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APOLLO SPACECRAFT SYSTEMS ANALYSIS PROGRAM
TECHNICAL REPORT
TASK E-34D

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A COMPARISON OF THE COMPUTED LR RECEIVED SIGNAL SPECTRUM AND THE 1967 PEARL DATA

Prepared For
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TRW
SYSTEMS GROUP

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APOLLO SPACECRAFT SYSTEMS ANALYSIS PROGRAM

A COMPARISON OF THE COMPUTED LR RECFIVED SIGNAL SPECTRUM AND THE 1967 PEARL DATA

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TABLE OF CONTENTS

LIST OF ILLUSTRATIONS

1.0 INTRODUCTION

The purpose of this report is to exhibit similarities between experimentally measured power spectral density (PSD) curves of the signal returned from a rough scattering surface and the curves obtained from a computer program for a sinusoidal surface. The report also shows how the shape of the computed PSD curves is affected by varying the geometrical parameters of the surface.

The PSD of the signal returned from the lunar surface is a quantity needed to evaluate the performance of the Landing Radar. Reference [1] formulates a numerical algorithm which could be used to compute the PSD whenever a detailed specification of the surface geometry is known. The specific surface considered in Reference [1] is a sinusoidal surface of limited extent. A computer program TEORR, (Terrain Effects on Radar Return), was developed as a tool to expedite this numerical algorithm and was used to generate the data for the PSD curves in this report.

The number of computed and measured cases compared in this report were limited because of the range of parameters available and the amount of computer time required for each comparison. Further comparisons will be made as additional data become available.

2.0 DISCUSSION

Power spectral density plots from the 1967 summer test program at WSMR of the Landing Radar were obtained from LEC (see Figures 1, 4, and 6) and were used to show similarities between the measured and the computed PSD curves. The geometrical inputs to the computer model are discussed in the Appendix and were constructed to simulate the configuration used in the actual test program.

All the PSD's in this report are for velocity sensor beam 3. Figure 1 shows the approximate upper and lower envelopes of an experimentally measured PSD plot for the WSMR LAVIC site. The large difference between the upper and lower envelopes is attributed to the signal-to-noise ratio of the data reduction system. Figures 2 and 3 are PSD curves from the computer program for the same velocity and altitude as given in Figure 1 but for a sinusoidal surface of 35 foot surface wavelength and an amplitude of 2 feet and 10 feet respectively. They have the same general shape as the experimental curve but differ in fine structure. The sidelobes occurring at approximately 700 and 1700 Hz are due to the antenna pattern employed in the calculations. This pattern is of the sin ρ/ρ type, hence the first pair of sidelobes is 26 db below the main lobe.

Figure 4 and Figure 6 are the approximate upper and lower envelopes of experimentally measured PSD plots for the WSMR AFSWC site for different altitudes and velocities. Figure 5 is a computed PSD curve for comparison with Figure 4. Figure 7 is a similar curve to compare with Figure 6. Both of these computed curves compare less favorably with the experimentally measured curve with respect to the mean frequency and shape. The computer program was used to show that a small change in the vehicle attitude resulted in a large change in the mean frequency of the main lobe. For example, a three degree shift in the vehicle attitude could shift the main lobe as much as 175 Hz. Since no attitude data was given on the WSMR PSD plots the mean frequency shift (as shown in Figures 5 and 7) can be attributed to a possible difference in the attitude data input to the computer program and the actual vehicle attitude.

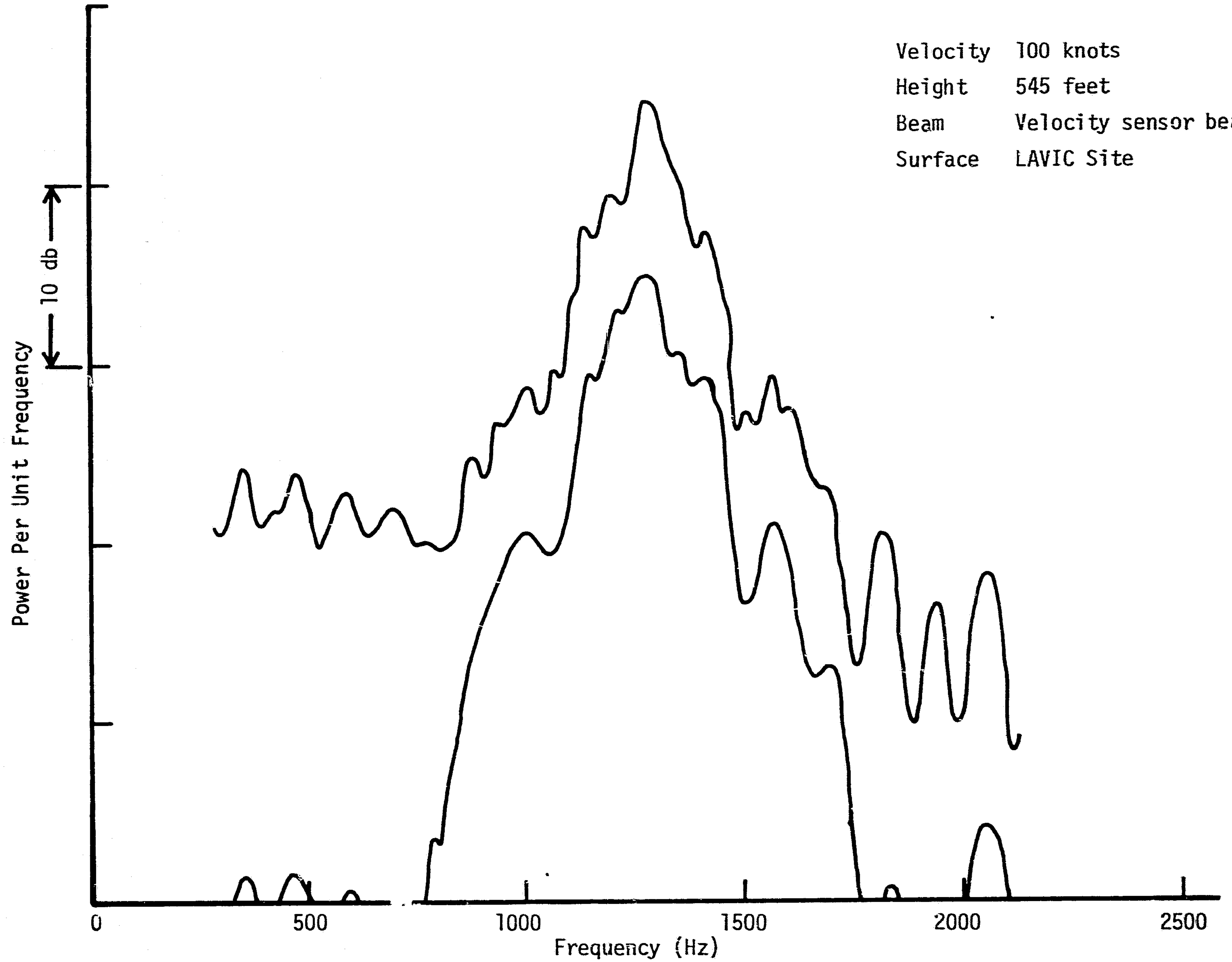

Figure 1. Upper and Lower Envelopes of a WSMR Summer 1967 Landing Radar PSD for the Lavic Site (545 foot altitude)

