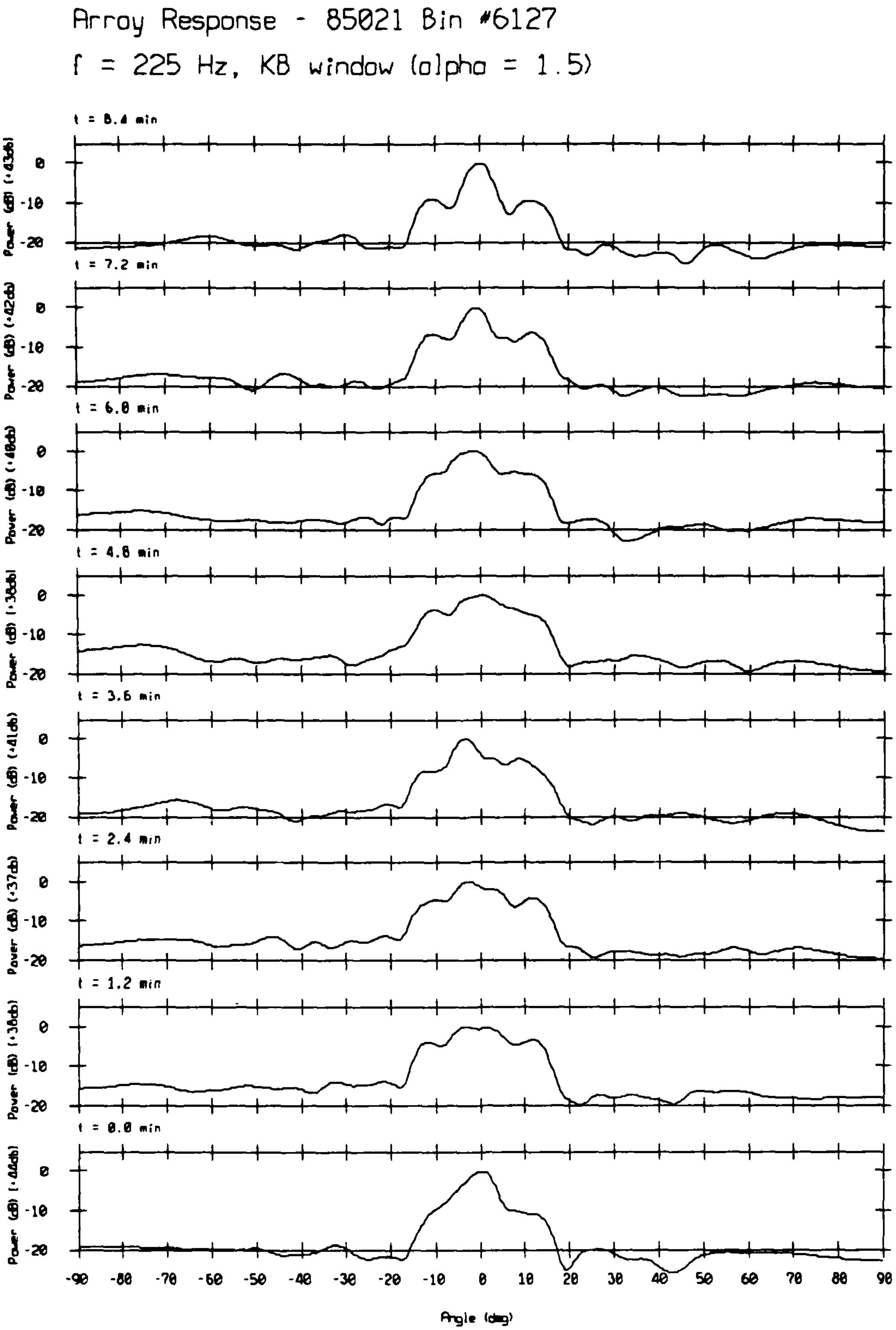


Figure 9(c).



Array Response - 85021 Bin #6127
f = 225 Hz, KB window (alpha = 1.5)
t = 8.4 min
Power (dB) (+43db)
t = 7.2 min
Power (dB) (+42db)
t = 6.0 min
Power (dB) (+40db)
t = 4.8 min
Power (dB) (+38db)
t = 3.6 min
Power (dB) (+41db)
t = 2.4 min
Power (dB) (+37db)
t = 1.2 min
Power (dB) (+38db)
t = 0.0 min
Power (dB) (+44db)
0
-10
-20
-90 -80 -70 -60 -50 -40 -30 -20 -10 0 10 20 30 40 50 60 70 80 90
Angle (deg)

Figure 9(d).

Array Response - 85021 Bin #6354

f = 250 Hz, KB window (alpha = 1.5)

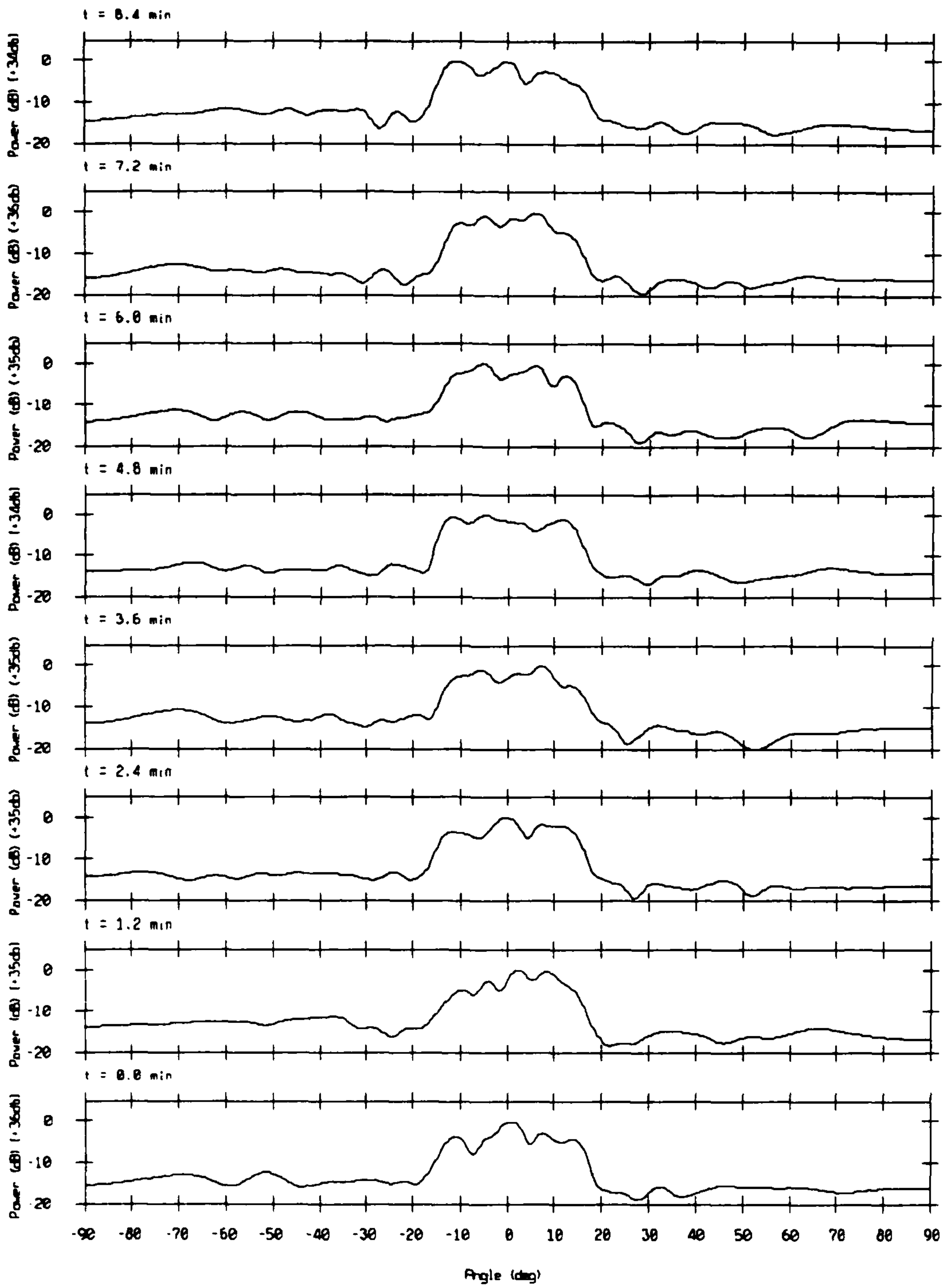


Figure 9(e).

Array Response - 85021 Bin #6579

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

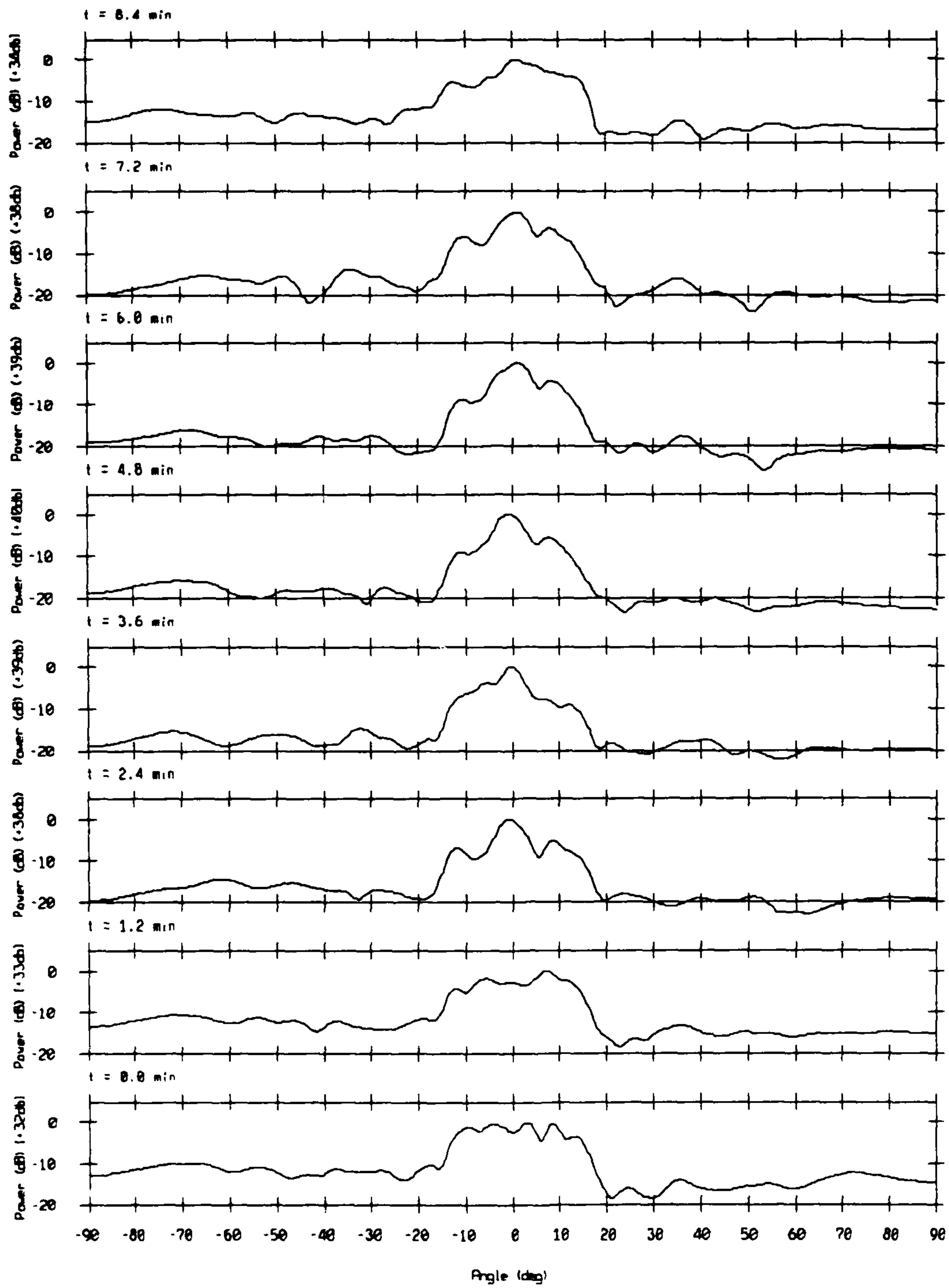
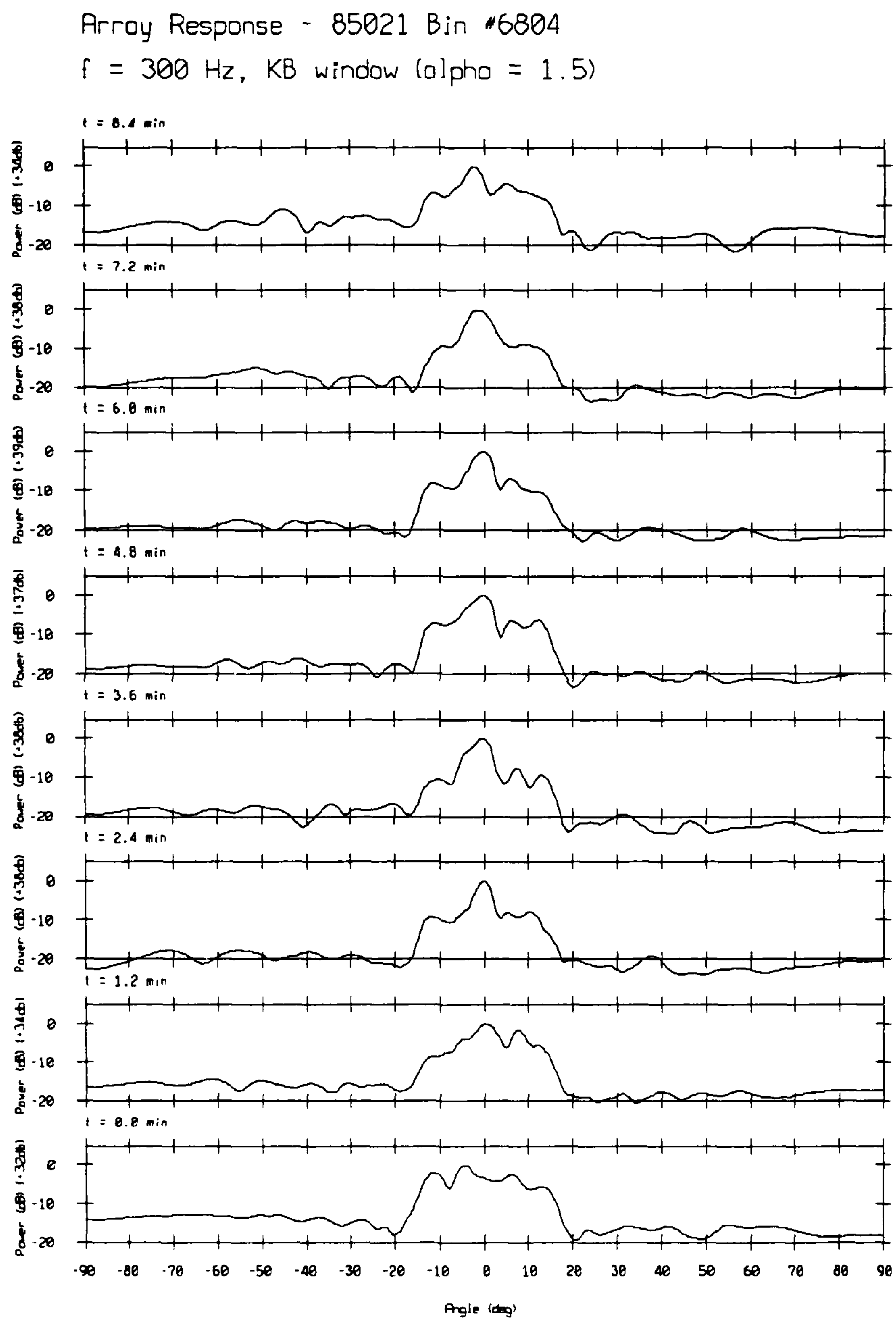


