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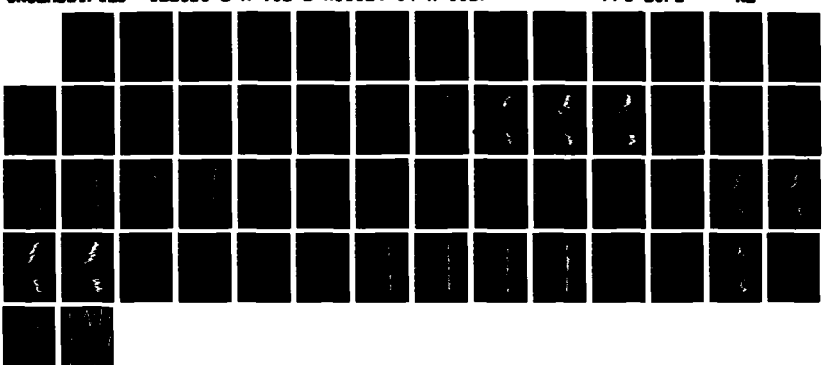

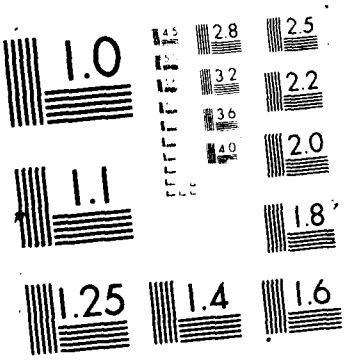
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Report 021535-2-M

(2)

1985 SOURCE MEASUREMENTS VOLUME 1: THE AUGUST 1985 HLF-5 MEASUREMENT

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In 1985, Cooley Electronics Laboratory (CEL) in conjunction with the Scripps Institution of Oceanography (SIO) and Woods Hole Oceanographic Institution (WHOI) measured the pulse responses of three acoustic sources used, or to be used, in making ocean acoustic propagation measurements. The three sources were the Hydroacoustics HLF-5 250 Hz source, the Doug Webb 400 Hz (DW-400) source and the Doug Webb 224 Hz (DW-224) source.

The basic goal of these measurements was to observe the source outputs at close range in a relatively controlled situation. Of particular interest were:

1) the source pulse response
2) the time delay through the source
3) the presence or absence of spurious pulses ("artifacts")

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1985 Source Measurements

Volume 1: The August 1985 HLF-5 Measurement

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February 3, 1986

1. Introduction

In 1985 Cooley Electronics Laboratory (CEL) in conjunction with the Scripps Institution of Oceanography (SIO) and Woods Hole Oceanographic Institution (WHOI) measured the pulse responses of three acoustic sources used, or to be used, in making ocean acoustic propagation measurements. The three sources were the Hydroacoustics HLF-5 250 Hz source, the Doug Webb 400 Hz (DW-400) source and the Doug Webb 224 Hz (DW-224) source. Both of the Webb sources have been used in past measurements. The Hydroacoustics source is a new source design and was undergoing acceptance testing. The HLF-5 was tested in April and August at Navy's Lake Seneca test facility and in October at sea off of San Diego. The two Webb sources were tested in August at Lake Seneca.

The basic goal of these measurements was to observe the source outputs at close range in a relatively controlled situation. Of particular interest were:

1) the source pulse response
2) the time delay through the source
3) the presence or absence of spurious pulses ("artifacts")

The results of these tests are contained in four separate volumes sharing a common introduction (this one).

At Lake Seneca the basic test procedure was as follows:

1. A BCSG-80 signal source was used to generate a sinusiodal carrier phase modulated using a binary linear maximal sequence to select phases. The specific sequence and the number of carrier cycles per modulation digit were varied depending on the measurement.

2. For the case of the HLF-5, the BCSG-80 output was fed to a Krohn-Hite power amplifier which was used to drive the source. Input pulse measurements were made at the Krohn-Hite output.

   For the DW sources, the BCSG-80 output was fed to a special clipper/drive box (supplied by WHOI) with the output of this box feeding the source electronics. The input pulse measurements were made at the BCSG-80 output.

3. The source output was monitored using a hydrophone suspended some distance away from the source. The output of this hydrophone was amplified and low pass filtered (1.5 KHz 2-pole Butterworth) before being fed to CEL's processing equipment.

4. The input waveform was sampled using a 12-bit A/D converter that was configured so that it emulated the

operation of one of CEL's beamformer outputs. This allowed it to directly feed the input of a one channel complex demodulator.

5. For the HLF-5 and DW-400 sources, demodulates were formed over half carrier cycles. For the DW-224 source they were formed over full carrier cycles.

6. Demodulates were circulating summed using a buffer length corresponding to the length of modulating sequence being used multipled by the number of samples per digit being taken.

7. Once a specified number of periods had been summed, the circulating sum was written onto cartridge tape for later processing and analysis.

8. The circulating sum was also processed on-line. This processing included pulse compression, generation of a display and estimation of the peak signal-to-noise ratio. The processed results were for "real time" use only and were not saved.

The October measurement of the HLF-5 source differed in that the drive waveform was generated by the SIO AVATAR system. The processing steps outlined above starting with step 3 apply.

As with most measurements, various problems arose, decisions (some good, some not so good) had to be made, parameter values were varied, and unexpected results were observed. As a consequence, sometimes parameters that should have been held constant were varied and measurements that should have been included were not. In particular, the number of periods summed together was often varied as the sequence length or digit duration varied. This was easily corrected for as a scale factor change and many of the plots have been suitably normalized in order to facilitate amplitude comparisons. In the case of the DW sources, the duration of the impulse response was much longer than expected and the longest digit durations used were shorter than otherwise would have been desirable. This problem was worked around by using the longest digit duration data to synthesize the results that would have been obtained had longer duration digits been used. The accuracy of this method was checked by using short digit responses to synthesize longer digit responses and then checking these against actual measurements. The long digit predicted and the test prediction results are both included.

The spectra contained in these volumes was formed in the following manner:

1. The circulating sums were read off of tape and processed to remove the effects of the binary sequence used to time spread the signal energy.

2. The location of the digit response peak was determined. This value was used to compute an index value "half way around the circle."

3. Starting at this index, a sufficient number of complex zeros were added to make the number of values equal to an integer power of two.

4. The DFT was formed using an FFT subroutine. The DFT magnitudes were plotted in dB.

The efficacity of this approach was tested by taking the inverse transforms of some data processed using the above procedure and comparing the results against the original data.

The four volumes making up this report are sub-titled:

Volume 1: The August 1985 HLF-5 Measurement

Volume 2: The August 1985 DW-400 Measurement

Volume 3: The August 1985 DW-224 Measurement

Volume 4: The October 1985 at Sea HLF-5 Measurement

2. Overview of the Data Sets

The August HLF-5 data were divided into three sets. In all cases, the test waveforms were generated using the BCSG-80 generator amplified by a Krohn-Hite amplifier. The reference digit waveforms were measured at the Krohn-Hite output. The carrier frequency was 250 Hz. The modulation angle was 15/64 th's of a cycle. The source was not pressure compensated. Demodulates were formed over half carrier cycles giving twice the number of samples per digit as there were carrier cycles per digit.

For set one, the source was at a depth of 306 feet and separated from the monitor hydrophone by 40 feet and 2 inches. The phone was placed at a depth corresponding to that of the center of the source. For a 250 Hz carrier and half-cycle demodulates, the separation corresponded to a time delay of approximately 4.3 demodulates (8.6 ms). A 255 digit binary linear maximal sequence was used to produce the modulation. The drive level to the source was set at 7 volts rms.

For set two, the drive level was reduced to 3.5 volts rms. All other parameters were left unchanged.

For set three, the source was lowered to 446 feet and the monitor hydrophone was placed 27 feet higher than the source at a horizontal distance of 40 feet and 2 inches. The source level was left at 3.5 volts rms.

3. Discussion of the Data Sets

3.1 Data Set One

Plots 1 through 4 show the transducer response to digits of length 1, 2, 4 and 8 cycles. Also shown are the associated drive waveforms shifted by 4.3 demodulate times to account for the propagation delay between the source and the monitor hydrophone. The digit responses have been scaled so that they are in correct amplitude relation to each other. The peak value of the eight cycle digit response was plotted as an amplitude of one.

Based on these plots it appears that four cycles of carrier per digit would be a reasonable choice of digit duration. For this case the delay from the leading edge of the drive digit to the peak of the pulse response is approximately 15 ms. There is a small amount of ringing present.

Plots 5 through 8 are of the phases associated with the digit responses presented in plots 1 through 4.

Plots 9 through 12 are of $20\log_{10}$ of the magnitudes of the DFTs of the plot 1 through 4 digit responses. These plots are individually normalized so that the largest spectral line plots at the 0 dB level. The horizontal axis runs from 0 Hz (far left side) through 500 Hz (far right side). Because the number of points per data set doubles

between succeeding plots, the frequency resolution increases correspondingly.

The plots tell us at least the following:

1. Aside from item 3 below, there are no significant anomalous dips or peaks in the HLF-5 transfer function.

2. There was a significant amount of 60 Hz interference present. This was due to ground loop problems.

3. There are spectral lines in the nulls of the transforms of the digit responses. Because these lines only appear in the nulls they are related to the digit duration. After some amount of soul searching, it is felt that these lines are indeed produced by the HLF-5. The reasons for this are: a) they are not present in the spectra formed using the data taken at the drive input to the HLF-5, b) no similar effect was observed for either the DW-400 or DW-224 sources and, c) with some imagination they also appear to be present in the October dip test DFTs.

Plots 13 through 19 are full period dB plots of the digit response of the transducer. A 255 digit sequence was used in all cases. The scale on the x-axis is the same for all plots. The start times of the various runs were not synchronized. These plots are normalized so that the peak amplitude in the 8 cycle per digit response (not included) plots at the zero dB point.

These plots are intended for use in establishing the severity of the "artifact" problem. The "artifact" is caused by an interaction of nonlinearity in the source along with the filtering caused by the source. The artifact arises when energy from one digit interval "rings" over into succeeding digit intervals and interacts in a nonlinear fashion with the succeeding digits' energy. Using the "shift-and-add" property of linear maximal sequences, the locations of the most energetic artifacts can be predicted. The amplitudes of the artifacts generally tend to decrease as the digit duration is increased. This is because proportionally less energy "rings" into adjacent digit intervals. The data used to generate these plots was obtained without any pressure compensation of the source. The data obtained during the October 1985 depth test shows similar artifact performance.

For the 765_8 sequence law (generates a 255 digit sequence), the major artifact locations relative to the main digit response are at digit positions 121, 242, and 179. These locations are listed in order of decreasing expected magnitude. Position 121 corresponds to what is called the 011 artifact, position 242 the 101 artifact, and position 179 the 111 artifact. The 011 artifact is the result of interaction between two adjacent digits, the 101 artifact is

the result of interaction between digits spaced two apart, and the 111 artifact is the result of interaction between three adjacent digits. In the data observed to date, these represent the dominant artifacts.

For the given measurement geometry, the surface bounced arrival followed the main arrival by about 123 ms (61.6 demodulate times).

Plot 13 shows the entire period of the one-cycle per digit response. On the plotted scale, digits are of length two. The main arrival is located at position 82, the surface arrival is not obvious, and there are two strong spurious responses corresponding to artifacts 011 and 111. The 101 artifact can be seen just in front of the main arrival but is smaller than expected. The reason for this is not understood, but then again, the mechanism by which these are generated is not understood either.

Plots 14 and 15 show the full period of the two cycles per digit response. The surface arrival can be seen just following the main arrival. The largest artifact is the 011, followed by the 101.

Plots 16 through 19 are of the full period of the four cycles per digit response. The surface bounce is readily visible as is the 011 artifact. The 101 artifact is significantly reduced.

3.2 Data Set Two

Data set two repeated the data set one parameters with the HLF-5 drive level reduced from 7 volts rms to 3.5 volts rms. The peak digit response values (unadjusted to account for varying numbers of circulating sums) for both data sets are listed below.

Cycles/digit	Max Peak (3.5 vrms)	Max Peak (7 vrms)	Ratio
1	1640437	1889155	0.87
2	2103717	2121372	0.99
4	1333409	1543955	0.86
8	680890	800863	0.85

The peak levels did not change in the same proportion as the drive level. At the time the data was taken it was acknowleged that the 7 vrms level was probably overdriving the source so this result is not unexpected.

Plots 20 through 23 are linear plots of driving digit overlayed on plots of the corresponding digit responses. The 4.3 demodulate propagation time has been removed as in plots 1 through 4. There appears to be somewhat more overshoot in these digit responses than was present in the 7 vrms results. However, there are no other major differences in the shapes of the digit responses. The phases associated with the digit responses are plotted in plots 24 through 27. The phases seems to roll faster going across the digit responses than in the 7 vrms cases. This is probably

associated with the additional overshoot.

Plots 28 through 31 are of the DFTs of the digit responses of plots 20 through 23. These differ from their 7 vrms counterparts in that the shoulder area around 375 Hz is higher.

Plots 32 through 38 are full period dB plots of the 3.5 vrms 1, 2, and 4 cycle digit responses. These plots are normalized so that the peak amplitude of the 8 cycle digit response (not included in this set) corresponds to 0 dB.

Plot 32 is of the single cycle digit response. The 011, 101 and 111 artifacts are all clearly visible. Some of the ripples may correspond to other higher order artifacts.

Plots 33 and 34 are of the two cycle digit response. The 011, 101, 111 and 1011 artifacts are easilly spotted. The 101 artifact is down from the one cycle level and the 1011 artifact is plainly visible. The surface reflection of the main pulse can clearly be seen.

Plot 35 shows the processed drive waveform used to produce the digit response shown in plot 36. This plot gives some idea of the noise floor of the processing and shows a small amount of tailing off of the digit. This tailing off is most likely due to the use of a long coax cable and has not been seen in direct connection lab tests. A lab test with a long coax cable will be made.

Plots 36 through 39 are of the four cycle digit response. Only the 011 artifact stands out. The surface reflection is very well defined. There appears to be sharp build up of "incoherent" energy just following the main pulse. This energy decays slowly following the pulse. This energy is probably due to volume reverberation.

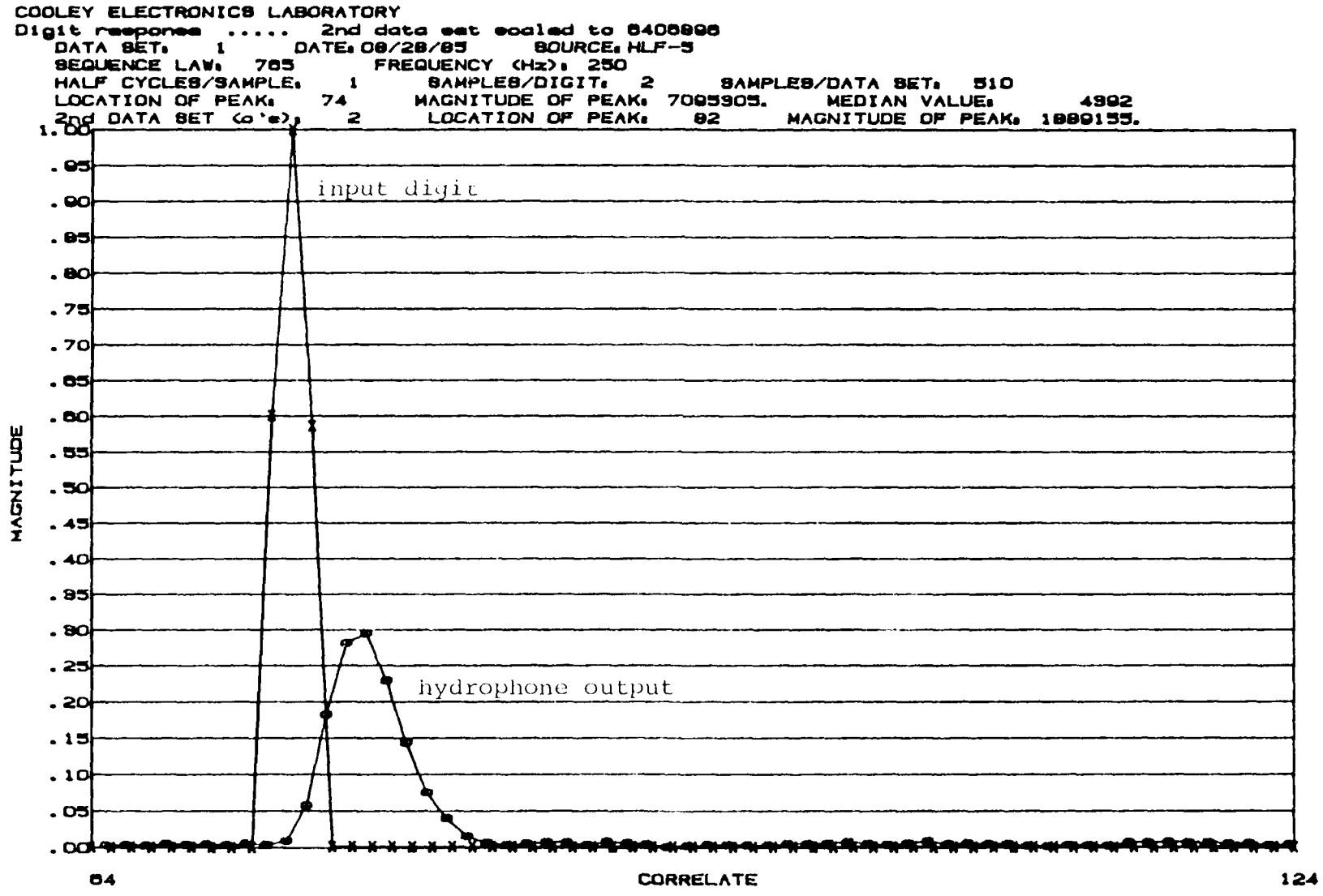
3.3 Data Set Three

Data set three involved lowering the HLF-5 to a depth of 446 feet with the monitor hydrophone having the same horizontal spacing as in data sets one and two but being positioned 27 feet higher than the HLF-5. Because of the lateness of this run only a few data sets were taken. The results of one of these is presented in plots 40 through 44. These plots are for a two cycle digit.

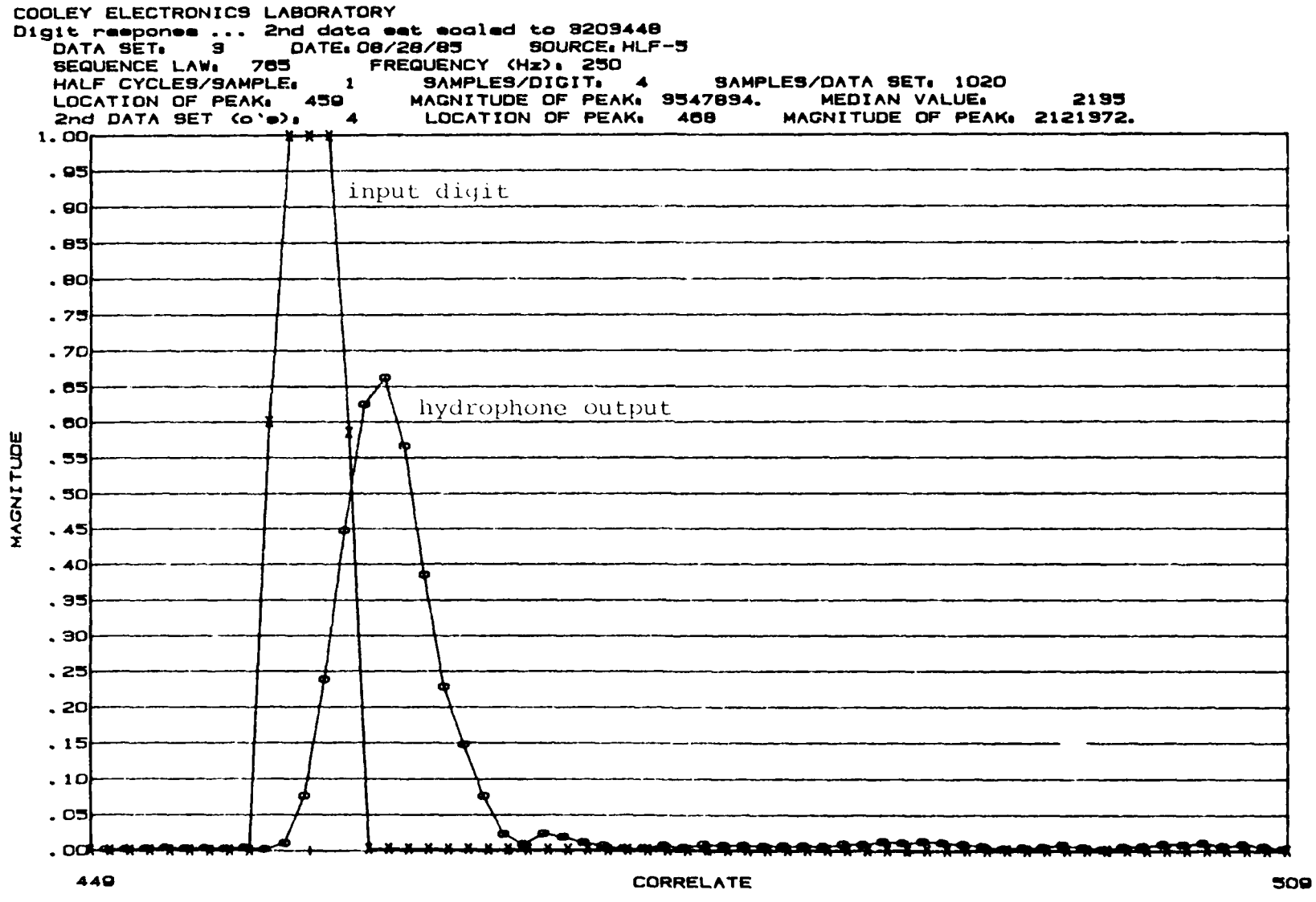
Plots 40 and 41 are of the magnitude and phase of the region around the main digit. Plot 40 shows both the drive digit and the associated response. The direct path propagation time has been removed.

Plot 42 shows the DFT of the digit response.

