University of California, Santa Barbara
California Nanosystems Institute
Site Vibration Study

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1 Introduction

This study has been carried out to provide an assessment of the proposed California Nanosystems Institute (CNSI) building site with regard to existing ground vibration. The proposed building site is located near the east entrance of the University of California Santa Barbara (UCSB) campus and is currently used as UCSB Parking Lot 10.

The survey and vibration measurements were conducted on 18 October 2002 between 3:00 AM and 6:30 PM. Vehicles on Mesa Road potentially generate ground vibration that could adversely affect the performance of sensitive equipment, which will be located on the ground floor of the CNSI building.

2 Vibration Criteria

The generic vibration criterion (VC) curves we use are described in Appendix A. Of these, the most stringent is VC-E (125 micro-inches/sec) for the critical laboratory areas. Since it is difficult to reduce low frequency vertical vibration levels within a building to much below the levels measured on the site, it is preferred that the site vibration levels be significantly lower than the critical floor design criterion. Transient vibration levels, such as those due to passing trucks, might also be a concern depending on the specific tool and how the tool is used. Site horizontal vibration levels, based on our past experience, will be substantially suppressed by the presence of the building. It should be noted here that the VC curves in Appendix A are intended to apply to “linear average” data, not “peak hold” data used for some transient vibration measurements. Also, it is our custom on site surveys and floor evaluation to categorize floors as the average plus one stand deviation of data at multiple locations.

3 Measurement Methodology and Data Presentation

The vibration data were acquired using a Bruel & Kjael Model 8318 accelerometer, in combination with a Bruel & Kjael Model 2635 charge amplifier and Rion Model SA-77 digital signal analyzer. The field data were first stored in the memory of the SA-77 and then transferred to a laptop computer for processing and formatting.

Our normal practice is to show the data in terms of RMS velocity, both as narrowband spectra and as one-third-octave band spectra, which are described as follows:

(a) Narrowband spectra having a fixed bandwidth, throughout the 0 to 100 Hz frequency range, of 0.75 Hz (Figure 1a) or 0.375 Hz (Figures 3a to 5a).

(b) One-third octave band spectra having a bandwidth of twenty-three percent of each band center frequency. This is the format of the vibration criterion curves. For reference, the vibration criterion curves (VC-C, VC-D, and VC-E) are superimposed on all the one-third octave band data plots.

The narrowband spectra are diagnostically useful if one wishes to identify sources of vibration and, perhaps, resonance phenomena that may amplify vibration amplitudes. Because of data processing limitations, data below 2 Hz are likely to be contaminated by system noise and are, therefore, disregarded.

Note that the calibration of the measurement instruments, which uses reference standards traceable to NIST, is performed yearly by an independent calibration laboratory. Single frequency calibration of the measurement system was verified in the field immediately prior to the measurements.

4 Discussion of Measurement Results

4.1 Measurements at Existing JEOL Room

For reference, we measured the ambient vibration in the Engineering Science II building at an existing lab that currently houses a JEOL 2010 system (one of the most sensitive tools in the building). The measurements were conducted on the slab-on-grade floor, and the main vibration sources were mechanical equipment inside and around the building, as opposed to construction activities or nearby traffic. The mechanical vibrations are characterized by tonal peaks at several frequencies as shown in the narrowband spectrum of Figure 1a. We were informed by Roger Monte of UCSB that a pile foundation is used for this building. Similar foundation structure is proposed for the CNSI building. Figure 1 shows that the measured floor vertical and horizontal vibration amplitudes lie at or below 125 micro-inches/sec (VC-E).

4.2 Measurements at CNSI Footprint

Figure 2 illustrates the proposed site plan of the CNSI building as well as measurements locations. Most of our measurements were conducted on the parking lot surface. Some were at the open area to the east of the site. At the time of measurements, various sizes and speeds of vehicles were observed on Mesa Road. Traffic was occasionally heavy.

The first seven locations (Locations 1 to 7) were selected to represent vibration sensitive areas. The distance between the center of the Mesa road and these measurement locations is about 90 ft. “Linear average” data taken at these seven measurement locations were used to construct the statistical spectra shown Figures 3 to 5. These display “maximum”, “minimum”, “mean”, and “mean + one standard deviation (Mean + SD)” spectra. The highest 1/3 octave band value of the Mean + SD spectrum is used to determine the “performance” of the site when compared to the generic vibration criterion curves.

As shown in Figure 3, we found that the maximum vertical vibration level (Mean + SD) is about 310 micro-inches/sec at about 16 Hz. In the Arup report[1], it was concluded that the traffic vibration amplitudes (L10 which is somewhat similar to Mean + SD) are on the order of 130 micro-inches/sec on the nearby proposed site for Engineering Science III. Any difference between vibration levels found in this study and in the Arup report is likely due to the distances from the measurement locations to the road and sizes/speeds of vehicles.

As for horizontal vibrations, Figures 4 and 5 show that the maximum Mean + SD vibration amplitudes are about 90 and 160 micro-inches/sec for the north-south and east-west directions, respectively.

For reference, all of the measurement descriptions (locations, types of measurements, and vibration sources) and vibration data are provided in Appendix B.

4.3 Comparison between Measurement data and Tool Specifications

As we indicated in our proposal[2], the vibration criterion of 125 micro-inches/sec (VC-E) was more appropriate for “Imaging and Spectroscopy” than the value of 250 micro-inches/sec (VC-D) originally proposed. Based on our measurement results, we find that the site might not meet 125 micro-inches/sec due to traffic vibration during rush hours. This finding, however, does not necessarily indicate that the site will not be acceptable for sensitive tools.

As shown in Figure 6, most of the sensitive tools can tolerate higher vibration levels at frequencies above 5 Hz. The predominant frequencies of traffic vibration are in the range of 8 to 30 Hz. As a result, the traffic vertical vibration levels lie below the required criteria and would not likely affect the performance of the tools, even though the vibration levels can be as high as 310 micro-inches/sec. Transient (short duration) vibration levels will be occasionally exceed the Mean + SD levels, however.

It appears in Figures 7 and 8 that the horizontal vibration levels at frequencies below 2 Hz could be excessive for the sensitive tools. As indicated earlier in Section 3, due to the inherent noise of the measurement instrument system, vibration data below 2 Hz tend to be contaminated and, thus, should be disregarded. Moreover, experience has shown us that placement of a building on the site will substantially suppress horizontal vibration amplitudes because the building footprint typically exceeds the wavelength of the Rayleigh ground wave. Therefore, the horizontal vibration due to traffic is not likely to be a problem for the proposed site.

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[1] “UCSB – Engineering Science Building 3, Site Vibration Study,” Arup Acoustics, 18 November 1999

[2] “Site Vibration Survey, CNSI, UCSB,” CGA P02162, 12 September 2002

4.4 Measured Vibration Attenuation Characteristics

The last nine measurement locations (Locations 8 to 16) were selected to determine the vibration propagation characteristics of the site. The distance between each location is approximately 10 ft, in the direction perpendicular to the Mesa road. The maximum 1/3 octave band rms velocity levels of both "linear average" and "peak hold" data are plotted against the distance from the road in Figure 9. "Best fit" trend lines are also superimposed.

If we consider the "linear average" trend line shown in Figure 9 as the "actual" vibration attenuation characteristics, a criterion of 125 micro-inches/sec (VC-E) could not be achieved at a distance within 150 ft from the center of Mesa Road. Using the trend line equation given in Figure 9, the site would meet 125 micro-inches/sec at about 210 ft from the road. Please note that we provide this vibration attenuation information for completeness of our site study and for reference only.

5 Conclusions

This report summarizes the assessment of the proposed California Nanosystem Institute building site for existing ground vibration. The conclusions from this study are summarized as follows.

- We find that the ambient floor vibration amplitudes lie at or below 125 micro-inches/sec (VC-E) at the JEOL room inside the Engineering Science II building.

- The vibration data measured at the CNSI building site show that the vertical linear average vibration amplitudes lie above 250 micro-inches/sec (VC-D). The exceedance, however, occurs in a frequency range (8 to 30 Hz) in which the tools are relatively insensitive. Thus, it is our opinion that the vertical vibrations will be acceptable for the sensitive tools at the proposed site.

