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Acoustic Noise Measurements of MBARI's Ventana ROV

by
Khosrow Lashkari
Engineering Department

ABSTRACT

This technical memorandum reports on the noise measurement results performed on MBARI's Ventana ROV. The measurement procedure and the instrumentation for this experiment are also described.

This report is organized as follows:

Section 1 provides some introductory information.

Section 2 describes the experiment and the instrumentation.

Section 3 presents the results.

Section 4 contains some concluding remarks.

KEYWORDS/PHRASES

1.- Remotely Operated Vehicle (ROV)
2.- Acoustic noise
3.- Spectral analysis
4.- Sensors

1. - INTRODUCTION

MBARI is in the process of designing ROV 1.5, its next generation remotely operated vehicle. ROV 1.5 will serve as a platform for a number of sensors to measure and study the properties of the ocean medium. These sensors include video cameras, chemical sensors, CTD's, ADCP's for measuring ocean circulation and a host of other sensors. To be a faithful sensor platform, the ROV must not intrude in the environment where sensing and measurement is taking place.

Its presence must cause minimum disturbance in the environment so that it does not perturb the very environment that it is trying to measure.

In real world however, the presence of the ROV creates various disturbances in the ocean medium such as water movement and optical and acoustic disturbances.

Acoustic emissions caused by moving mechanical parts such as thruster mechanisms, articulated arms, samplers and electronics equipments such as transformers could scare away biological life and have an adverse impact on these observations. It is therefore important to keep these emissions to a minimum wherever possible.

This report describes an experiment conducted on October 7, 1991 to measure acoustic emissions from MBARI's ROV Ventana. The purpose of this experiment was to get a general idea about the noise levels from this ROV under various operational scenarios.

2.- NOISE MEASUREMENT EXPERIMENT

In this section, we describe the experiment and the instrumentation.

2.1 - DESCRIPTION OF THE EXPERIMENT

Noise from ROV Ventana was measured in two locations:

1) at Moss Landing dock in about 12 feet of water.
2) at sea in about 500 feet of water.

In both locations, the ROV was launched and recovered off of MBARI ship, POINT LOBOS. Noise measurements were made under various operational conditions: during launch and recovery operations, when the ROV thrusters were operating and when the ROV was powered off. The dock noise measurements were done with a "dead ship" that is ship's engines and generators turned off. At sea measurements were done under two conditions: 1)ship's engine and generated running and 2)ship's engines off but generators running. In all the measurements, hydrophone was suspended from the starboard side of the ship about 10 feet into the water. For the dock measurements, the noise was predominantly due to the ROV. For at sea measurements, because of the relative proximity of the hydrophone to the ship(3 meters), versus the ROV(170 meters), the predominant emissions were due to the ship.

2.2 - INSTRUMENTATION

Figure 1 shows the instrumentation used during this experiment. The sound was picked up by a model 1AD/HC12 hydrophone from Sea Acoustics Limited. This is an omnidirectional hydrophone with a nominal sensitivity of about -166 dBV relative to one micropascal. Figure 2 shows the receiving characteristics of this hydrophone as a function of frequency. This hydrophone was powered by a 18 volts battery power supply system that also serves as a signal pickup circuit as shown in figure 3. A BNC connector supplies the required DC power to the hydrophone across the pin designated as HYDROPHONE on this figure and the supply ground. Hydophone AC signal is picked up across the pin designated as SIGNAL (across the 1 uF capacitor) and the signal ground using another BNC connector. Supply and signal grounds are the same.

The hydrophone signal is fed into a configurable variable frequency filter from A.P. CIRCUIT Corp. This filter can be configured as a lowpass, highpass or bandpass filter with the choice of RC or Butterworth filters for each component filter. For this experiment, the filter was configured as a Butterworth bandpass filter with 3dB cut-offs at 4Hz and 10KHz respectively.

The filtered hydrophone signal is simultaneously fed into three parallel systems as shown in Figure 1. The recording system was a 20 channel TEAC XR-7000 instrumentation recorder. This system provides three high fidelity recording options: FM recording, direct recording and PCM digital recording.

For this experiment the FM recording mode was selected because of the need to record very low frequencies. The FM recording mode provides a flat recording characteristic from DC to 40KHz. The upper end of the receiving characteristic is a linear function of the tape speed. At a tape speed of 9.52cm/sec, the upper end is 5KHz and at 76.2cm/sec, the upper end is 40KHz.

The spectrum analyzer was Hewlett-Packard 35660A Dynamic Signal Analyzer. This system allows real-time spectrum analysis with various coherent and incoherent averaging and windowing options.

For this experiment, no windows were used. Both coherent and incoherent RMS averaging was selected to produce periodogram spectral estimates with number of averages ranging from 10 to 200 ensembles. An HPIB cable, interfaces the spectrum analyzer to an HP 7475A pen plotter to produce hardcopy plots from the analyzer screen.

A high quality DENON audio amplifiler and a Beyerdynamics DT 330 headset was used for listening purposes.

3.- MEASUREMENT RESULTS

The hydrophone signal is a continuous time record of the acoustic pressure impinging upon the hydrophone. This signal is recorded in analog form by the TEAC recorder to preserve all the information in the signal. Analog recording prevents potential aliasing and dynamic range problems that could arise in digital recording if digitization is not handled properly. During subsequent processings, analog hydrophone signal is filtered and digitized for spectrum analysis.