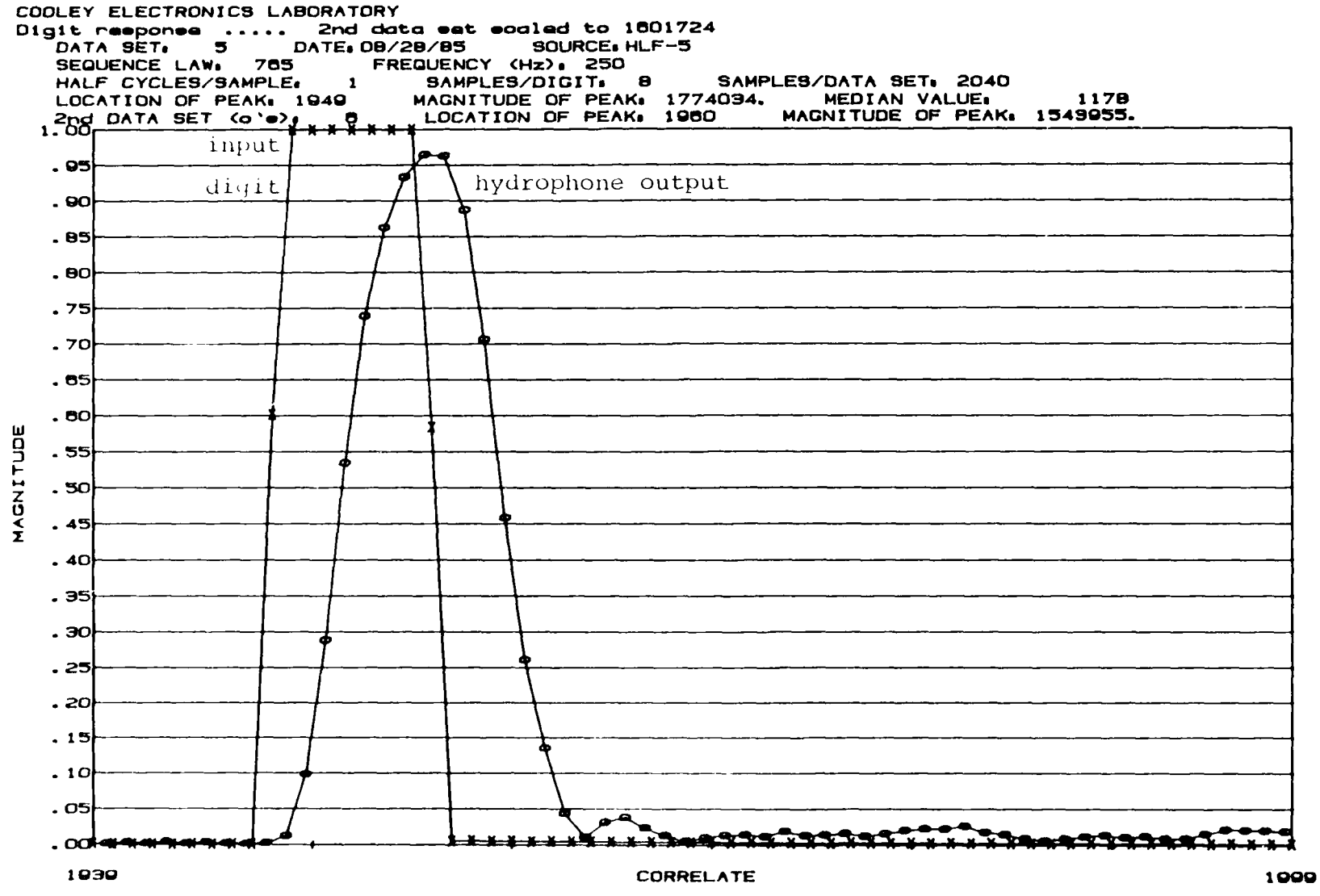
Plots 43 and 44 make up the full period dB plot of the magnitude of the digit response. The 011, 101, and 111 artifacts are very apparent as is the surface reflection of the main response.



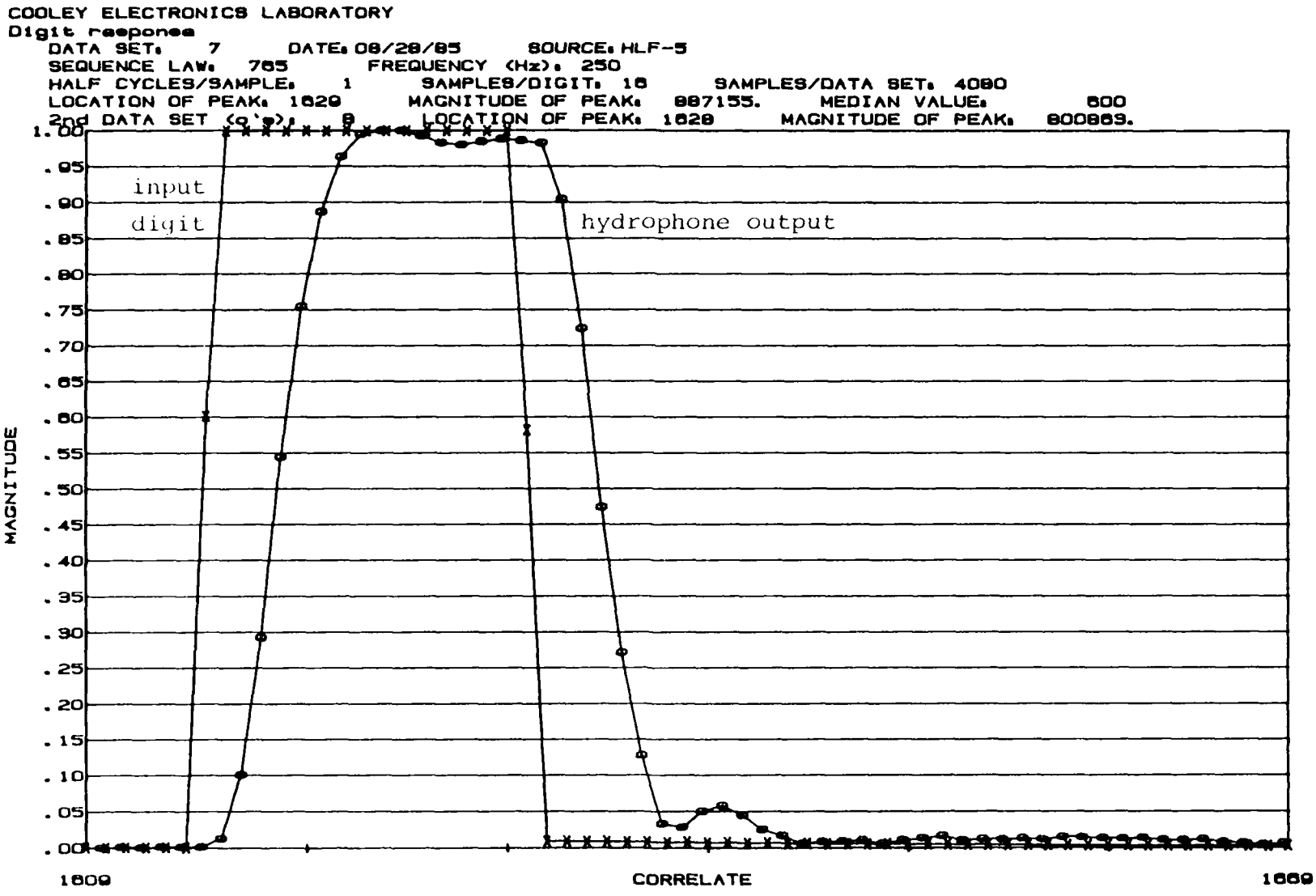
Plot 1. One cycle digit response, direct path delay removed.
Drive level = 7 vrms.



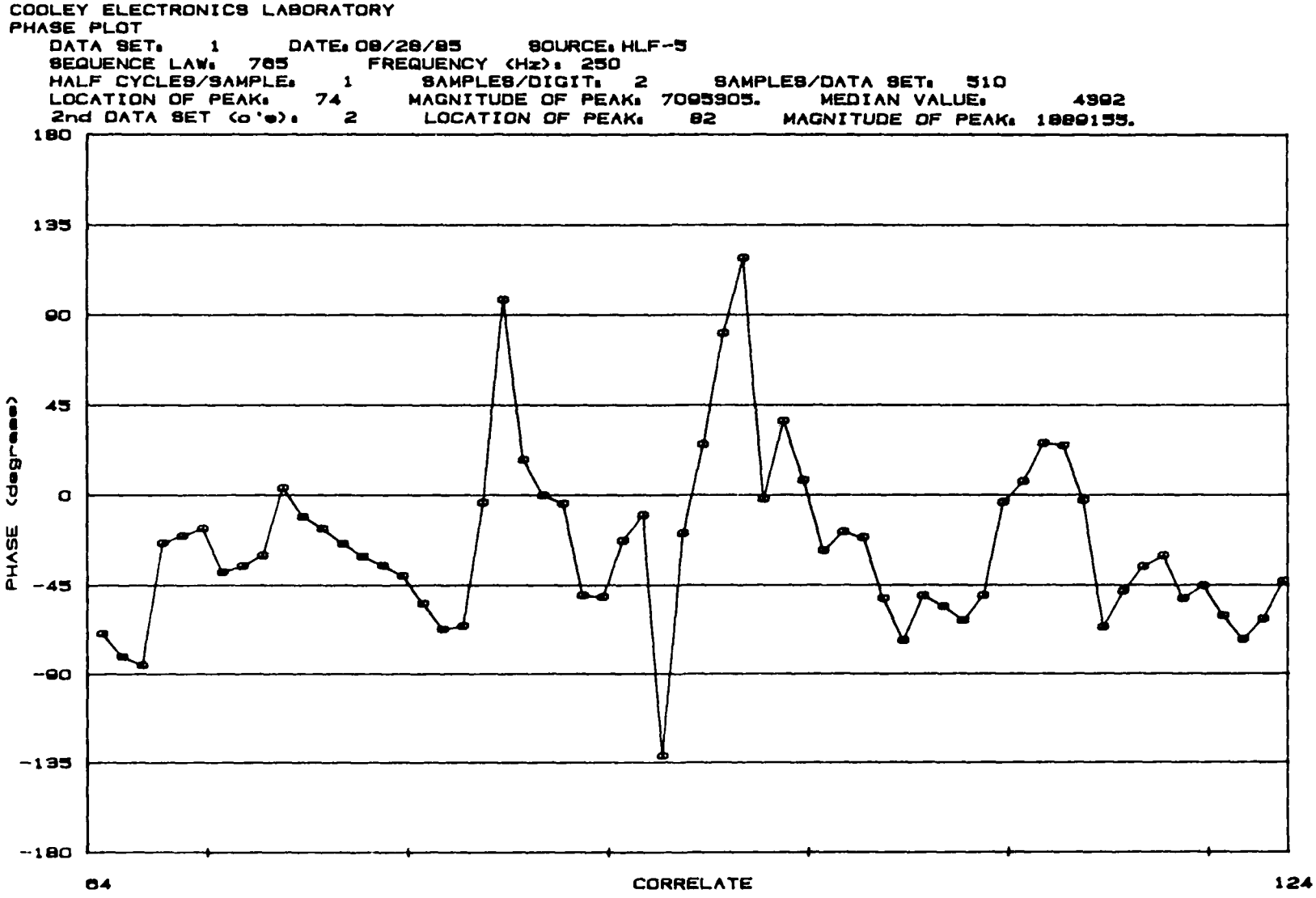
Plot 2. Two cycle digit response, direct path delay removed. Drive level = 7 vrms.



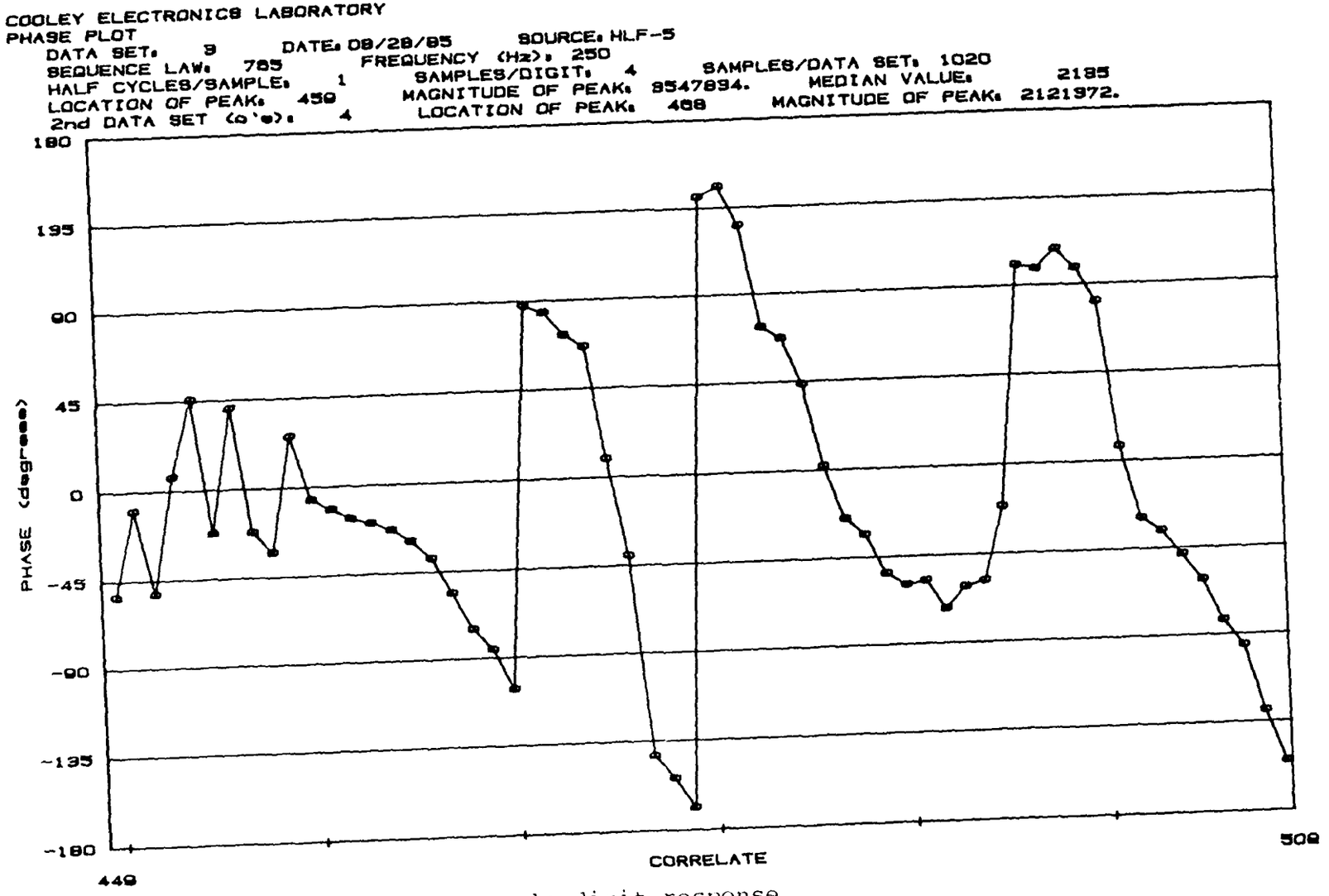
Plot 3. Four cycle digit response, direct path delay removed. Drive level = 7 vrms.



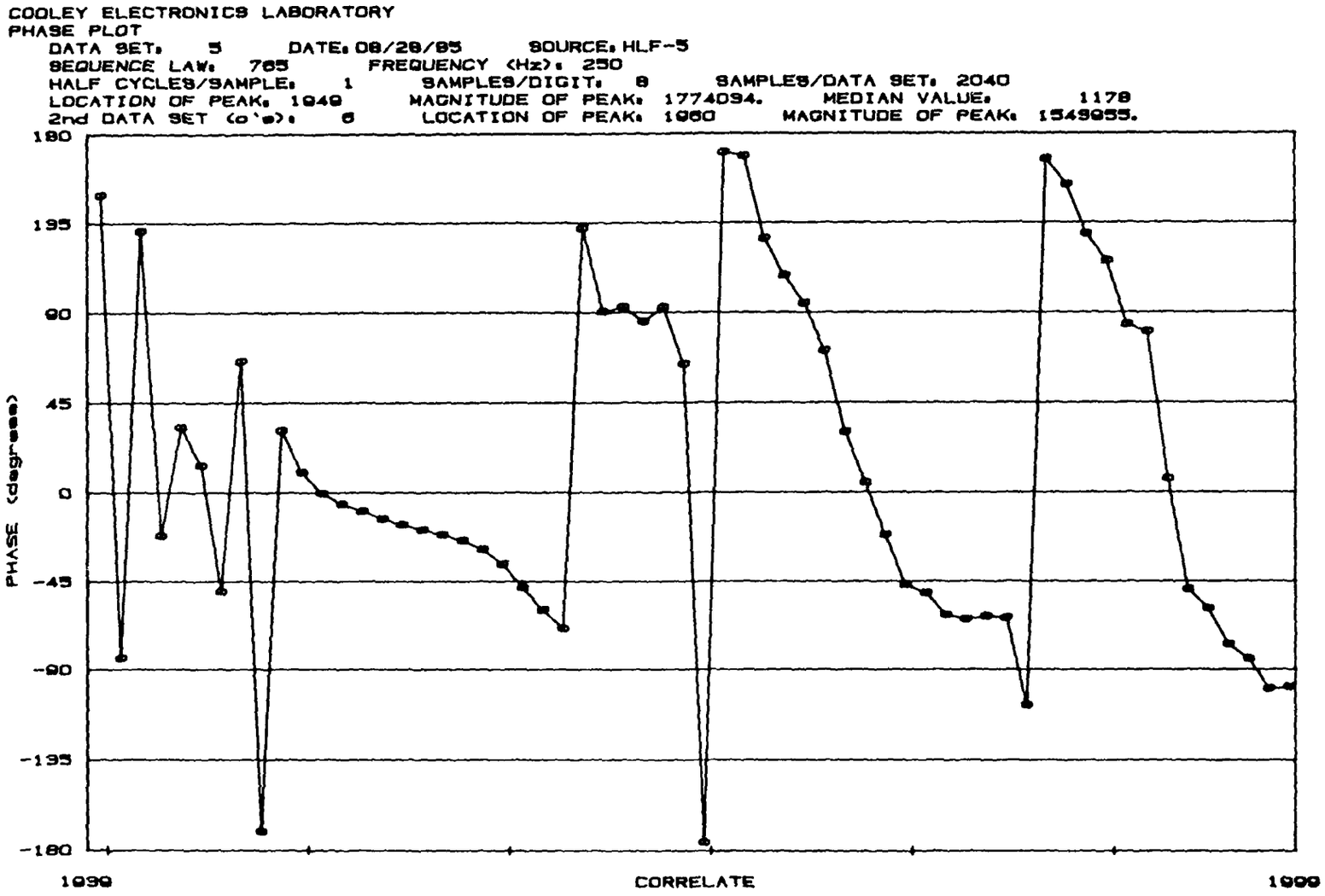
Plot 4. Eight cycle digit response, direct path delay removed. Drive level = 7 vrms.



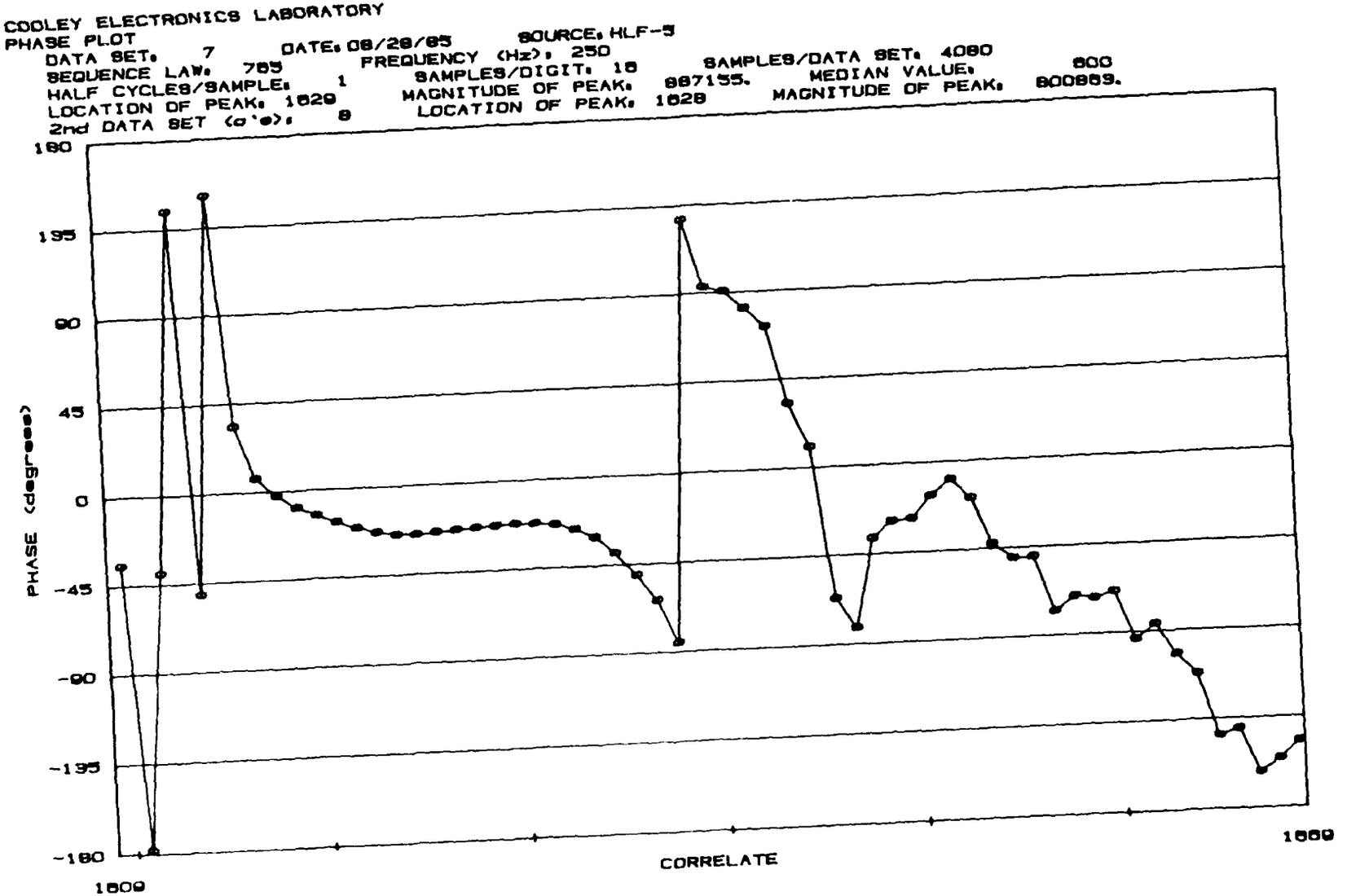
Plot 5. Phase of the one cycle digit response.
Drive level = 7 vrms.