- The measured horizontal vibration levels are found to be quite close to the allowable limits for the tools. However, the presence of the CNSI building will significantly suppress the horizontal vibration amplitudes and, thus, the impact from traffic-generated horizontal vibrations is not a concern.

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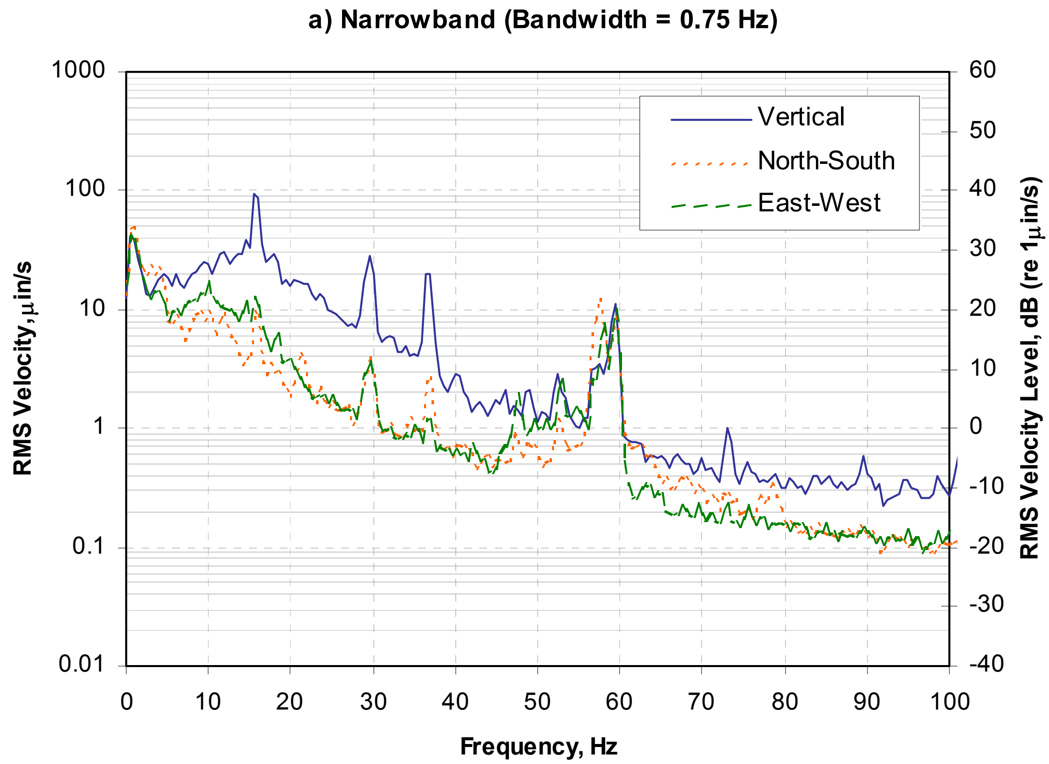
This concludes our report. Please call if you have any questions.



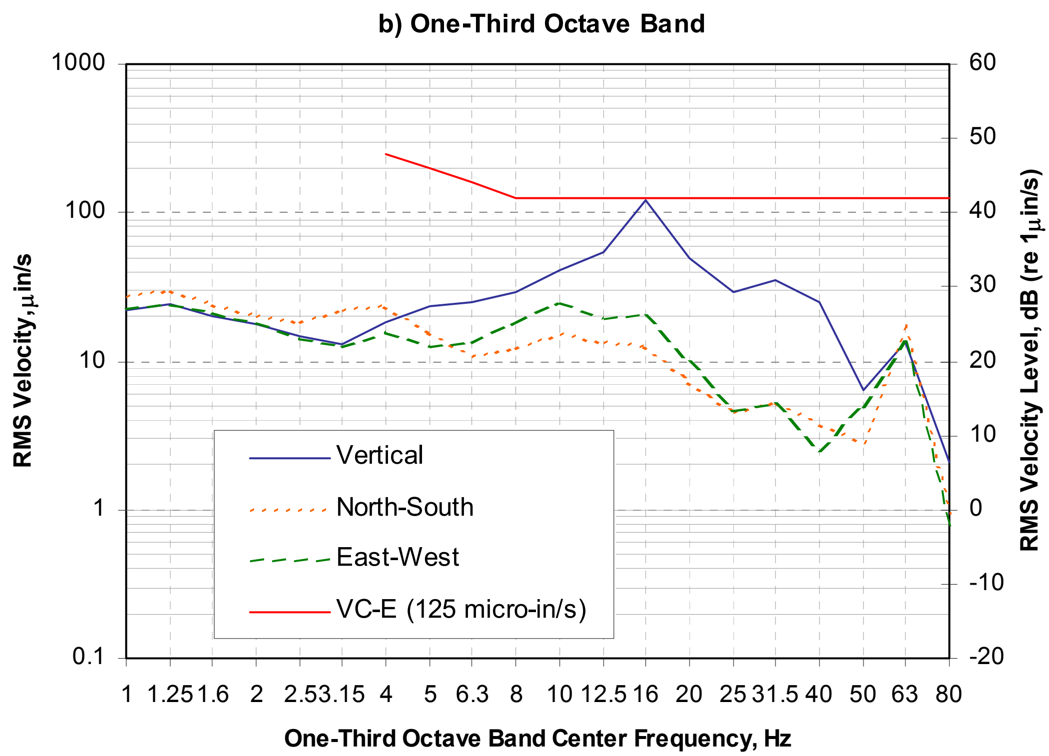


Figure 1: Measured Vibration Amplitudes at JEOL 2010 Room, Engineering Science II Building