Figure 9(f).



Array Response - 85021 Bin #6804
f = 300 Hz, KB window (alpha = 1.5)
t = 8.4 min
Power (dB) (+34db)
t = 7.2 min
Power (dB) (+38db)
t = 6.0 min
Power (dB) (+39db)
t = 4.8 min
Power (dB) (+37db)
t = 3.6 min
Power (dB) (+38db)
t = 2.4 min
Power (dB) (+38db)
t = 1.2 min
Power (dB) (+34db)
t = 0.0 min
Power (dB) (+32db)
0
-10
-20
-90 -80 -70 -60 -50 -40 -30 -20 -10 0 10 20 30 40 50 60 70 80 90
Angle (deg)

Figure 9(g).

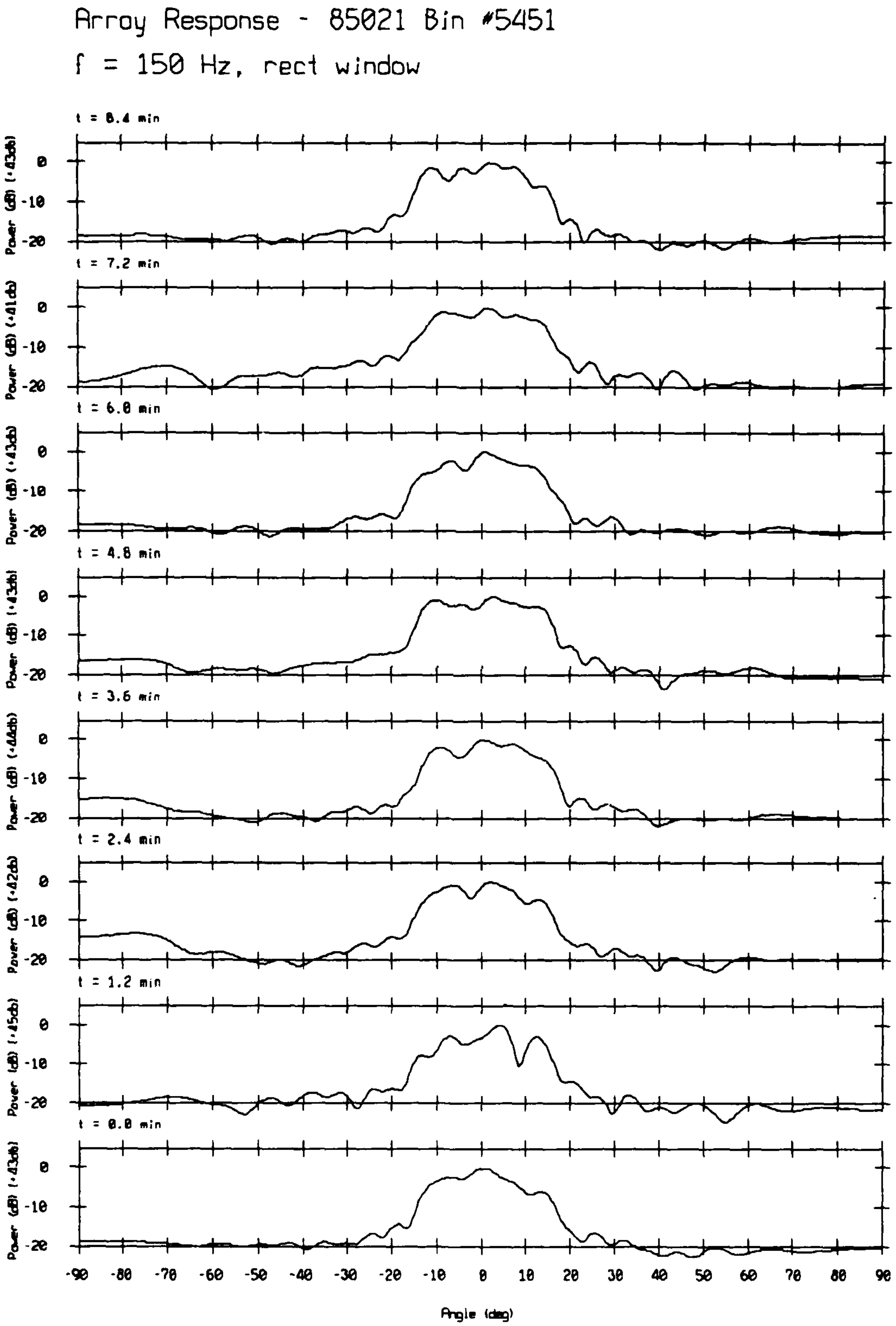
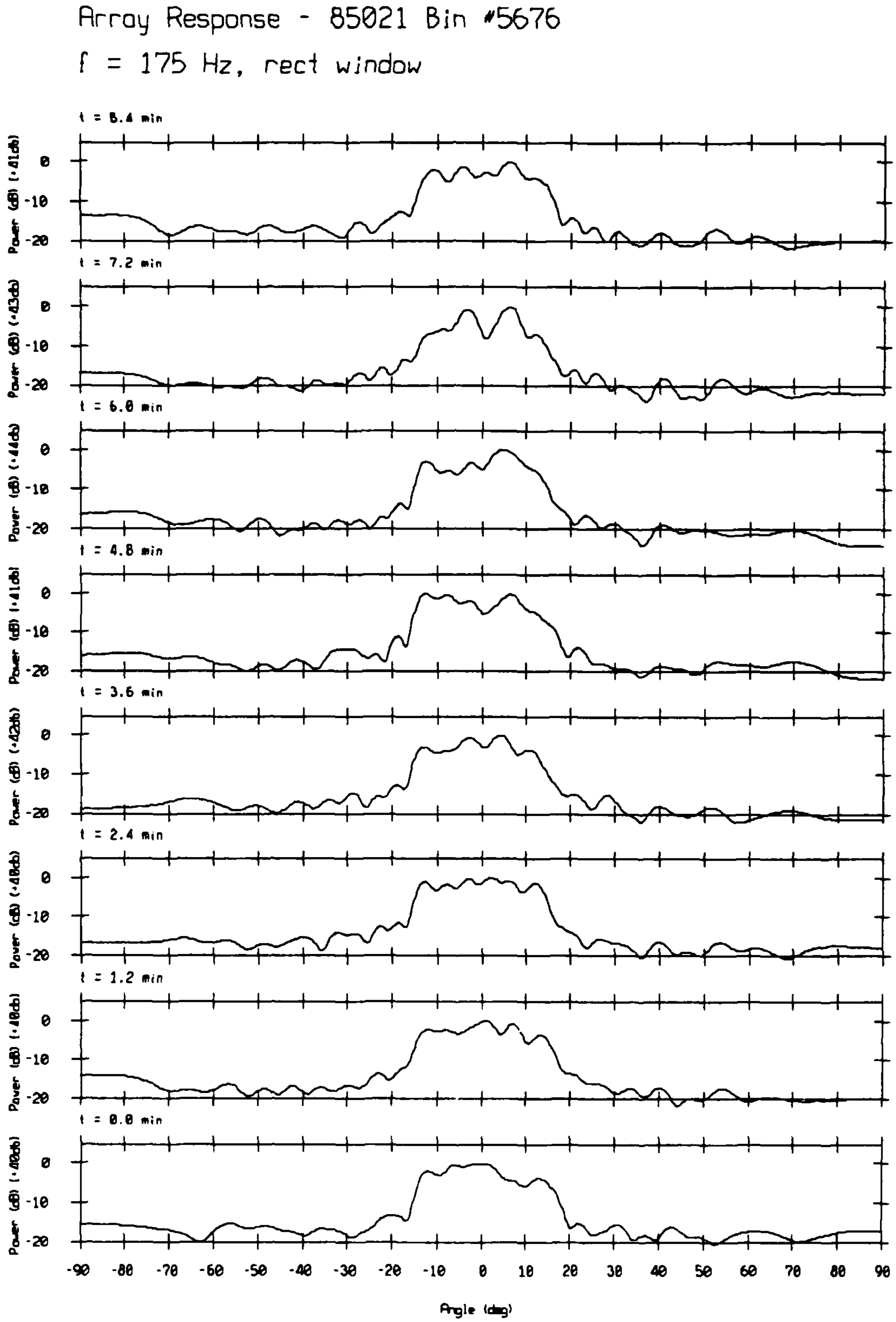
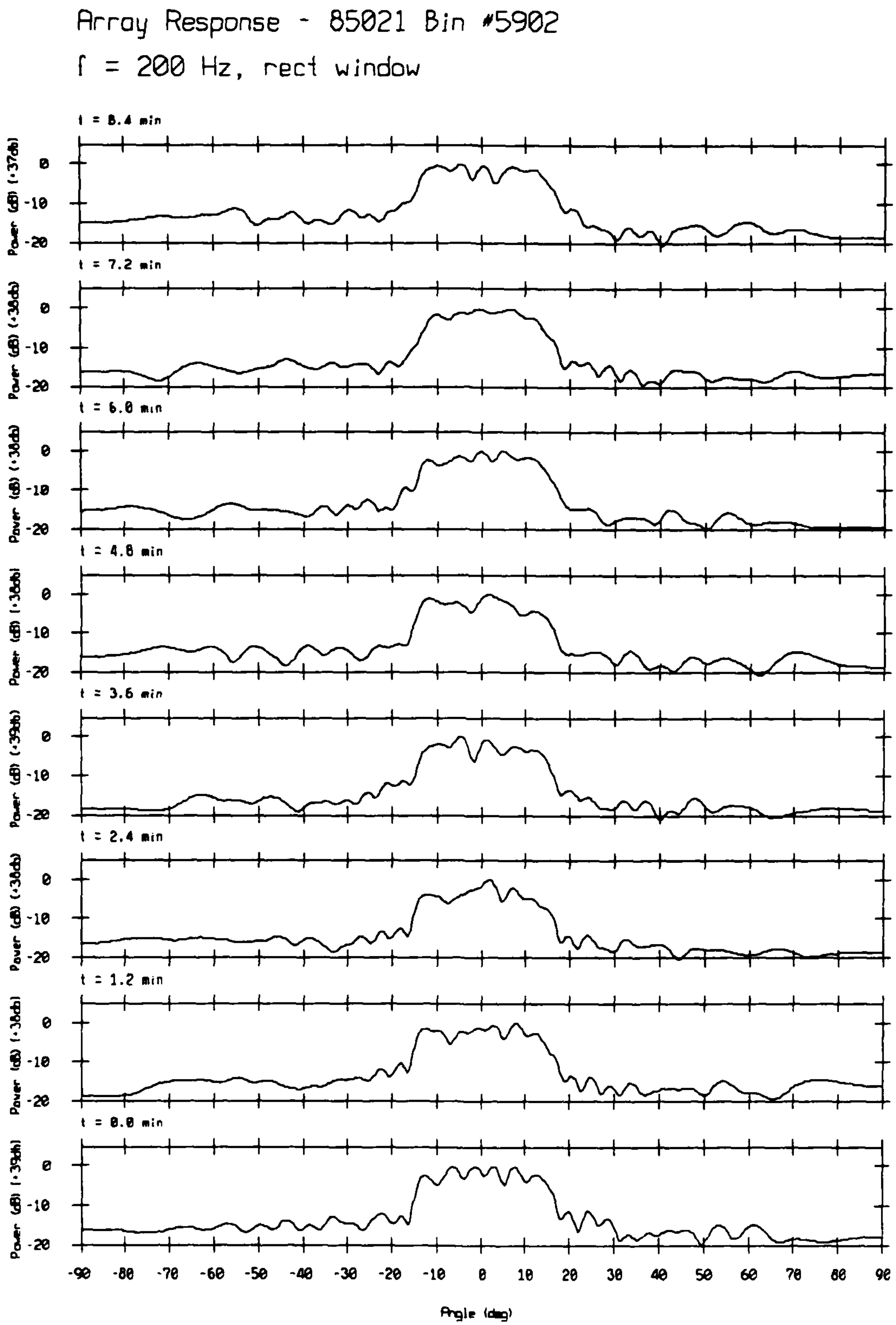