Figures 4 through 10 show typical measurements of the RMS power spectral density(PSD) for various situations. The vertical axis on these plots shows the RMS PSD in dBV (decibel volts). Each PSD is computed by averaging a number of ensembles. The number of averages is shown at the bottom right corner of each plot and vary from 40 to 200. This averaging is done to smooth out the random fluctuations due to the statistical nature of the signals and /or presence of the noise. The measurements are shown over a frequency range of 0 to 6.4 KHz. The time bandwidth product (BT) for this analysis is 400. This means that each ensemble's duration is:

$$T = 400/6400 = 1/16 \text{ seconds}$$

Thus a PSD computed based on 100 averages uses a total of 6.25 seconds of data.

To arrive at the sound pressure levels(SPL) the following calculations must be done:

$$\text{SPL(dB re 1 micropascal)} = \text{PSD(dB)} - 20 + 166$$

or:

$$\text{SPL(dB re 1 micropascal)} = \text{PSD(dB)} + 146$$

During recording, filter gain was set at 20dB and the hydrophone had a nominal sensitivity of -166dB relative to 1 micropascal.

Figure 4 shows the PSD when ROV is at Moss Landing dock with thrusters running at normal power. This plot shows a pattern of tone-like components that resemble a harmonic behavior with harmonics approximately 530Hz apart. The amplitude of the peak at 3.728KHz is -57.4dBV corresponding to a SPL of 88.6 dB relative to 1 miropascal. As a reference the ambient noise level in Monterey Bay is around 80 dB.

The average PSD level is around -65dBV or 81dB relative to 1 micropascal.

Figure 5 shows the PSD with ROV thrusters at their full power. As seen in this figure the general level of noise is about 91dB which is 10dB higher than figure 4.

Figures 6 and 7 show the ambient noise spectra at sea and Moss Landing dock respectively. These measurements were done with filter gain set to 0dB. It is seen from these figures that the SPL for ambient noise is around 74dB for open ocean and 86dB for the Moss Landing dock.

Figures 8, 9 and 10 show PDS's of POINT LOBOS at sea at 600rpm, 1000rpm and 1500rpm respectively. As seen in these figures, below 2KHz the emissions from POINT LOBOS is around 102dB.

Source Levels

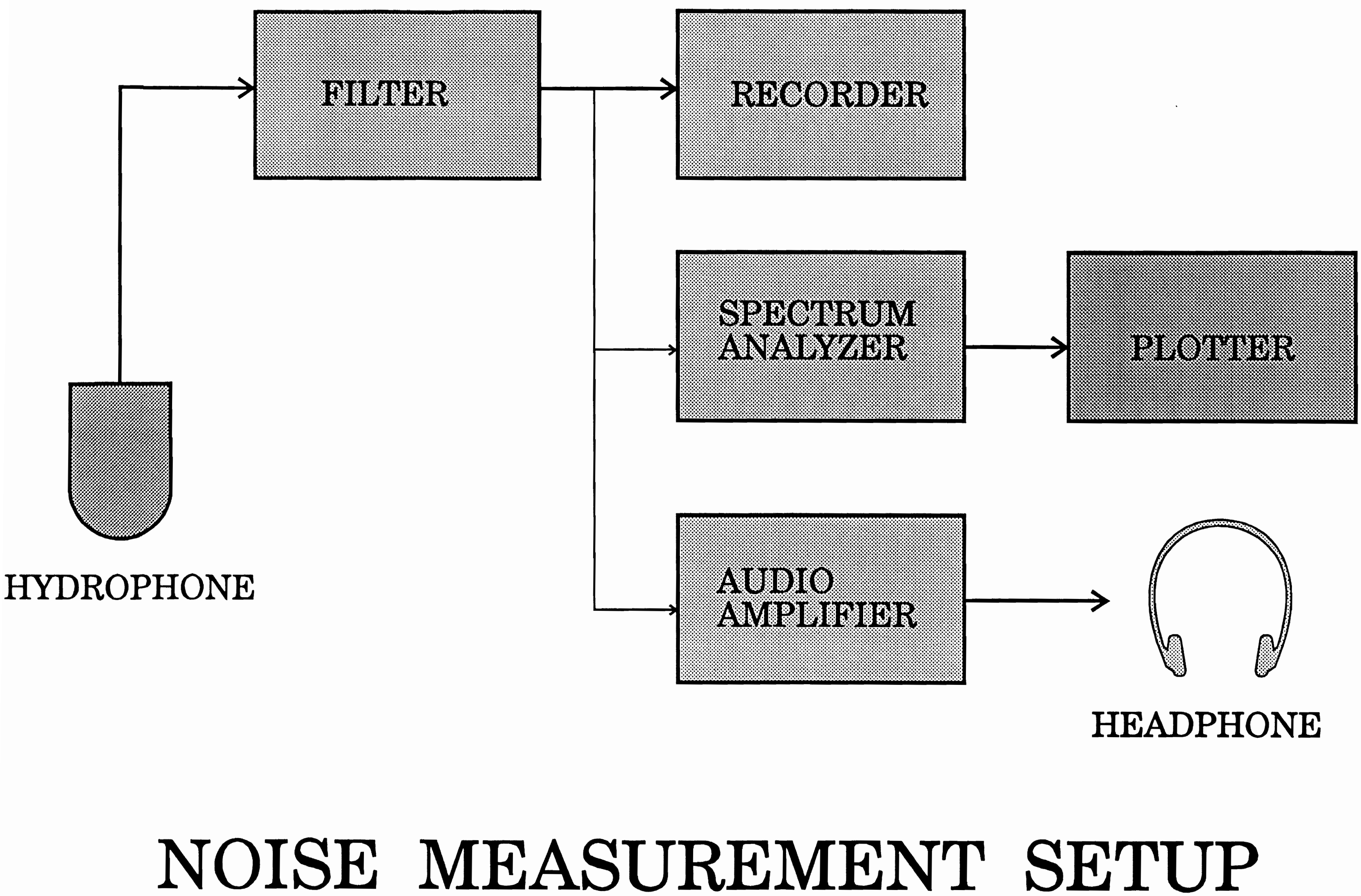
Figures 4 thru 10 show the received signal levels, not the source levels.