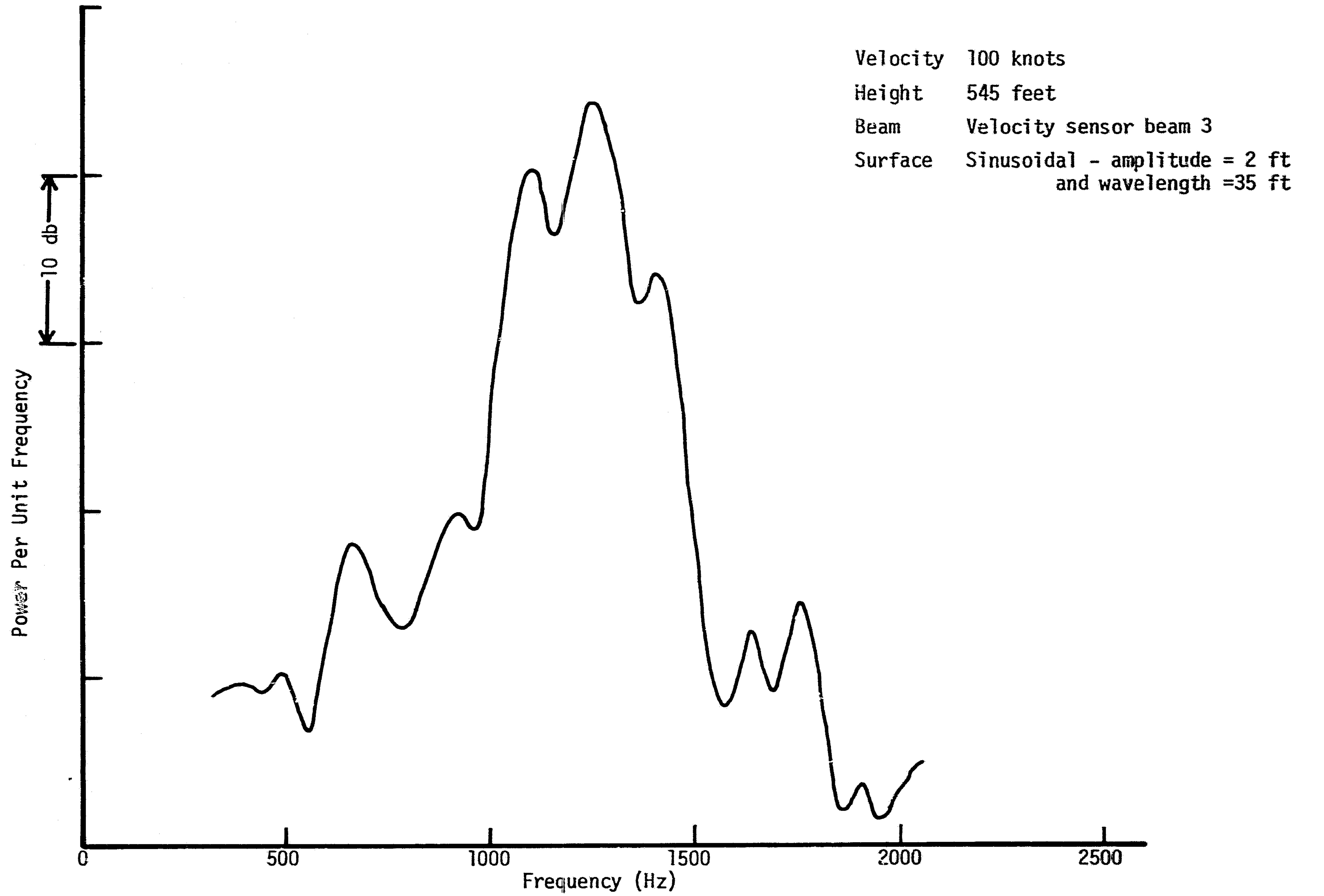

Figure 2. Computed Power Spectral Density Plot

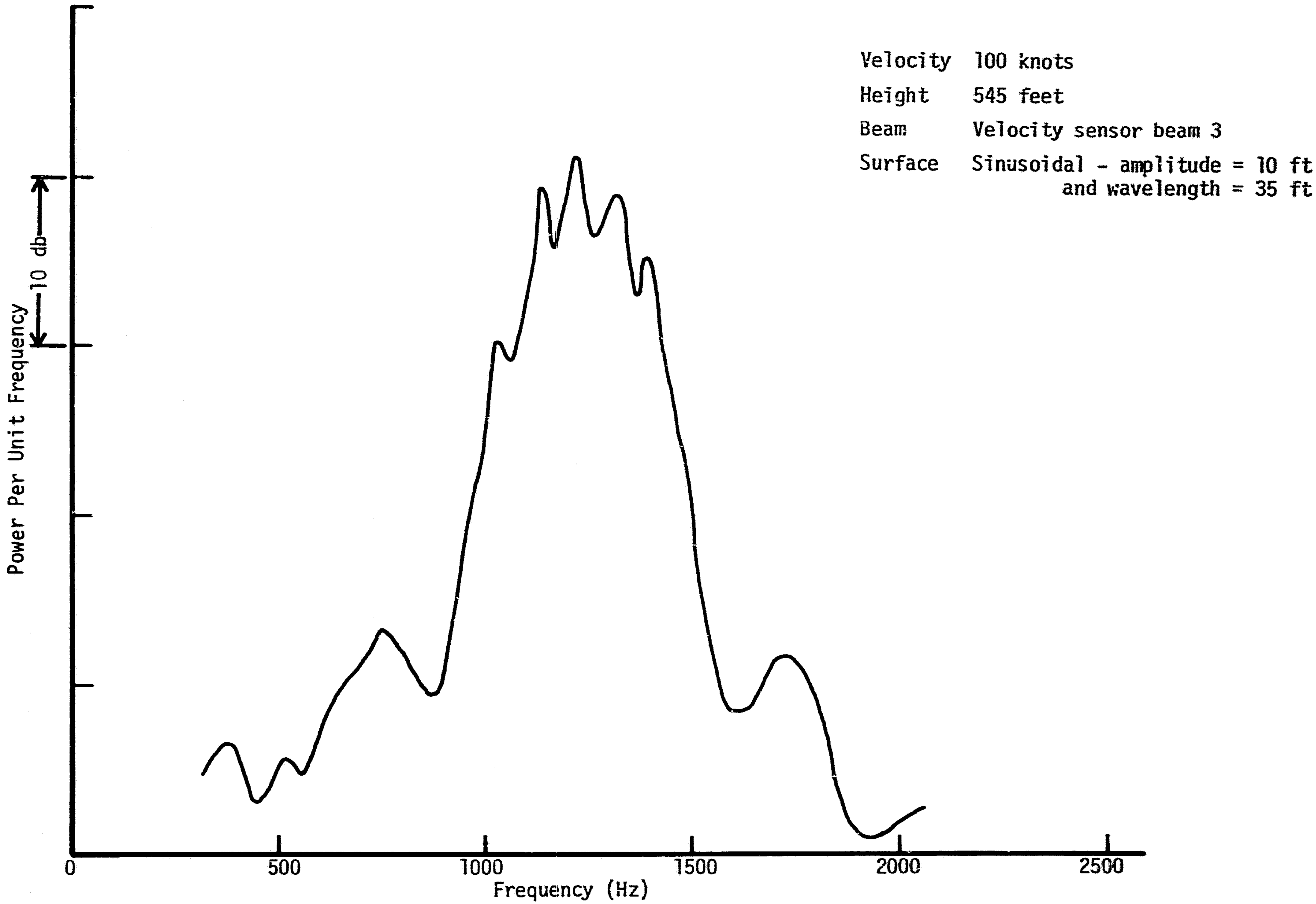

Figure 3. Computed Power Spectral Density Plot