Array Response - 85021 Bin #5451
f = 150 Hz, rect window
t = 8.4 min
t = 7.2 min
t = 6.0 min
t = 4.8 min
t = 3.6 min
t = 2.4 min
t = 1.2 min
t = 0.0 min
Power (dB) (+43db)
Power (dB) (+41db)
Power (dB) (+43db)
Power (dB) (+43db)
Power (dB) (+44db)
Power (dB) (+42db)
Power (dB) (+45db)
Power (dB) (+43db)
0
-10
-20
-90 -80 -70 -60 -50 -40 -30 -20 -10 0 10 20 30 40 50 60 70 80 90
Angle (deg)

Figure 10(a).



Array Response - 85021 Bin #5676
f = 175 Hz, rect window
t = 8.4 min
t = 7.2 min
t = 6.0 min
t = 4.8 min
t = 3.6 min
t = 2.4 min
t = 1.2 min
t = 0.0 min
Power (dB) (+41db)
Power (dB) (+43db)
Power (dB) (+44db)
Power (dB) (+41db)
Power (dB) (+42db)
Power (dB) (+40db)
Power (dB) (+40db)
Power (dB) (+40db)
0
-10
-20
-90 -80 -70 -60 -50 -40 -30 -20 -10 0 10 20 30 40 50 60 70 80 90
Angle (deg)

Figure 10(b).



Array Response - 85021 Bin #5902
f = 200 Hz, rect window
t = 8.4 min
t = 7.2 min
t = 6.0 min
t = 4.8 min
t = 3.6 min
t = 2.4 min
t = 1.2 min
t = 0.0 min
Power (dB)
0
-10
-20
-90 -80 -70 -60 -50 -40 -30 -20 -10 0 10 20 30 40 50 60 70 80 90
Angle (deg)

Figure 10(c).

Array Response - 85021 Bin #6127

f = 225 Hz, rect window

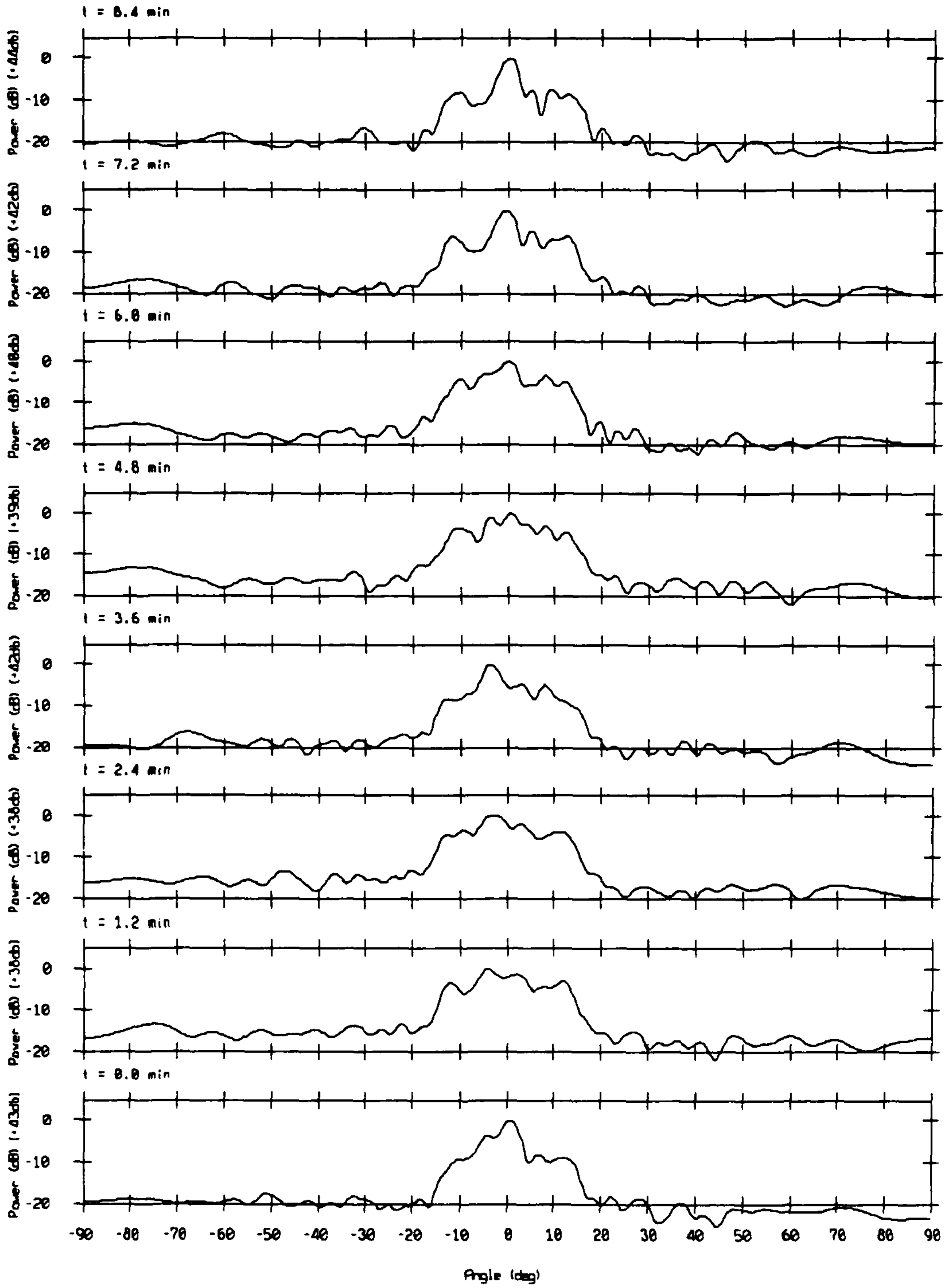


Figure 10(d).

Arroy Response - 85021 Bin #6354

f = 250 Hz, rect window

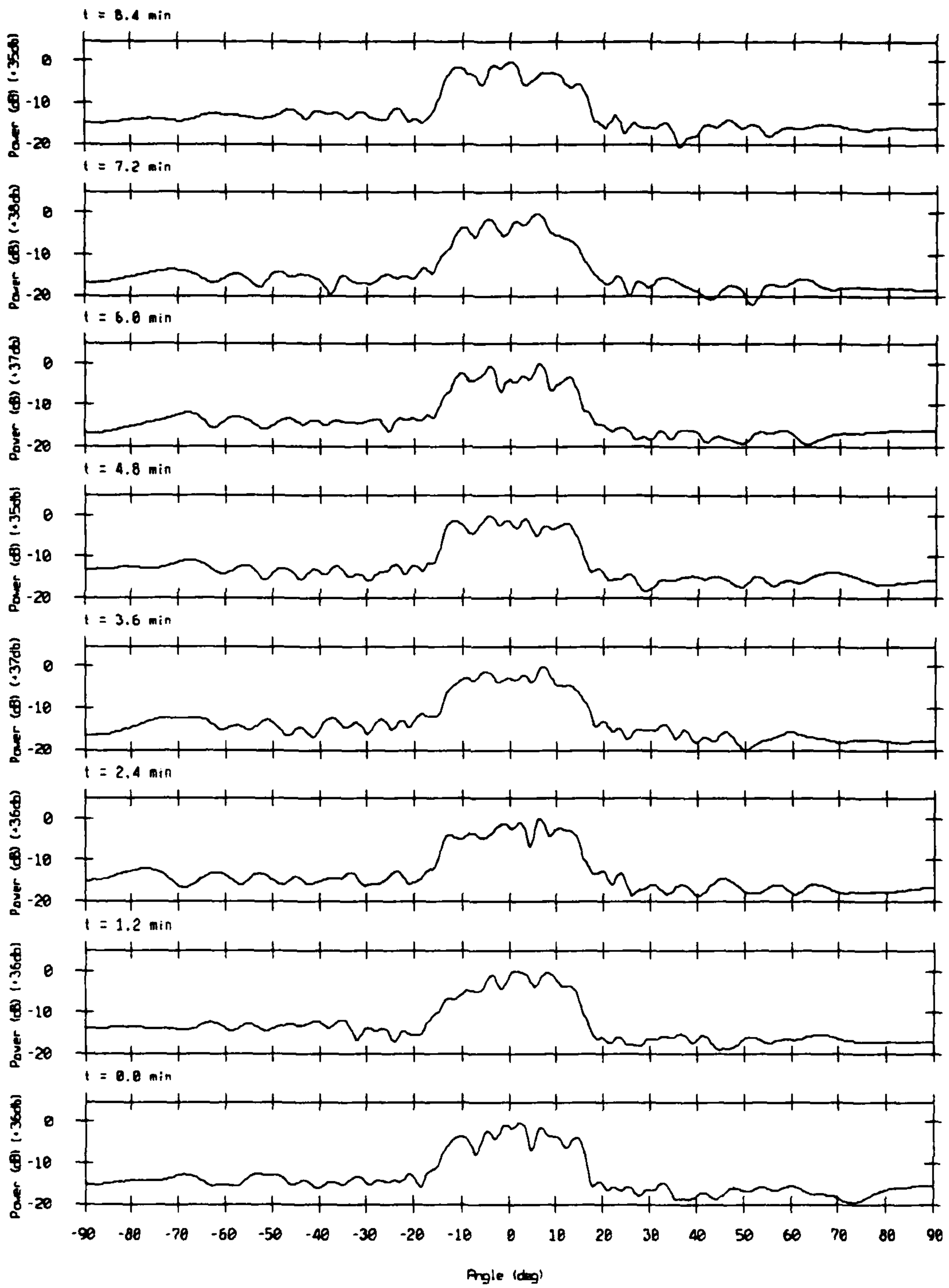
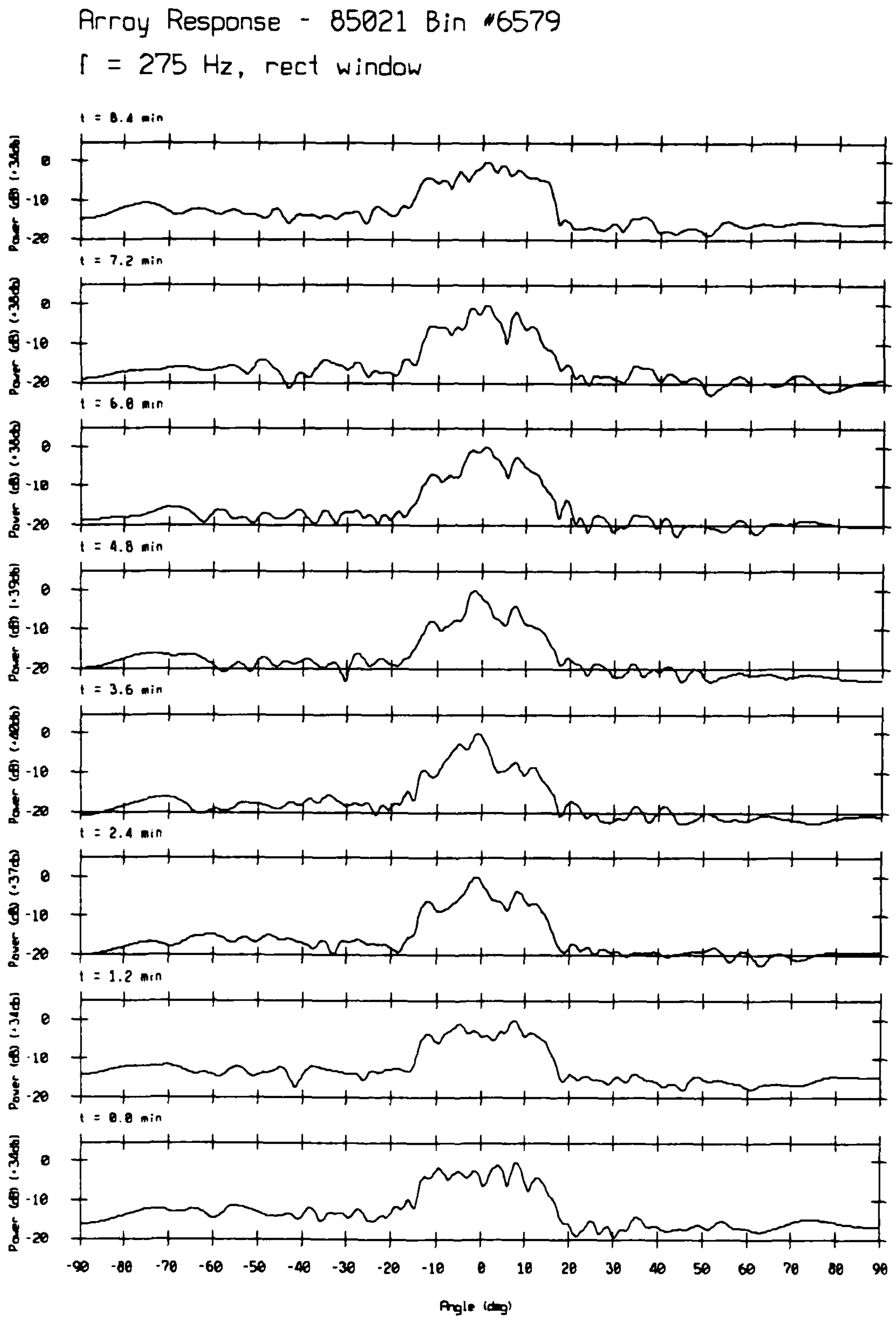