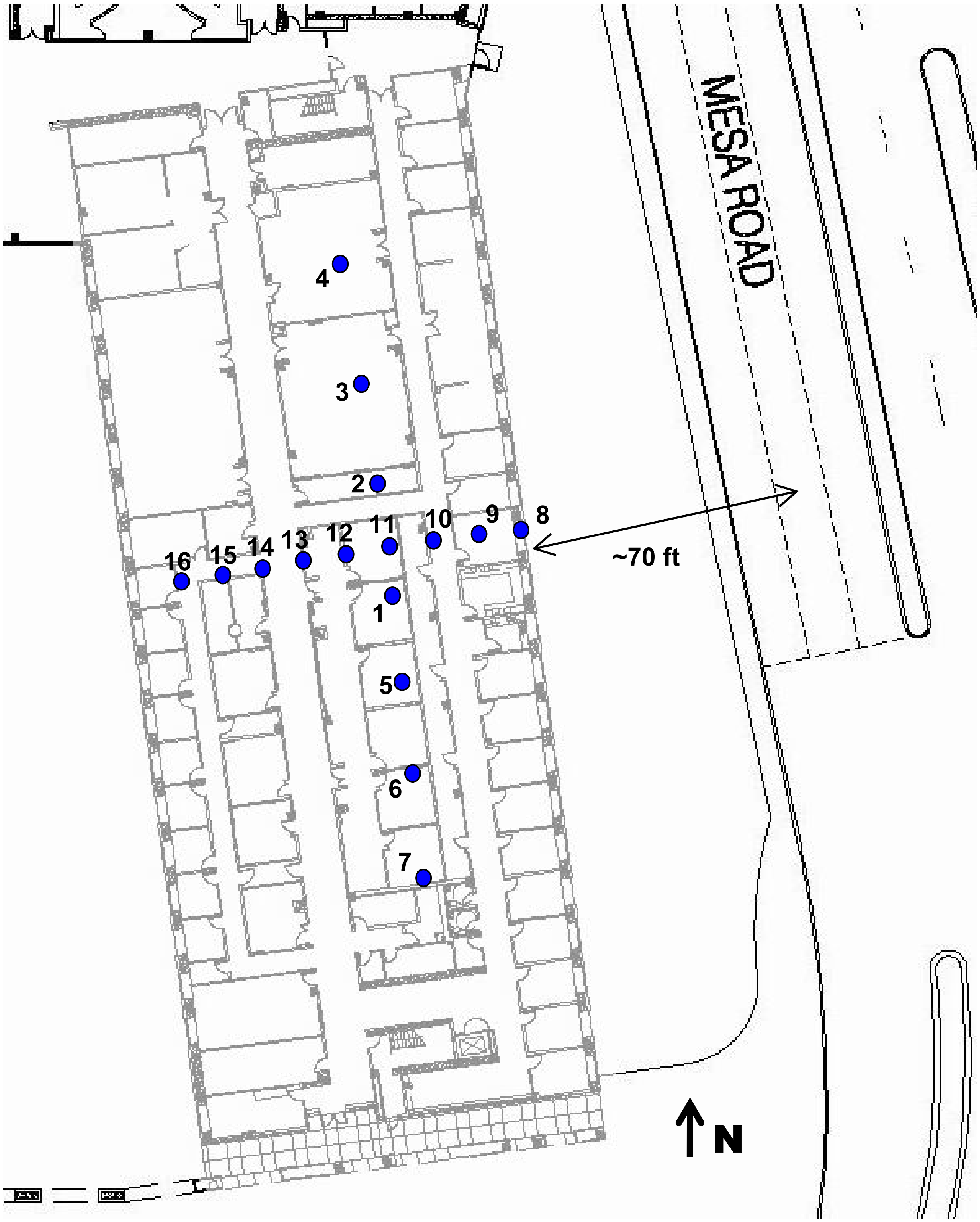
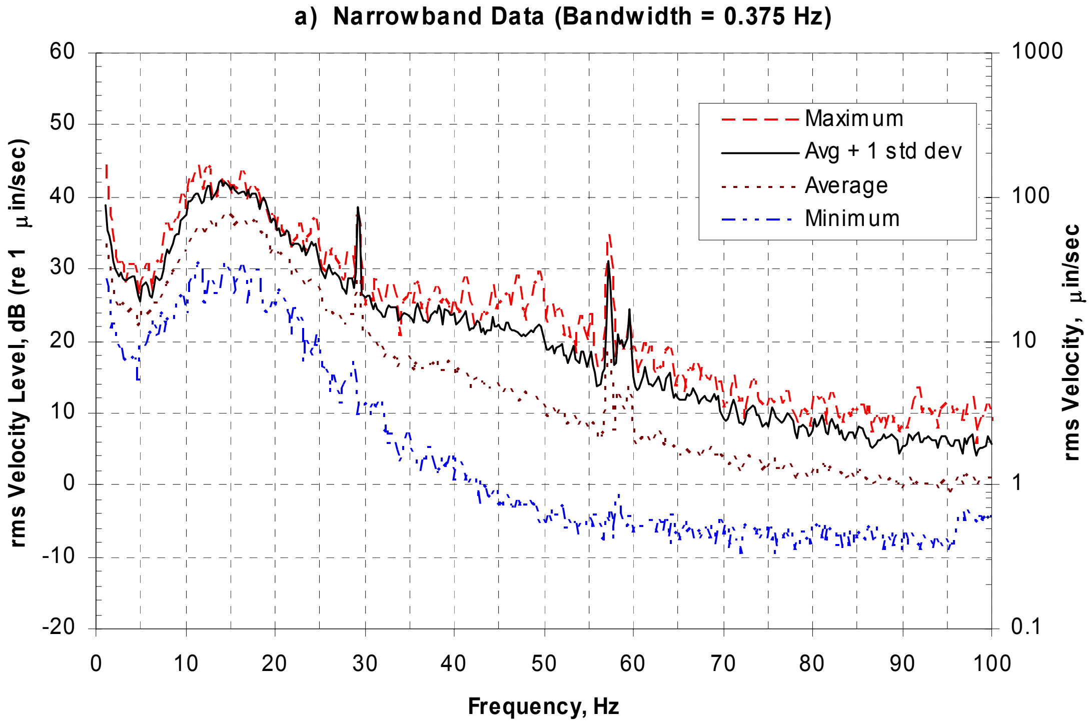


Figure 2: Site Plan and Measurement Locations



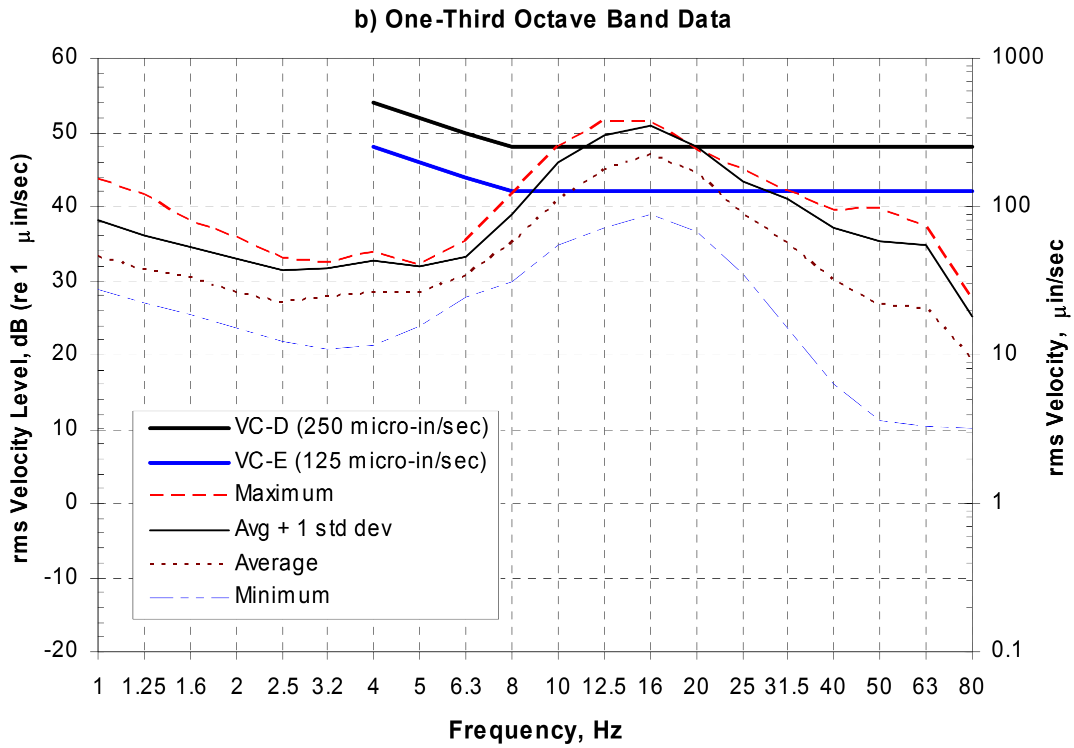
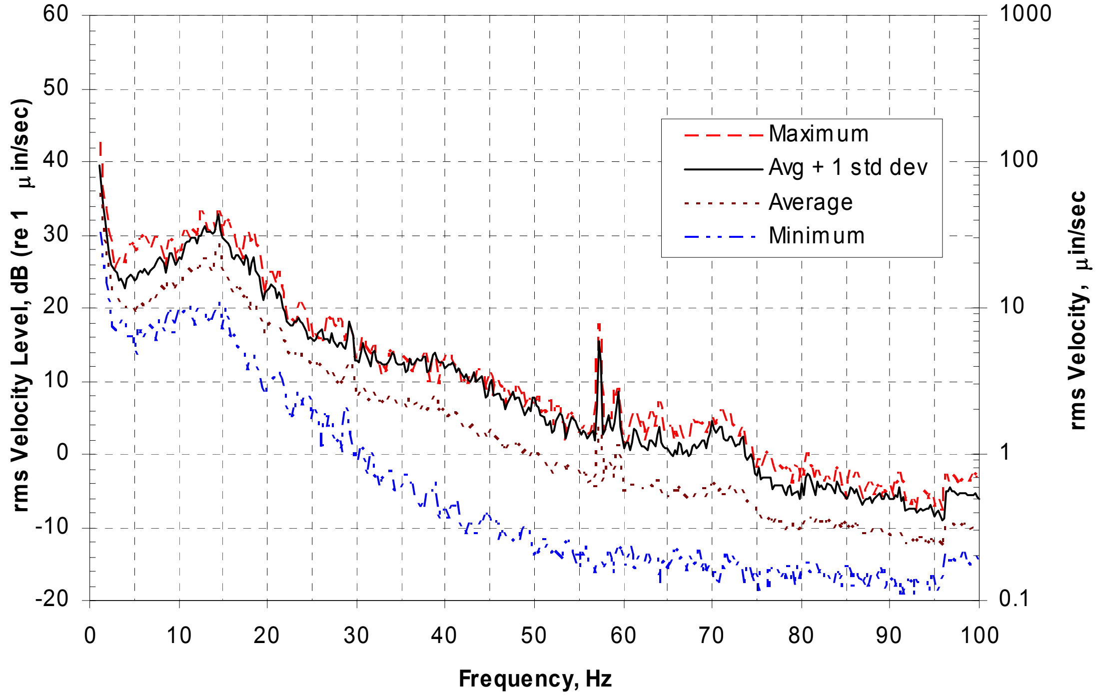