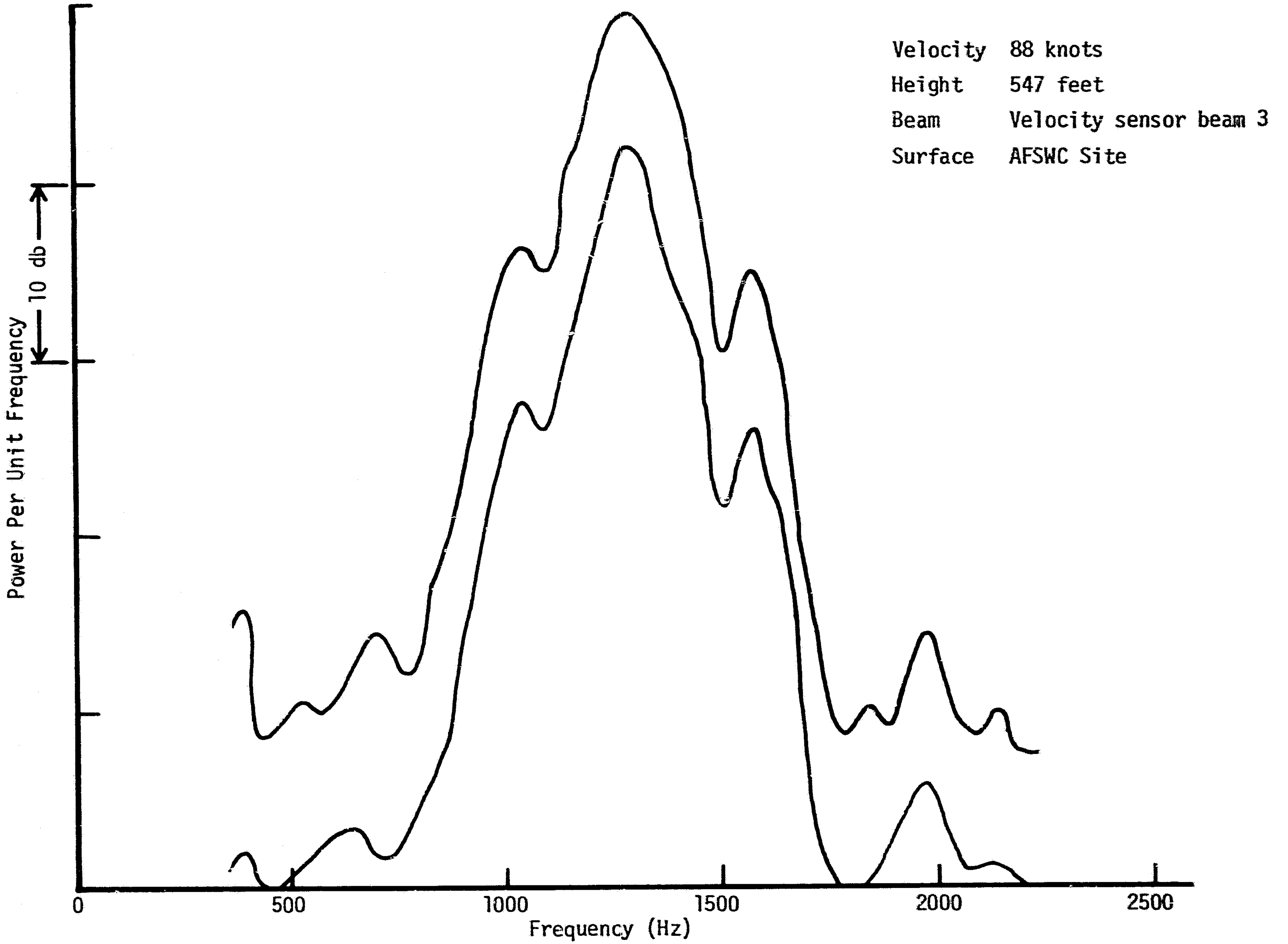

Figure 4. Upper and Lower Envelopes of a WSMR Summer 1967 Landing Radar PSD for the AFSWC Site (547 foot altitude)