Figure 10(e).



Array Response - 85021 Bin #6579
f = 275 Hz, rect window
t = 8.4 min
t = 7.2 min
t = 6.0 min
t = 4.8 min
t = 3.6 min
t = 2.4 min
t = 1.2 min
t = 0.0 min
Power (dB) (+34db)
Power (dB) (+38db)
Power (dB) (+38db)
Power (dB) (+39db)
Power (dB) (+40db)
Power (dB) (+37db)
Power (dB) (+34db)
Power (dB) (+34db)
0
-10
-20
-90 -80 -70 -60 -50 -40 -30 -20 -10 0 10 20 30 40 50 60 70 80 90
Angle (deg)

Figure 10(f).

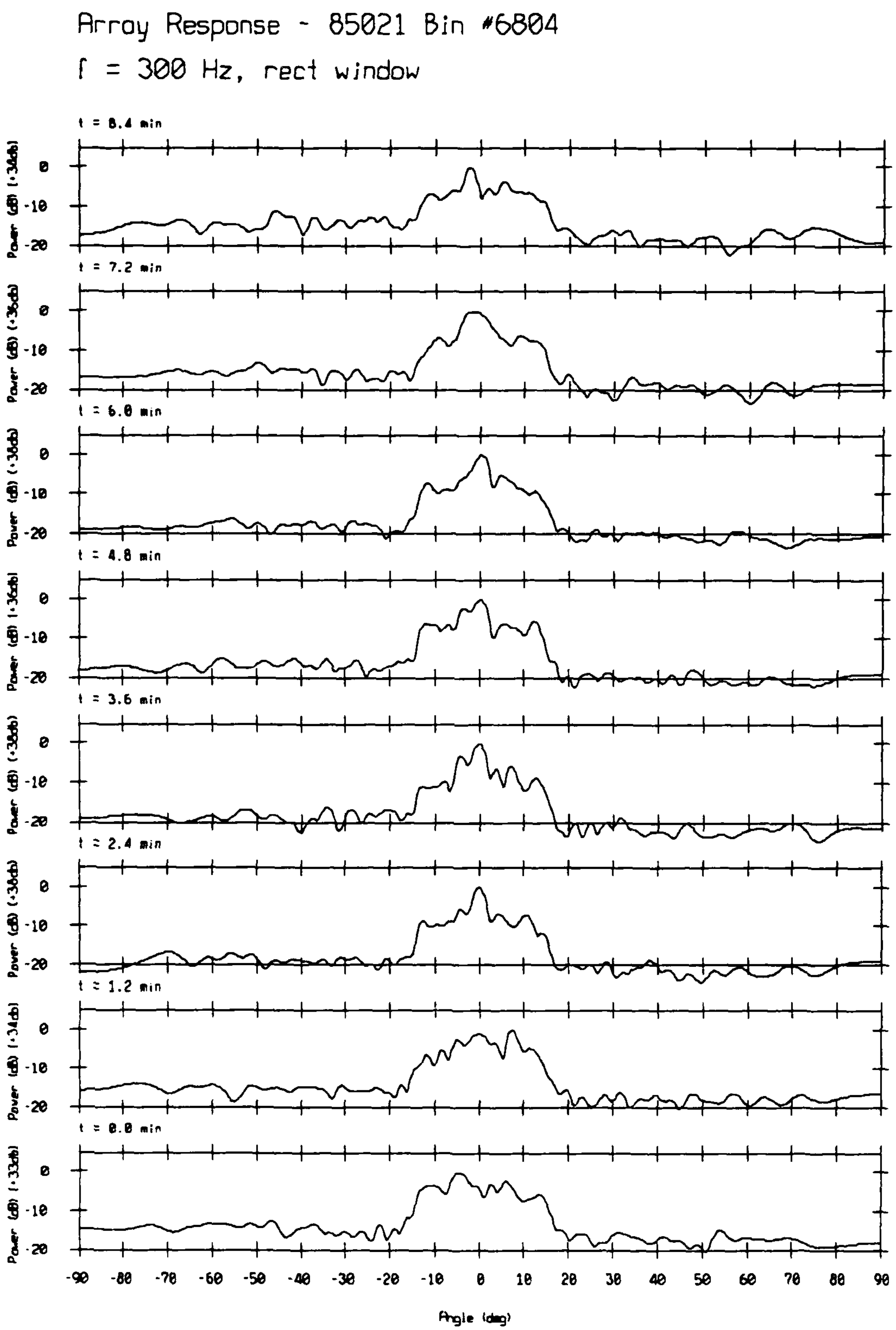

Array Response - 85021 Bin #6804
f = 300 Hz, rect window
t = 8.4 min
t = 7.2 min
t = 6.0 min
t = 4.8 min
t = 3.6 min
t = 2.4 min
t = 1.2 min
t = 0.0 min
Power (dB)
0
-10
-20
-90 -80 -70 -60 -50 -40 -30 -20 -10 0 10 20 30 40 50 60 70 80 90
Angle (deg)

Figure 10(g).

Arroy Response - 85042 Bin #5451

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

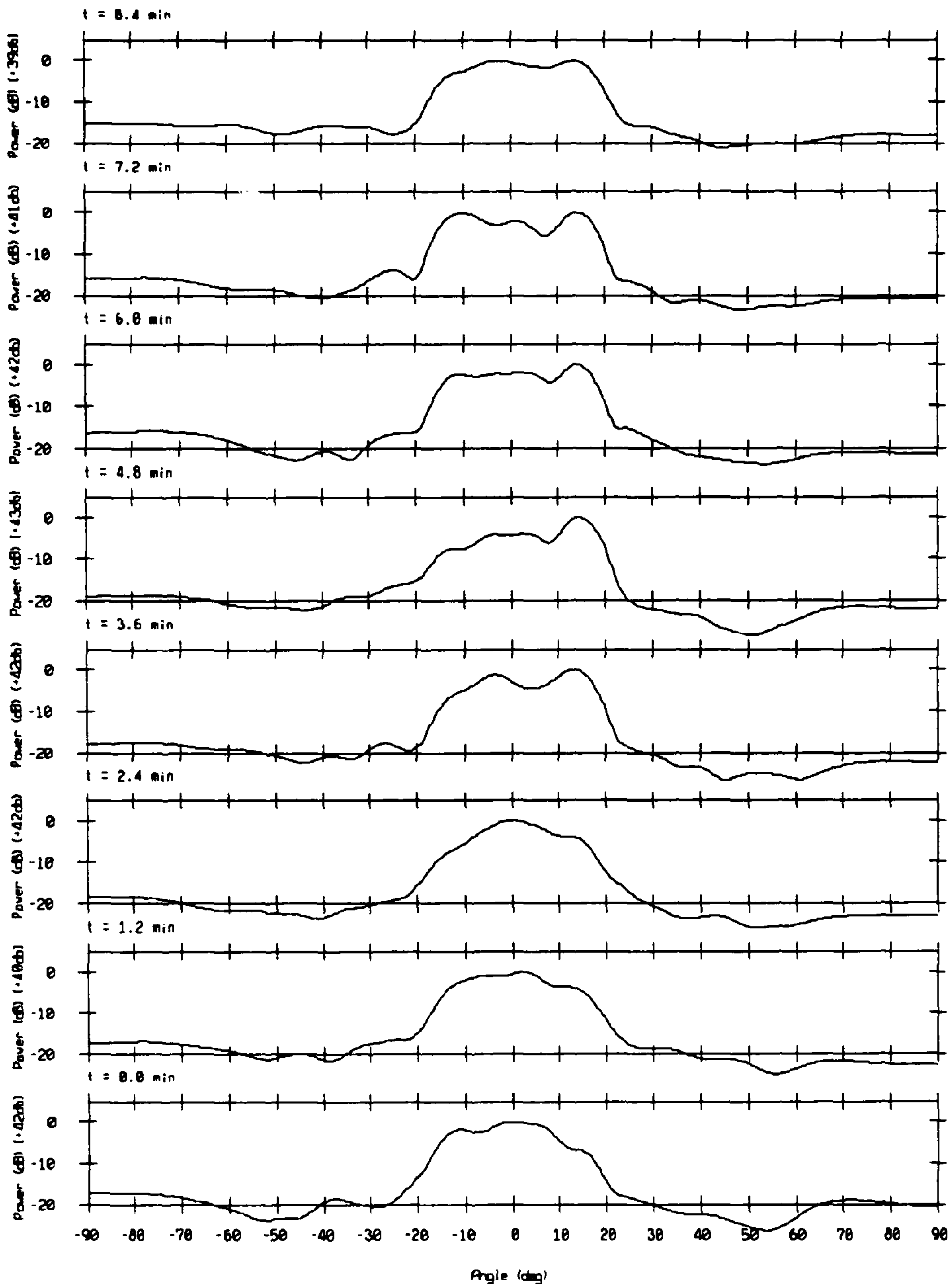


Figure 11(a).

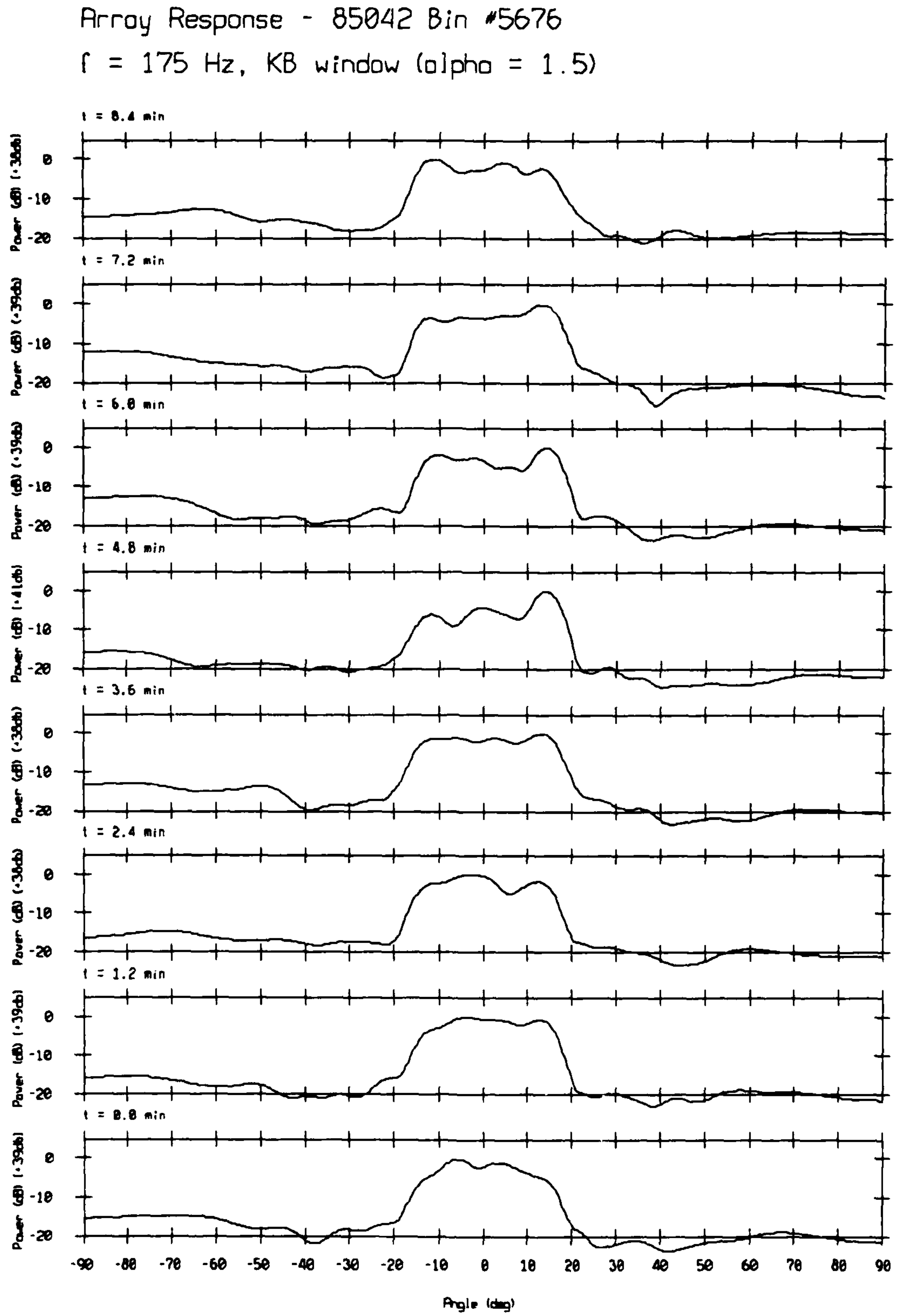

Array Response - 85042 Bin #5676
f = 175 Hz, KB window (alpha = 1.5)
t = 8.4 min
t = 7.2 min
t = 6.0 min
t = 4.8 min
t = 3.6 min
t = 2.4 min
t = 1.2 min
t = 0.0 min
Power (dB)
0
-10
-20
-90 -80 -70 -60 -50 -40 -30 -20 -10 0 10 20 30 40 50 60 70 80 90
Angle (deg)

Figure 11(b).