For dock measurements, hydrophone and ROV were about 70ft. (20 meters) apart. Assuming an inverse square law propagation, the source level for the ROV can be computed by adding 10 log (400)= 26dB to the received signal levels. Square level is acoustic pressure relative to one micropascal at a distance of one meter from the source.

4.- CONCLUSION

This experiment gives us a general idea about the sound pressure levels (SPL's) for the ROV, POINT LOBOS , the ambient ocean noise and noise at Moss Landing dock. While, it is relatively straightforward to measure the ship and ambient noise, there are several problems in measuring the ROV noise. First, ambient noise at dock is about 10dB higher than the ambient noise in ocean, thus it is better to measure the ROV noise in ocean. This will be closer to the real operational environment. Second, since ship(engine and generator) cannot be completely turned off when ROV is in water, ship noise will mask the ROV noise if the ROV is not far away from the ship and the hydrophone is not close to the ROV. Because of this masking, none of the ROV noise measurements at sea could be used for this report.
In conclusion we recommend the following scheme for ROV noise measurements:
1)mount a hydrophone on the ROV, telemeter the data to surface through tether
2)launch the ROV as far as possible from the ship
3)shut the ship's engines off.
4)perform the noise measurements

Figure 1: Instrumentation setup for noise measurement



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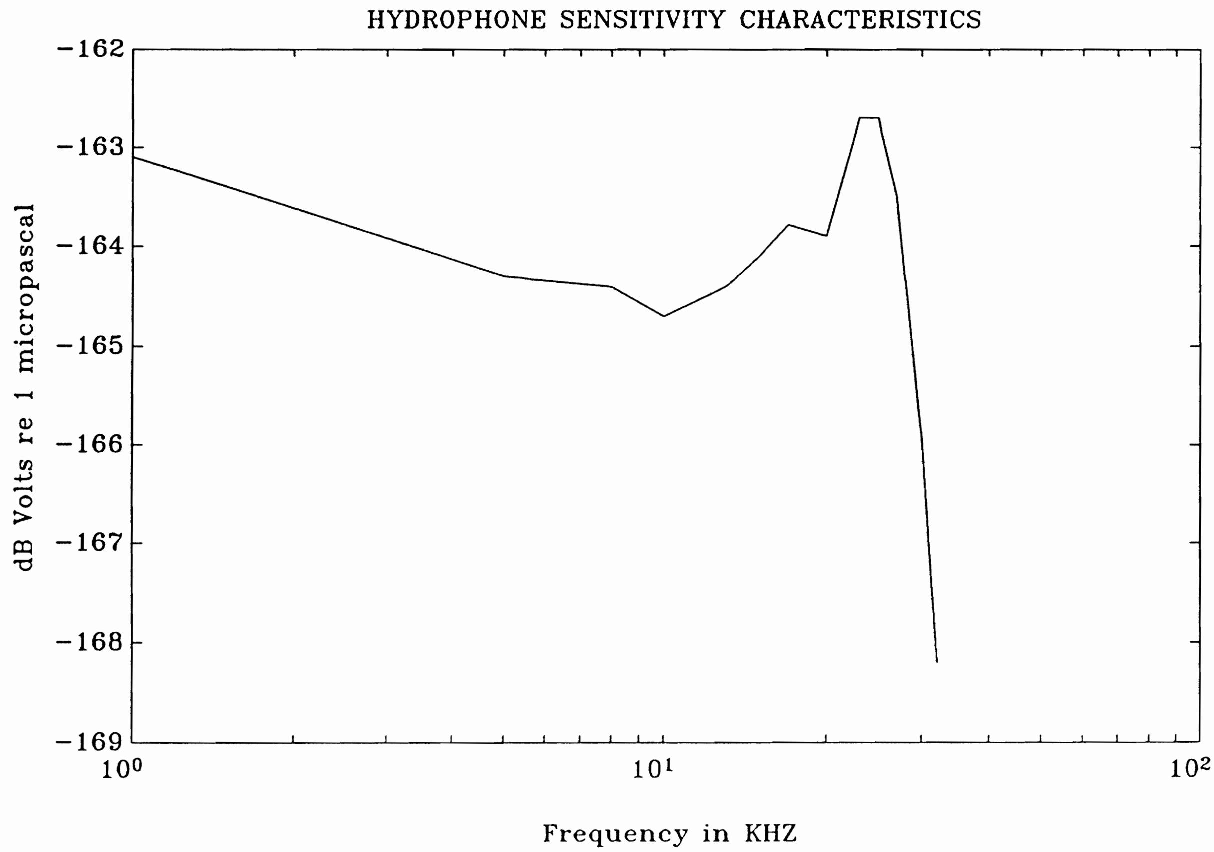