Figure 3: UCSB CNSI Site Study – 17 October 2002
Statistical Summary of Vertical Vibration Levels

a) Narrowband Data (Bandwidth = 0.375 Hz)



b) One-Third Octave Band Data

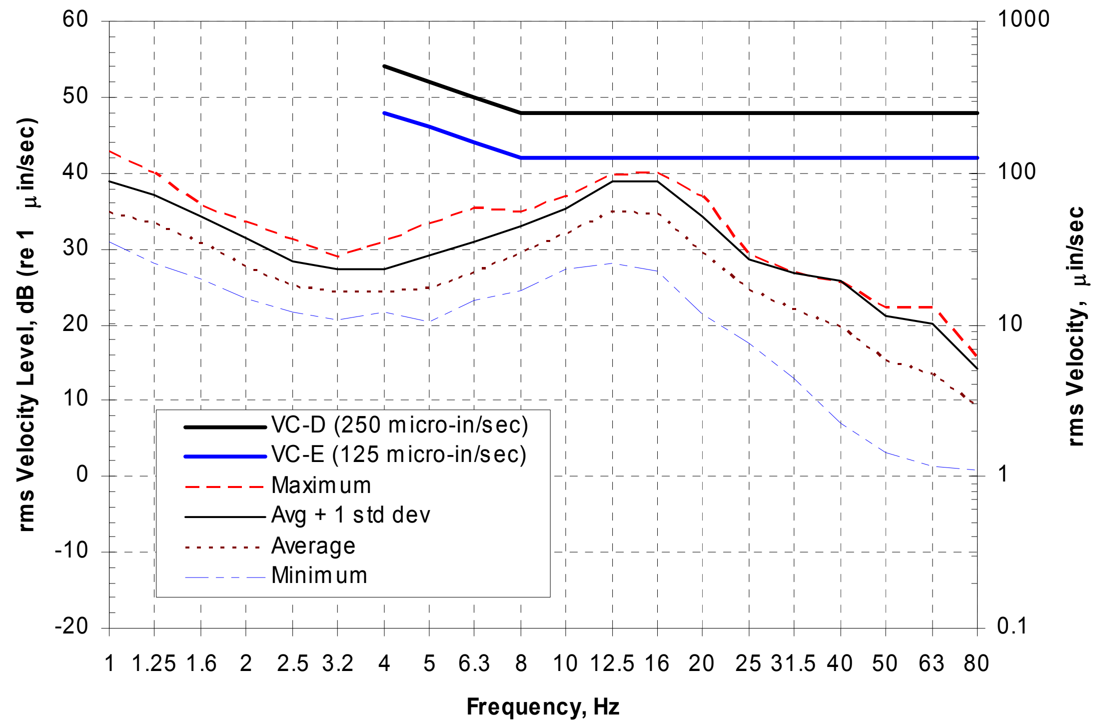


Figure 4: UCSB CNSI Site Study – 17 October 2002
Statistical Summary of Horizontal Vibration Levels
(North-South Direction)

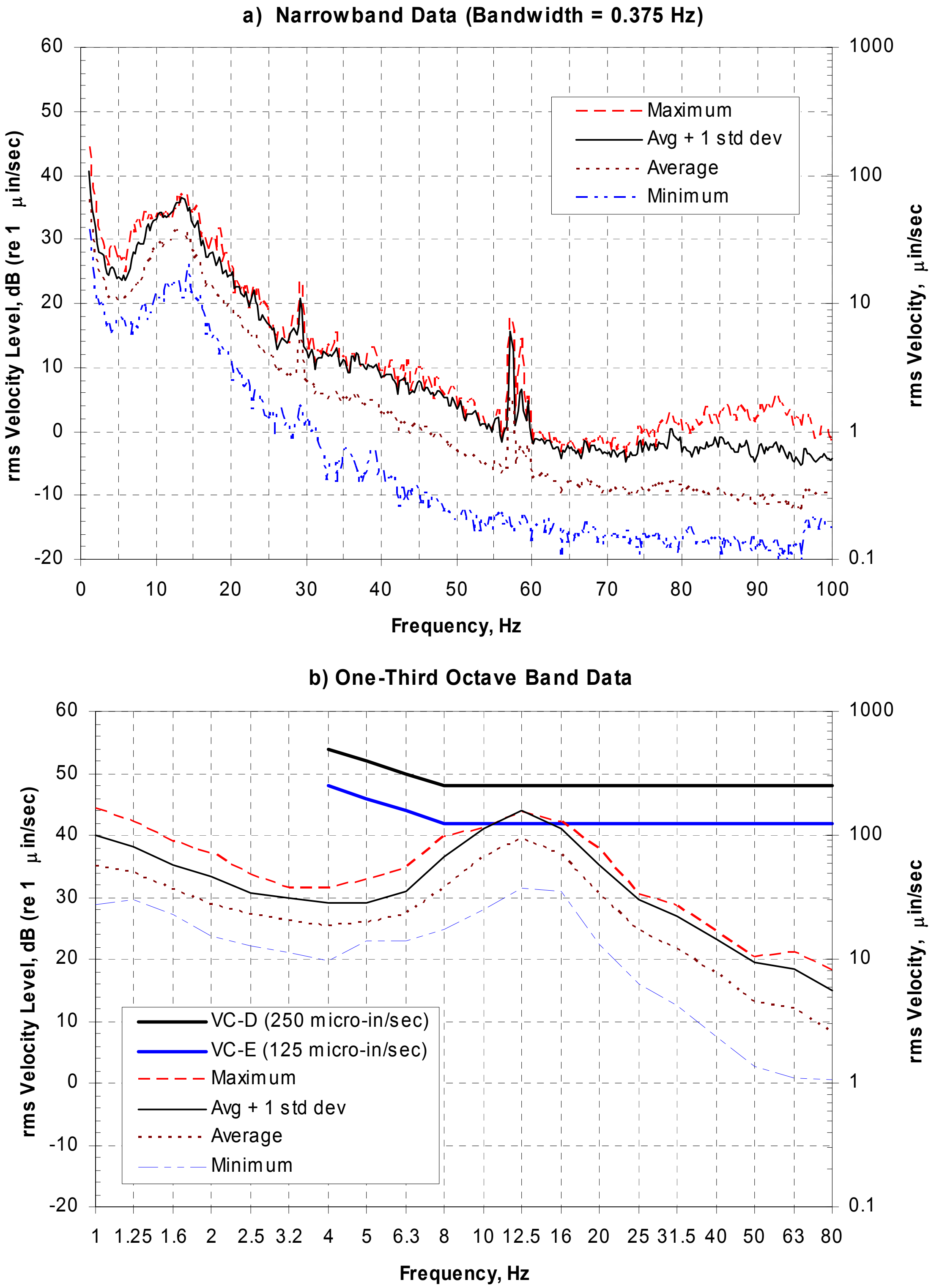


Figure 5: UCSB CNSI Site Study – 17 October 2002
Statistical Summary of Horizontal Vibration Levels
(East-West Direction)