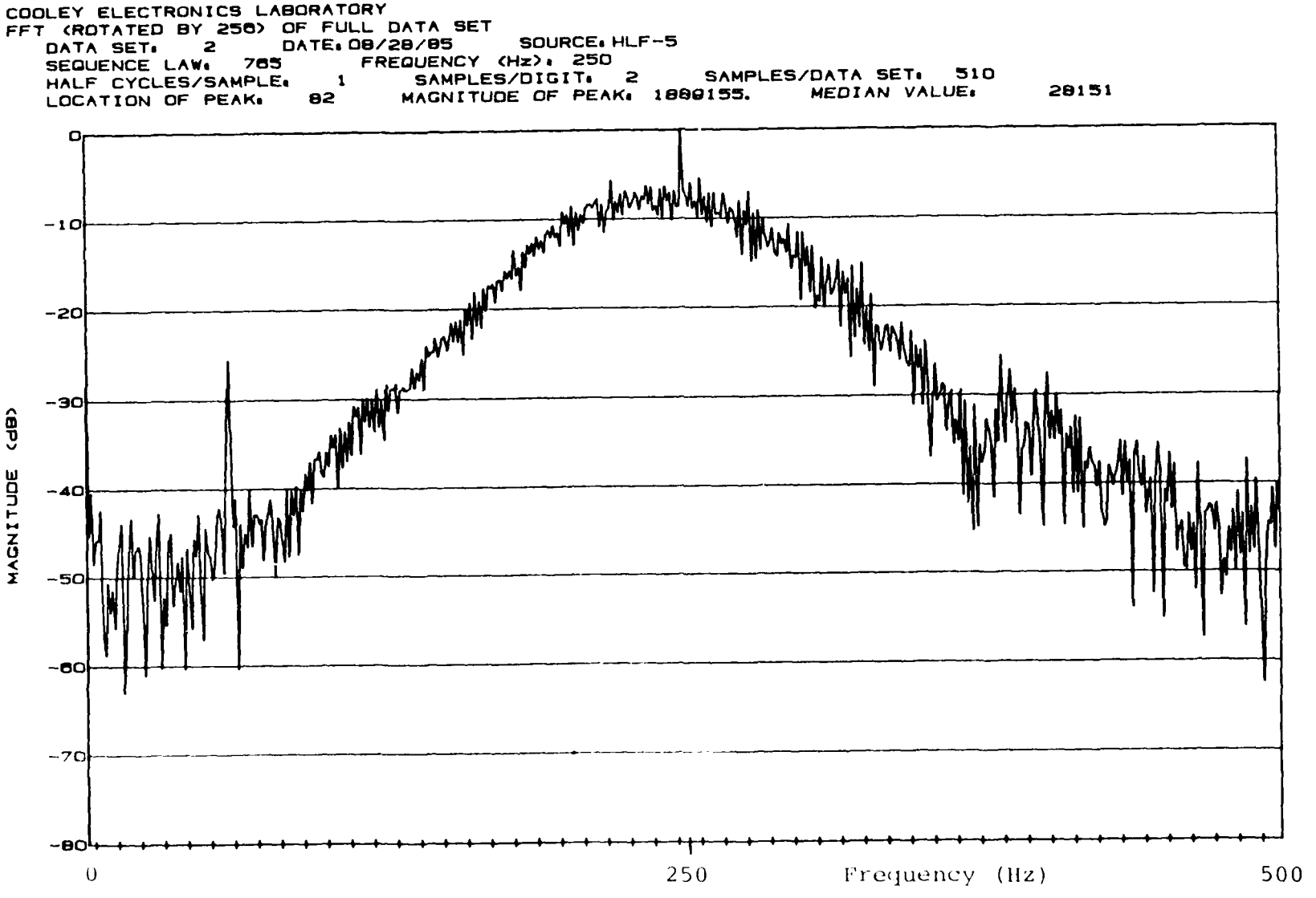
Plot 6. Phase of the two cycle digit response.
Drive level = 7 vrms.



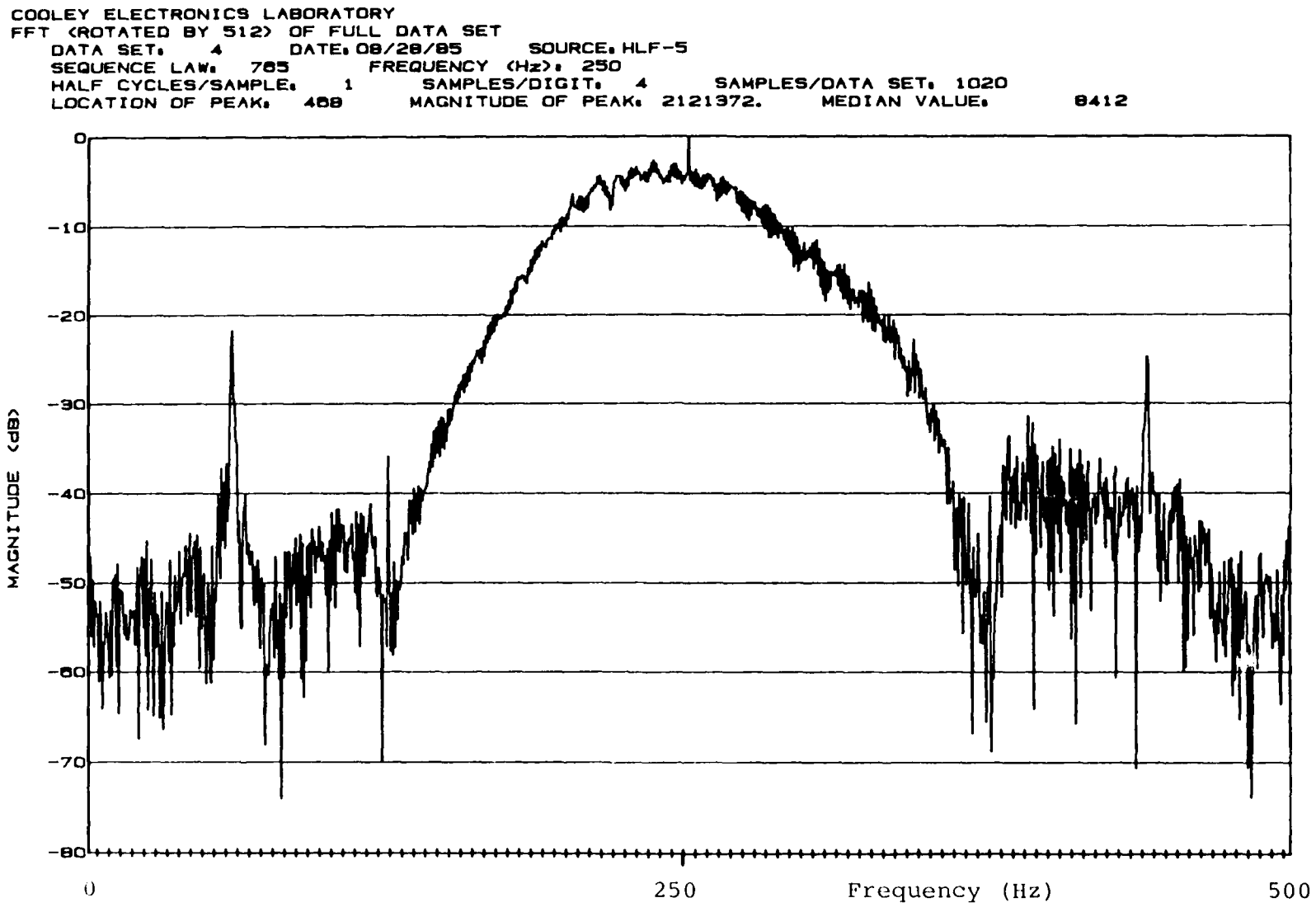
Plot 7. Phase of the four cycle digit response. Drive level = 7 vrms.



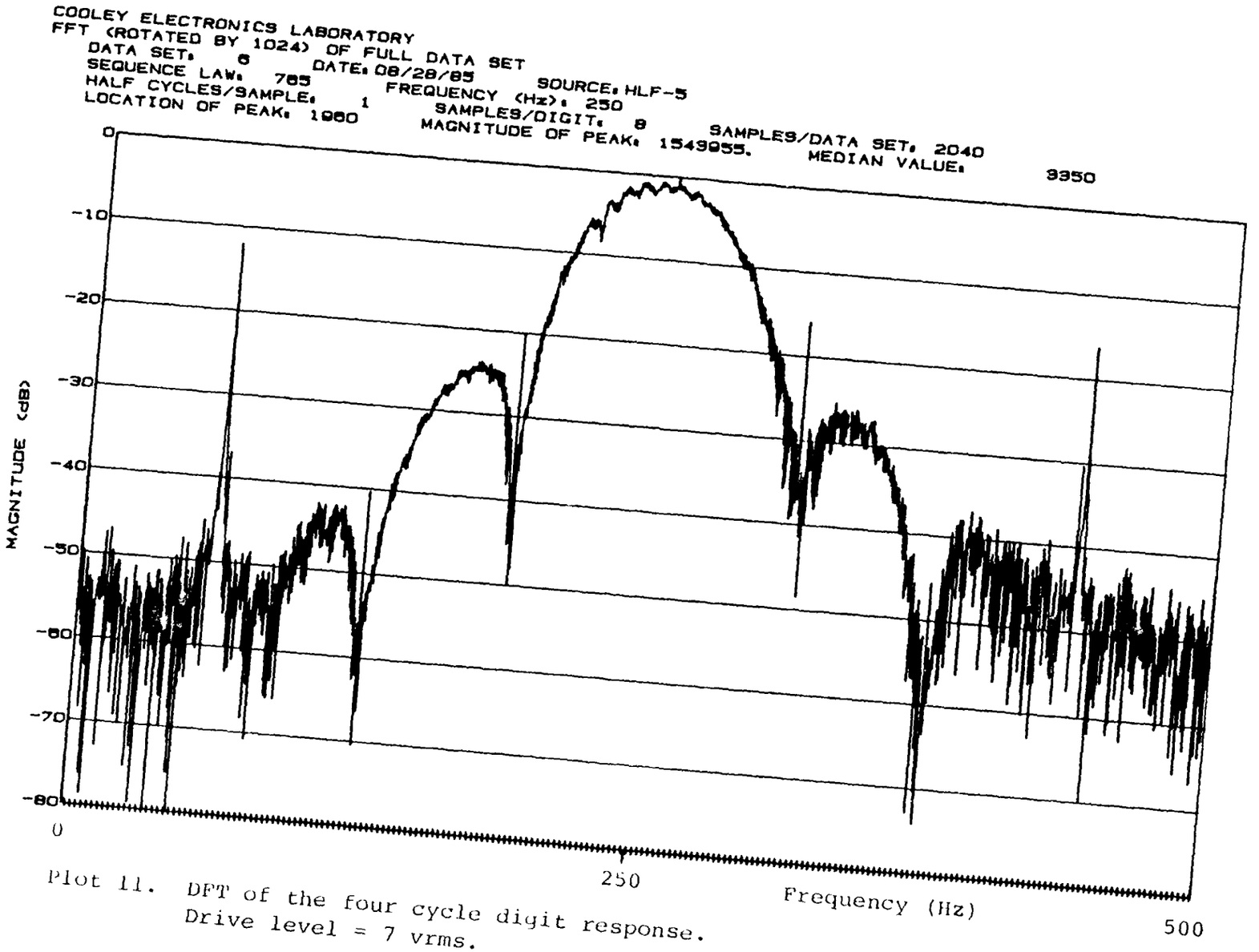
Plot 8. Phase of the eight cycle digit response.
Drive level = 7 vrms.



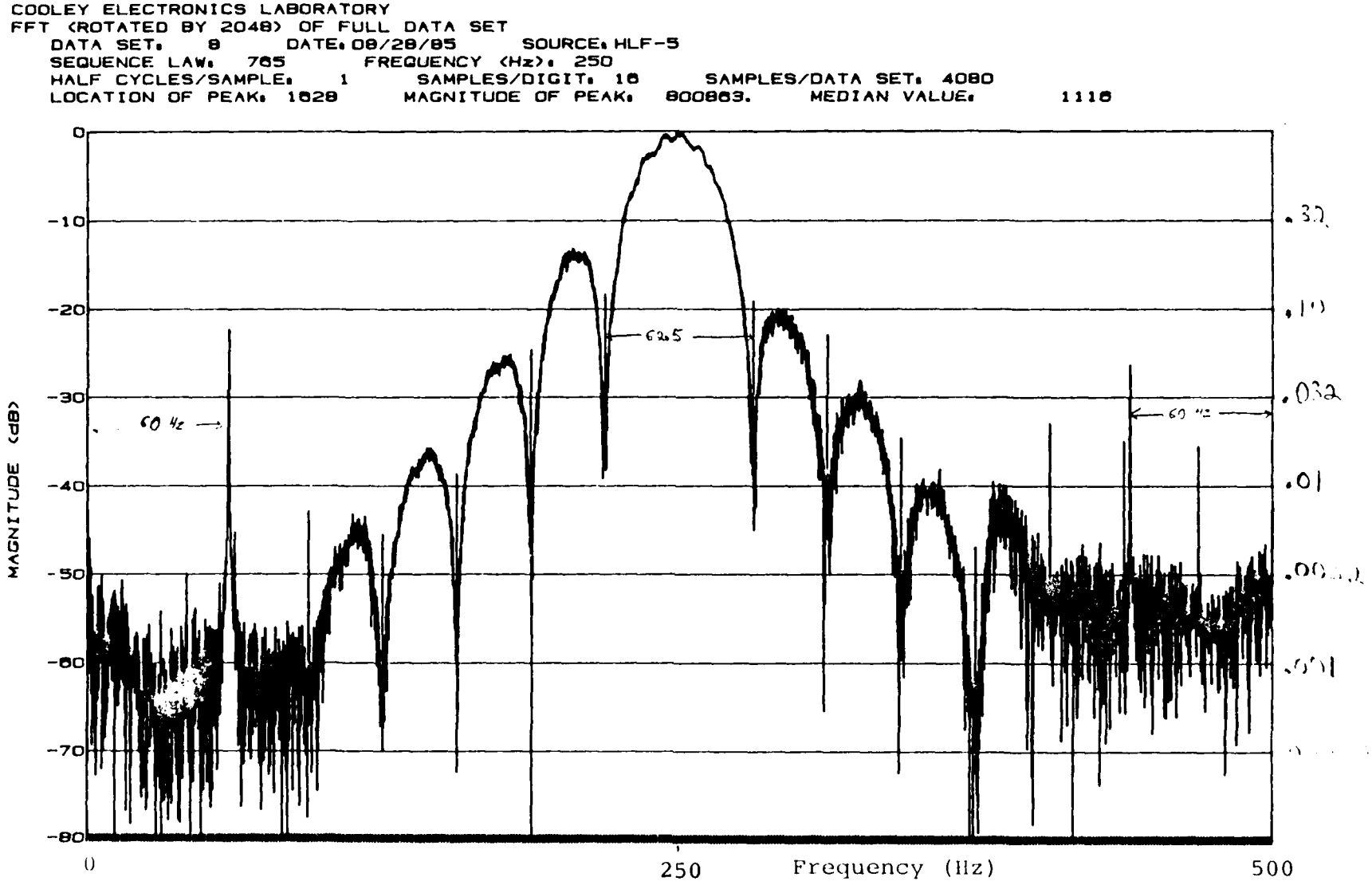
Plot 9. DFT of the one cycle digit response.
Drive level = 7 vrms.



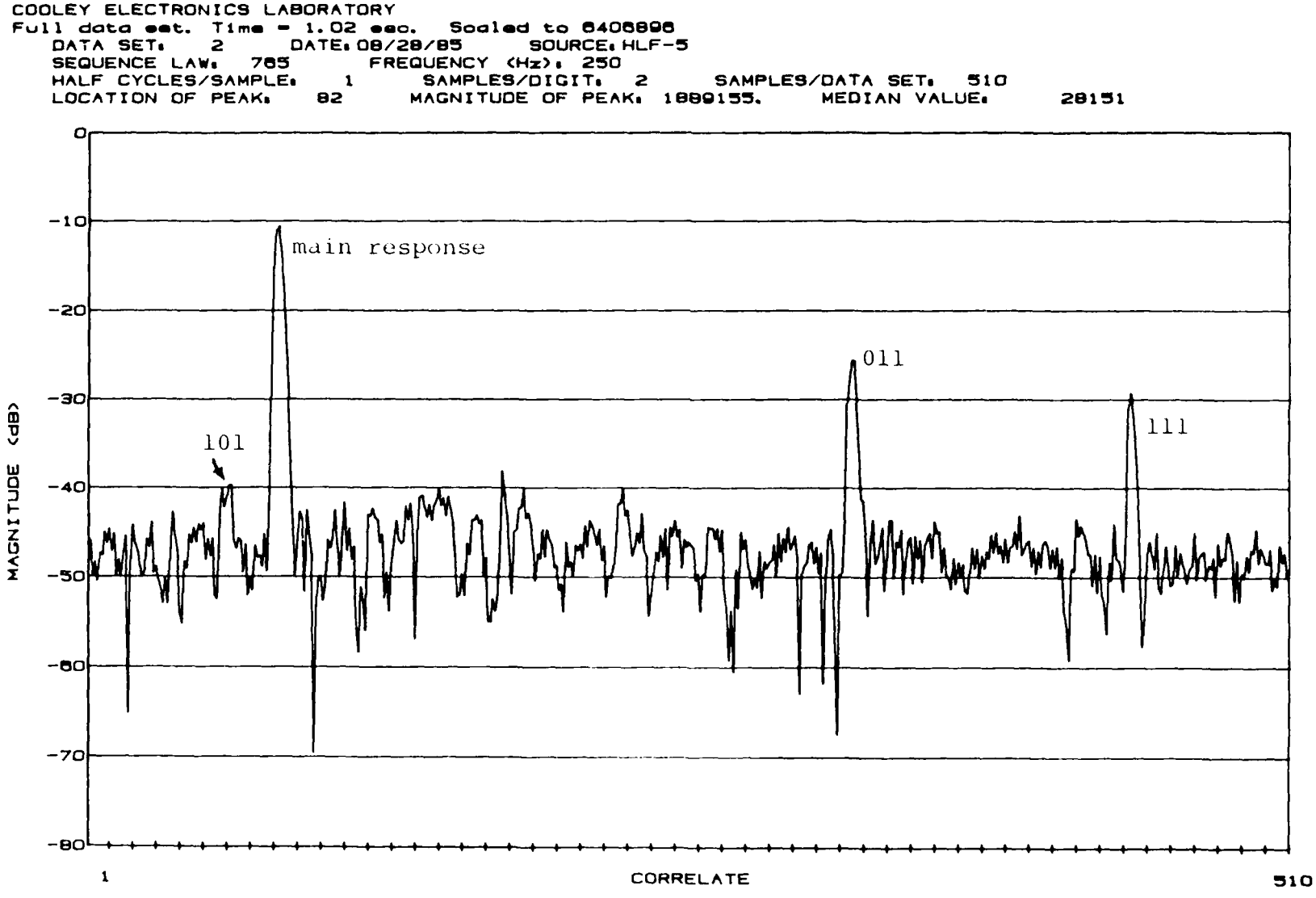
Plot 10. DFT of the two cycle digit response.
Drive level = 7 vrms.



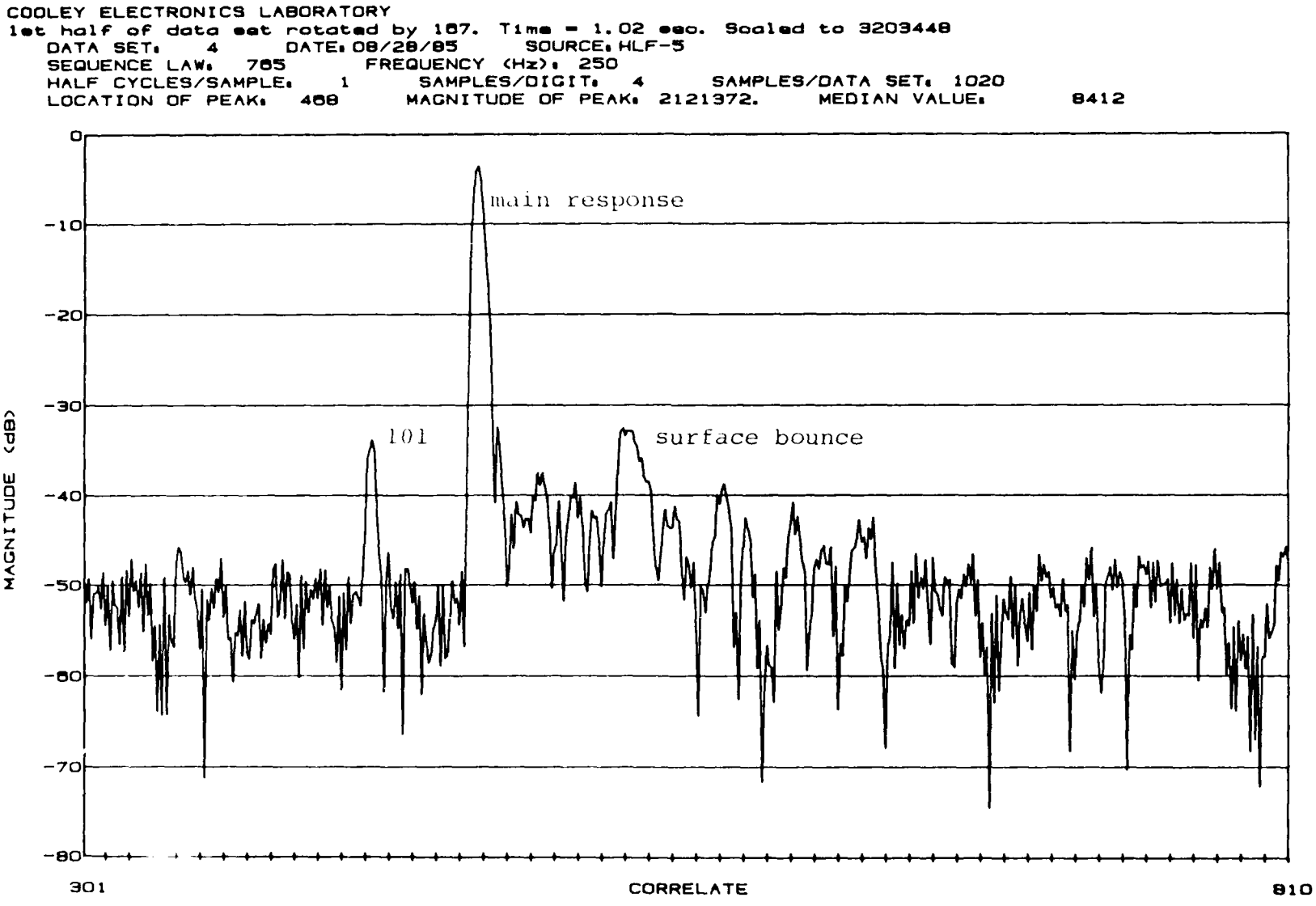
Plot 11. DFT of the four cycle digit response.
Drive level = 7 vrms.