Array Response - 85042 Bin #5902

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

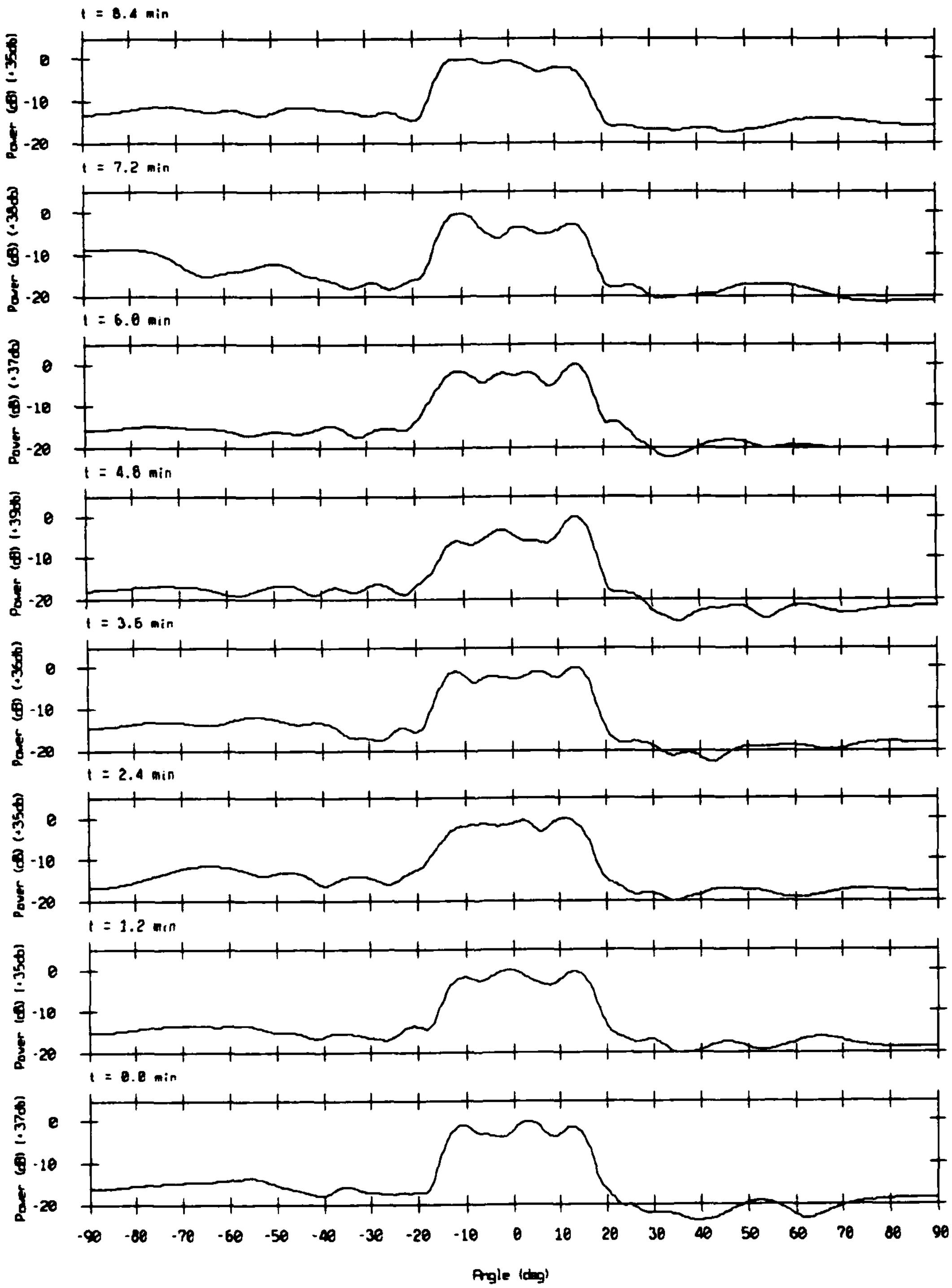
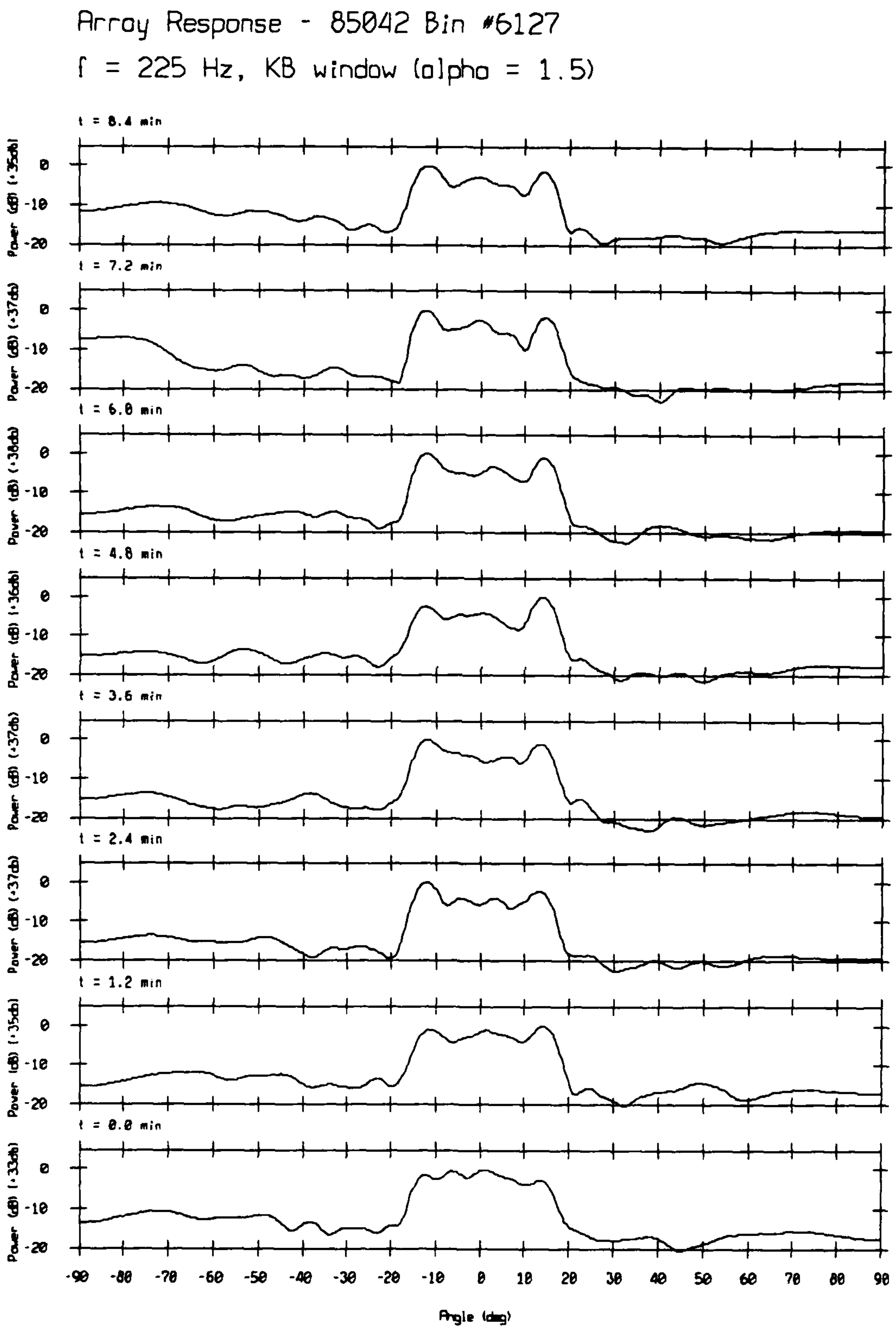


Figure 11(c).



Array Response - 85042 Bin #6127
f = 225 Hz, KB window (alpha = 1.5)
t = 8.4 min
t = 7.2 min
t = 6.0 min
t = 4.8 min
t = 3.6 min
t = 2.4 min
t = 1.2 min
t = 0.0 min
Power (dB) (+35db)
Power (dB) (+37db)
Power (dB) (+38db)
Power (dB) (+36db)
Power (dB) (+37db)
Power (dB) (+37db)
Power (dB) (+35db)
Power (dB) (+33db)
0
-10
-20
-90 -80 -70 -60 -50 -40 -30 -20 -10 0 10 20 30 40 50 60 70 80 90
Angle (deg)

Figure 11(d).

Array Response - 85042 Bin #6354

f = 250 Hz, KB window (alpha = 1.5)

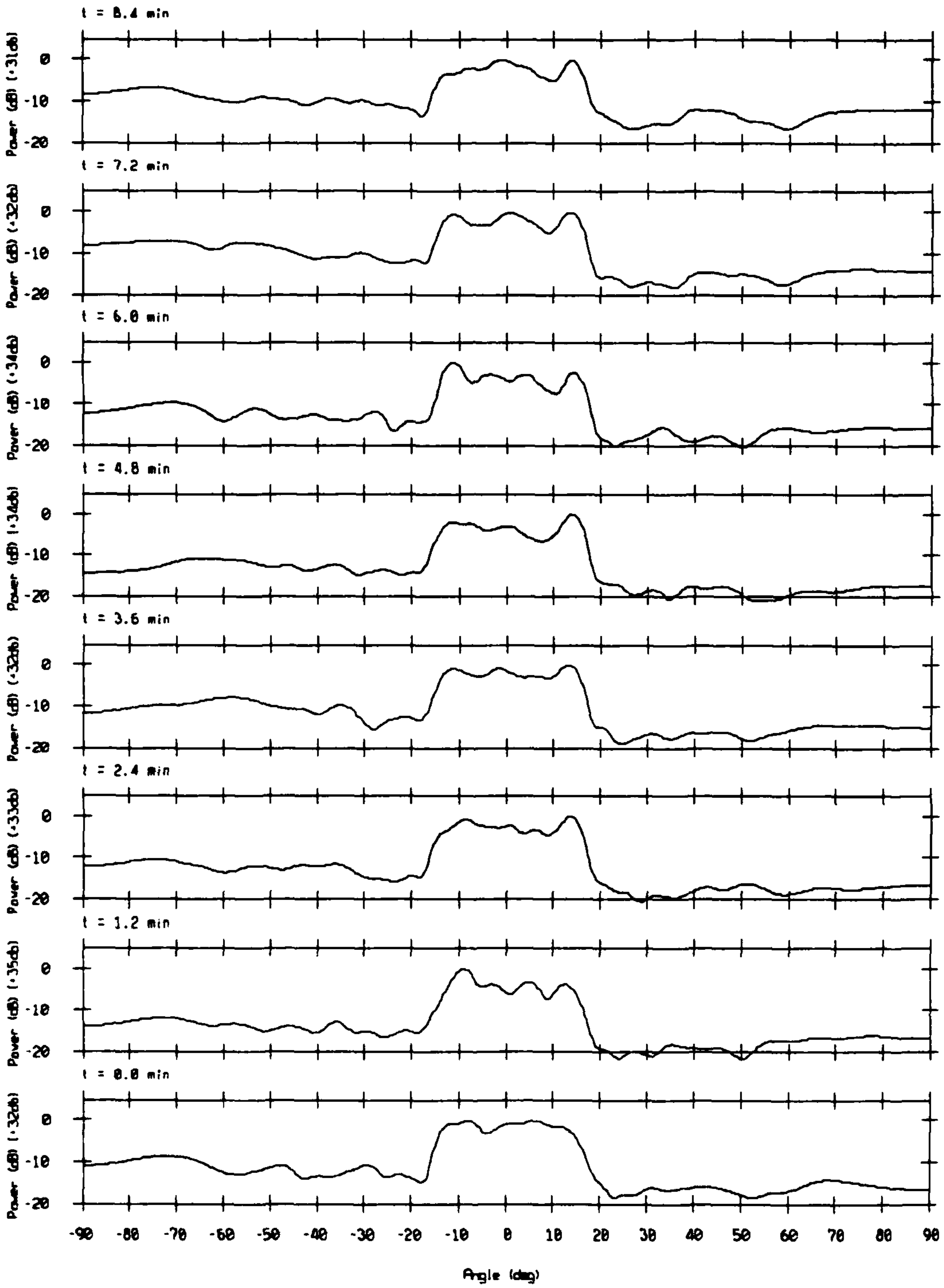


Figure 11(e).