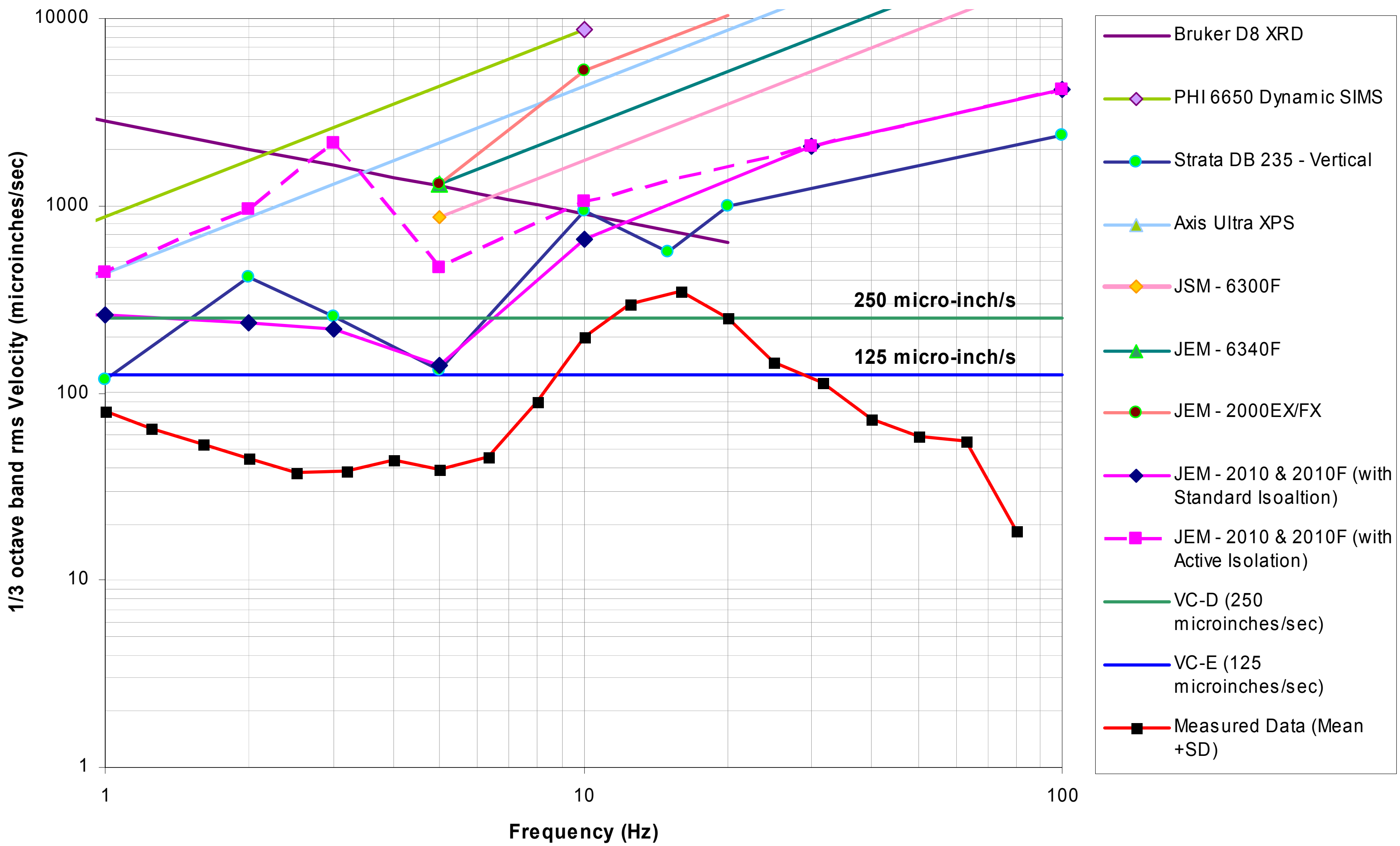


Figure 6: Comparison of Measurement Data with Tool Specifications (Vertical Vibration)

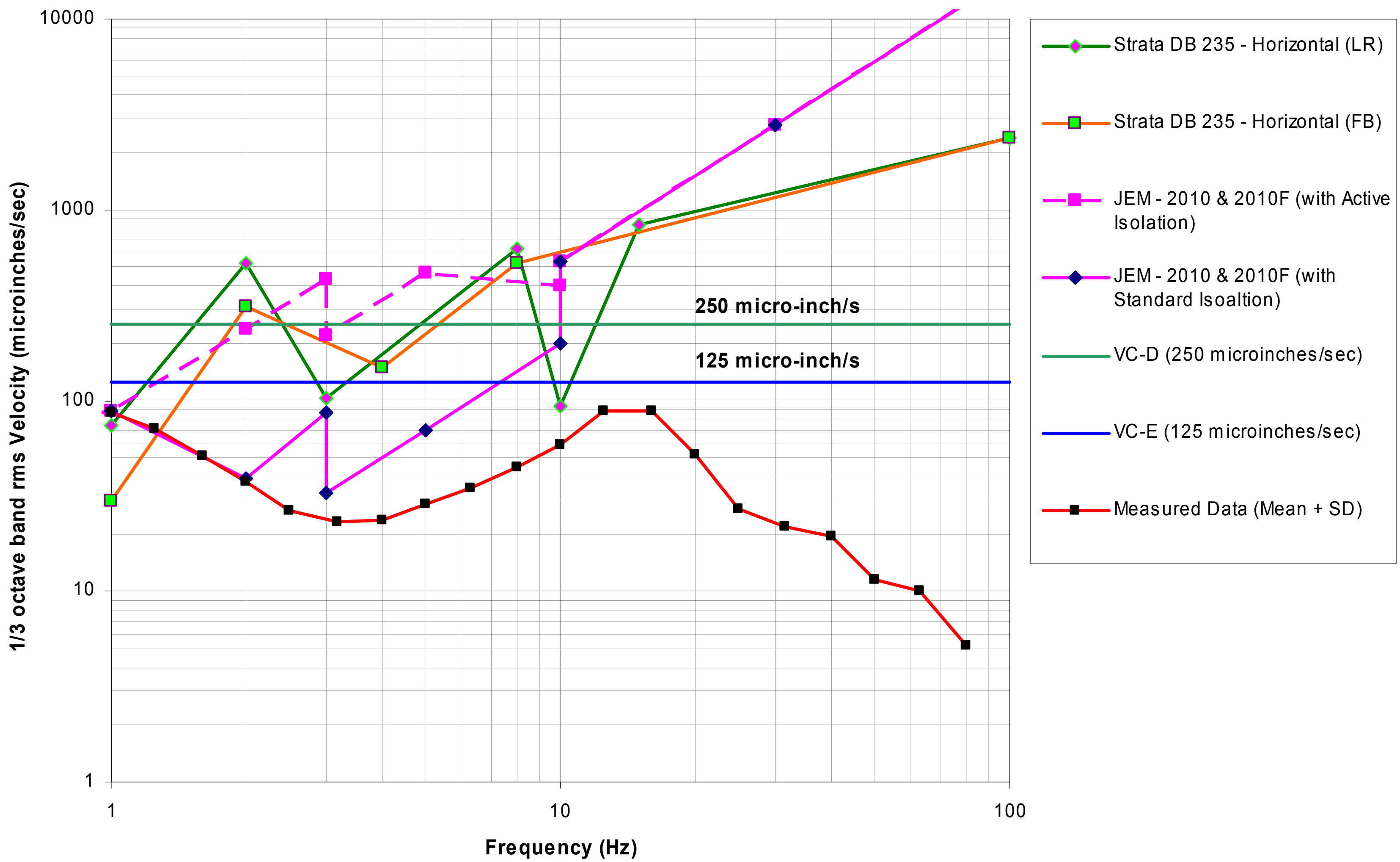


Figure 7: Comparison of Measurement Data with Tool Specifications (Horizontal Vibration, North-South Direction)