Figure 2: Hydrophone Sensitivity Characteristics

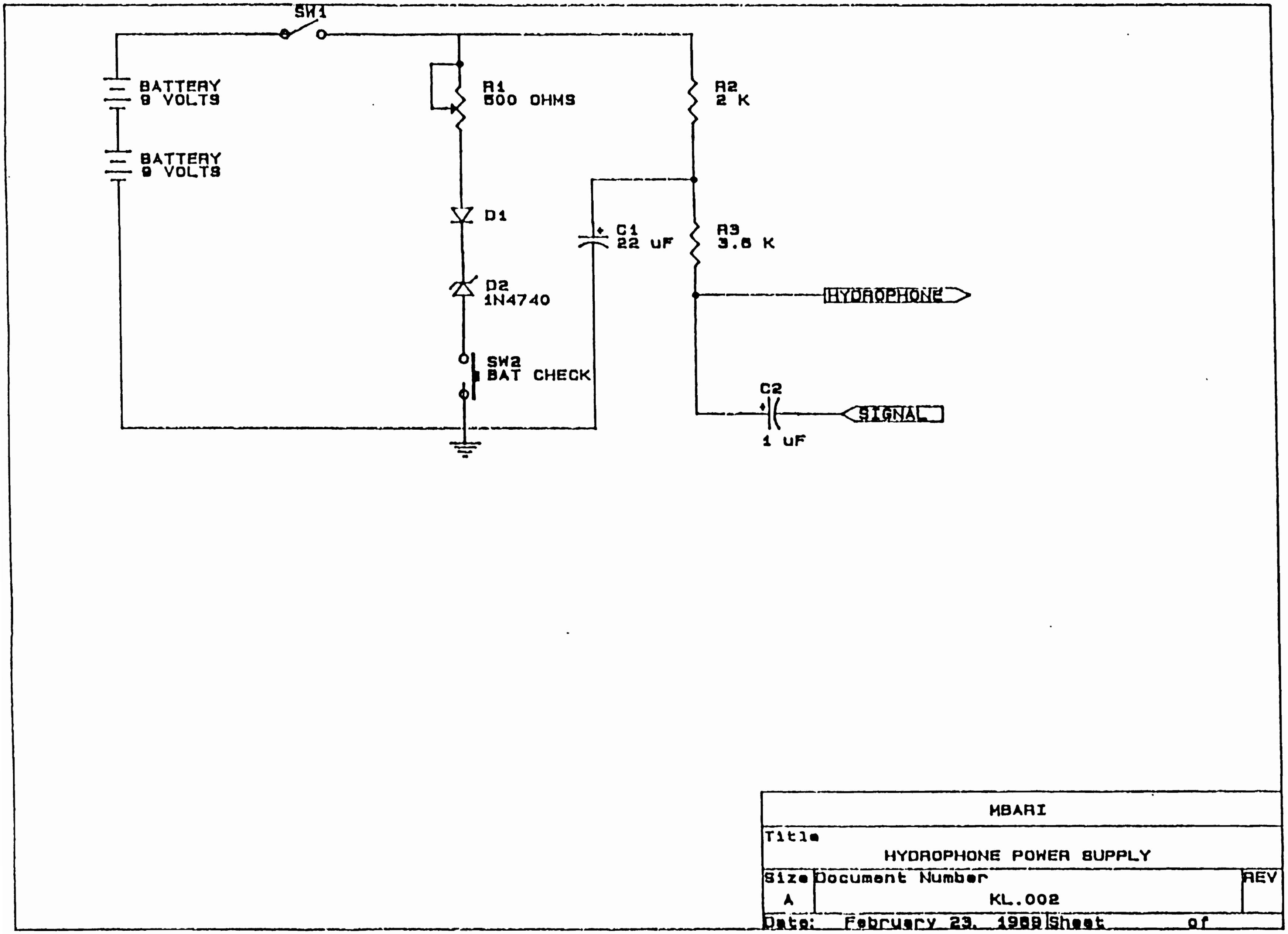

Figure 3: Hydrophone power supply and biasing circuit