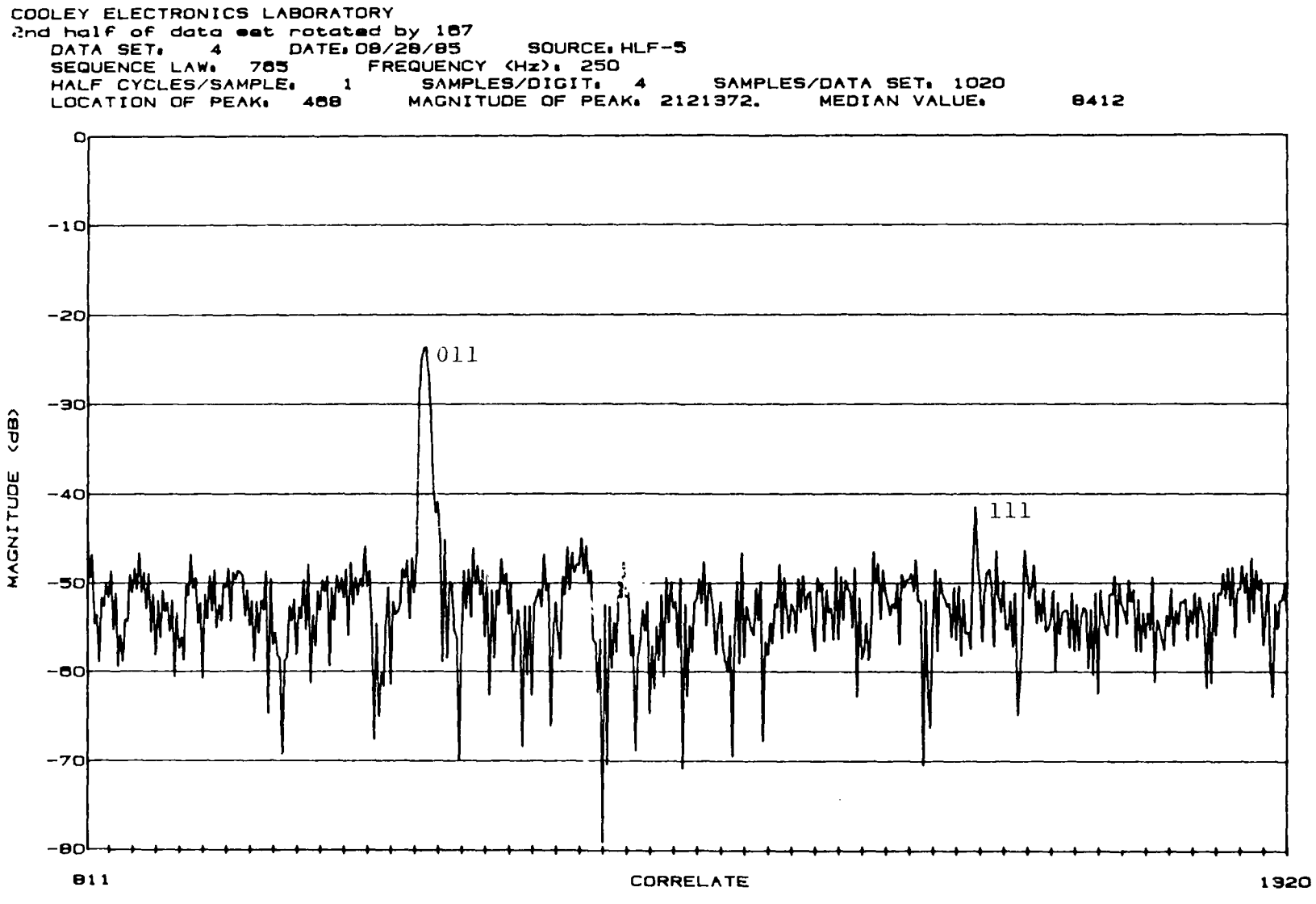
Plot 12. DFT of the eight cycle digit response.
Drive level = 7 vrms.



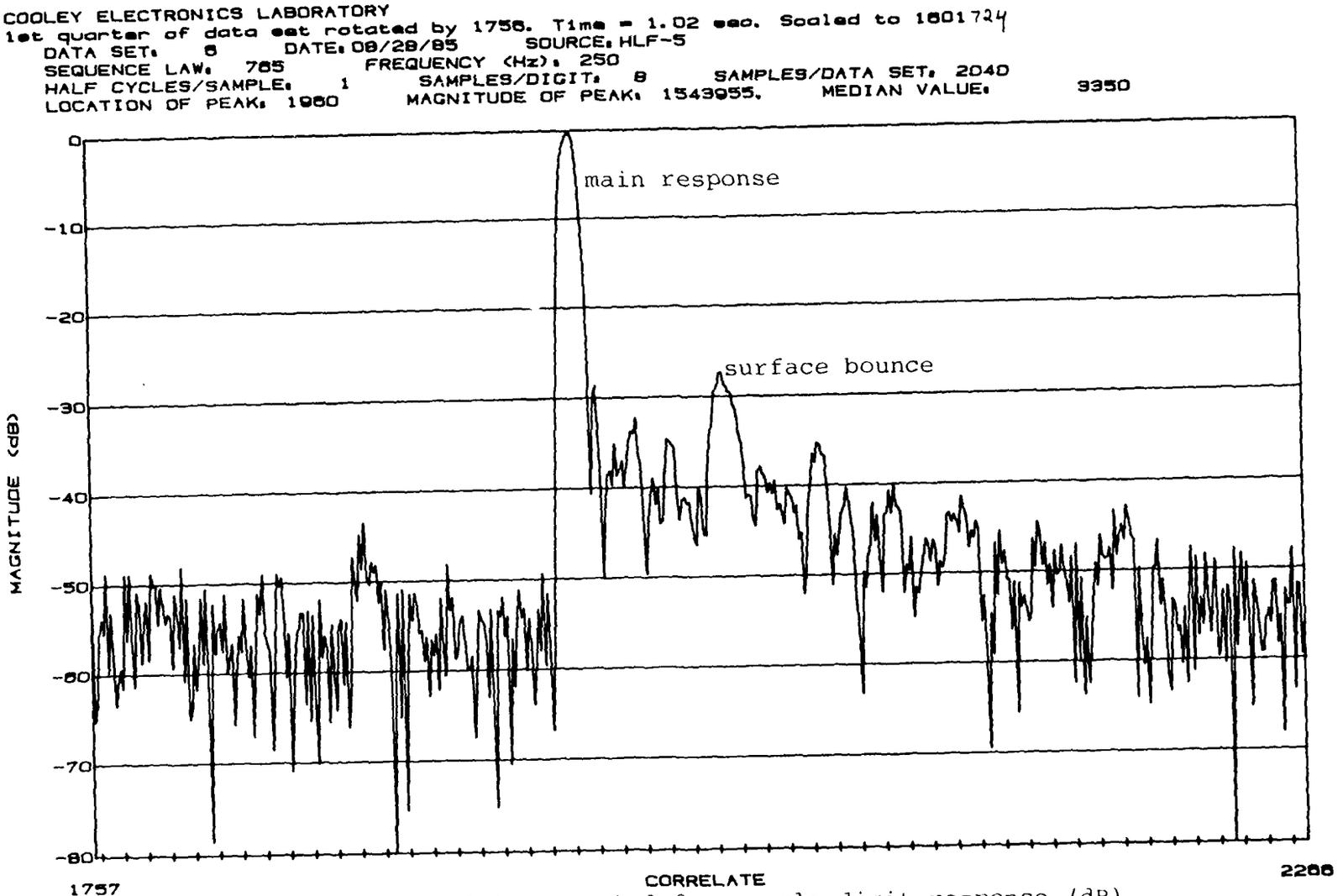
Plot 13. Full period of one cycle digit response (dB). Drive level = 7 vrms.



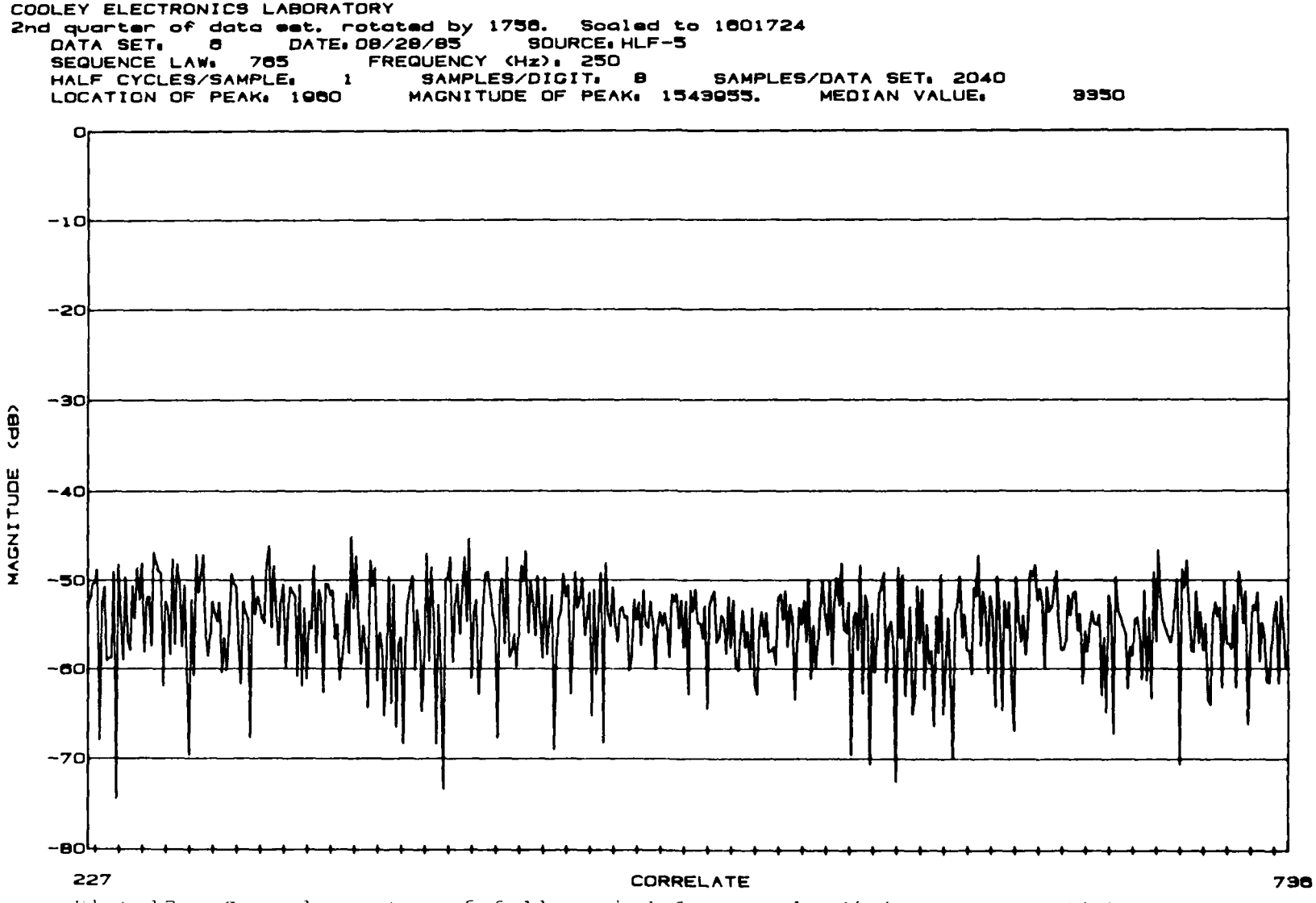
Plot ... First half of full period two cycle digit response (dB). Drive level = 7 vrms.



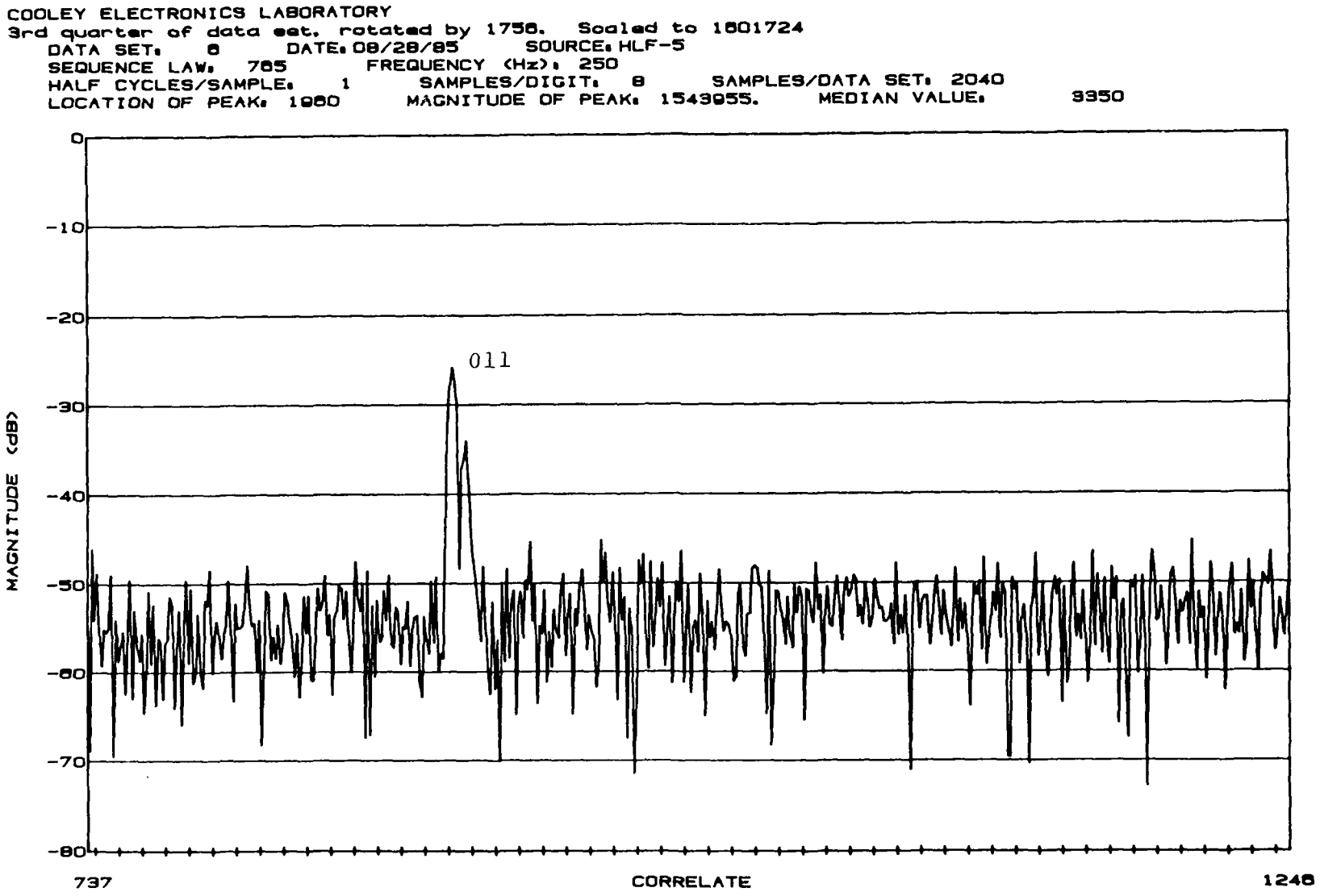
Plot 15. Second half of full period two cycle digit response (dB). Drive level = 7 vrms.



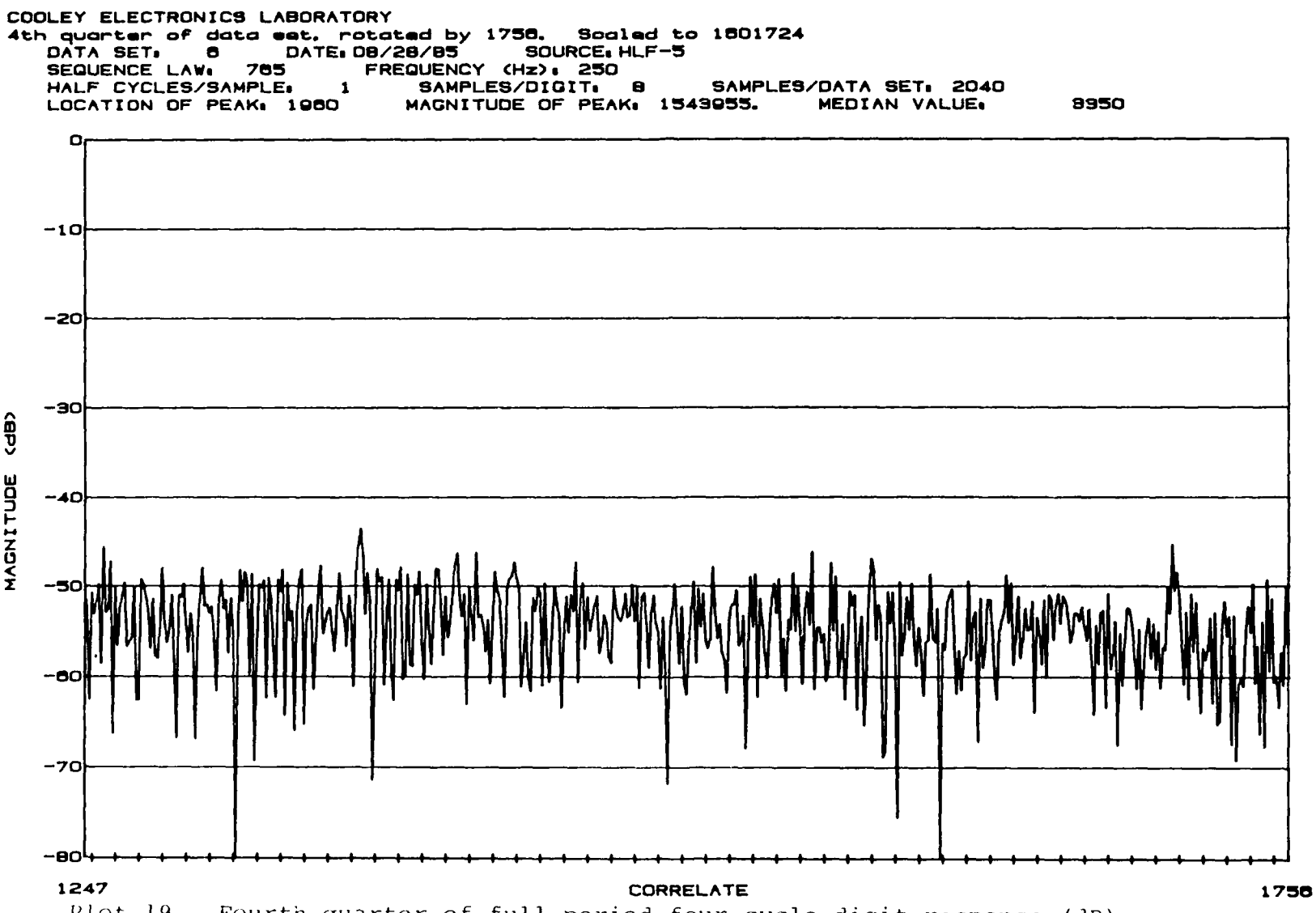
Plot 16. First quarter of full period four cycle digit response (dB). Drive level = 7 vrms.



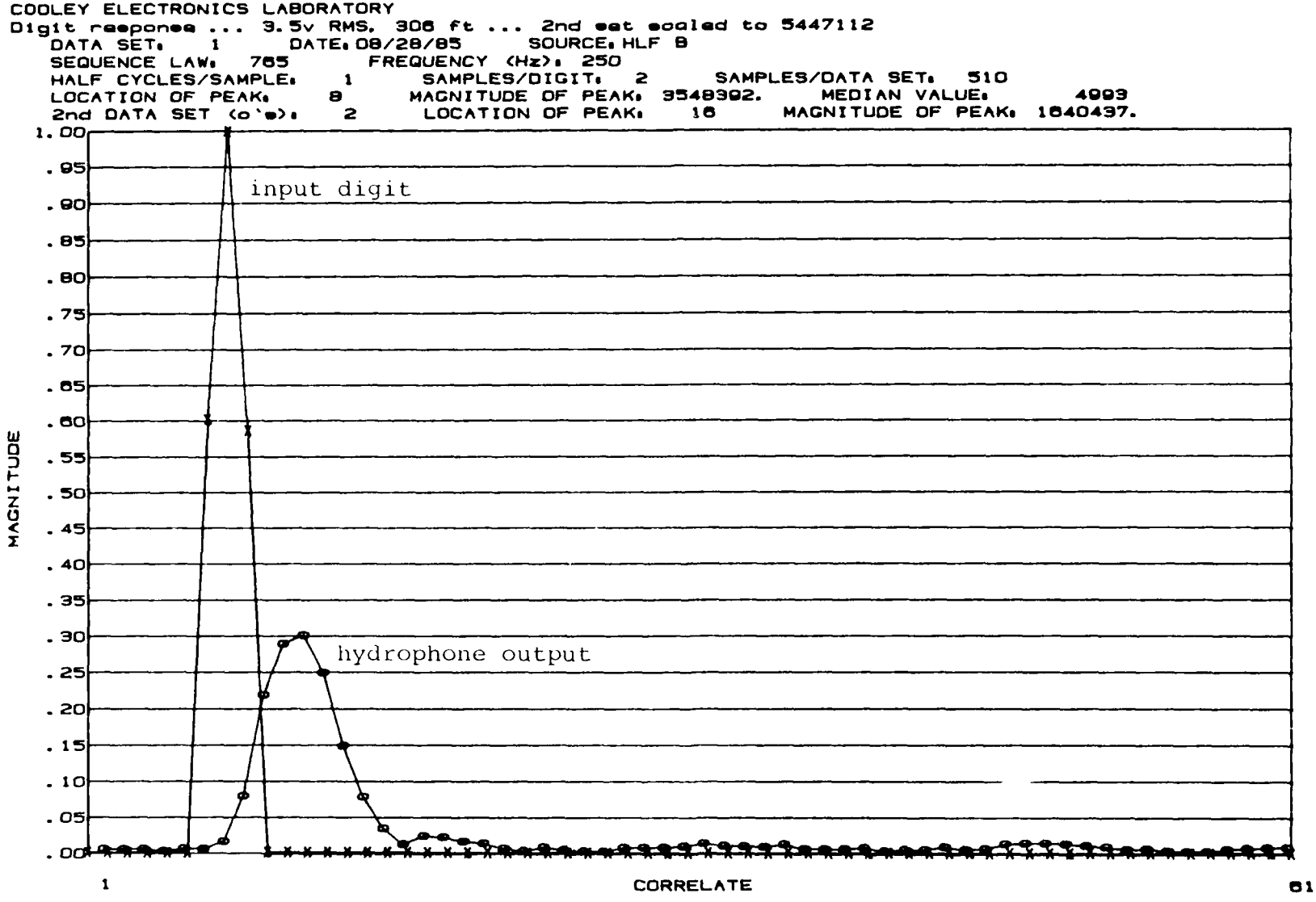
Plot 17. Second quarter of full period four cycle digit response (dB). Drive level = 7 vrms.



Plot 18. Third quarter of full period four cycle digit response (dB). Drive level = 7 vrms.



Plot 19. Fourth quarter of full period four cycle digit response (dB). Drive level = 7 vrms.



Plot 20. One cycle digit response, direct path delay removed. Drive level = 3.5 vrms.