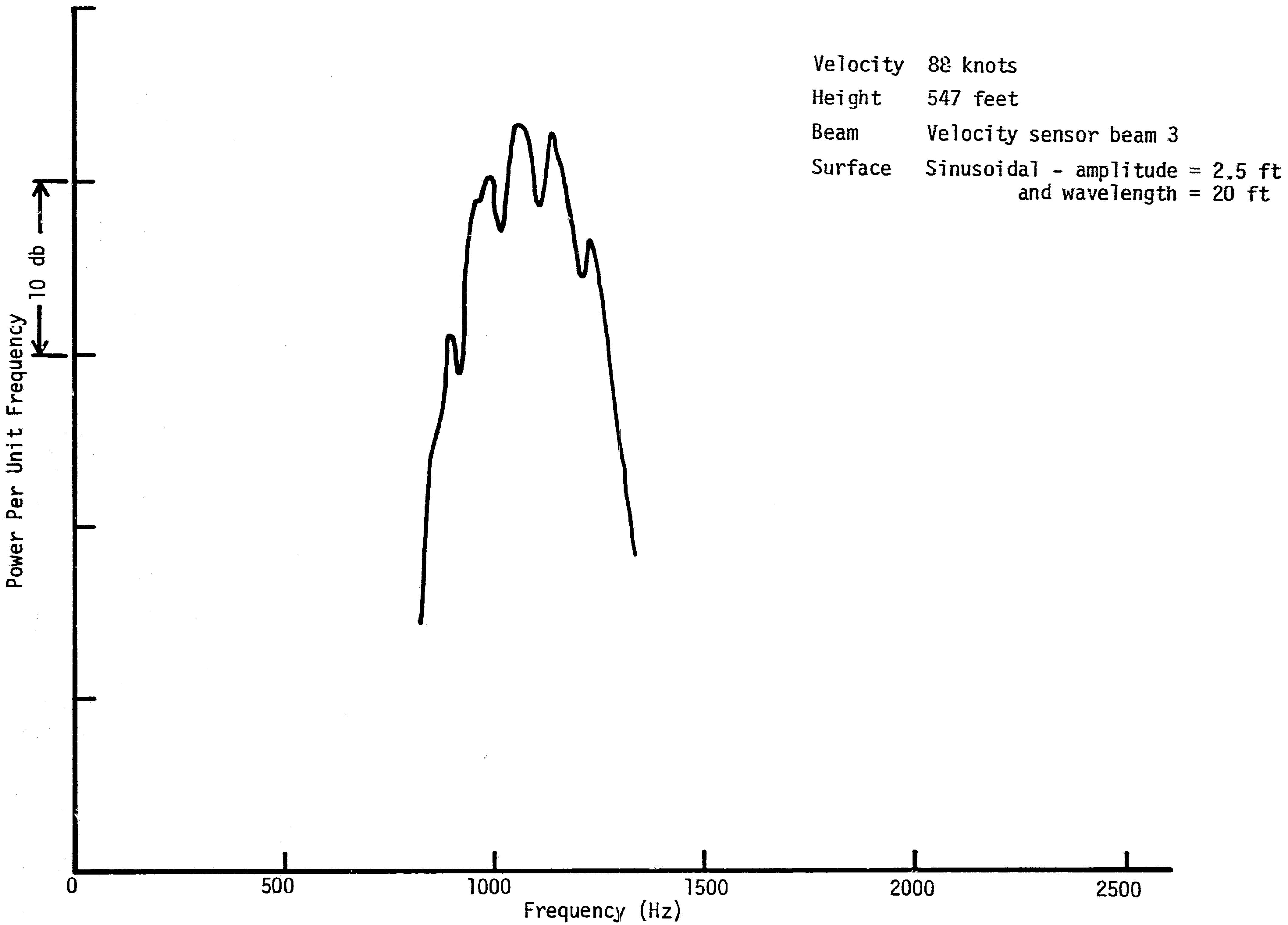

Figure 5. Computed Power Spectral Density Plot

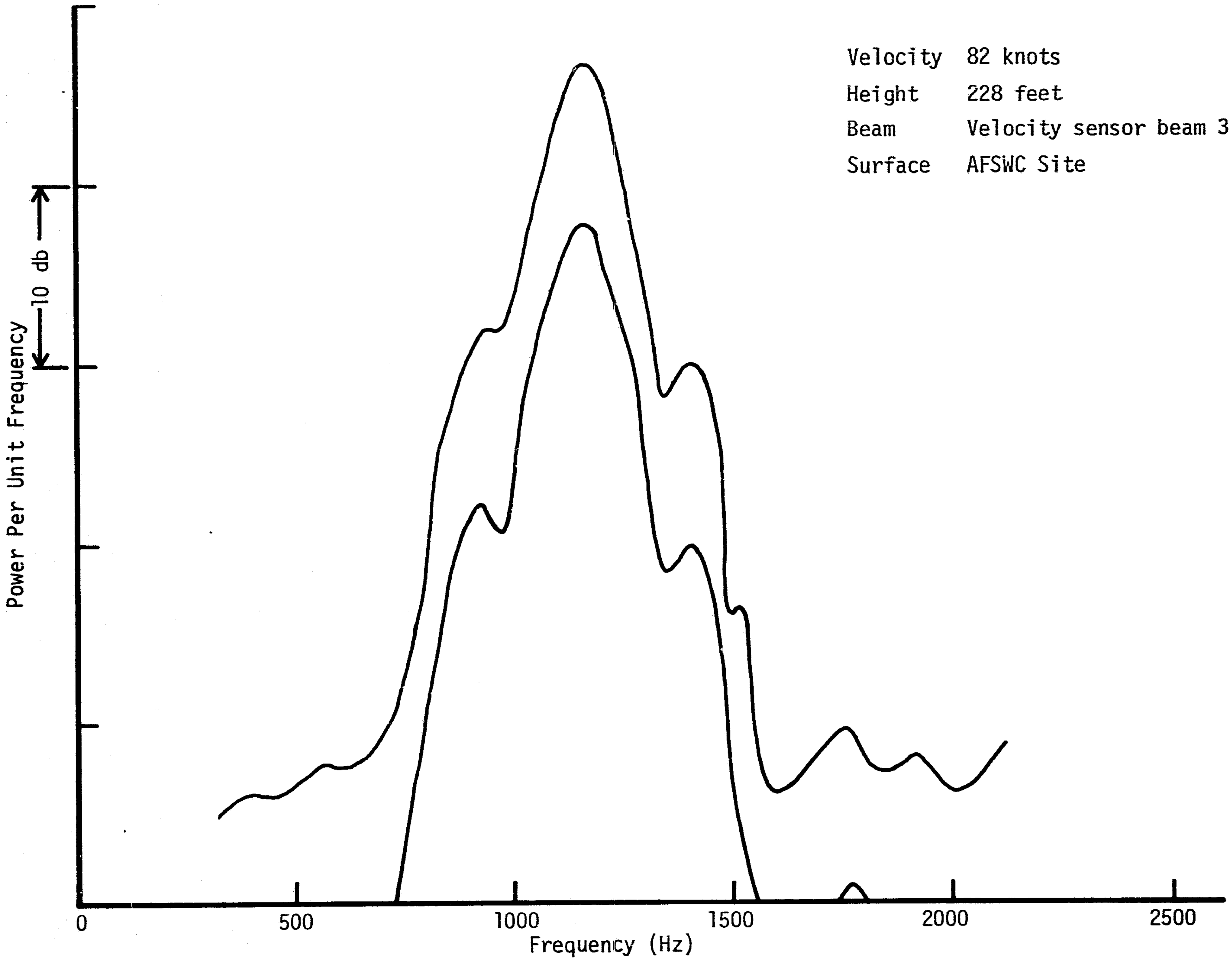

Figure 6. Upper and Lower Envelopes of a WSMR Summer 1967 Landing Radar PSD for the AFSWC Site (228 foot altitude)

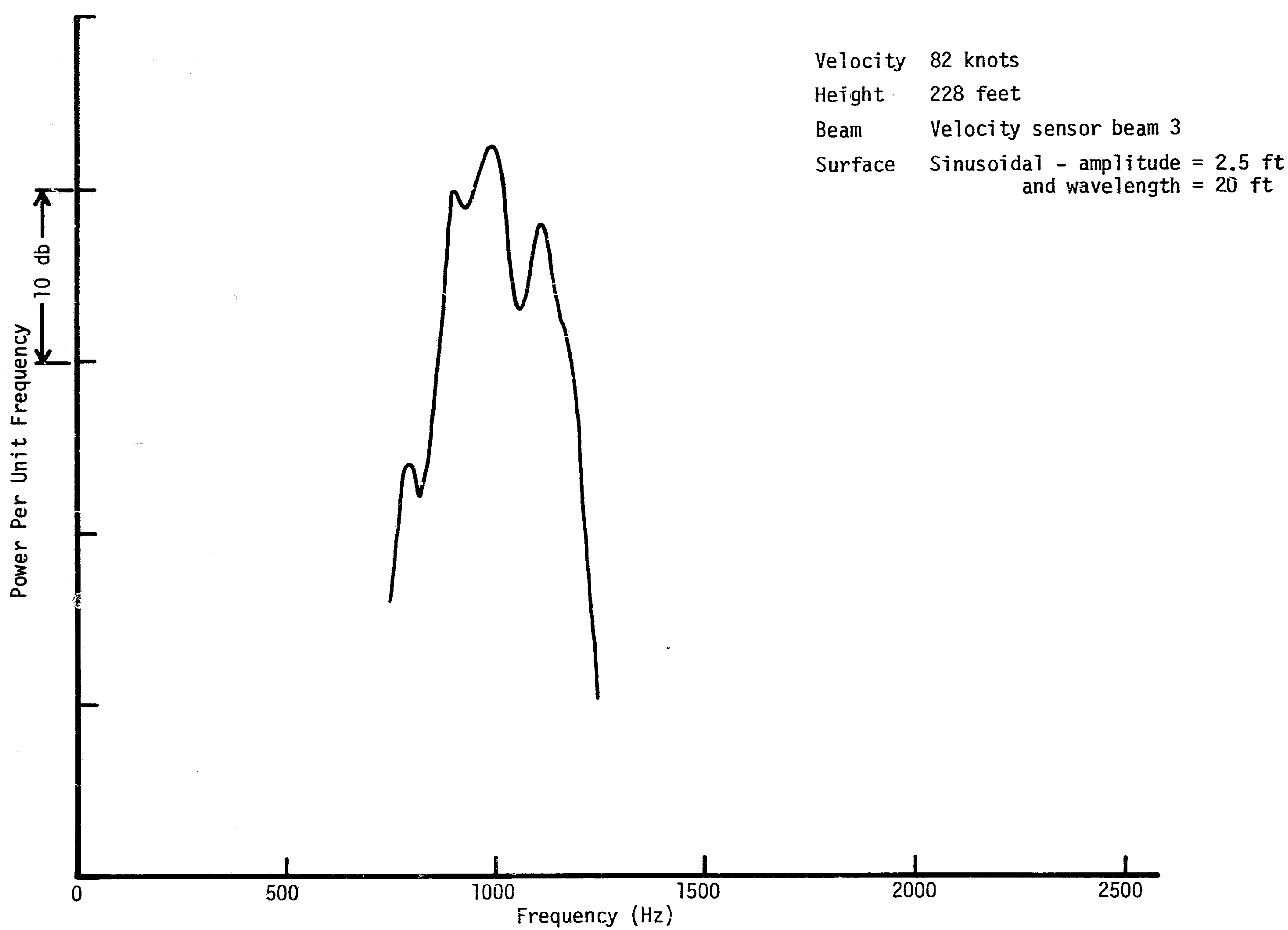

Figure 7. Computed Power Spectral Density Plot

The effects of varying the geometrical parameters of the sinusoidal surface on the shape of the computed PSD curves is illustrated in Figures 8, 9 and 10. All three of these figures were for the physical conditions used in Figure 1. The PSD return from a planar surface with small scale scattering properties is shown in Figure 8. It is mainly a function of the two-way antenna pattern and is a smooth curve. It can be thought of as a sinusoidal surface of zero amplitude. As the amplitude increases, small undulations start appearing in the vicinity of the main lobe. These are caused by the surface terrain since for a sinusoidal surface of constant wavelength variations in the wave amplitude causes the undulations to vary in magnitude but to remain in approximately the same location. Figure 9 shows these undulations for amplitudes of 5, 7.5 and 10 feet. Figure 2 is the same curve for an amplitude of 2 feet and is a much smoother curve. The surface wavelength is 35 feet on Figures 2 and 9.

The wavelength of the sinusoidal surface can also affect the shape of the PSD curves as is shown in Figure 10. The amplitude is 10 feet and wavelengths of 35, 70 and 100 feet are shown. Figure 10 shows that as the wavelength gets larger the PSD curves get smoother as could be expected.