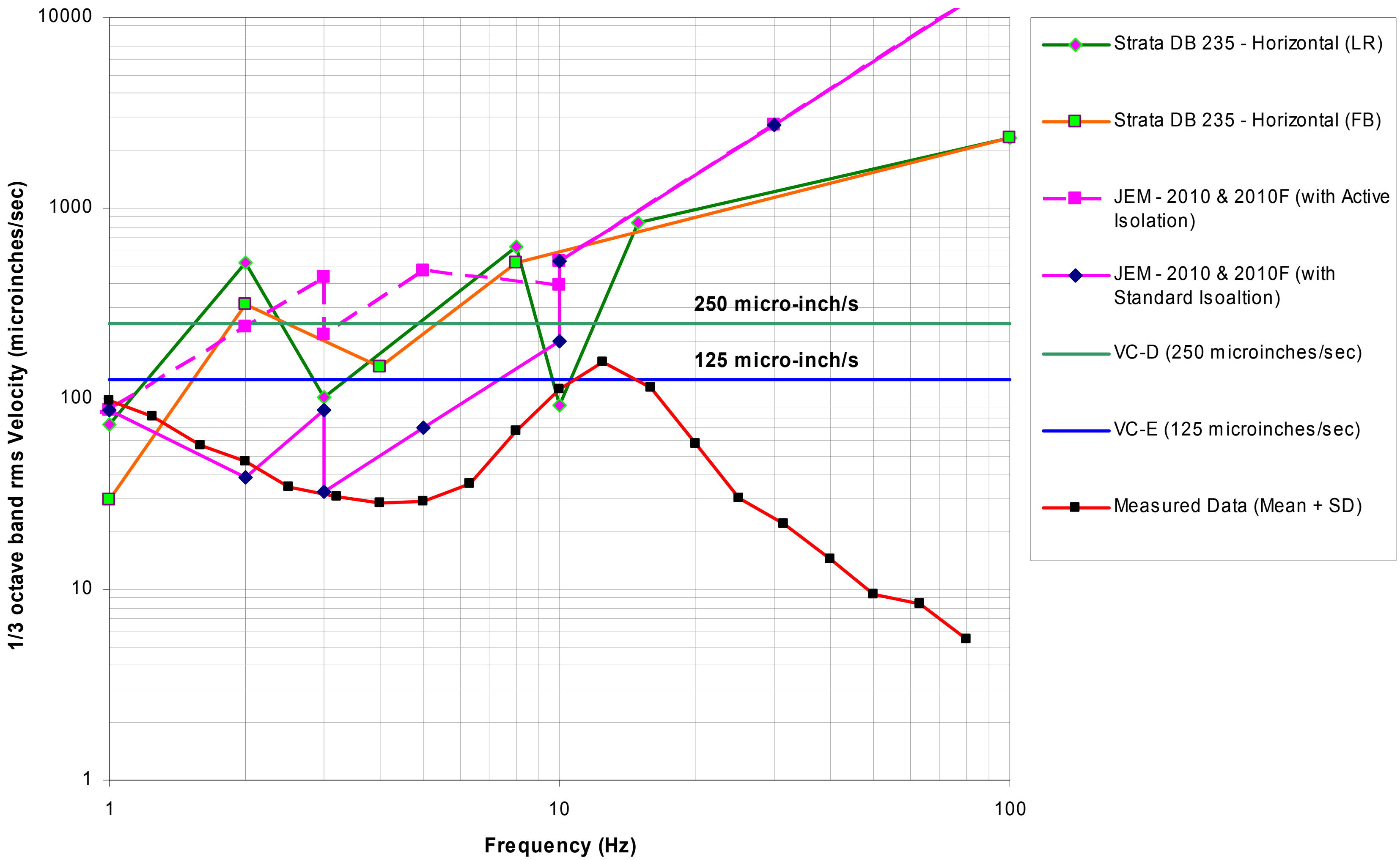


Figure 8: Comparison of Measurement Data with Tool Specifications (Horizontal Vibration, East-West Direction)

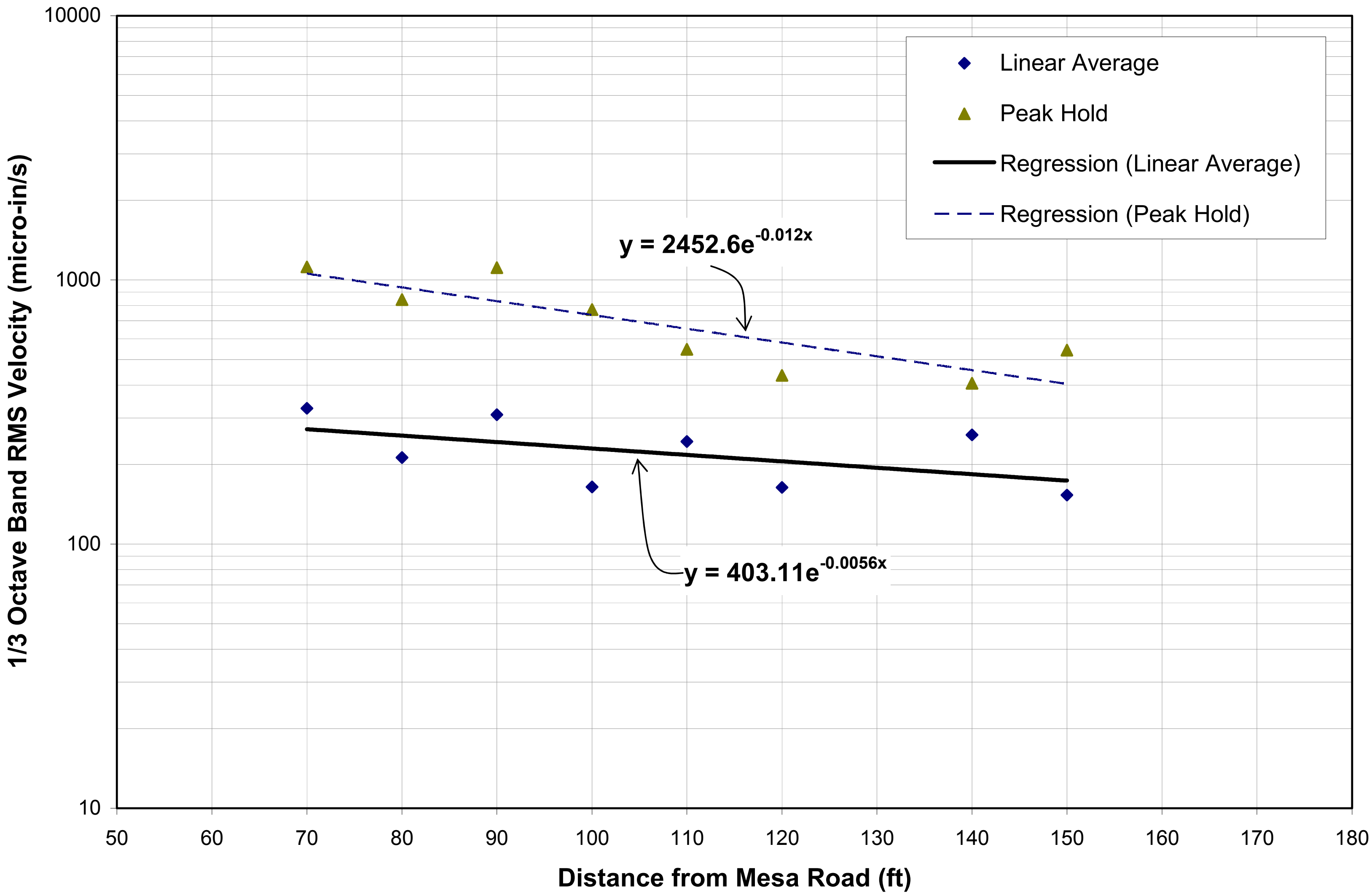


Figure 9: Maximum Vibration Amplitudes Compared with Distance from Center of Mesa Road

APPENDIX A Generic Design Criteria For Vibration-Sensitive Equipment And Processes

This appendix presents vibration criteria that have been used quite extensively for several years, particularly by the microelectronics industry and research communities.

The criteria take the form of a set of one-third octave band velocity spectra labeled vibration criterion curves VC-A through VC-E. These are shown in Figure A.1, together with the International Standards Organization (ISO) guidelines for the effects of vibration on people in buildings*. The criteria apply to vibration as measured in the vertical and two orthogonal horizontal directions.

For environments that are continuous and steady state in time, the criteria apply to the "linear average" of data samples acquired over a period of 20 seconds or longer. In instances where the environment is impacted by occasional disturbances such as vehicular movements, "stage" movements (in tools), passing trains, etc., these may be evaluated in the "peak hold" or "maximum RMS" mode of the measuring system. If the disturbing event is long enough (i.e., "Quasi-static", or steady-state during the averaging time) the linear average mode should be used. The importance attributed to these occasional events will depend upon the frequency of occurrence and other parameters relating to the process.

The application of these criteria as they apply to people and vibration-sensitive equipment is described in Table A.1. The criteria do not necessarily apply to experimental systems used in laboratory research. Such systems often have not received the benefits of dynamic modeling and vibration isolation available to the equipment manufacturer.