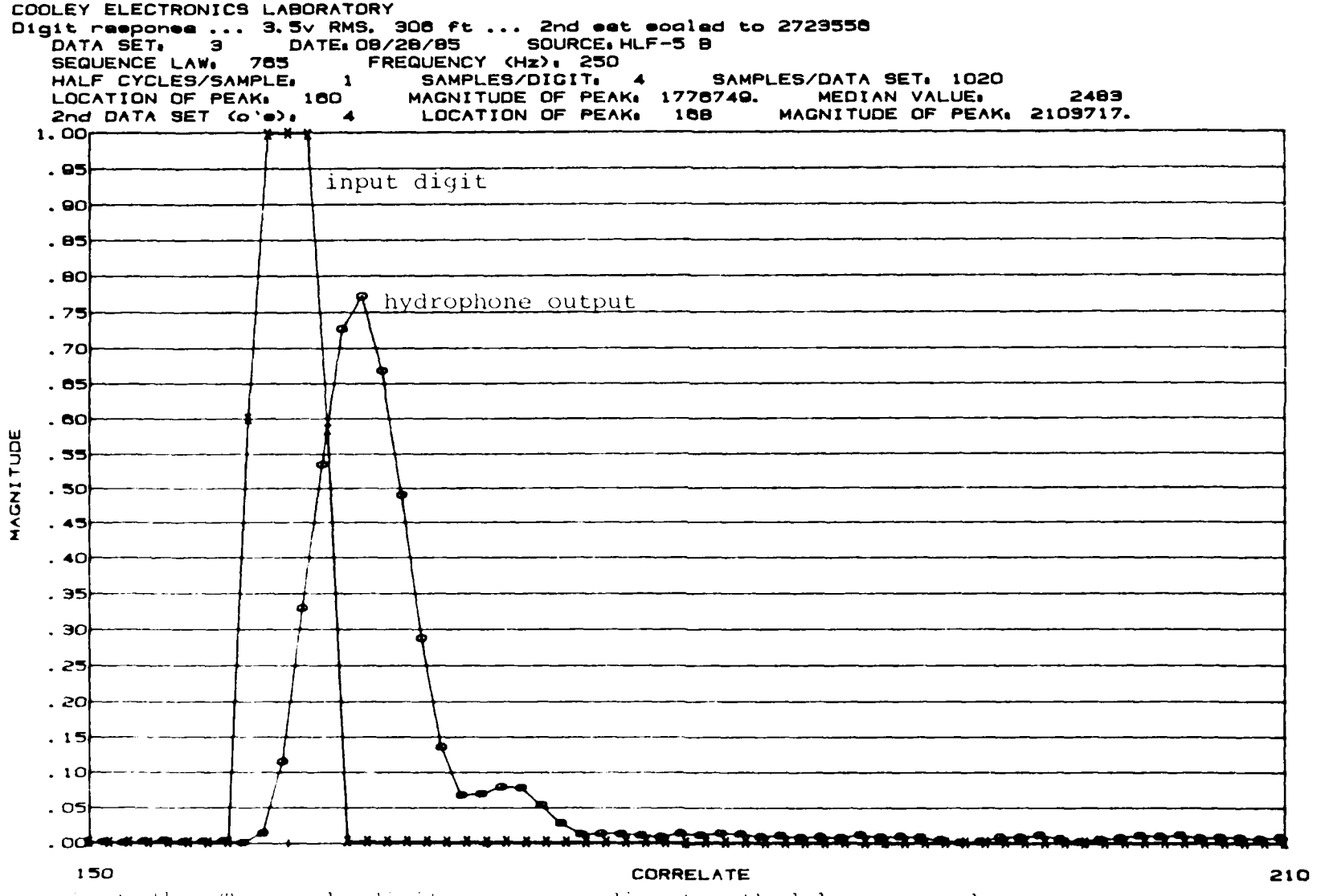
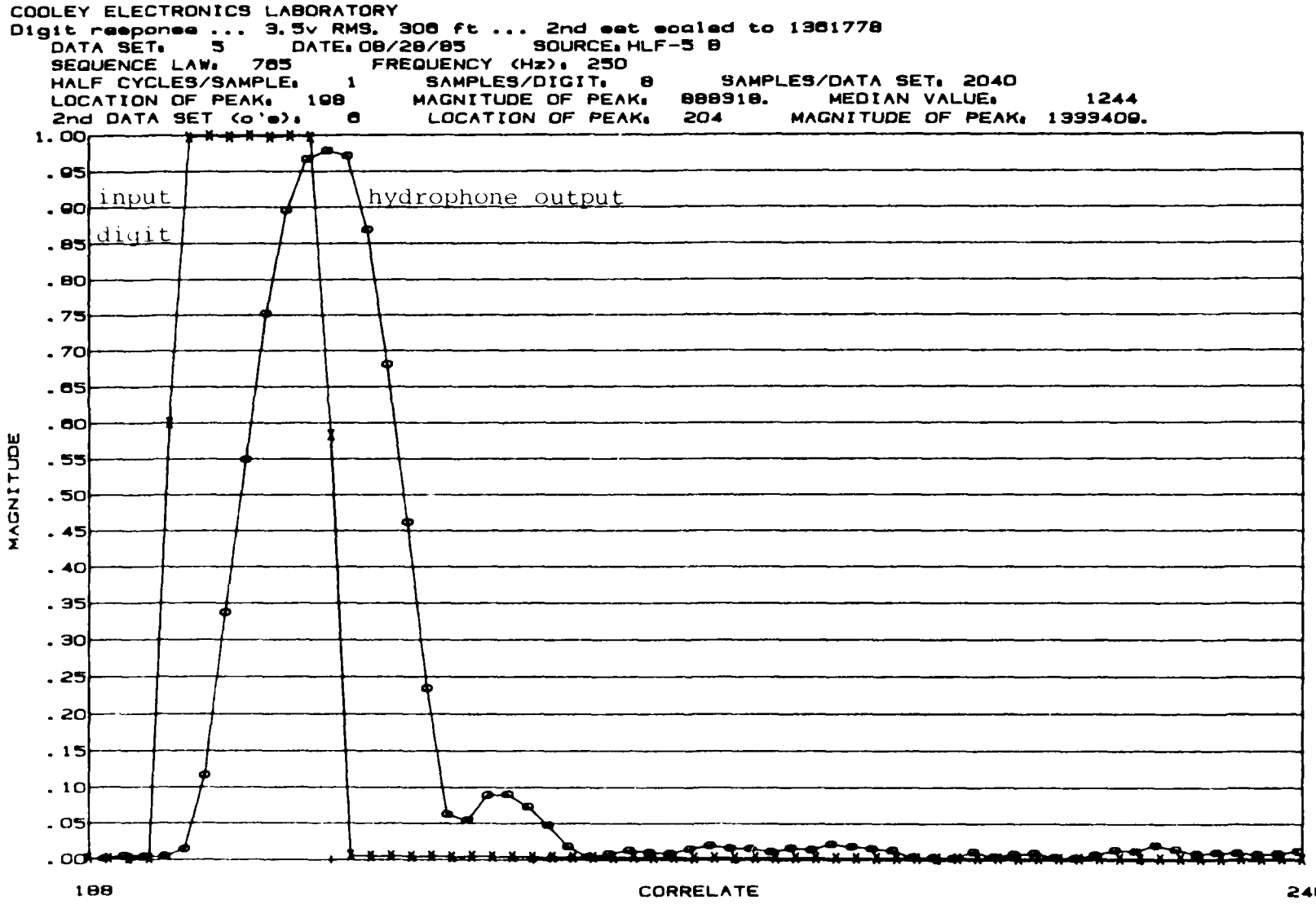
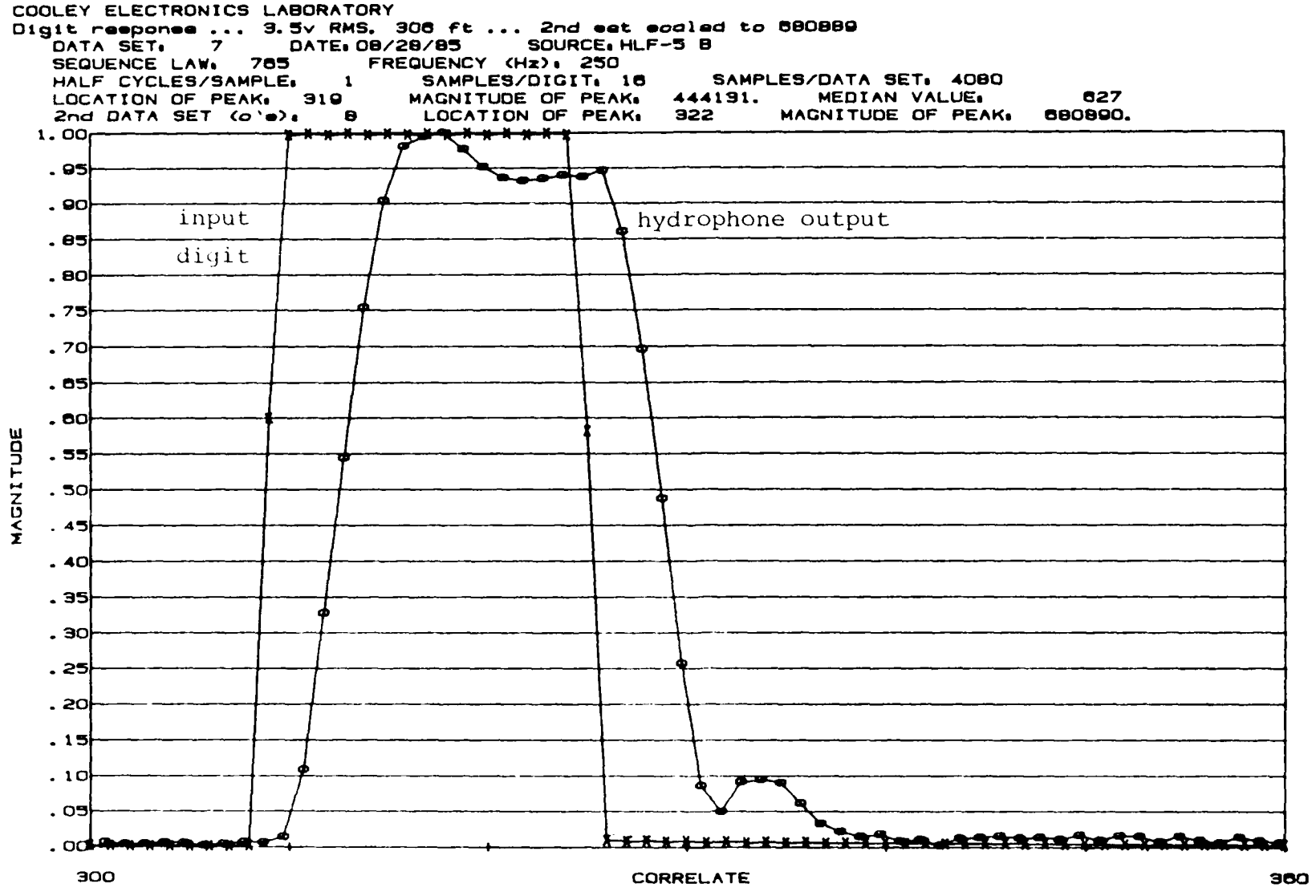


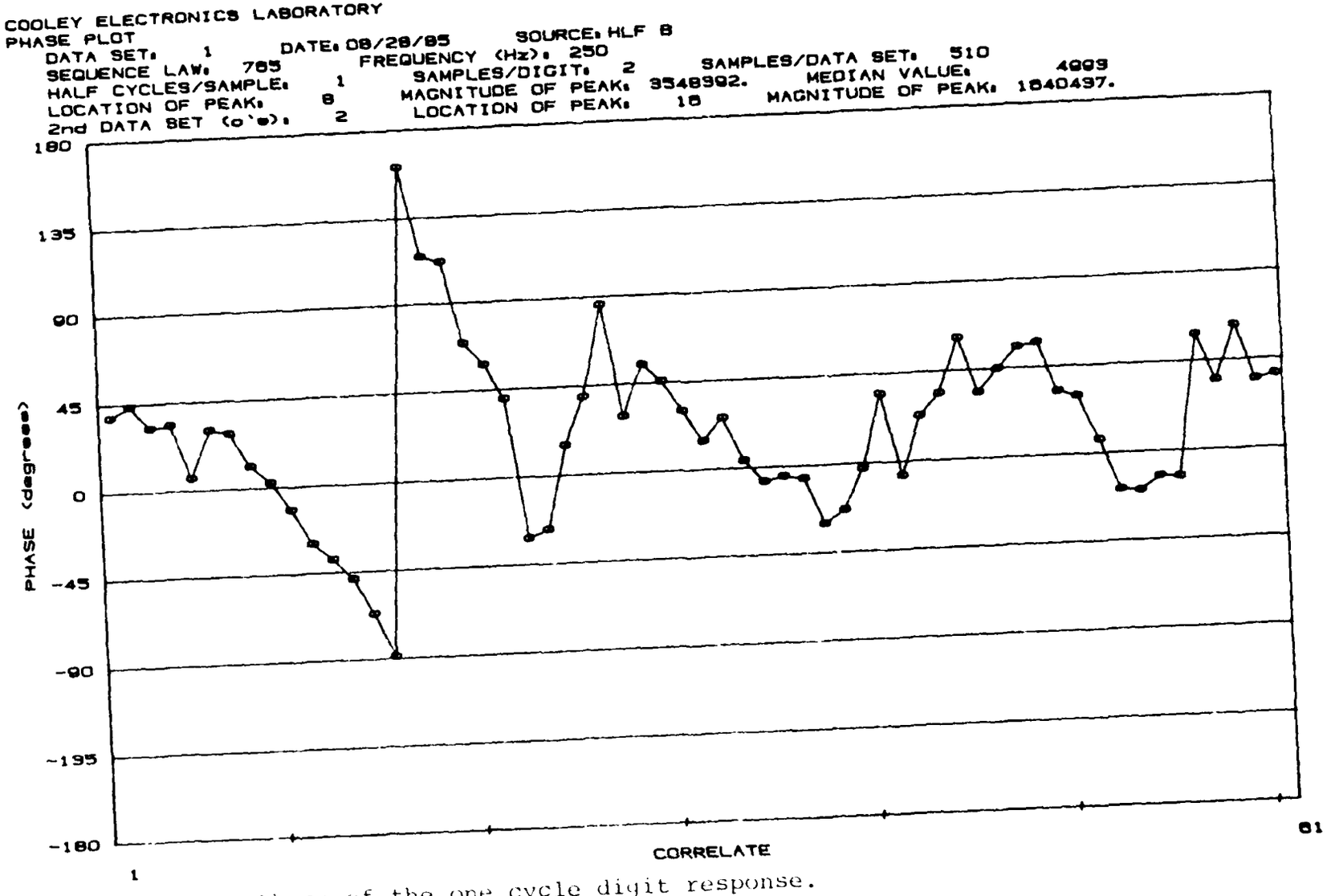
Fig. 21. Two cycle digit response, direct path delay removed. Drive level = 3.5 vrms.



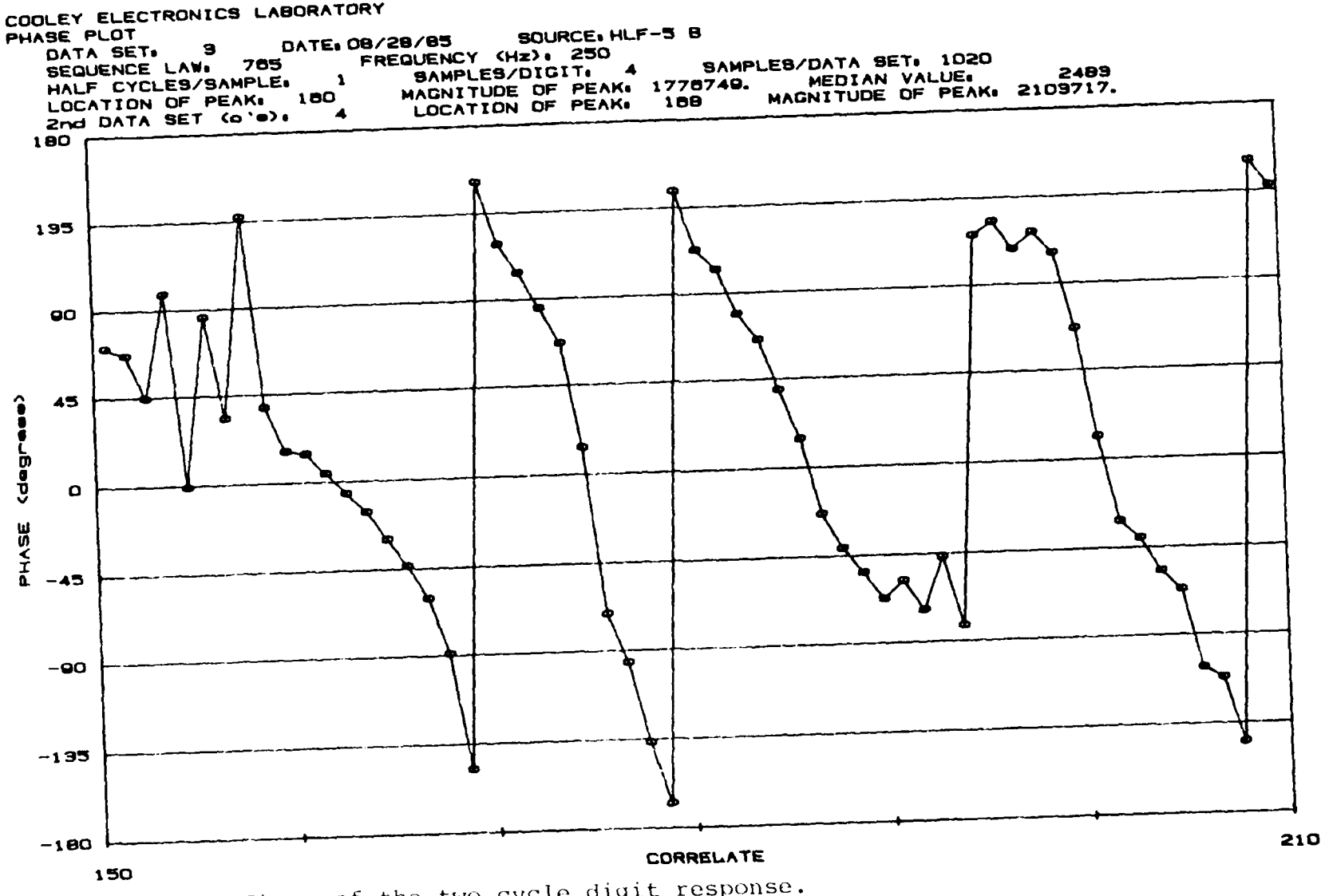
Plot 22. Four cycle digit response, direct path delay removed. Drive level = 3.5 vrms.



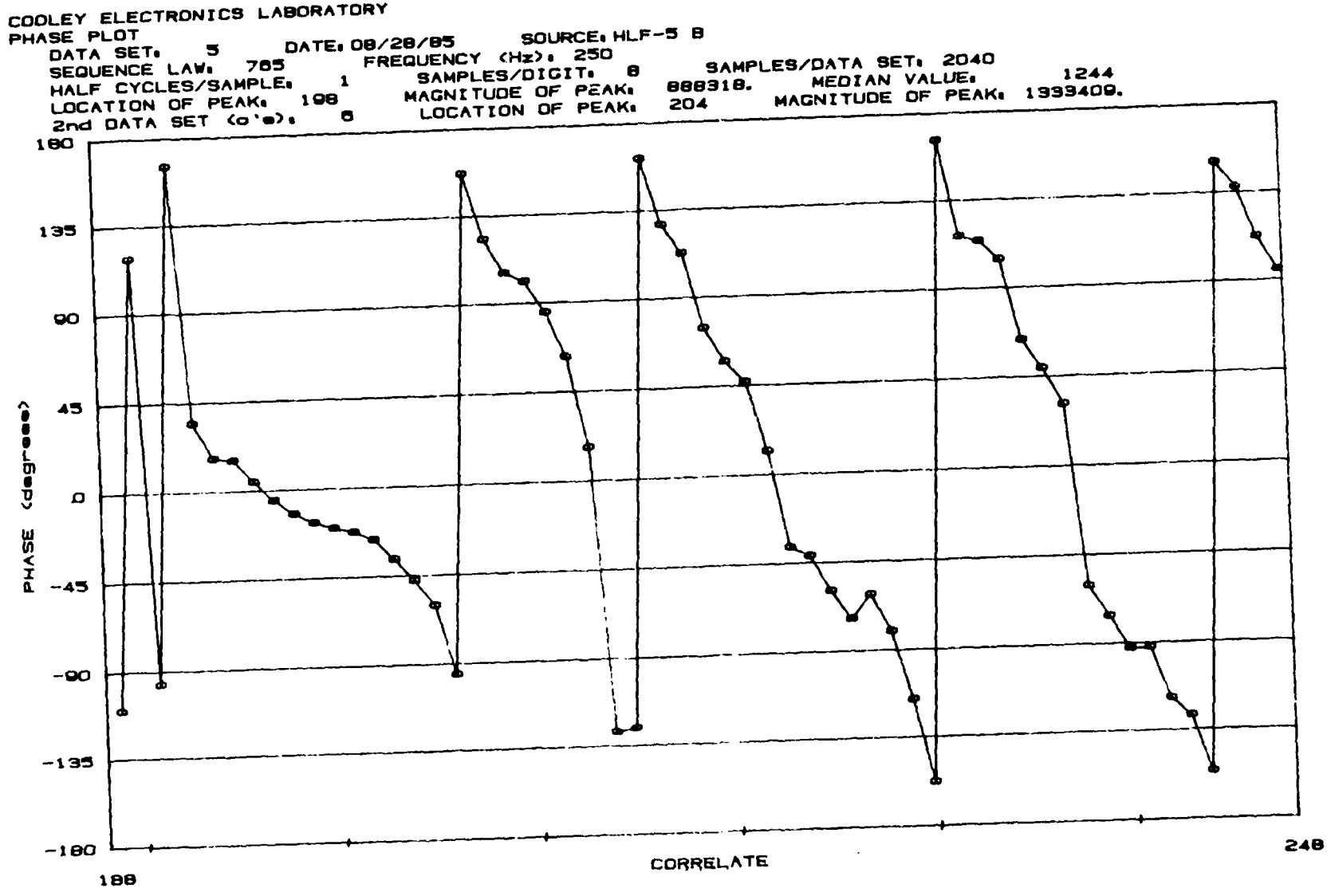
Plot 23. Eight cycle digit response, direct path delay removed. Drive level = 3.5 vrms.