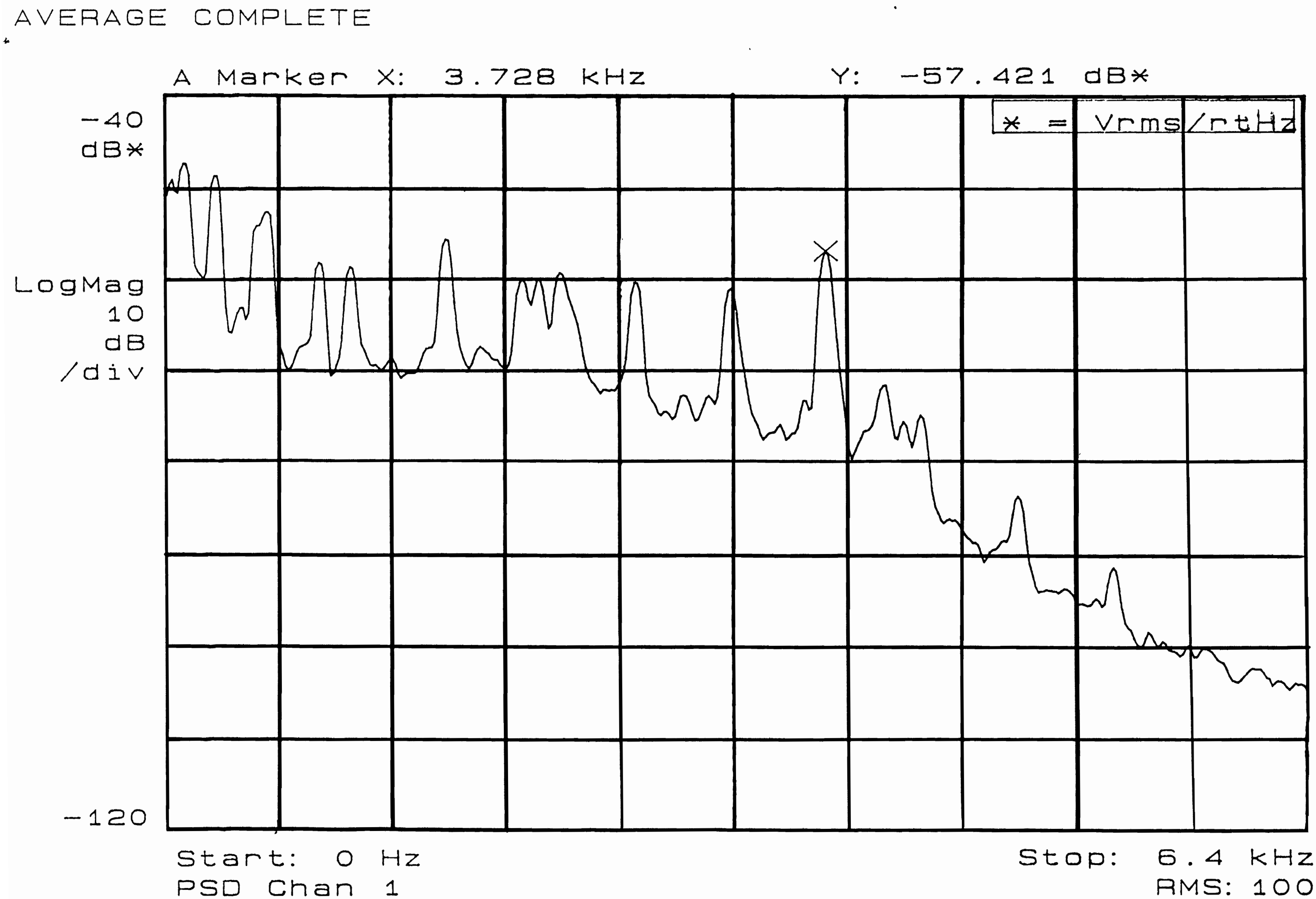

Figure 4: Rov at Moss Landing, Normal Thruster Power

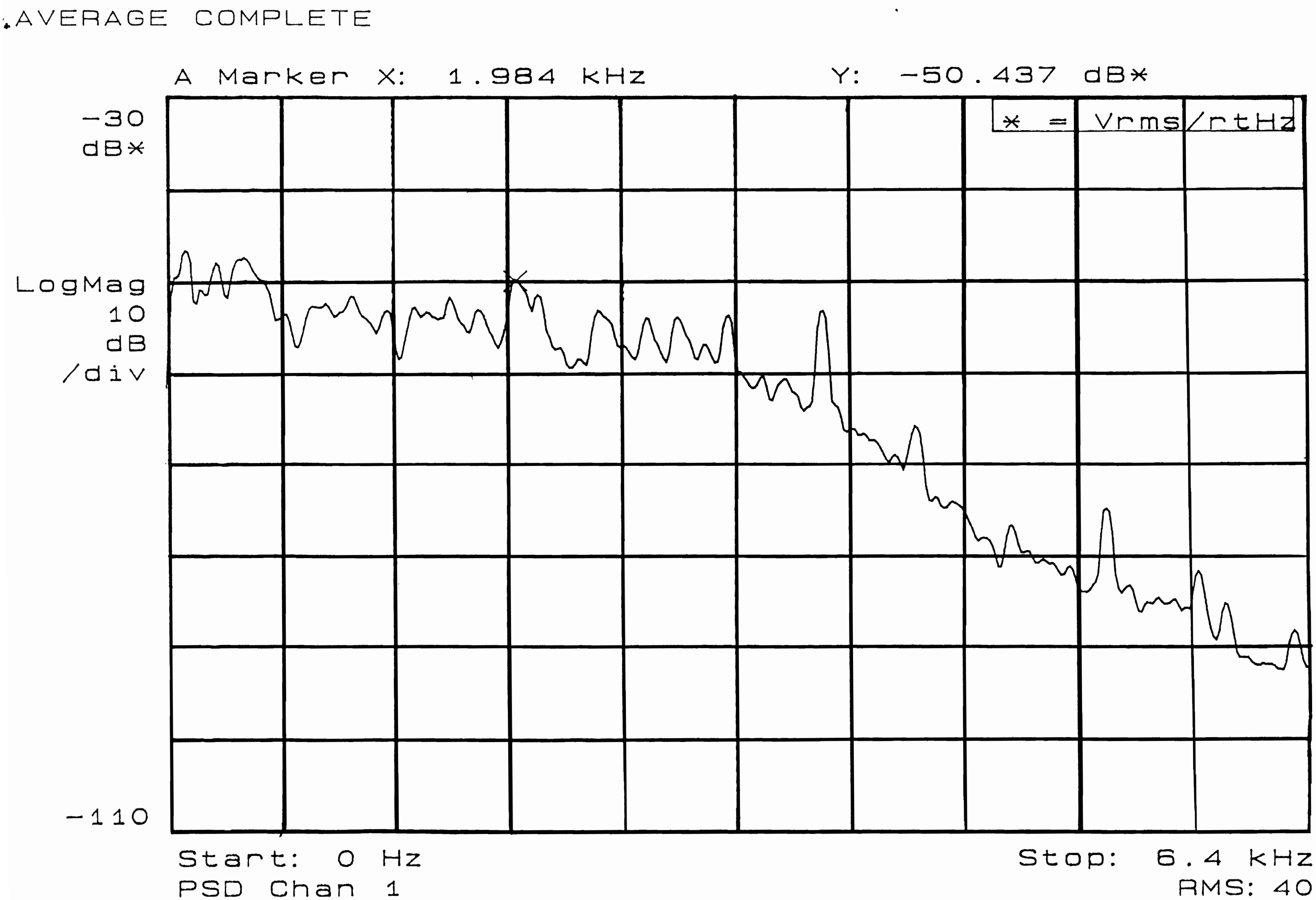