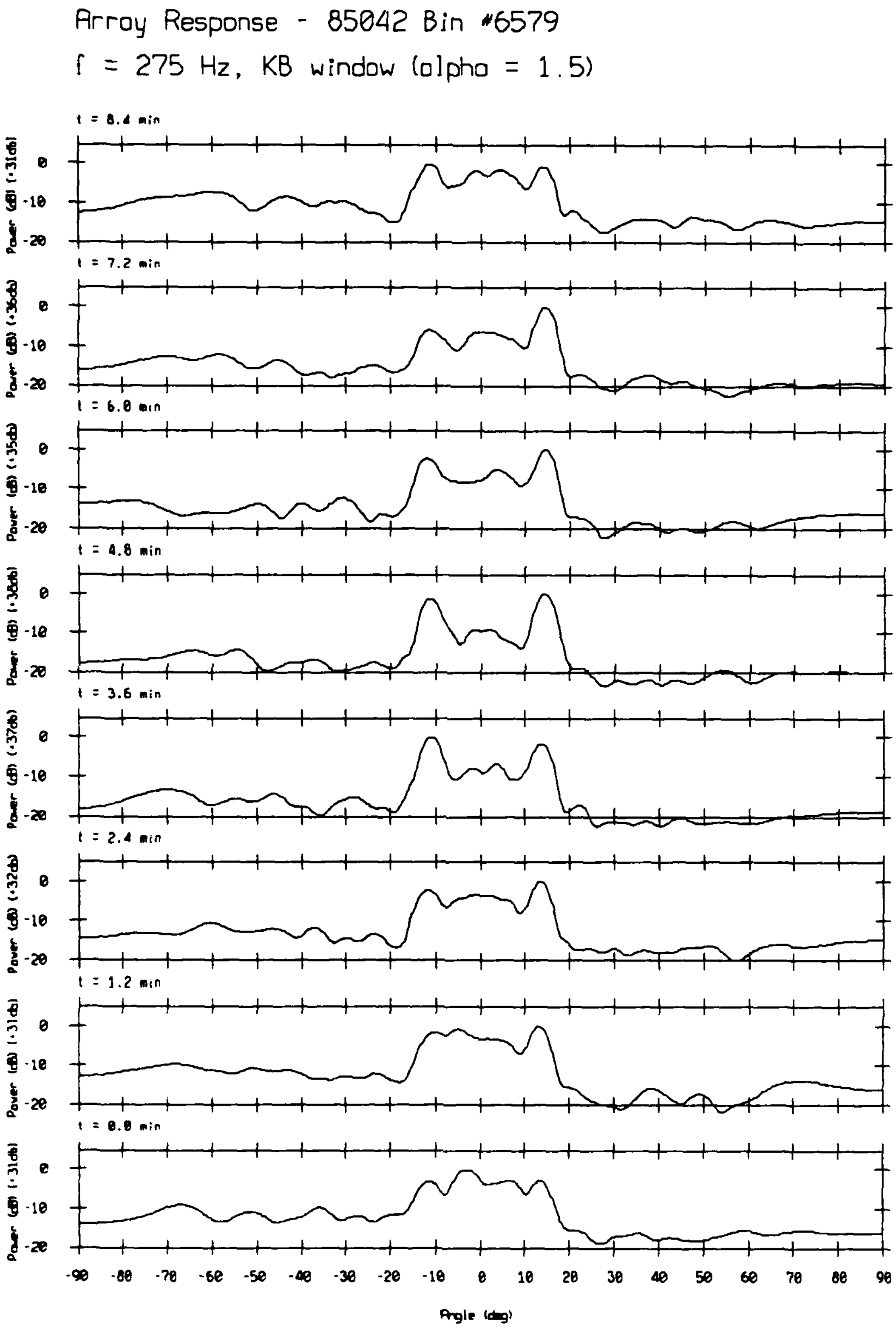

Array Response - 85042 Bin #6579
f = 275 Hz, KB window (alpha = 1.5)
t = 8.4 min
t = 7.2 min
t = 6.0 min
t = 4.8 min
t = 3.6 min
t = 2.4 min
t = 1.2 min
t = 0.0 min
Power (dB) (+31db)
Power (dB) (+36db)
Power (dB) (+35db)
Power (dB) (+38db)
Power (dB) (+37db)
Power (dB) (+32db)
Power (dB) (+31db)
Power (dB) (+31db)
0
-10
-20
-90 -80 -70 -60 -50 -40 -30 -20 -10 0 10 20 30 40 50 60 70 80 90
Angle (deg)

Figure 11(f).

Array Response - 85042 Bin #6804

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

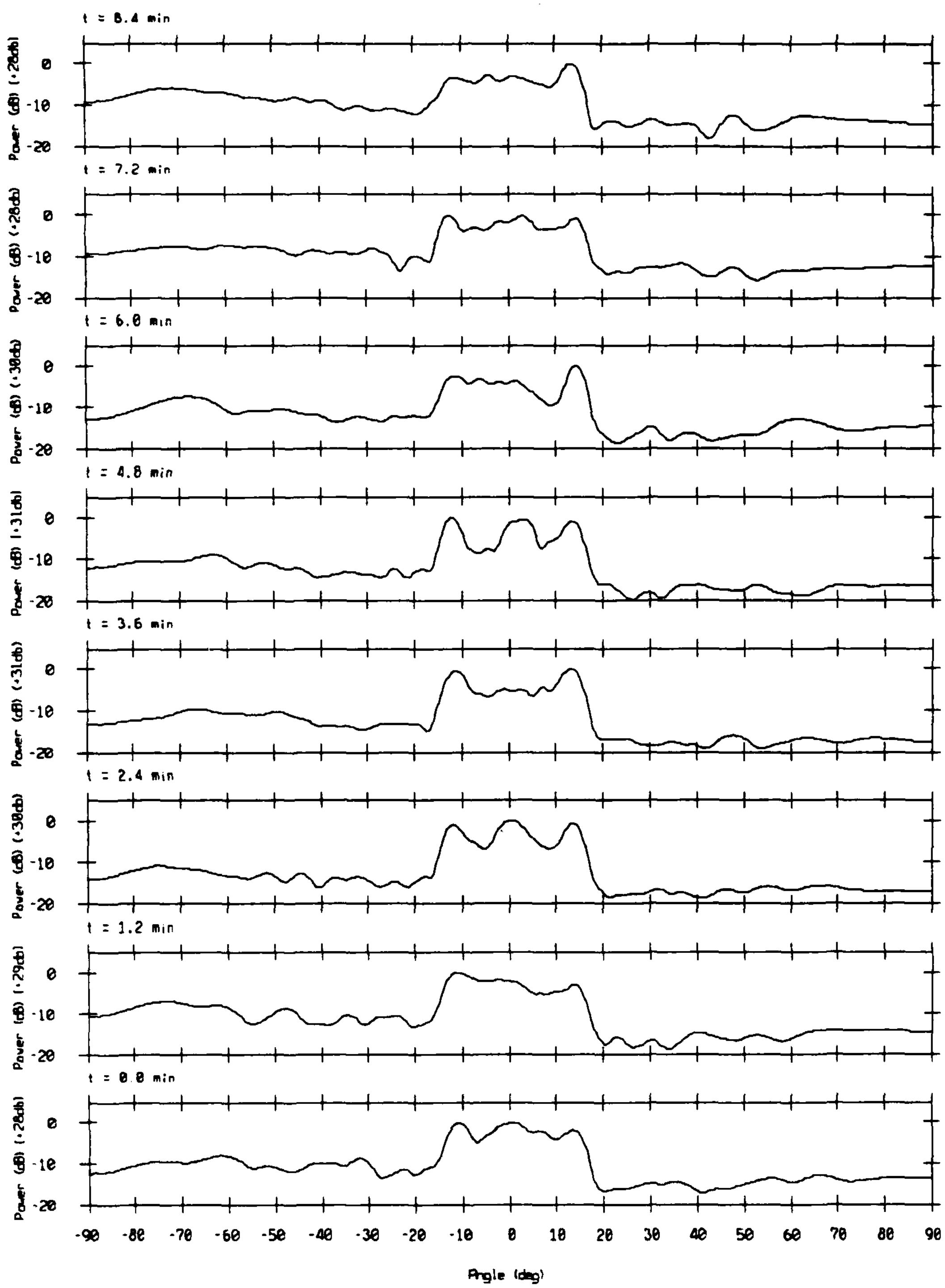
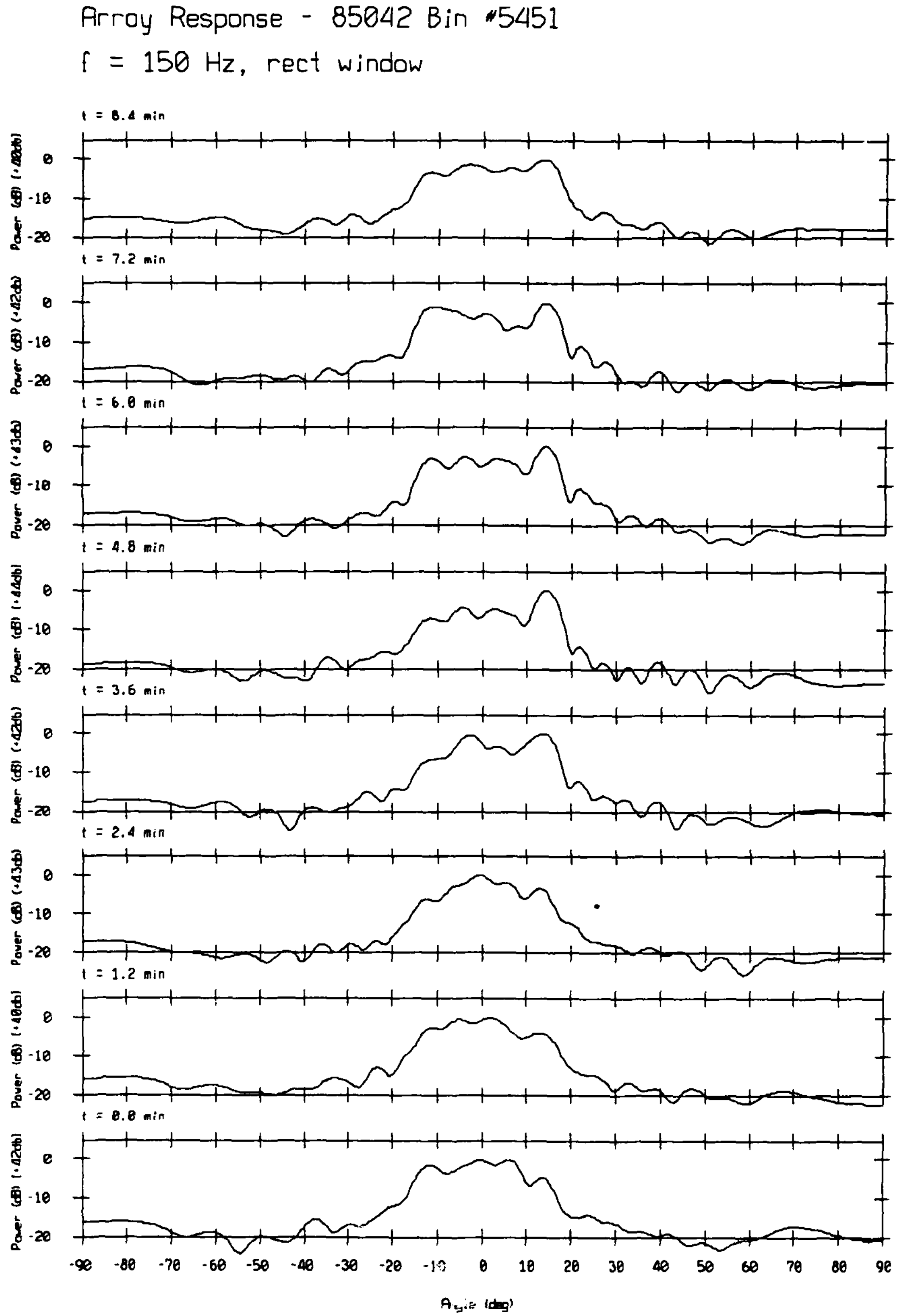


Figure 11(g).