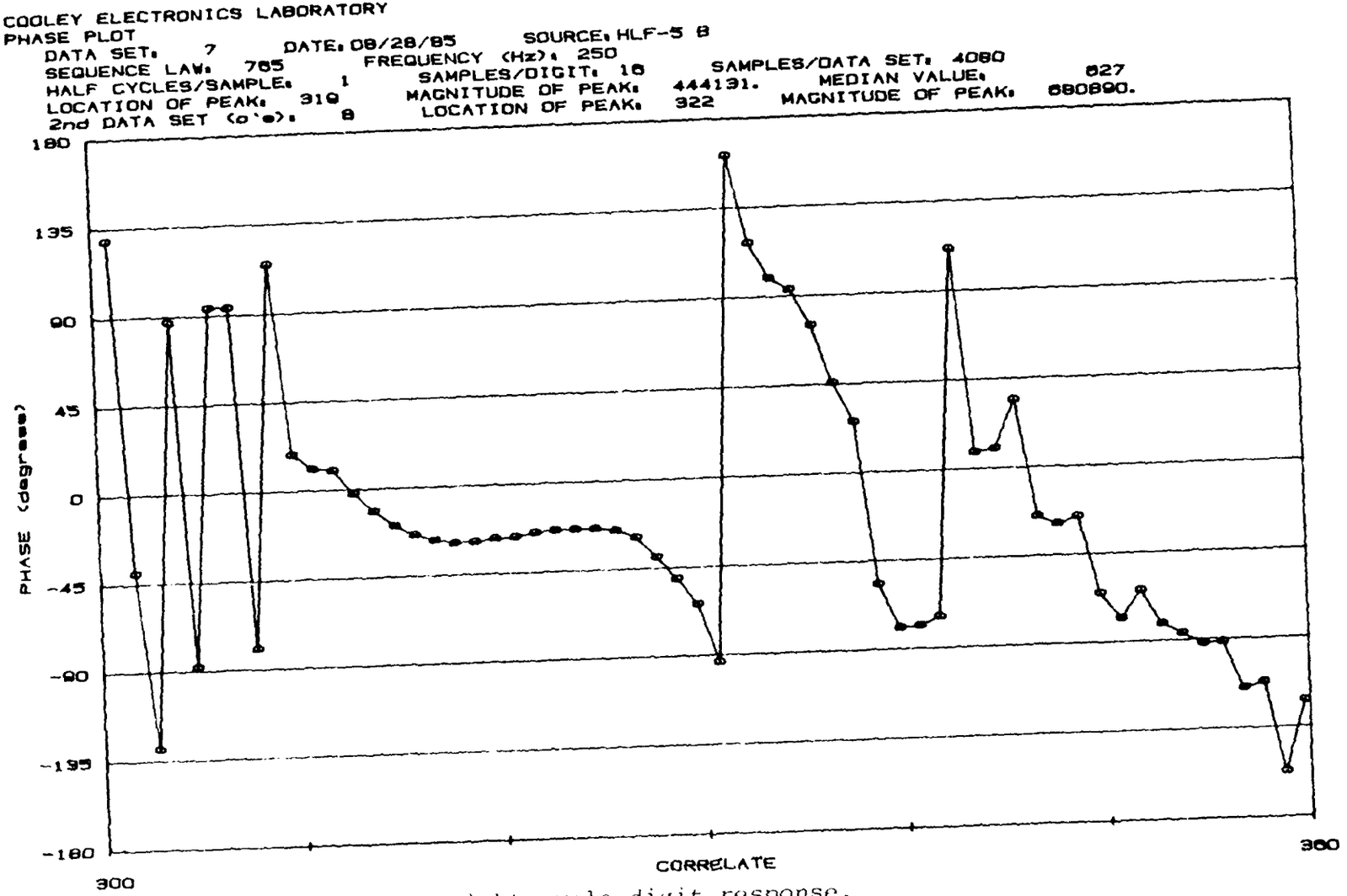
Plot 24. Phase of the one cycle digit response. Drive level = 3.5 vrms.



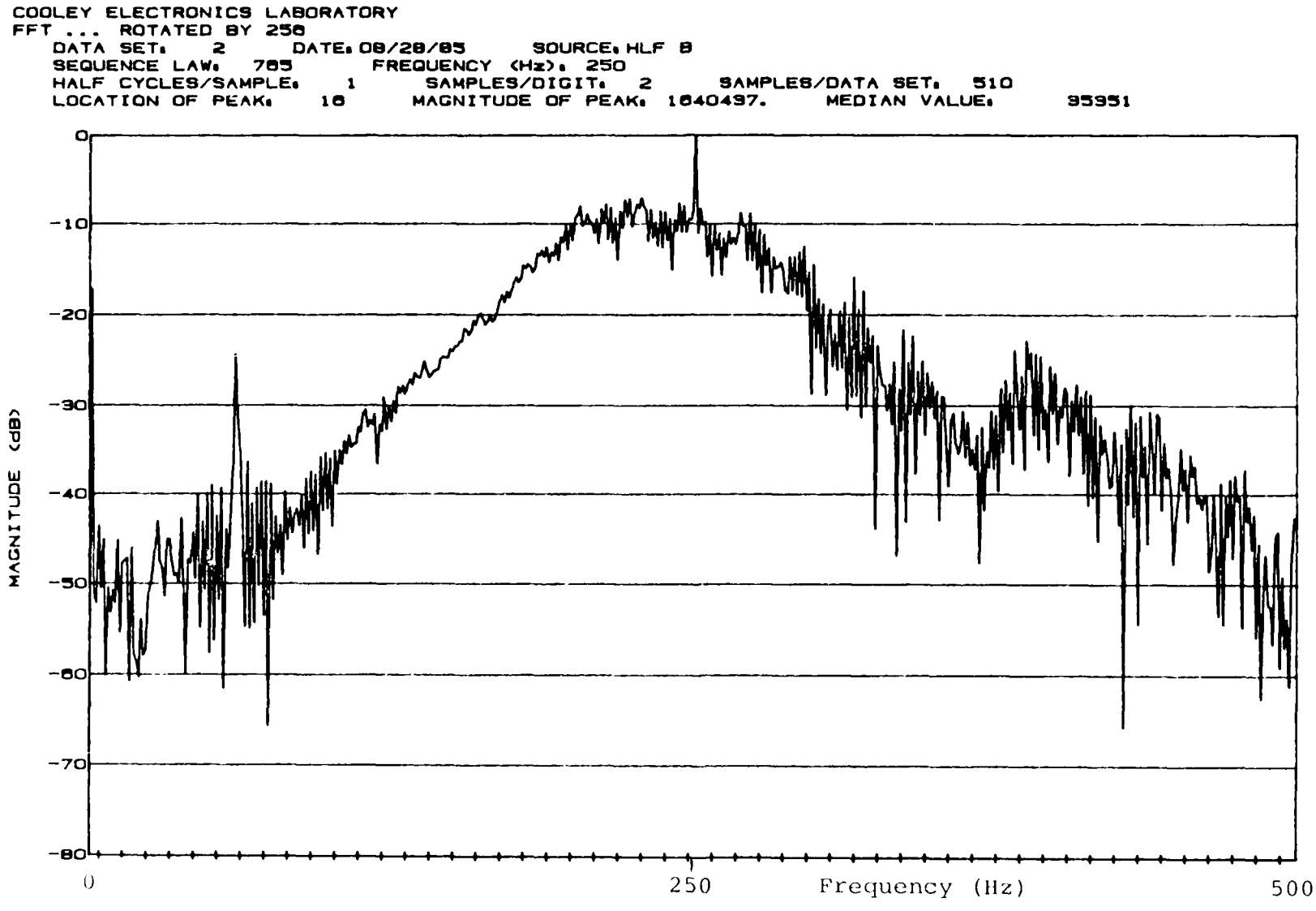
Plot 25. Phase of the two cycle digit response.
Drive level = 3.5 vrms.



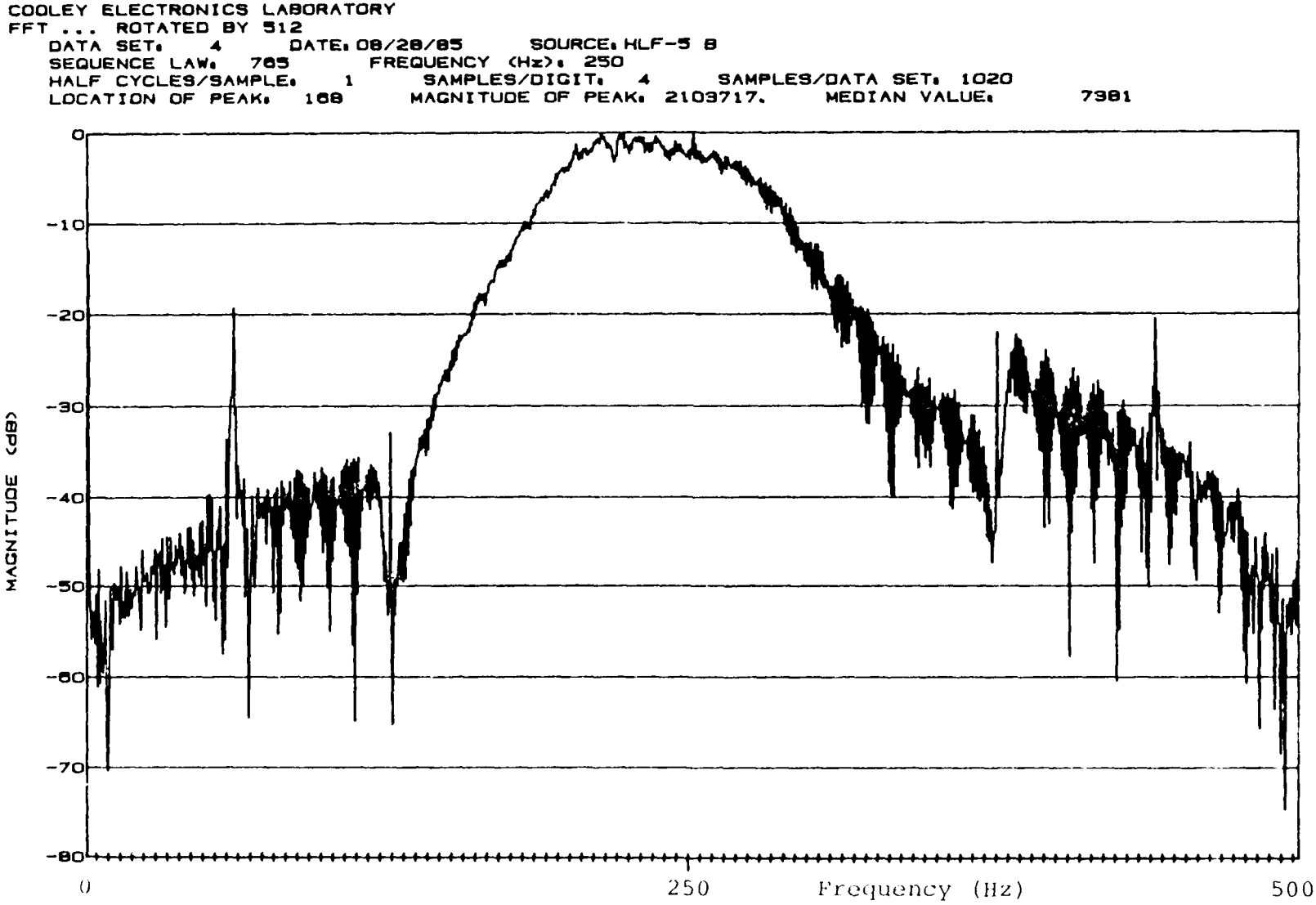
Plot 26. Phase of the four cycle digit response. Drive level = 3.5 vrms.



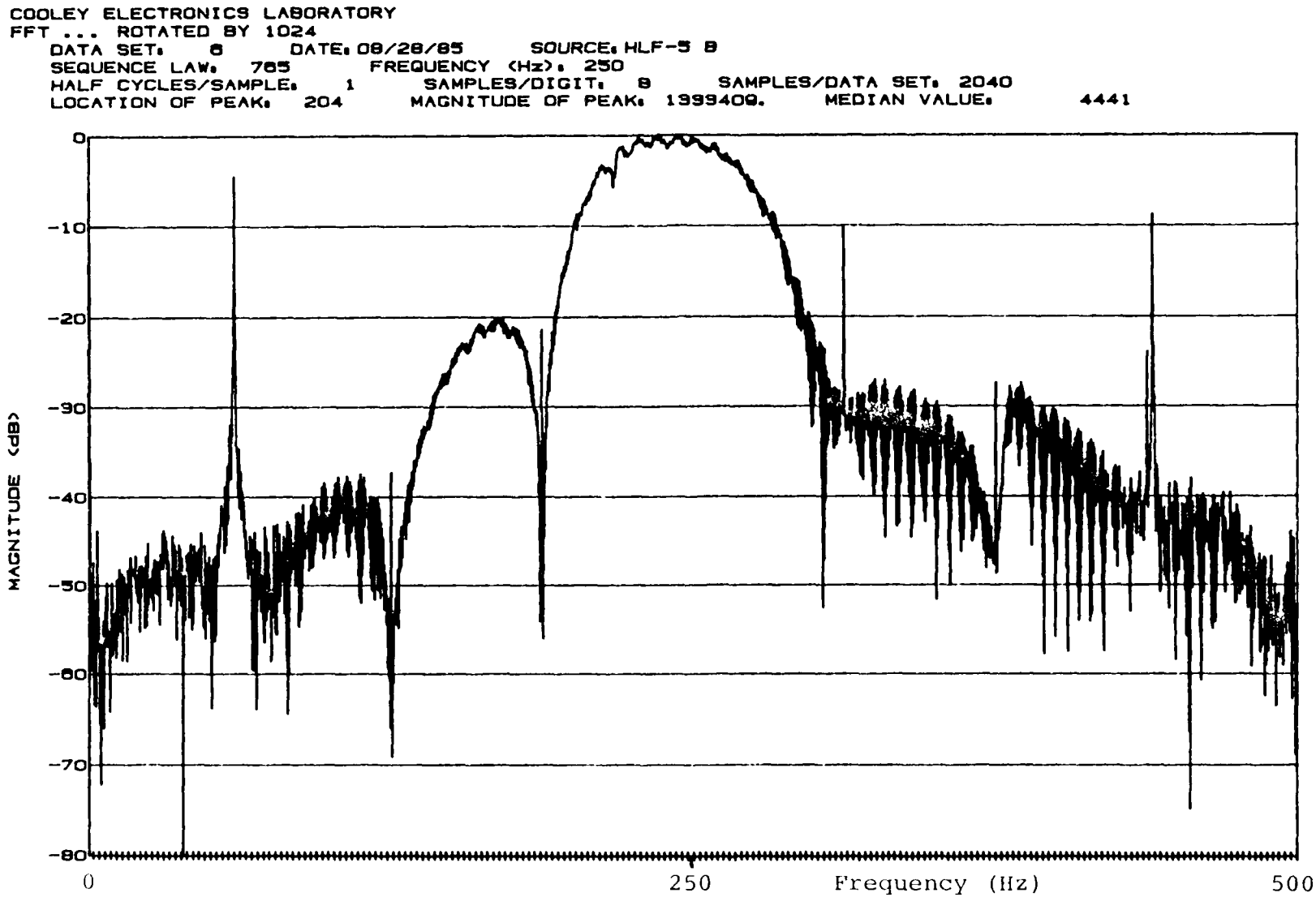
Plot 27. Phase of the eight cycle digit response. Drive level = 3.5 vrms.



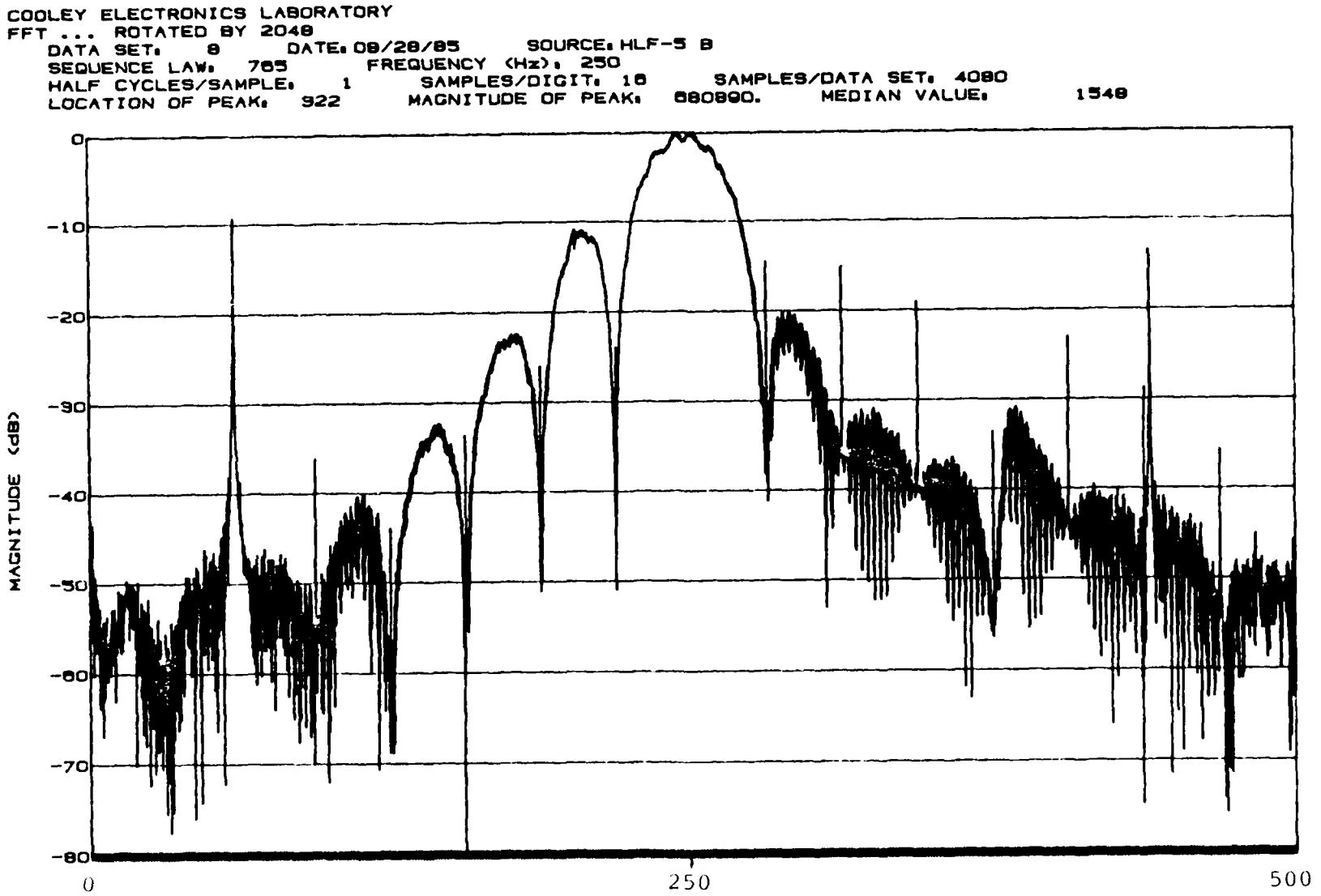
Plot 28. DFT of the one cycle digit response.
Drive level = 3.5 vrms.



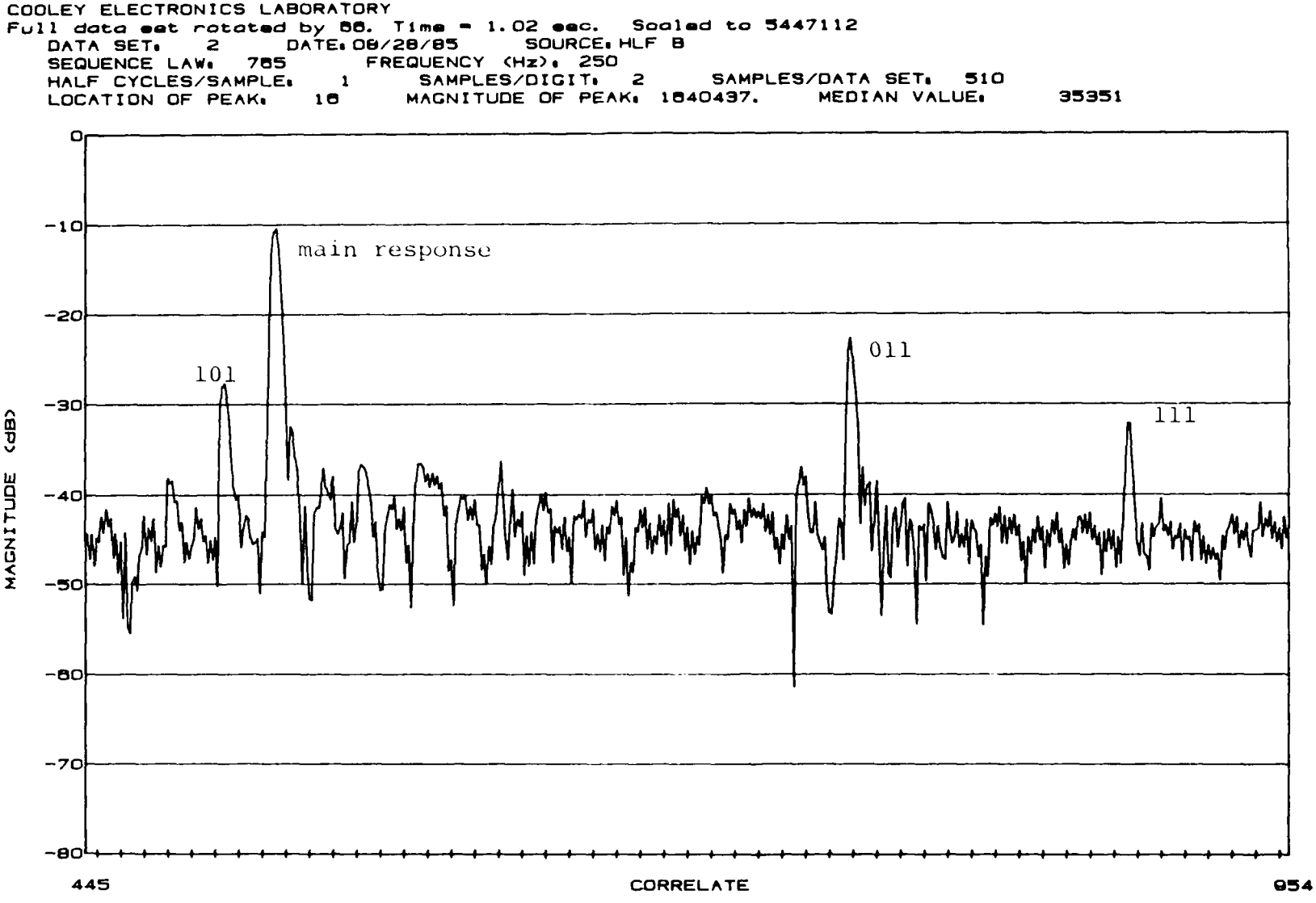
Plot 29. DFT of the two cycle digit response.
Drive level = 3.5 vrms.