Figure 5: Rov at Moss Landing, Full Thruster Power

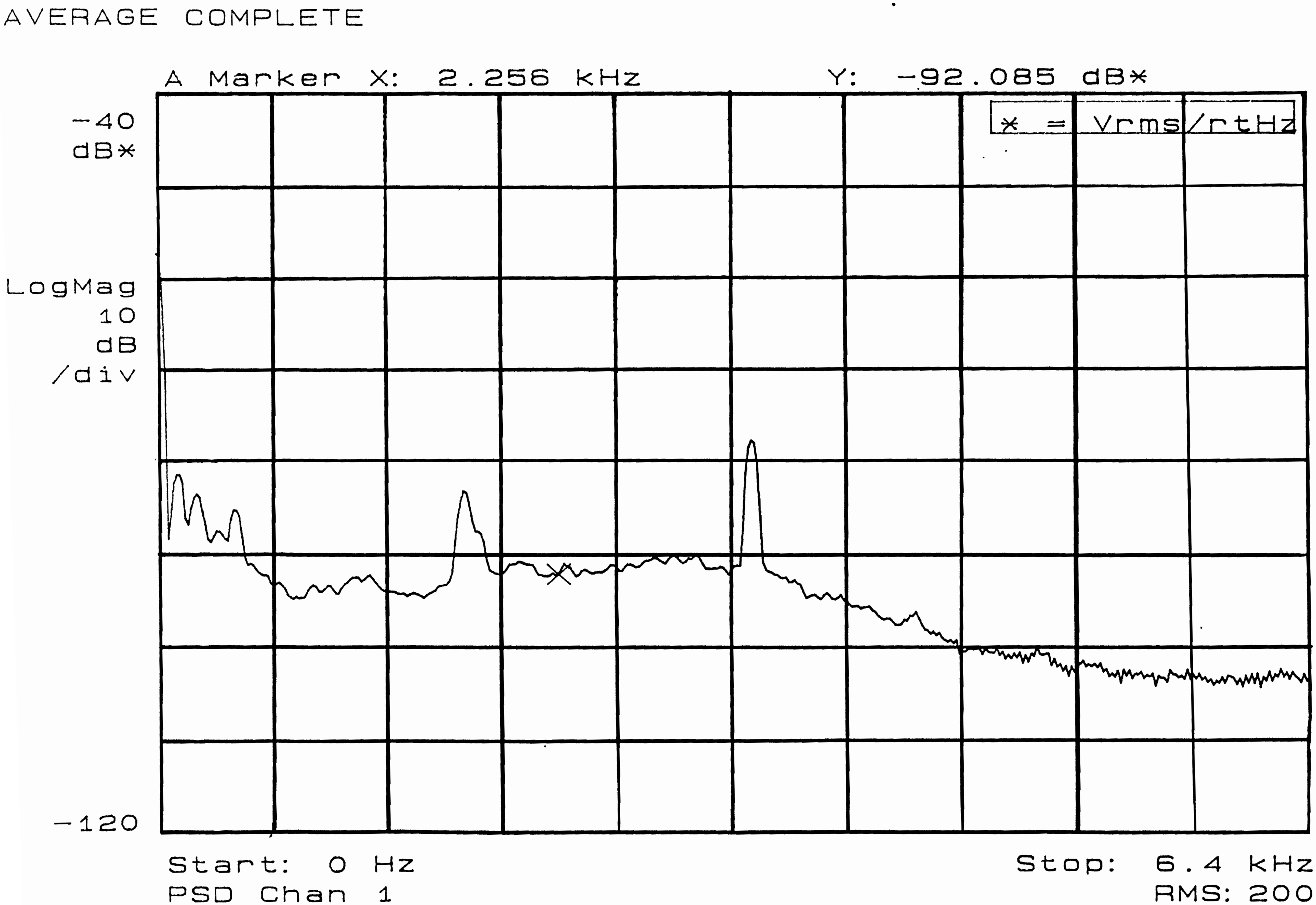

Figure 6: Spectrum of Ambient Noise at Sea