Array Response - 85042 Bin #5451
f = 150 Hz, rect window
t = 8.4 min
Power (dB)
t = 7.2 min
Power (dB) (+42db)
t = 6.0 min
Power (dB) (+43db)
t = 4.8 min
Power (dB) (+44db)
t = 3.6 min
Power (dB) (+42db)
t = 2.4 min
Power (dB) (+43db)
t = 1.2 min
Power (dB) (+40db)
t = 0.0 min
Power (dB) (+42db)
0
-10
-20
-90 -80 -70 -60 -50 -40 -30 -20 -10 0 10 20 30 40 50 60 70 80 90
Angle (deg)

Figure 12(a).

Array Response - 85042 Bin #5676

f = 175 Hz, rect window

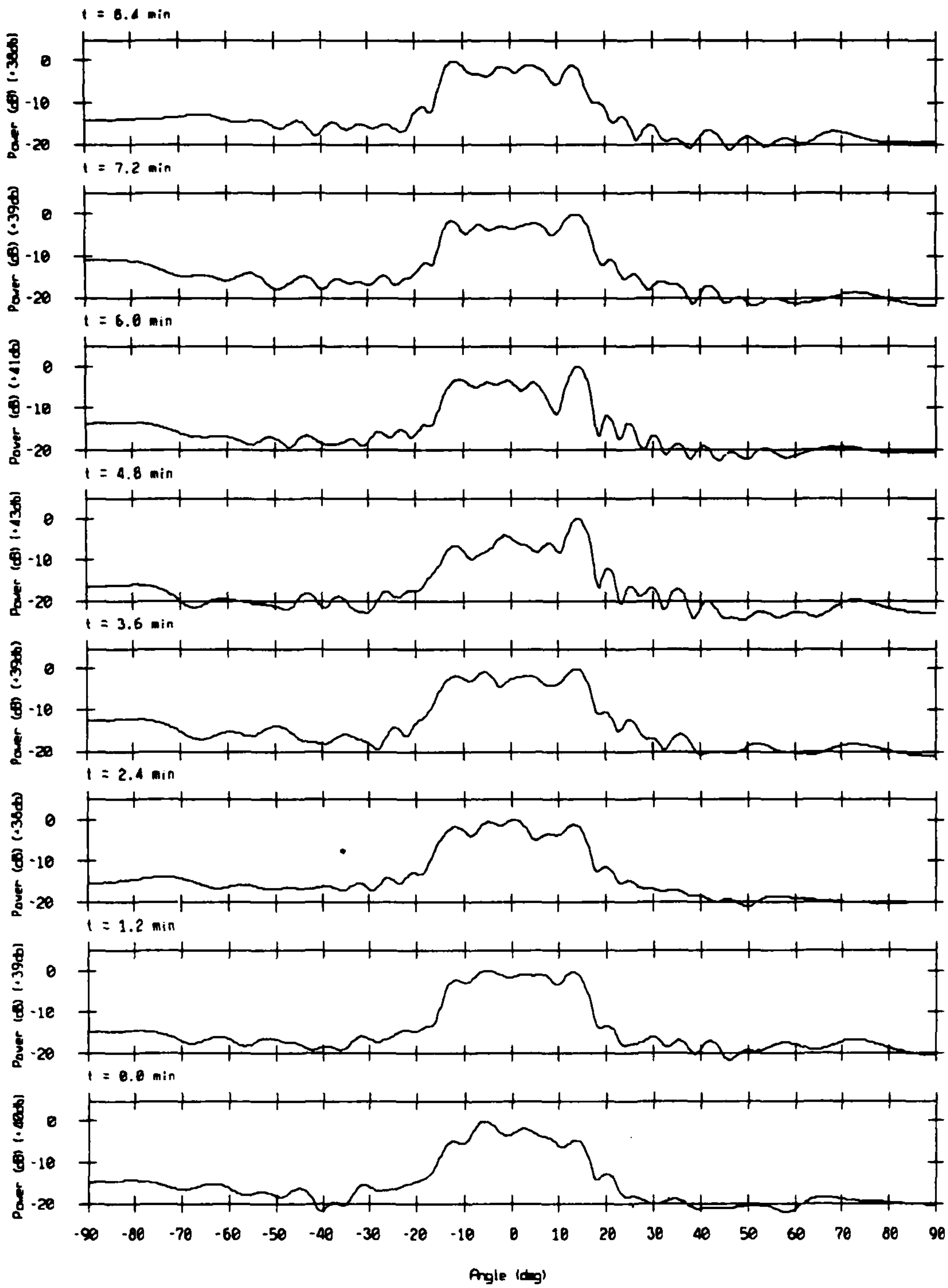


Figure 12(b).

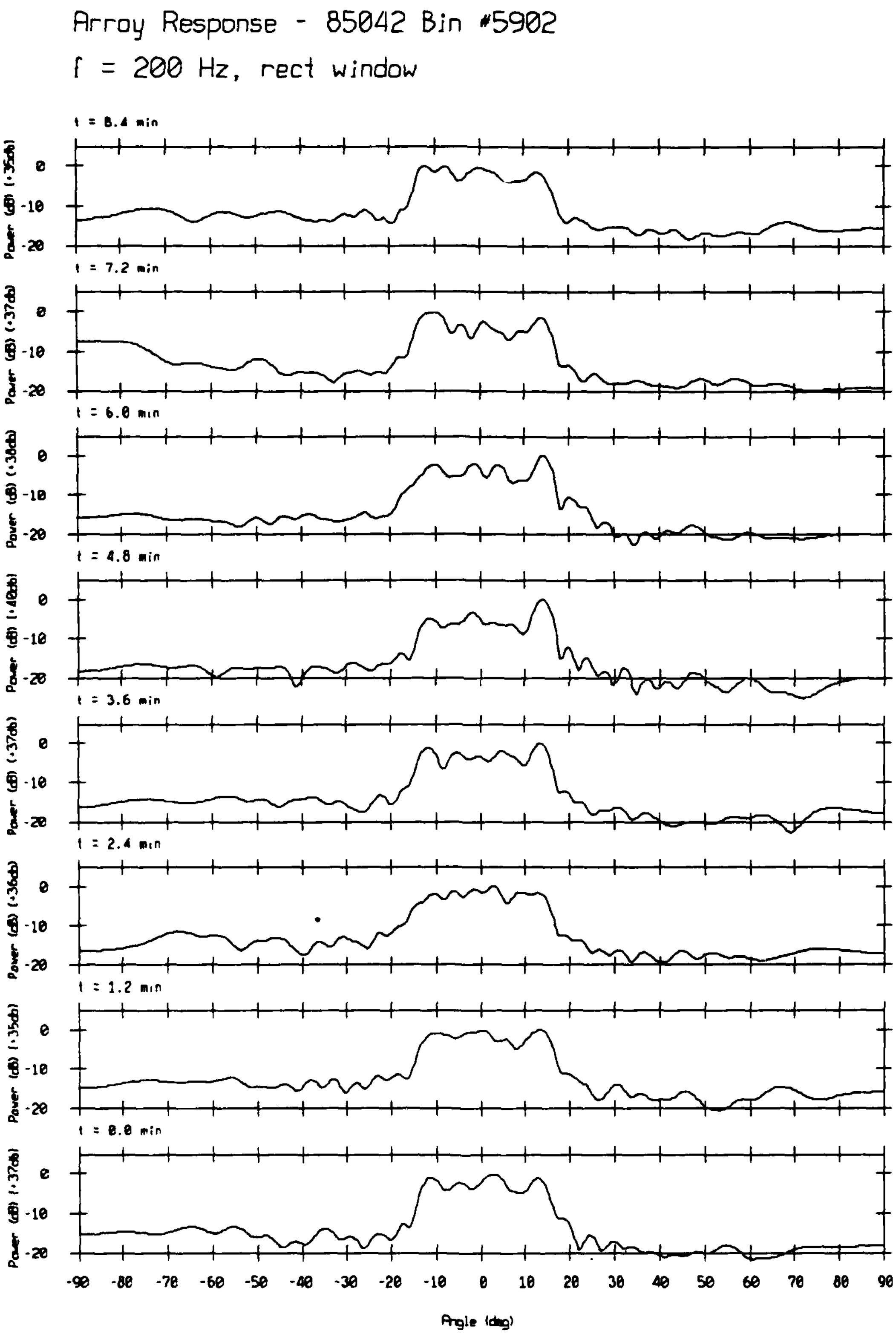

Array Response - 85042 Bin #5902
f = 200 Hz, rect window
t = 8.4 min
t = 7.2 min
t = 6.0 min
t = 4.8 min
t = 3.6 min
t = 2.4 min
t = 1.2 min
t = 0.0 min
Power (dB) (+35db)
Power (dB) (+37db)
Power (dB) (+38db)
Power (dB) (+40db)
Power (dB) (+37db)
Power (dB) (+36db)
Power (dB) (+35db)
Power (dB) (+37db)
0
-10
-20
-90 -80 -70 -60 -50 -40 -30 -20 -10 0 10 20 30 40 50 60 70 80 90
Angle (deg)

Figure 12(c).

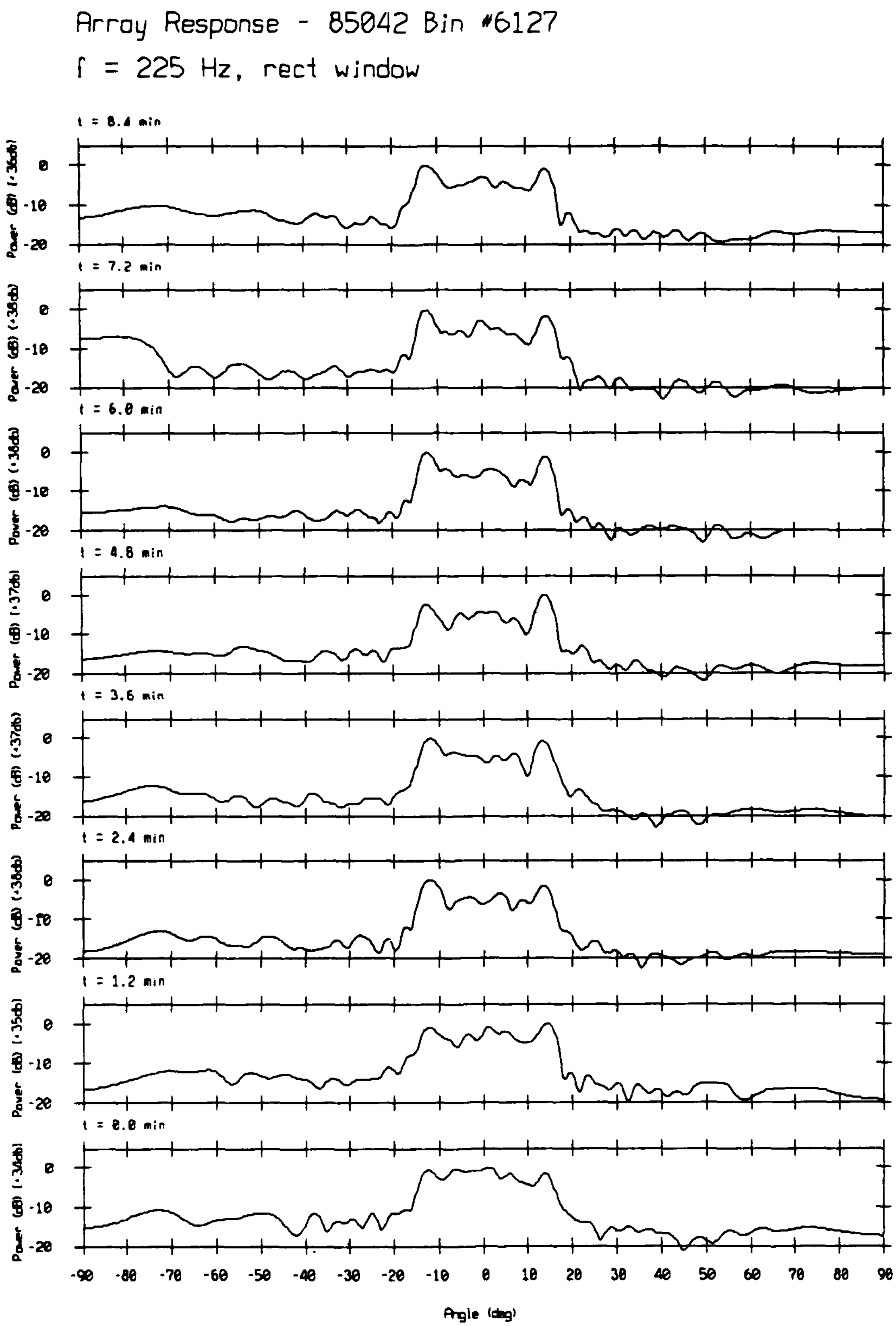

Array Response - 85042 Bin #6127
f = 225 Hz, rect window
t = 8.4 min
t = 7.2 min
t = 6.0 min
t = 4.8 min
t = 3.6 min
t = 2.4 min
t = 1.2 min
t = 0.0 min
Power (dB) (+36db)
Power (dB) (+38db)
Power (dB) (+38db)
Power (dB) (+37db)
Power (dB) (+37db)
Power (dB) (+38db)
Power (dB) (+35db)
Power (dB) (+34db)
0
-10
-20
-90 -80 -70 -60 -50 -40 -30 -20 -10 0 10 20 30 40 50 60 70 80 90
Angle (deg)

Figure 12(d).