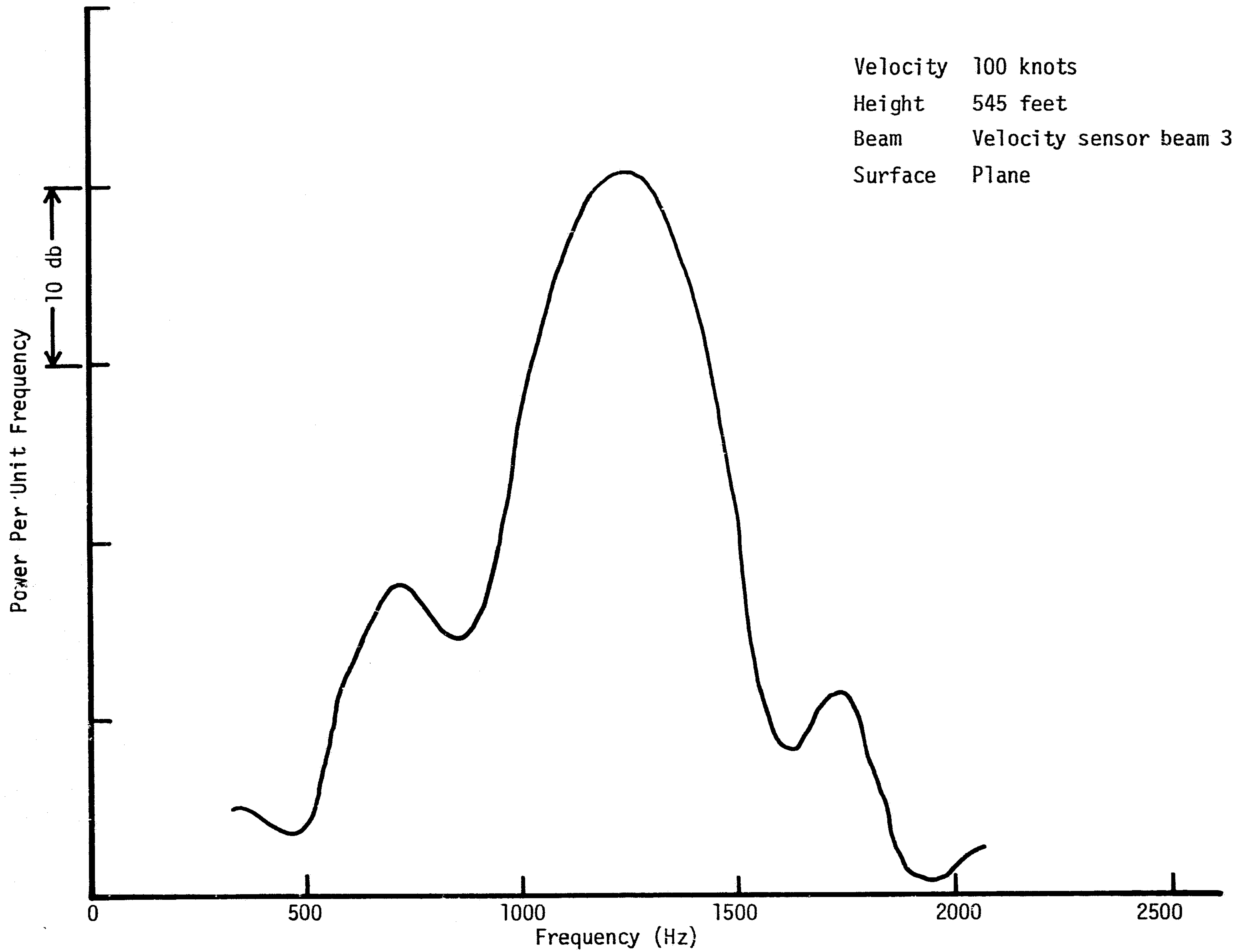

Figure 8. Computed PSD Plot for a Plane Surface

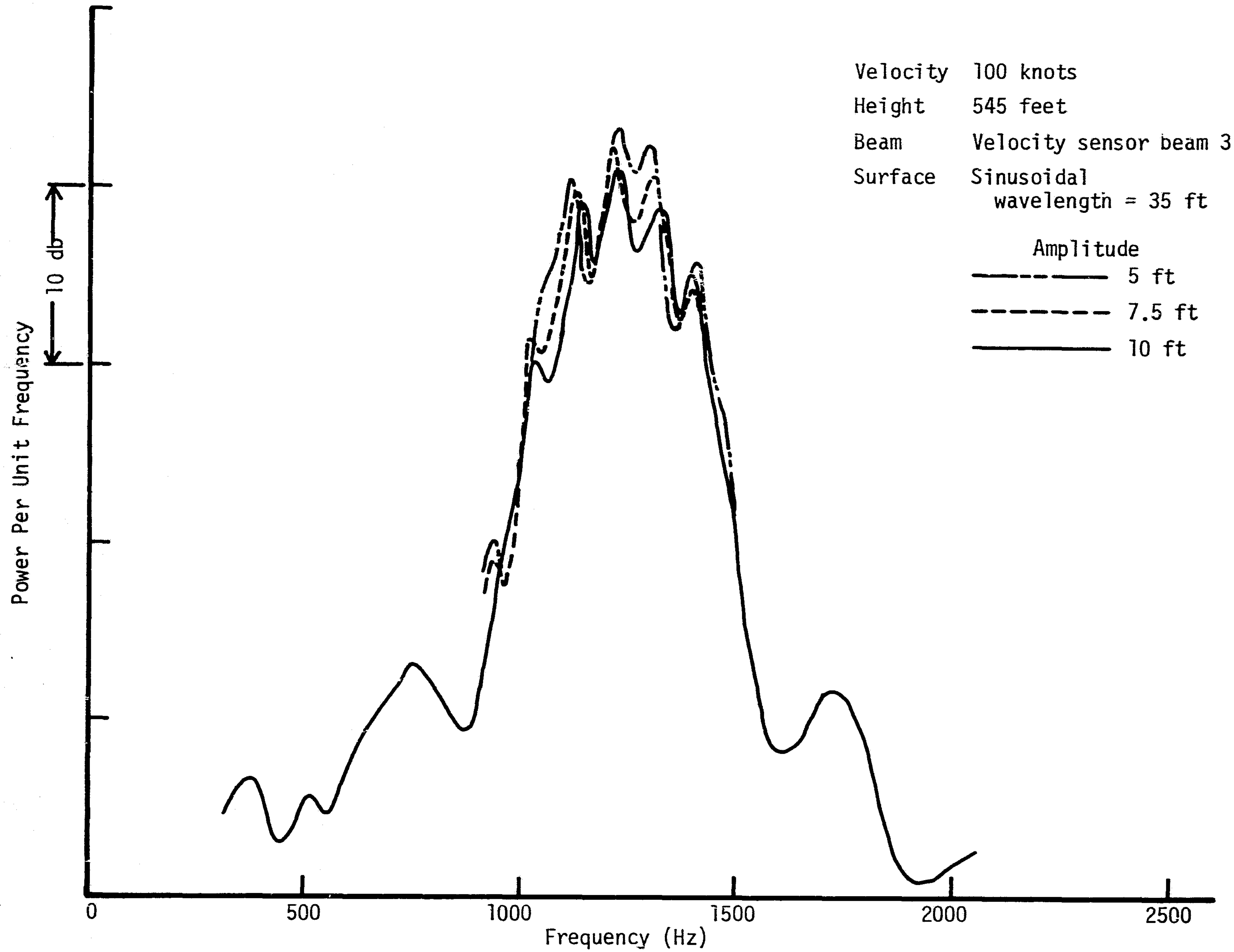

Figure 9. Effects of Surface Amplitude on Computed PSD Curves

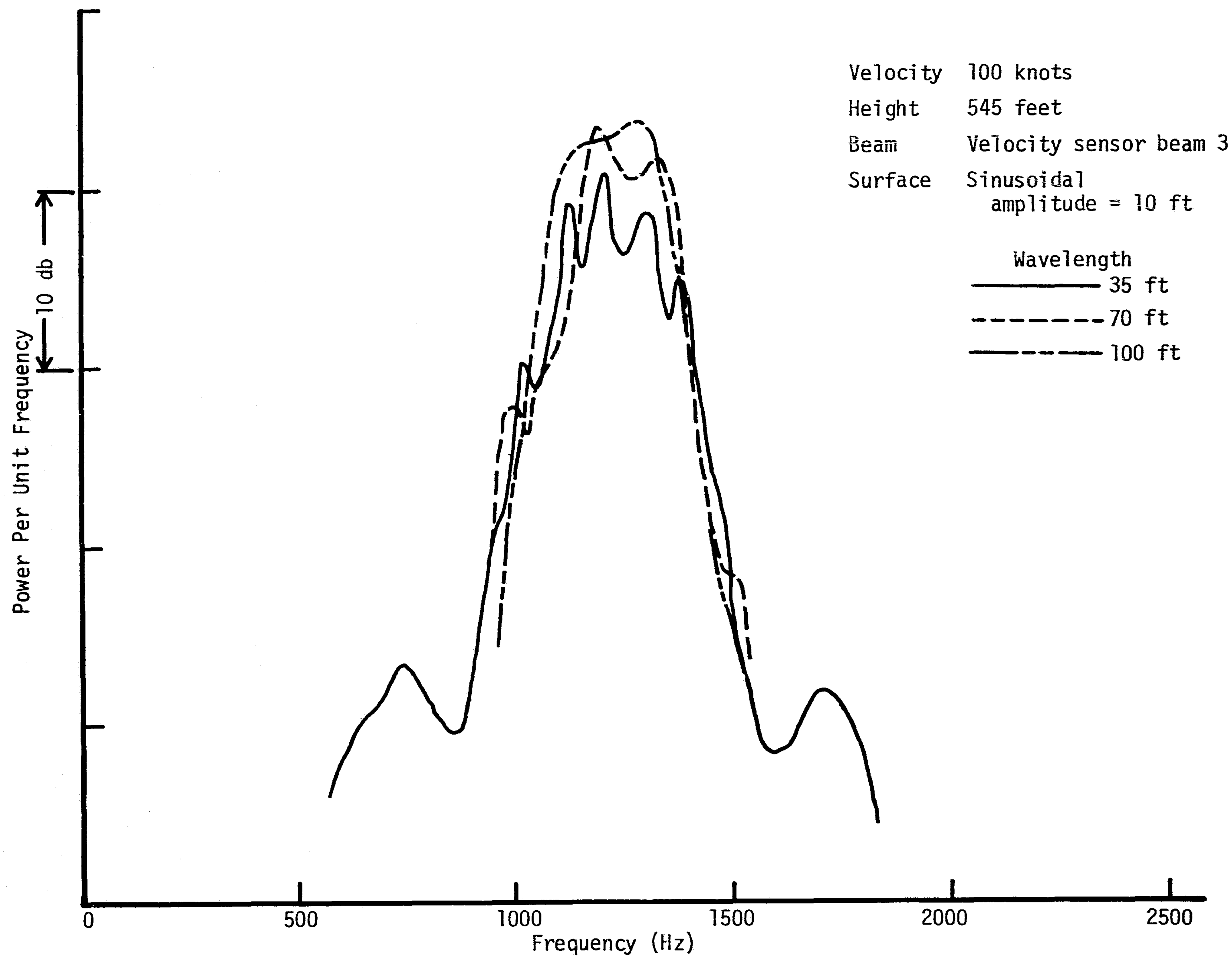

Figure 10. Effects of Surface Wavelength on Computed PSD Curves

3.0 SUMMARY

It has been shown that the antenna pattern is the primary factor in determining the shape of the power density spectrum for low altitude flights. The specific geometry of the terrain can perturb the shape of the spectrum only slightly around the envelope of the antenna pattern. Undulations in the vicinity of the main lobe caused by the sinusoidal surface could be smoothed by allowing the transmitter-receiver to move over several positions, calculating the PSD data for each position and averaging the data for each frequency. A curve so obtained would be more similar to an actual measured curve since in the actual case the vehicle is in motion and the measurement takes place over a finite time.

Since the antenna used during the data collection was an early prototype model, information concerning the antenna sidelobe structure is not available. For this reason no attempt was made to compare the computed to measured curves in the sidelobe region.

It was shown with the computer program that small attitude changes (3 deg) resulted in a large shift of the mean frequency (175 Hz). That is a possible explanation for the difference in the mean frequency between the measured and computed PSD curves in some cases. Otherwise, the general shape of the measured PSD curves can be predicted by the computer program using a sinusoidal surface to simulate the actual experimental site.

REFERENCES

1. W. B. Warren and L. Armijo, A Technique for Computing Terrain Effects on Radar Return, TRW Project Technical Report, Task E-34C-1, 05952-H503-R0-00, 14 May 1968.