The main elements of the criteria are as follows:

1) The vibration is expressed in terms of its root-mean-square (rms) velocity (as opposed to displacement or acceleration). It has been found in various studies that while different items of equipment (and people) may exhibit maximum sensitivity at different frequencies (corresponding to internal resonances), often these points of maximum sensitivity lie on a curve of constant velocity.

2) The use of a proportional bandwidth (the bandwidth of the one-third octave is twenty-three percent of the band center frequency) as opposed to a fixed bandwidth is justified on the basis of a conservative view of the internal damping of typical equipment components. Experience shows that in most environments the vibration is dominated by broadband (random) energy rather than tonal (periodic) energy.

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* International Standards Organization, "Guide To The Evaluation Of Human Exposure to Vibration and Shock in Buildings (1 Hz to 80Hz)." ISO 2631, 1981.

3) The fact that the criterion curves allow for greater vibration velocity for frequencies below 8 Hz reflects experience that this frequency range, in most instances, lies below the lowest resonance frequency of the equipment components. Relative motions between the components are, therefore, harder to excite and the sensitivity to vibration is reduced.

4) For a site to comply with a particular equipment category the measured one-third octave band velocity spectrum must lie below the appropriate criterion curve of Figure A.1.

The equipment criterion curves have been developed on the basis of data on individual items of equipment and from data obtained from measurements made in facilities before and after vibration-related problems were solved. The curves are generic in the sense that they are intended to apply to broadly defined classes of equipment and processes. **They are intended to apply to the more sensitive equipment within each category that is defined.**

The criteria assume that bench-mounted equipment will be supported on benches that are rigidly constructed and damped so that amplifications due to resonances are limited to a small value. The criteria take into account the fact that certain types of equipment (such as stepper scanners) are supplied by the manufacturer with built-in vibration isolation.

It is important to note that these criteria are for guidance only. The “detail sizes” given in Table A.1 appear to represent experience at the time of writing. They reflect the fact that the quality of design and of built-in isolation in most equipment tends to improve as dimensional requirements become more stringent. In some instances the criteria may be overly conservative because of the high quality of built-in isolation.

In most instances it is recommended that the advice of a vibration consultant be sought in selecting a design standard.

Table A.1: Application and interpretation of the generic vibration criterion (VC) curves (as shown in Figure A.1)

Criterion Curve (see Figure 1)	Max Level (1) μin/s (dB)	Detail Size (2) Microns	Description of Use
Workshop (ISO)	32000 (90)	N/A	Distinctly feelable vibration. Appropriate to workshops and nonsensitive areas.
Office (ISO)	16000 (84)	N/A	Feelable vibration. Appropriate to offices and nonsensitive areas.
Residential Day (ISO)	8000 (78)	75	Barely feelable vibration. Appropriate to sleep areas in most instances. Probably adequate for computer equipment, probe test equipment and low-power (to 20X) microscopes.
Op. Theatre (ISO)	4000 (72)	25	Vibration not feelable. Suitable for sensitive sleep areas. Suitable in most instances for microscopes to 100X and for other equipment of low sensitivity.
VC-A	2000 (66)	8	Adequate in most instances for optical microscopes to 400X, microbalances, optical balances, proximity and projection aligners, etc.
VC-B	1000 (60)	3	An appropriate standard for optical microscopes to 1000X, inspection and lithography equipment (including steppers) to 3 micron line widths.
VC-C	500 (54)	1	A good standard for most lithography and inspection equipment to 1 micron detail size.
VC-D	250 (48)	0.3	Suitable in most instances for the most demanding equipment including electron microscopes (TEMs and SEMs) and E-Beam systems, operating to the limits of their capability.
VC-E	125 (42)	0.1	A difficult criterion to achieve in most instances. Assumed to be adequate for the most demanding of sensitive systems including long path, laser-based, small target systems and other systems requiring extraordinary dynamic stability.

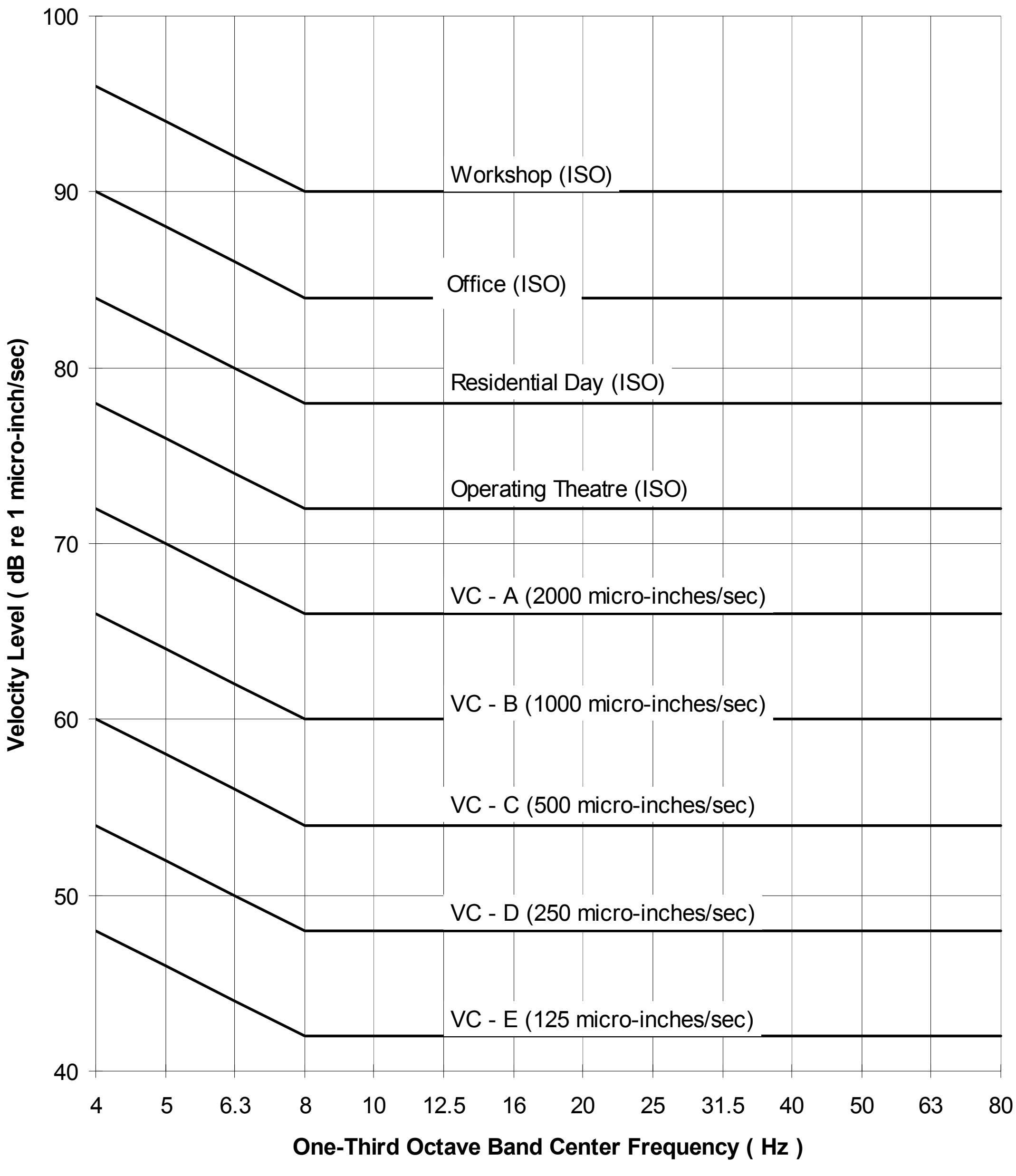
Notes:

(1) As measured in one-third octave bands of frequency over the frequency range 8 to 100 Hz. The dB scale is referenced to 1 μin/s.

(2) The detail size refers to the line widths for microelectronics fabrication, the particle (cell) size for medical and pharmaceutical research, etc. The values given take into account the observation that the vibration requirements of many items depend upon the detail size of the process.

The information given in this table is for guidance only. In most instances, it is recommended that the advice of someone knowledgeable about applications and vibration requirements of the equipment and process be sought.