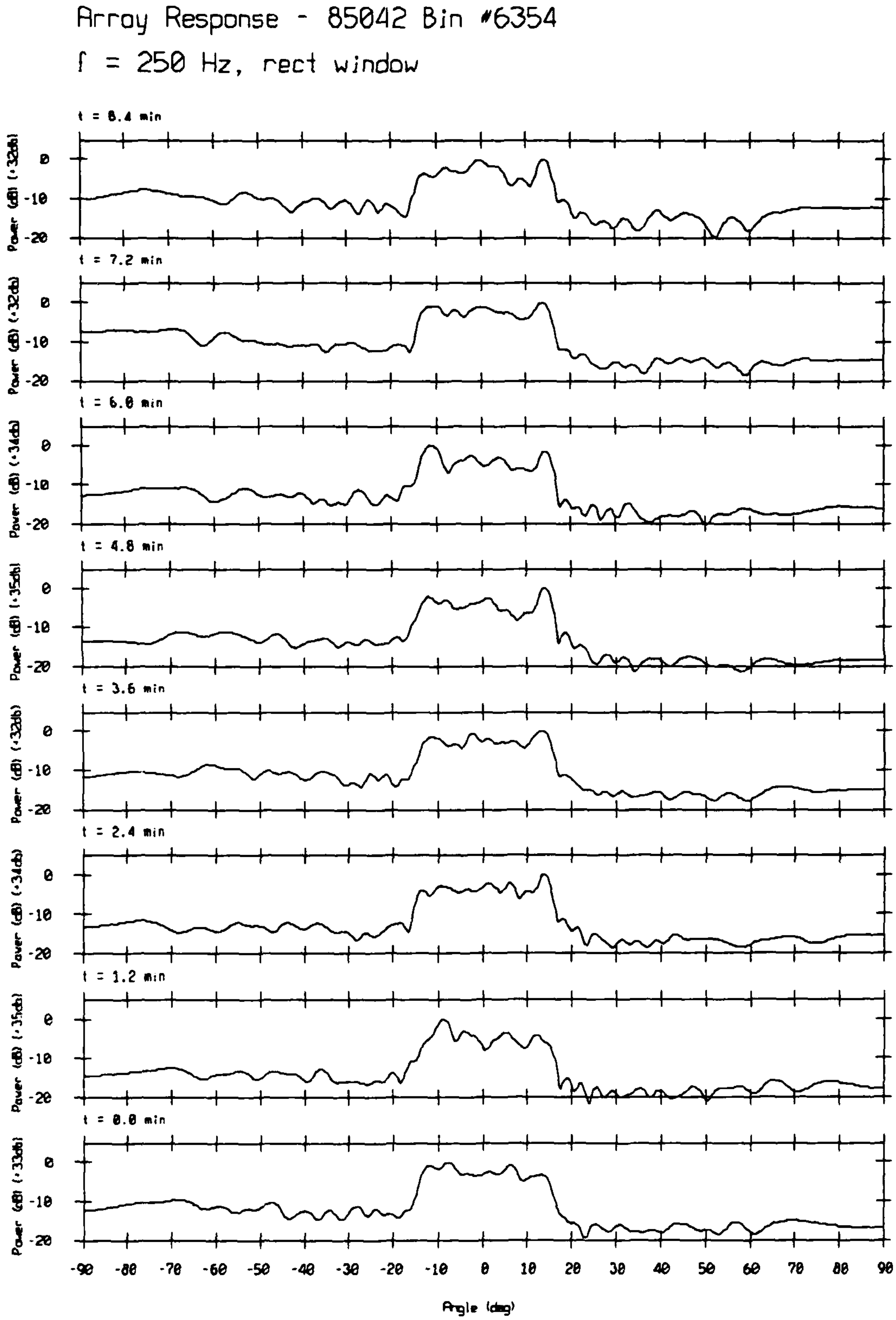
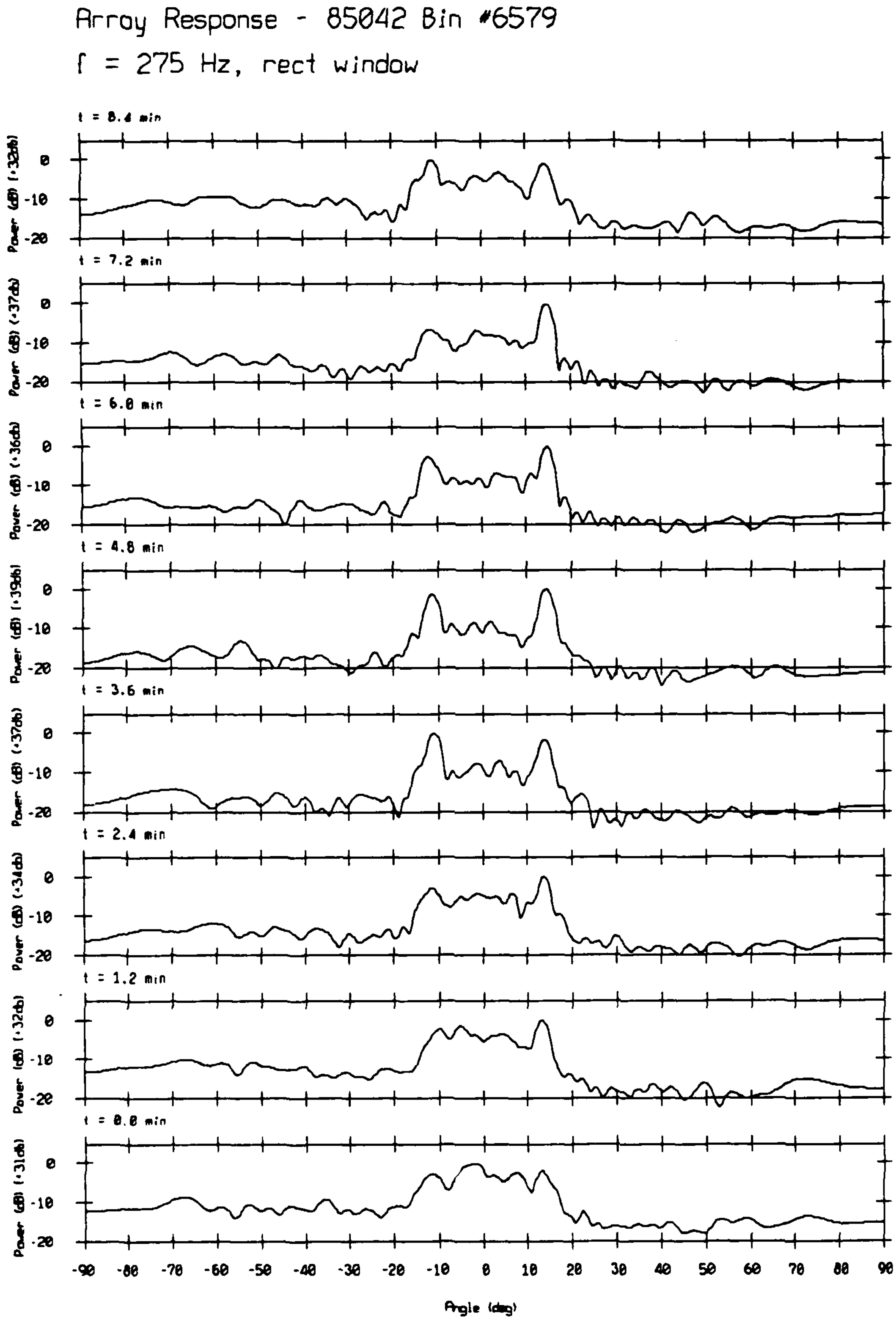

Array Response - 85042 Bin #6354
f = 250 Hz, rect window
t = 8.4 min
t = 7.2 min
t = 6.0 min
t = 4.8 min
t = 3.6 min
t = 2.4 min
t = 1.2 min
t = 0.0 min
Power (dB) (+32db)
Power (dB) (+32db)
Power (dB) (+34db)
Power (dB) (+35db)
Power (dB) (+32db)
Power (dB) (+34db)
Power (dB) (+35db)
Power (dB) (+33db)
0
-10
-20
-90 -80 -70 -60 -50 -40 -30 -20 -10 0 10 20 30 40 50 60 70 80 90
Angle (deg)

Figure 12(e).



Array Response - 85042 Bin #6579
f = 275 Hz, rect window
t = 8.4 min
Power (dB) (+32db)
t = 7.2 min
Power (dB) (+37db)
t = 6.0 min
Power (dB) (+36db)
t = 4.8 min
Power (dB) (+39db)
t = 3.6 min
Power (dB) (+37db)
t = 2.4 min
Power (dB) (+34db)
t = 1.2 min
Power (dB) (+32db)
t = 0.0 min
Power (dB) (+31db)
0
-10
-20
-90 -80 -70 -60 -50 -40 -30 -20 -10 0 10 20 30 40 50 60 70 80 90
Angle (deg)

Figure 12(f).

Array Response - 85042 Bin #6804

f = 300 Hz, rect window

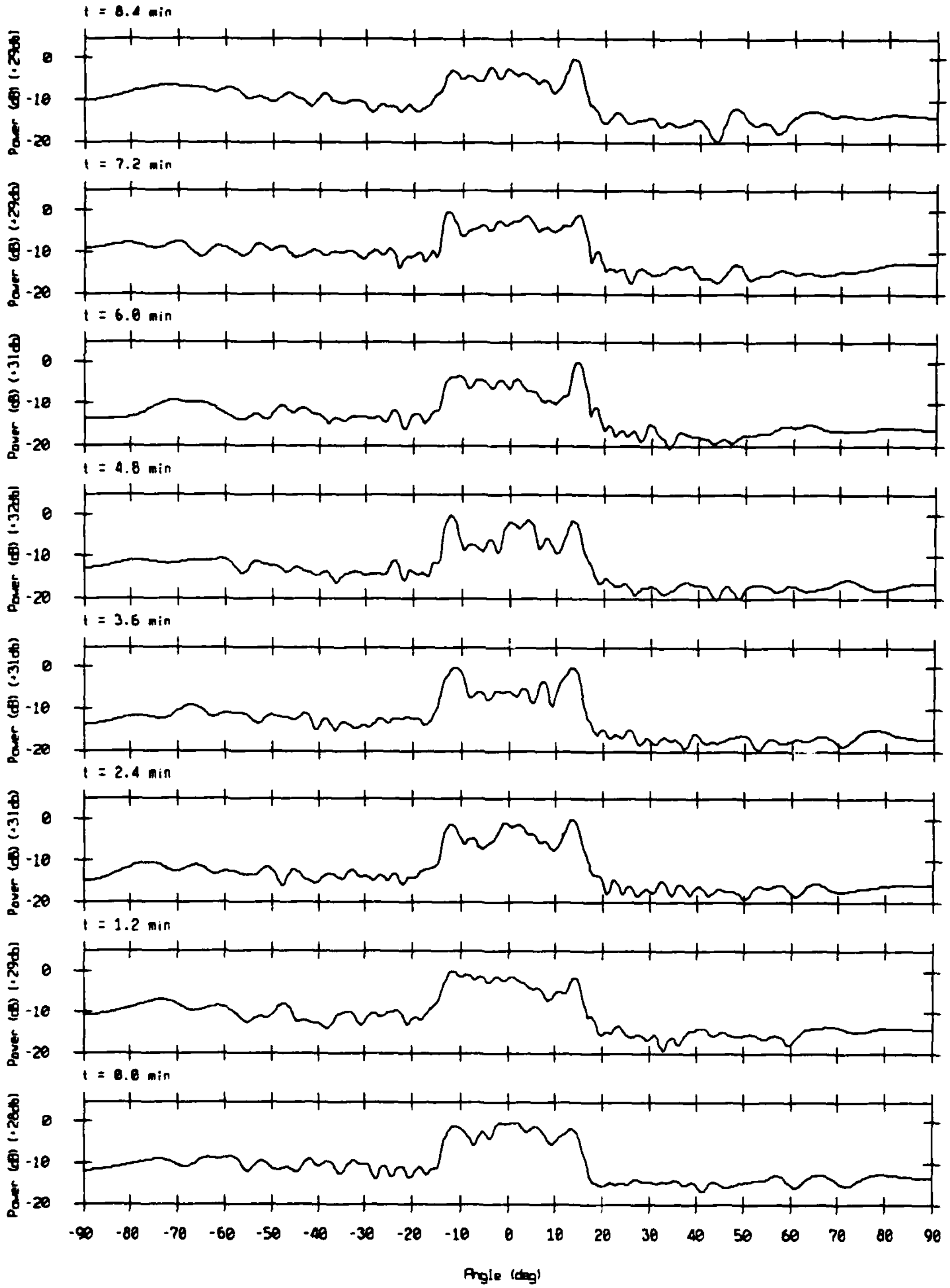


Figure 12(g).

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