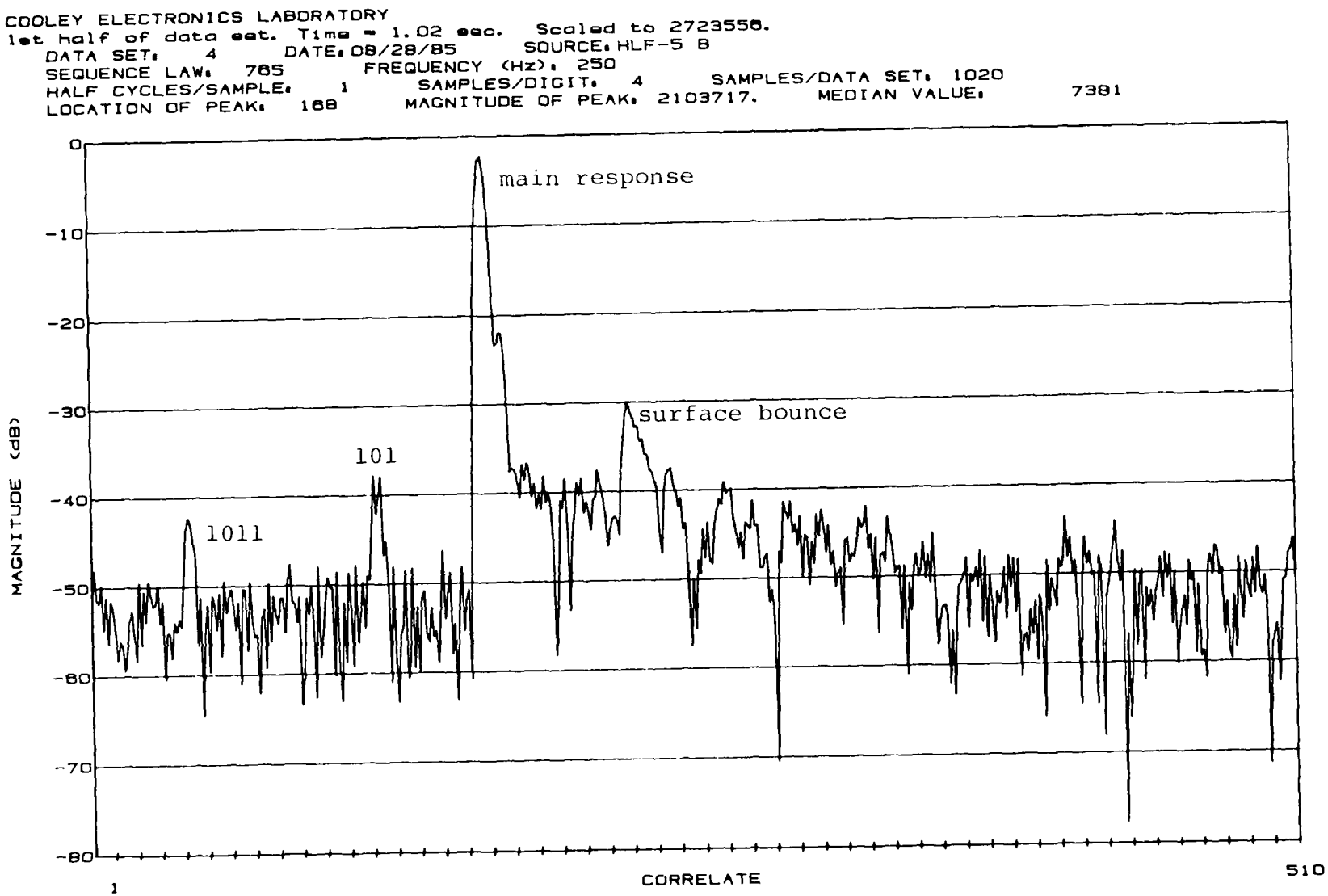
Plot 30. DFT of the four cycle digit response.
Drive level = 3.5 vrms.



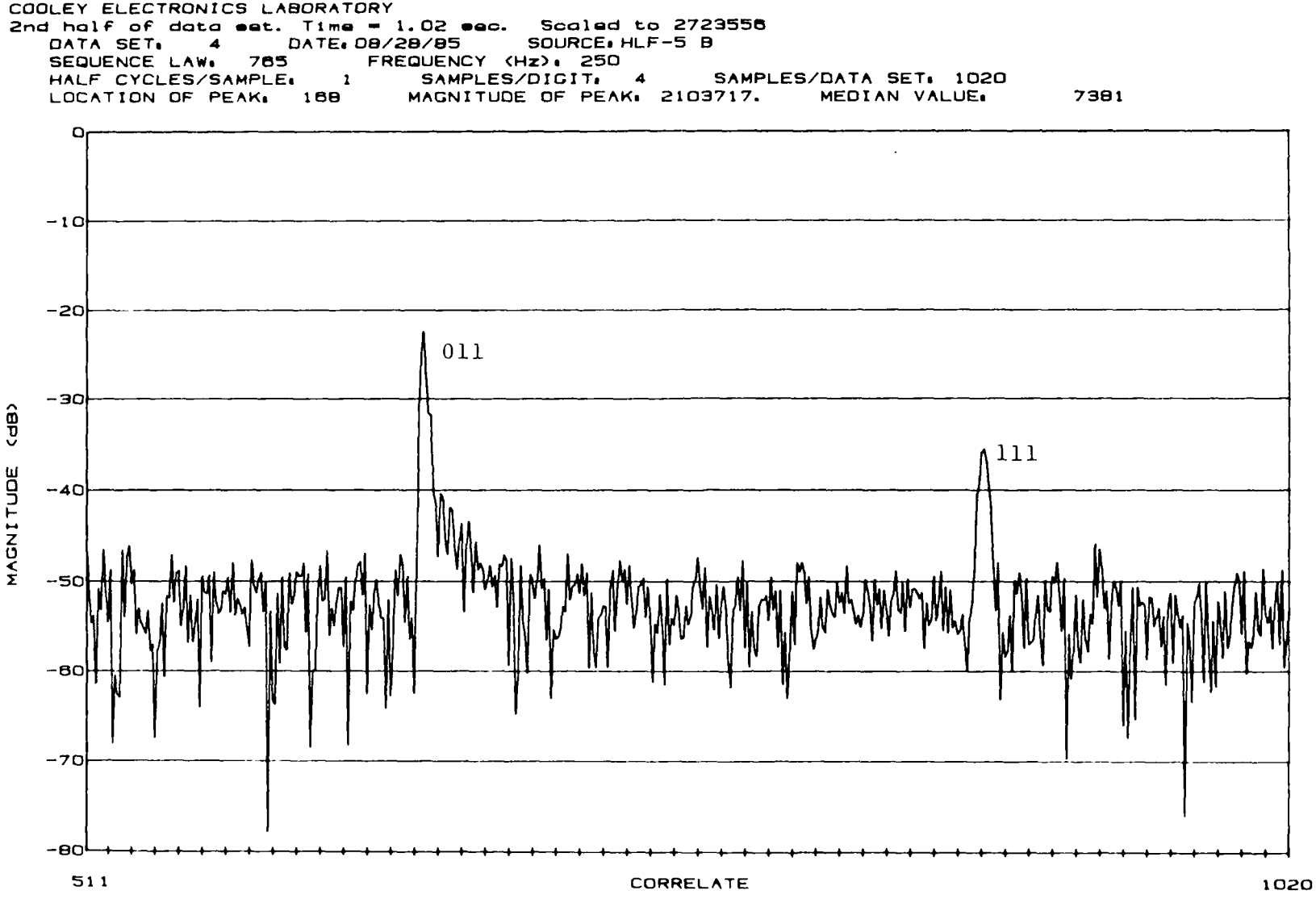
Plot 31. DFT of the eight cycle digit response.
Drive level = 3.5 vrms.



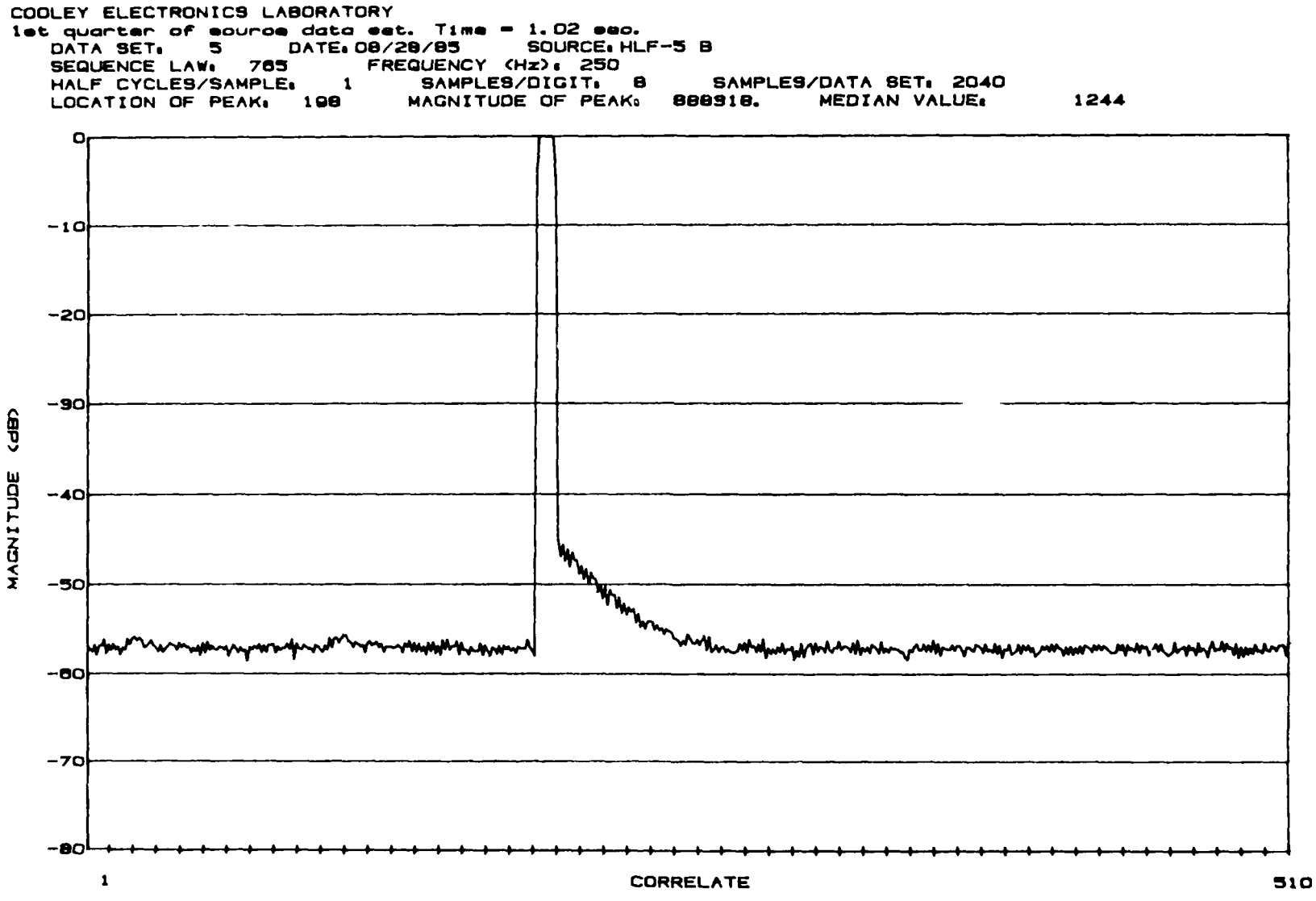
Plot 32. Full period of one cycle digit response (dB). Drive level = 3.5 vrms.



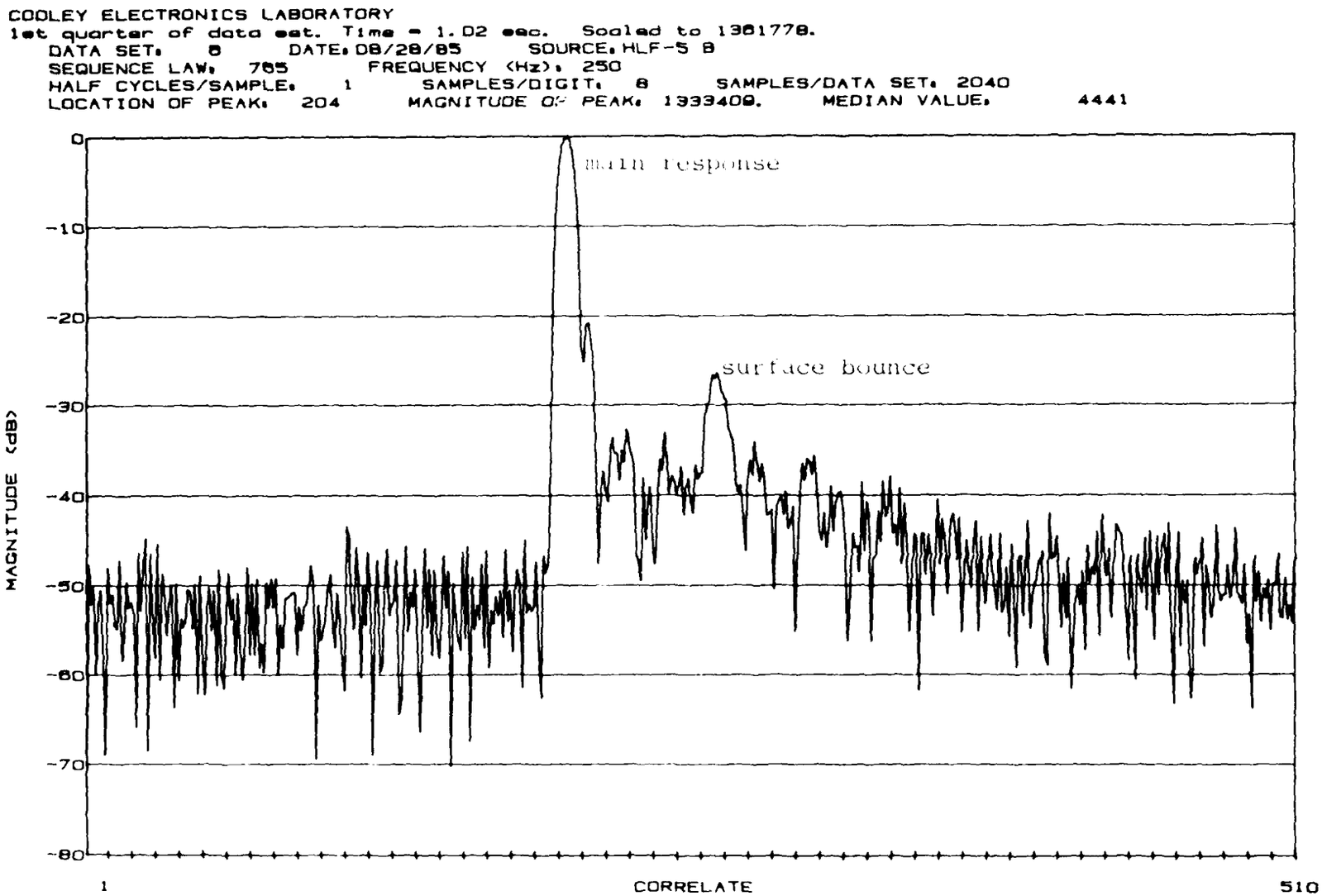
Plot 33. First half of full period two cycle digit response (dB). Drive level = 3.5 vrms.



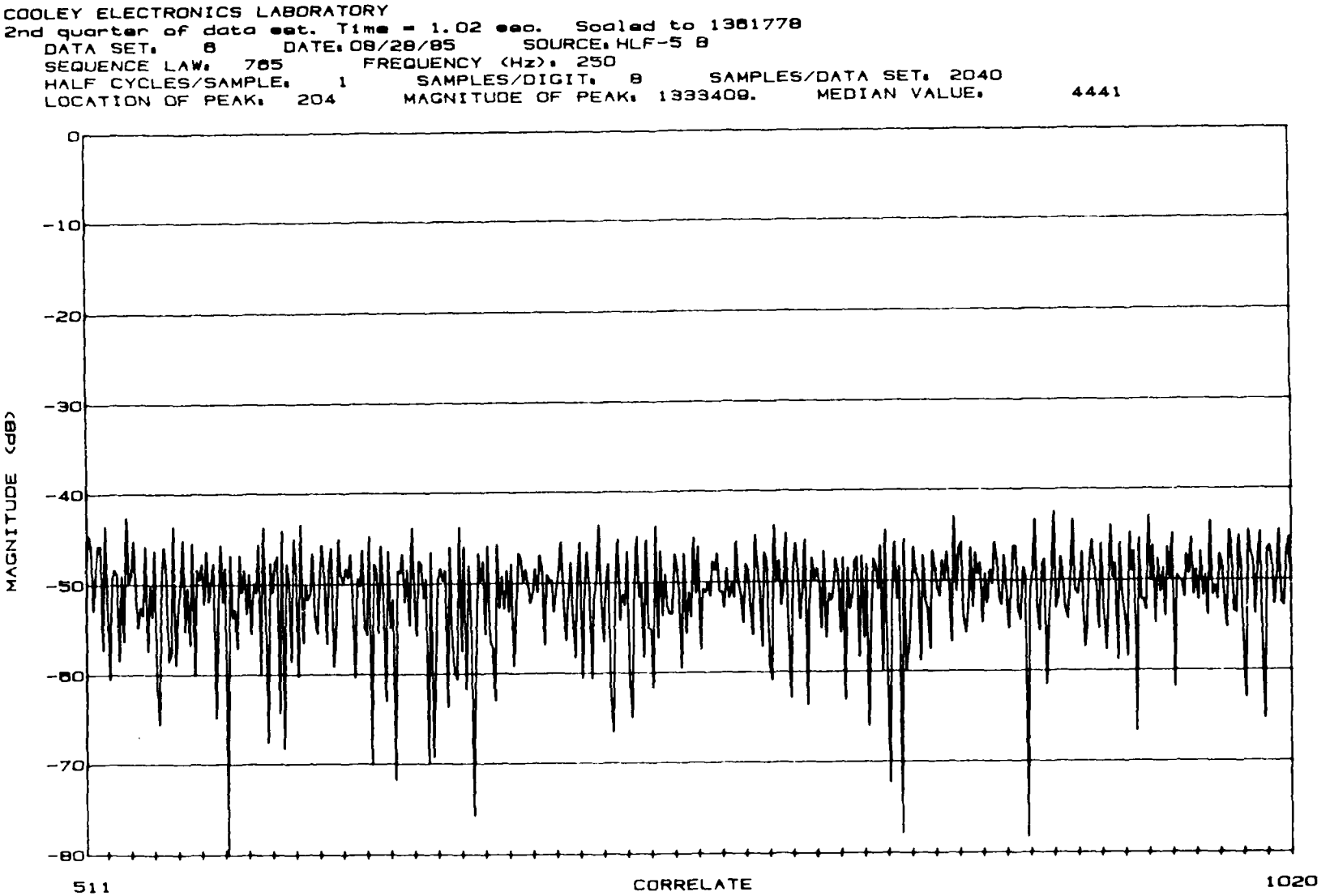
Plot 34. Second half of full period two cycle digit response (dB). Drive level = 3.5 vrms.



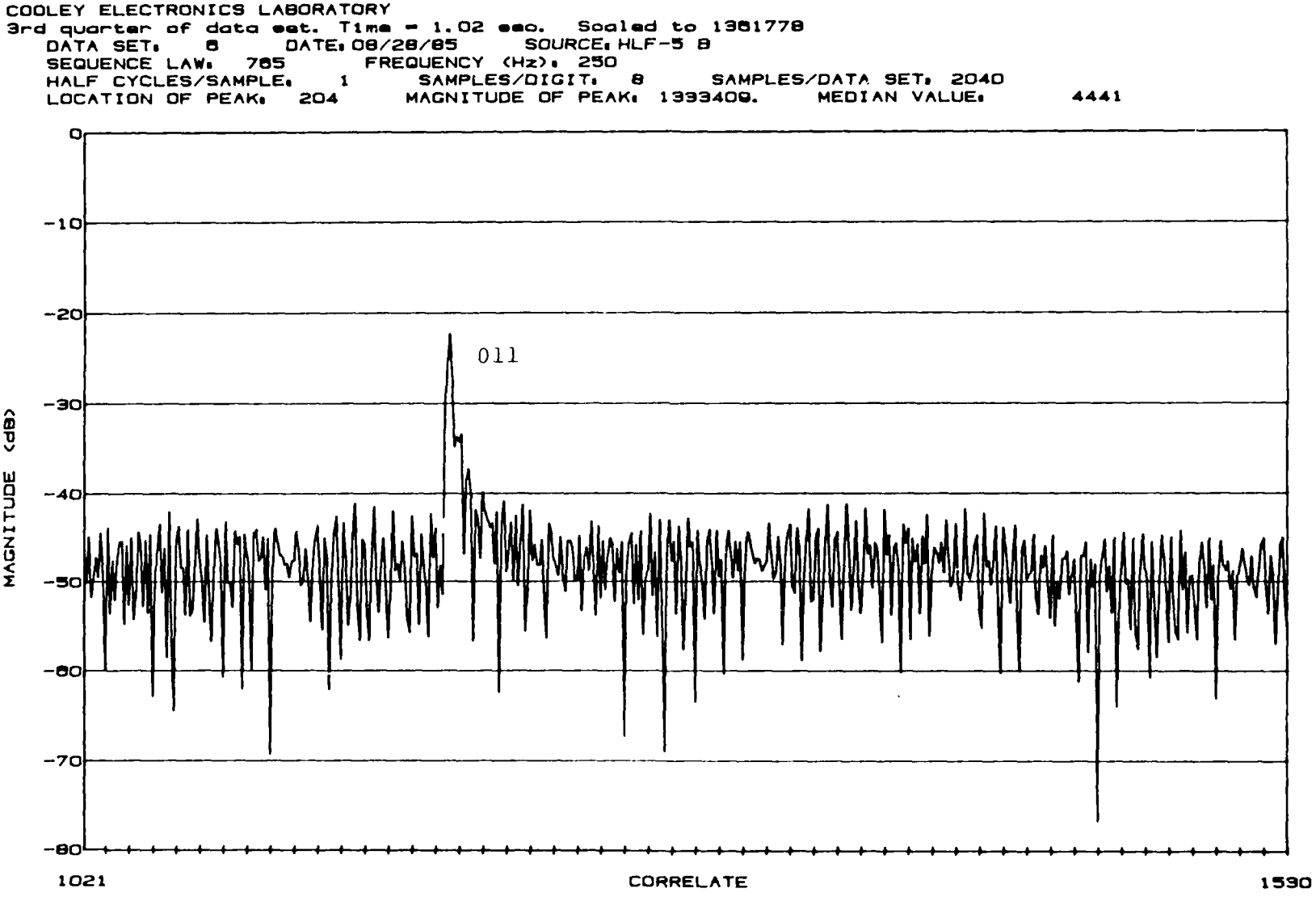
Plot 35. Drive waveform for four cycle digit measurement (dB). Drive level = 3.5 vrms.