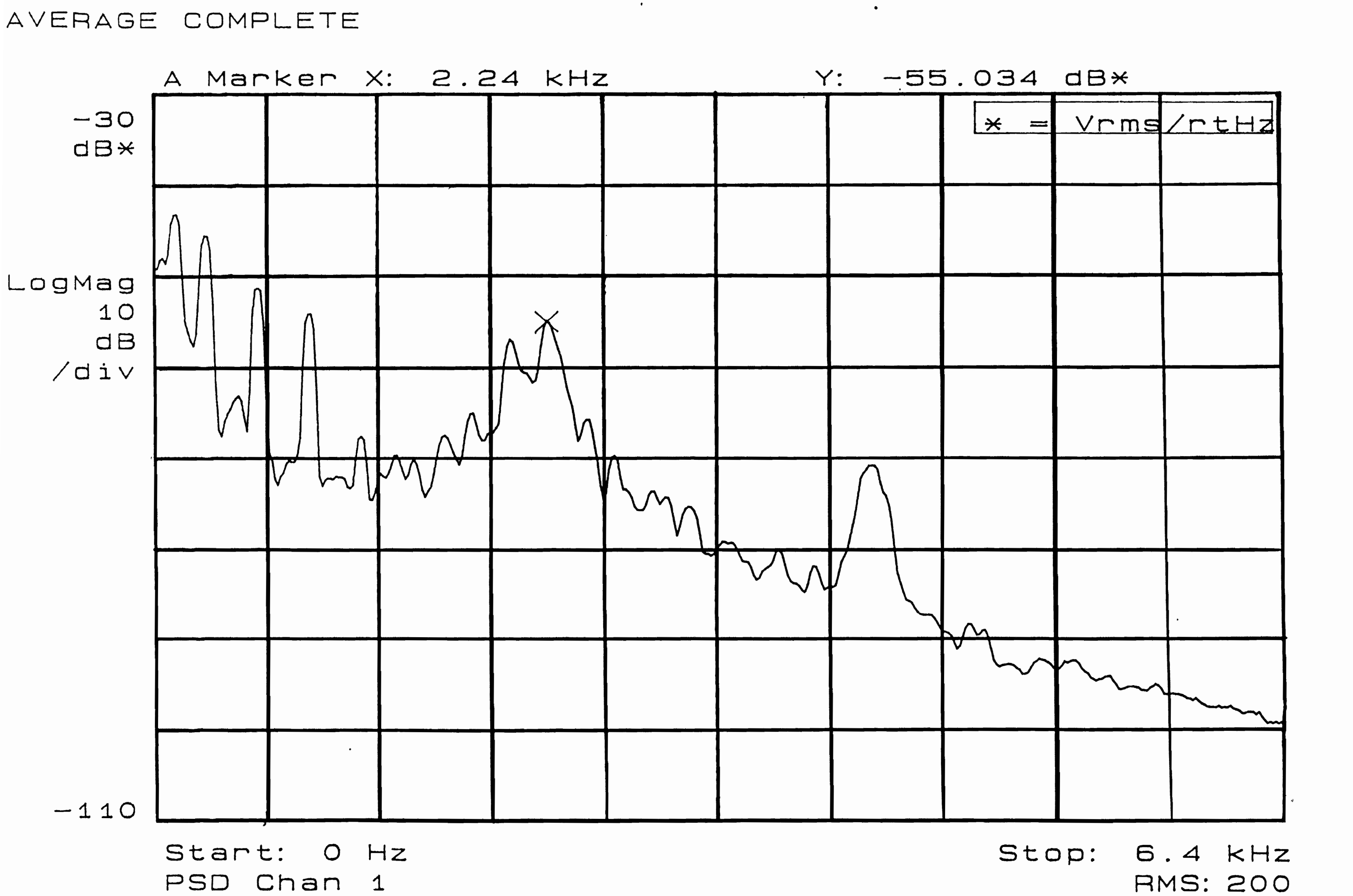

Figure 7: Spectrum of Ambient Noise at Moss Landing Dock

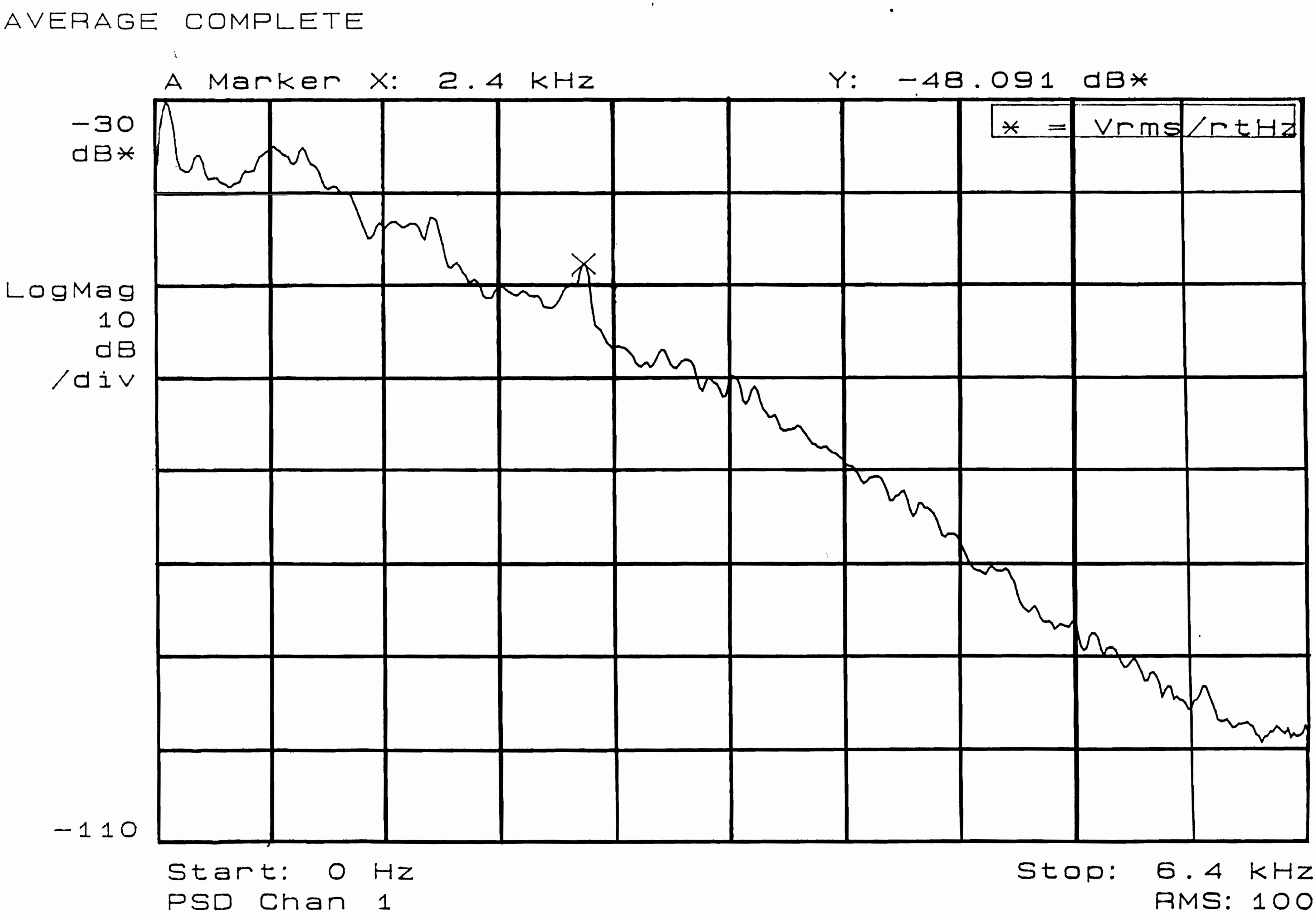