2. R. Mireles and L. Armijo, Geometric Transformations Associated with Project PEARL, TRW Project Technical Report. Task 34B, 05952-H263-R0-00, 14 July 1967.

3. R. Mireles and J. Wilson, LM Landing Radar Evaluation Program (LRTRW1), TRW Project Technical Report, Task 34B, 05952-H211-R0-00, 1 June 1967.

4. E. T. Dickerson, Interim LR Reflectivity Model, TRW Project Technical Report, Task E-34D, 11176-H018-T0-00, 9 August 1968.

APPENDIX

GEOMETRICAL AND PHYSICAL PARAMETERS USED IN THE COMPUTER PROGRAM

The sinusoidal surface used in the computer program is given by

$$X_s = A \sin\left(\frac{2\pi Z_s}{\lambda_s}\right)$$

where A is the amplitude and λ_s is the surface wavelength. The first quadrant of the surface is illustrated in Figure 11. The extent of the sinusoidal surface is limited in the Z_s direction to

$$|Z_s|_{max} = \frac{(h-A)\ \lambda_s}{2\pi A}$$

for analytical expediency. Beyond $|Z_s|_{max}$ the surface is a plane. A and λ_s were chosen for these runs so that the sinusoidal surface extended far beyond the intersection of beam 3 with the surface.

The surface coordinate system (X_s, Y_s, Z_s) has origin on the surface plane and is oriented so that X_s is vertical and goes through the transmitter-receiver which is at an altitude h above the surface. It was assumed that the antenna coordinate system (X_A, Y_A, Z_A) with origin at the transmitter-receiver was oriented so that except for translation it was coincident with the surface coordinate system. The velocity sensor beam 3 was modeled with Θ_1 = 24.460018 deg and ϕ_1 = 34.379734 deg according to p. 27 of Reference [2] and the wavelength of the transmitted signal was 0.09358 feet (10.51 GHz). The vehicle velocity was assumed to be along the positive Z_s direction.

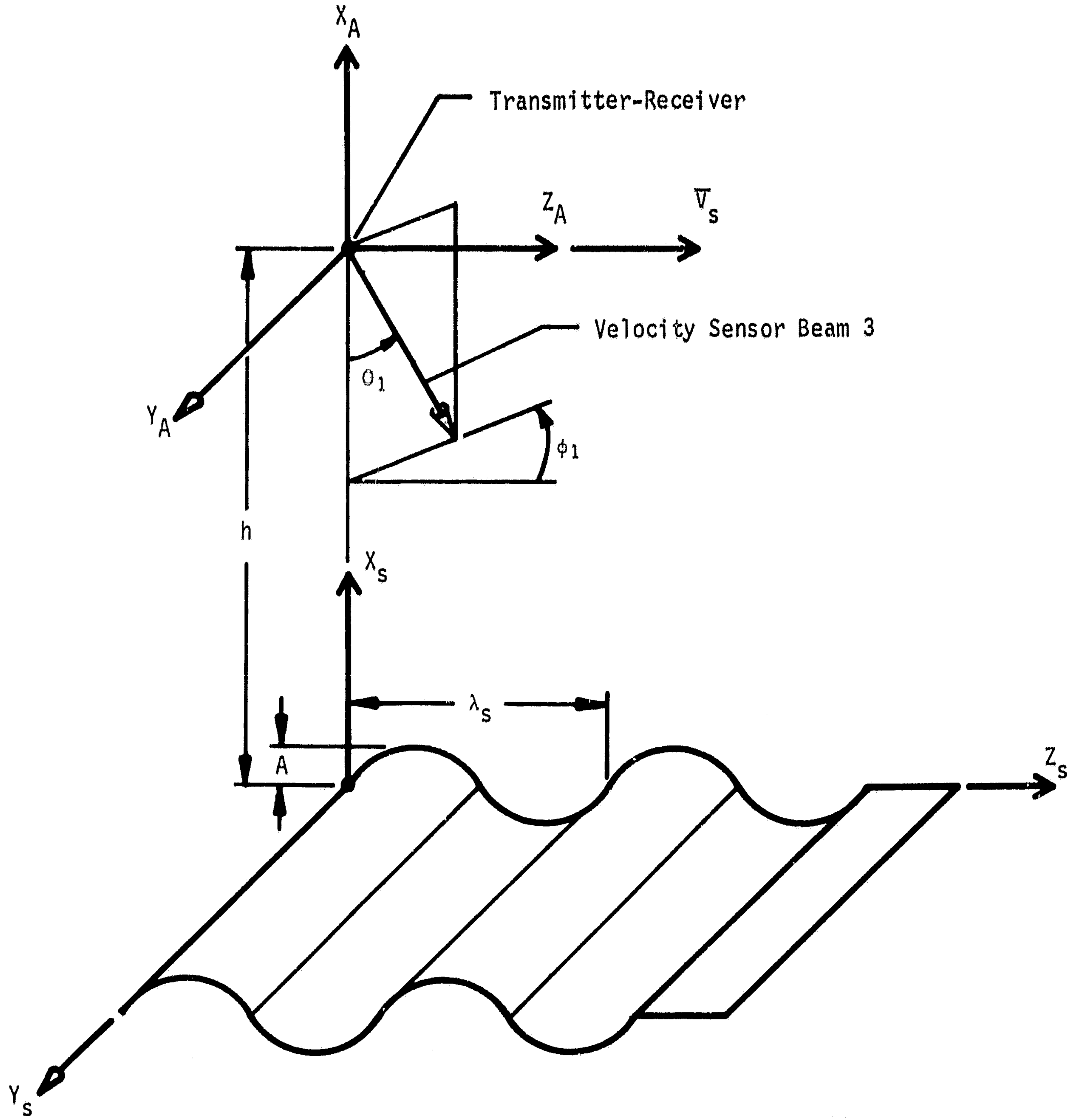

Figure 11. Geometrical Quantities Associated with the Computer Comparison PSD Curves

A sin ρ/ρ type function was used to compute the two-way normalized antenna beam pattern. The constants of the function were adjusted to give major and minor beamwidths of 6.3 deg and 3.7 deg, respectively, which were obtained from the August 1968 revision of the training manual for the LM-3.

The reflectivity was computed using the Beckmann-Smith theoretical reflectivity function. For these runs an initial reflectivity for $\Theta_s = 0$ deg was chosen to be -8 db in accordance with Reference [4].