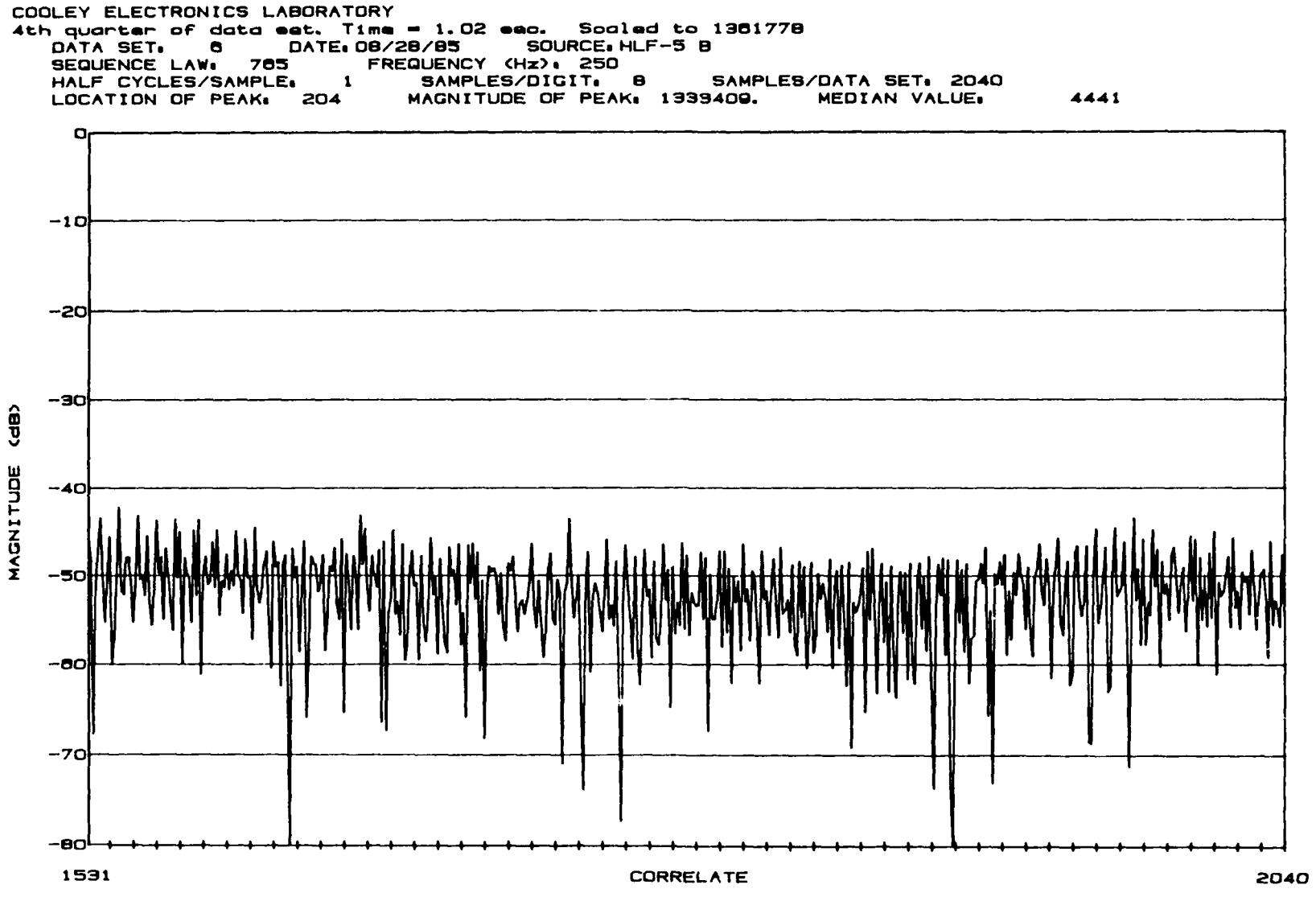
Plot 36. First quarter of full period four cycle digit response (dB). Drive level = 3.5 vrms.



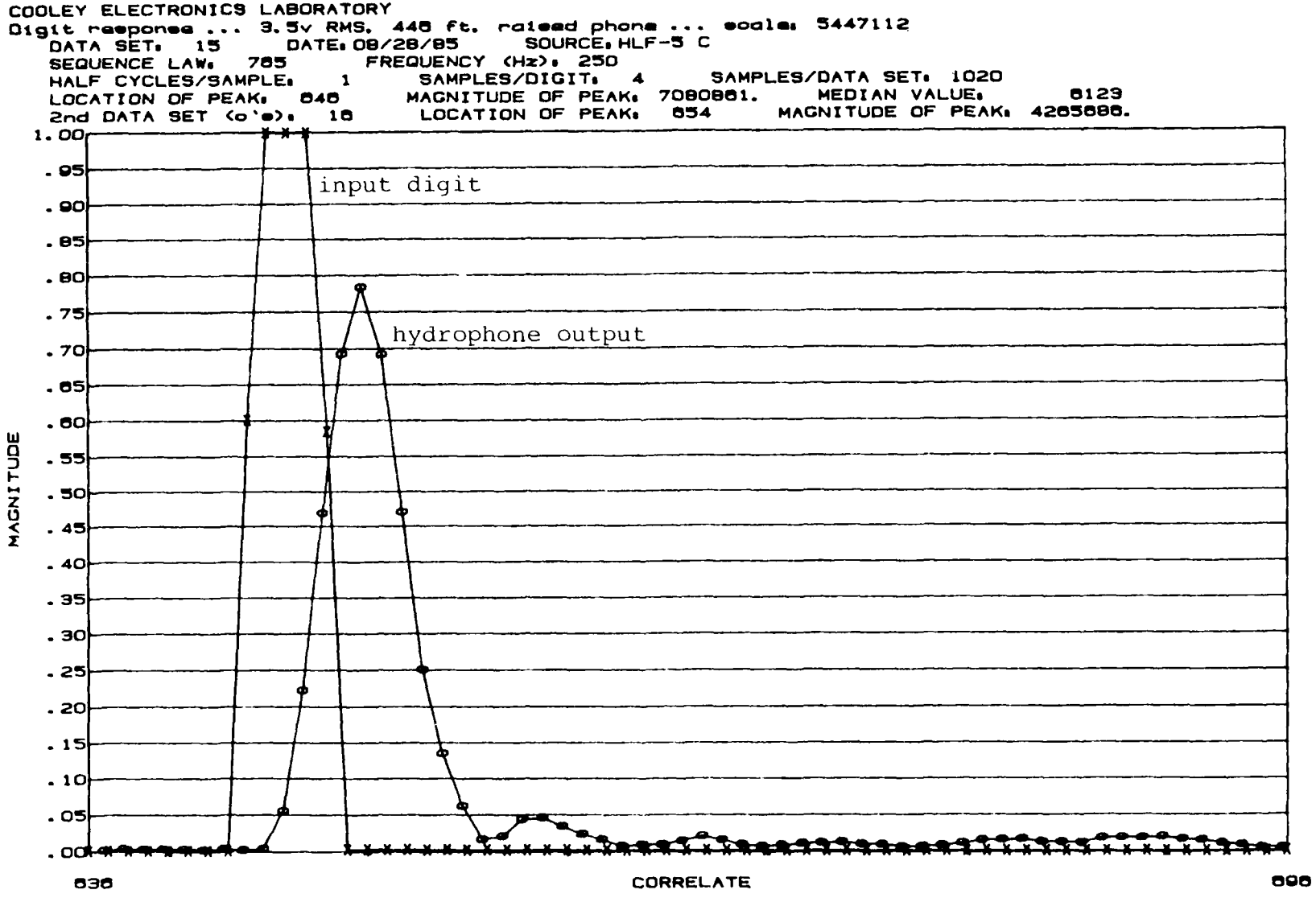
Plot 37. Second quarter of full period four cycle digit response (dB). Drive level = 3.5 vrms.



Plot 38. Third quarter of full period four cycle digit response (dB). Drive level = 3.5 vrms.

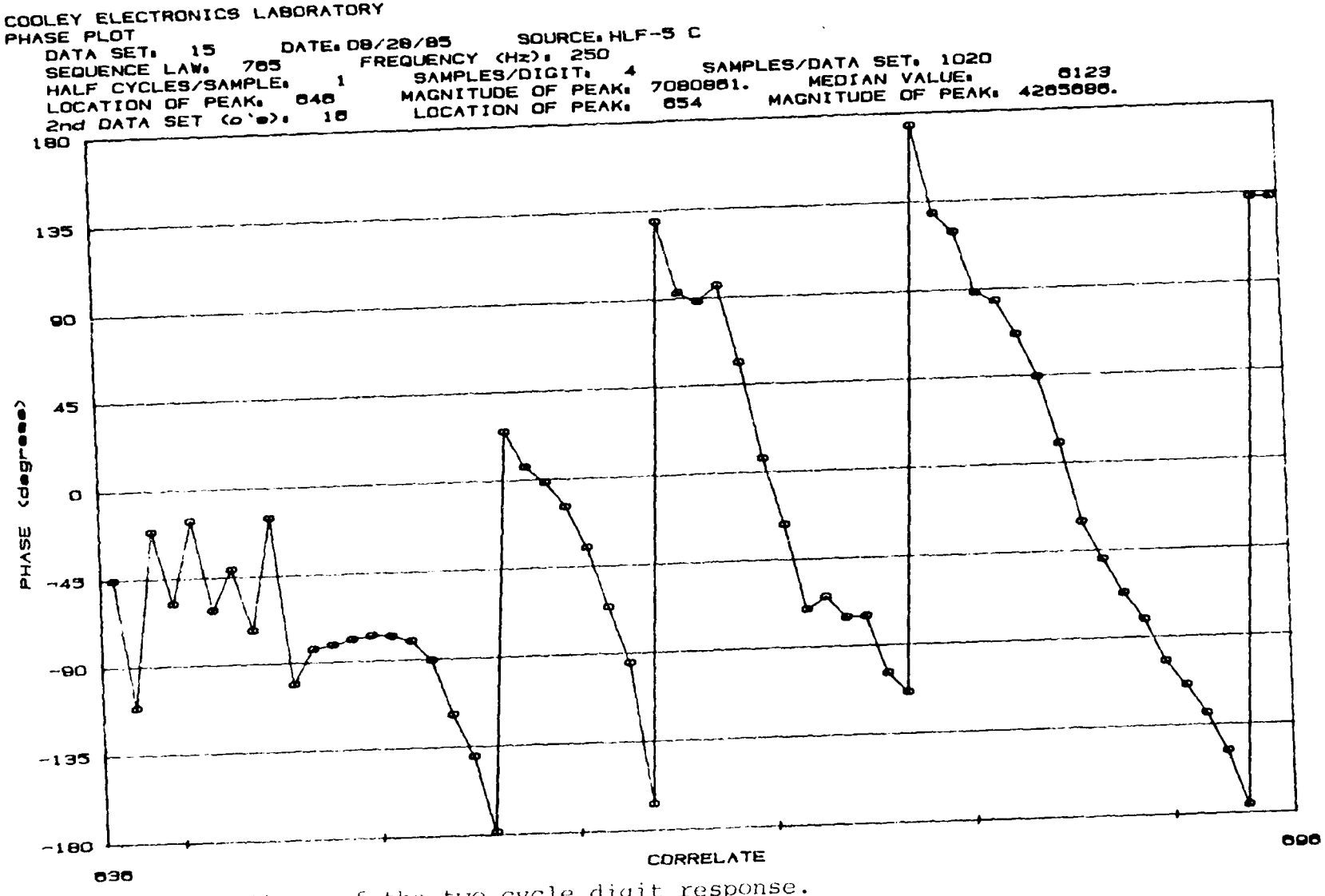


Plot 39. Fourth quarter of full period four cycle digit response (dB). Drive level = 3.5 vrms.

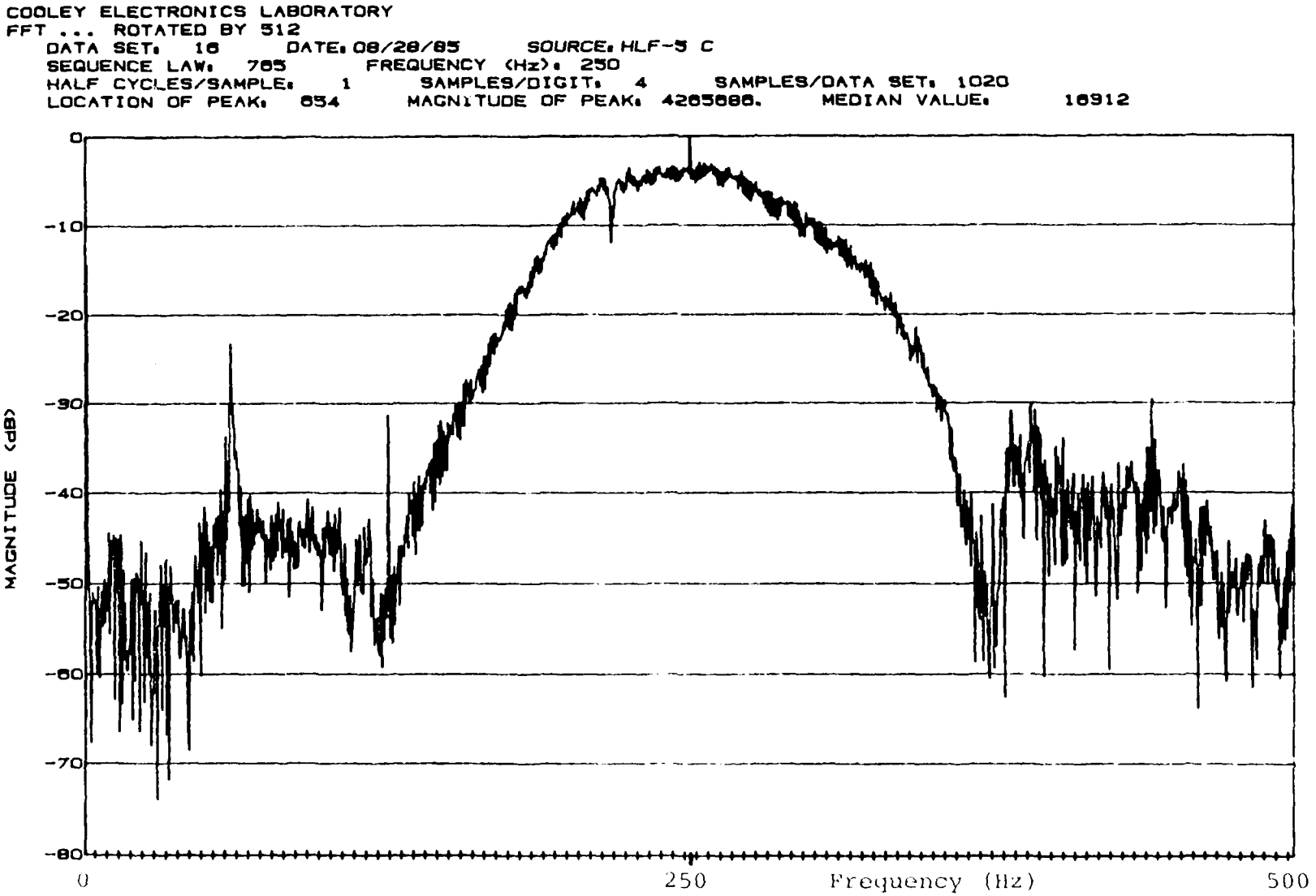


Plot 40. Two cycle digit response, direct path delay removed.

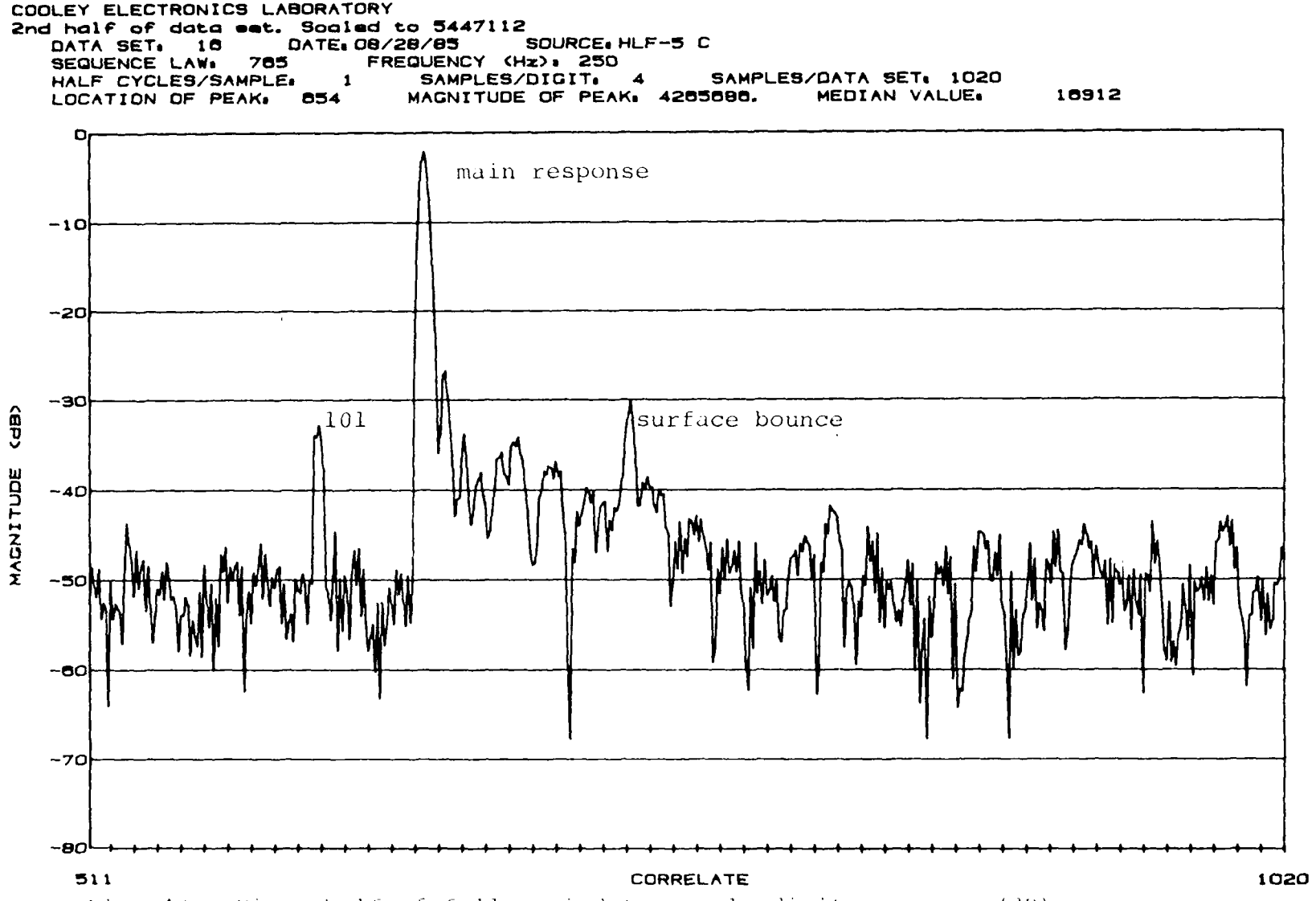
Source lowered to 446 feet.



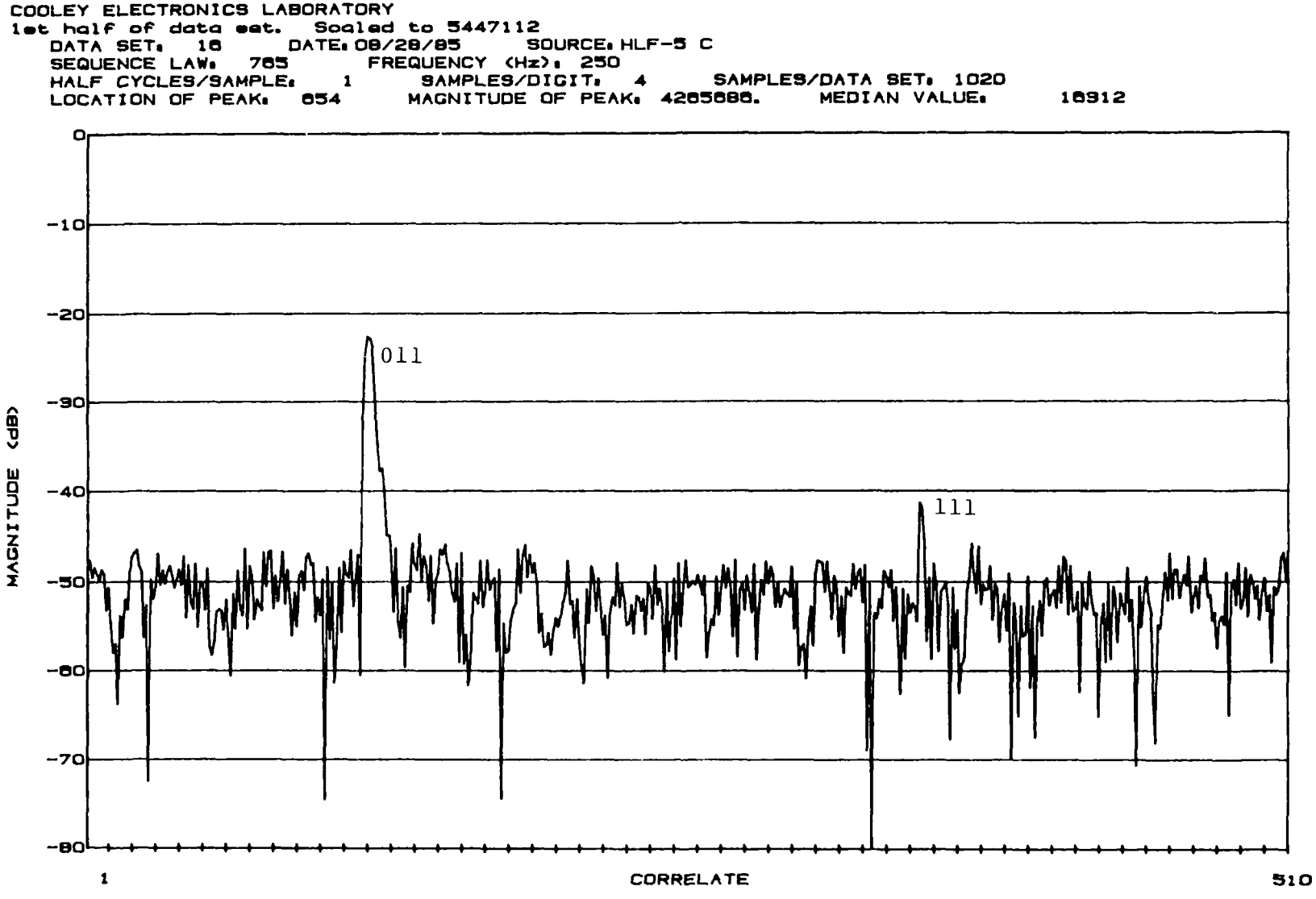
Plot 41. Phase of the two cycle digit response. Source lowered to 446 feet.



Plot 42. DFT of the two cycle digit response.
Source lowered to 446 feet.



Plot 43. First half of full period two cycle digit response (dB). Source lowered to 446 feet.



Plot 44. Second half period two cycle digit response (dB). Source lowered to 446 feet.

END

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