Figure 8: Point Lobos at Sea 600 rpm

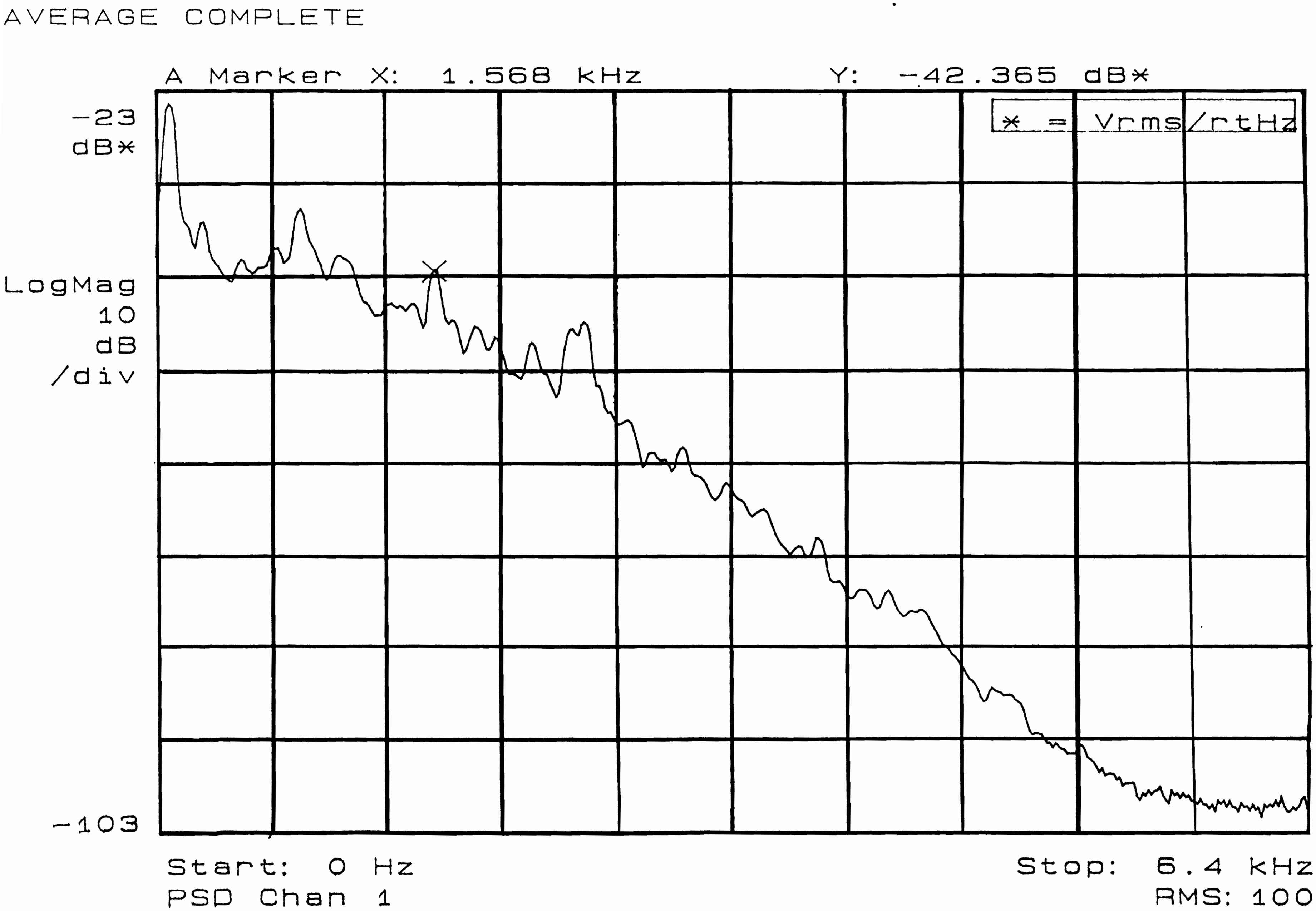

Figure 9: Point Lobos at Sea 1000 rpm

Figure 10: Point Lobos at Sea 1500 rpm