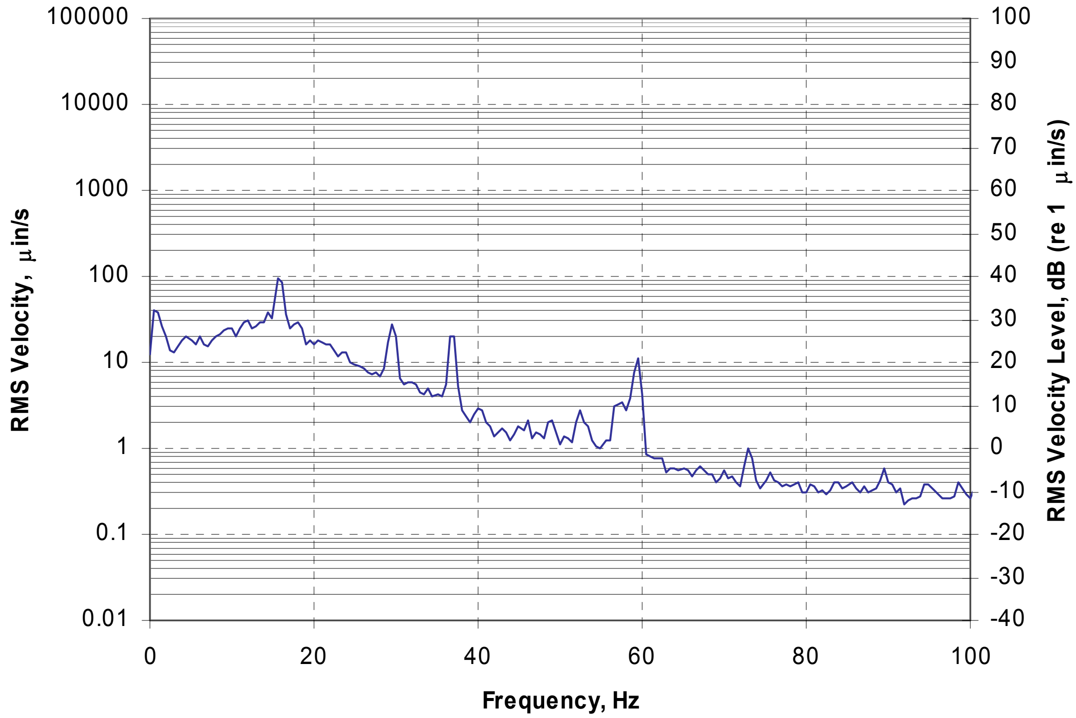
Figure A.1. Generic Vibration Criterion (VC) Curves for vibration-sensitive equipment - Showing also the ISO Guidelines for People in Buildings (see Table A.1 for description of equipment and uses.)



APPENDIX B Measured Vibration Data

Figure B1: UCSB CNSI Site Study - 10/17/2002
Engineering Science II, JEOL 2010, Vertical, Linear Average

a) Narrowband (Bandwidth = 0.75 Hz)



b) One-Third Octave Band

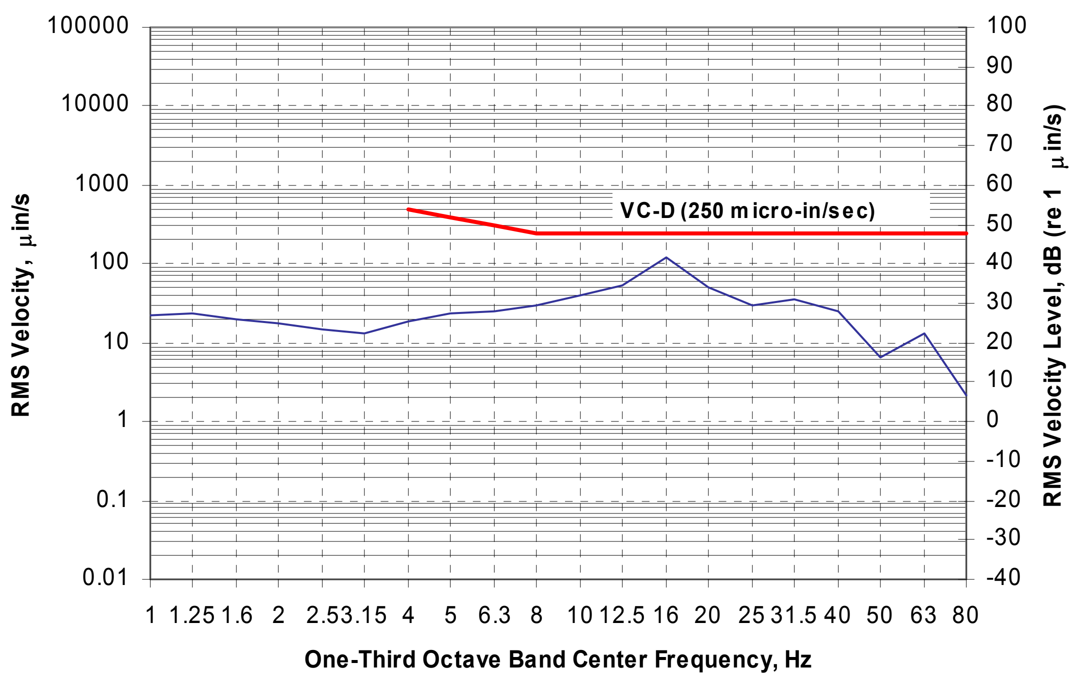
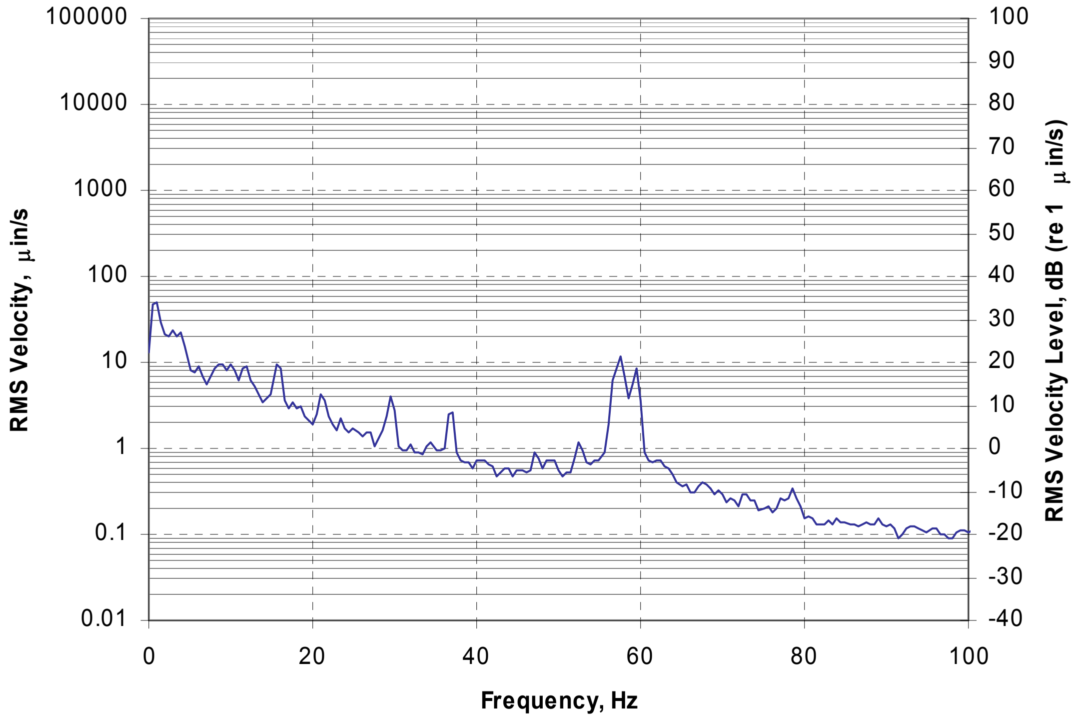


Figure B2: UCSB CNSI Site Study - 10/17/2002
Engineering Science II, JEOL 2010, North-South, Linear Average

a) Narrowband (Bandwidth = 0.75 Hz)



b) One-Third Octave Band

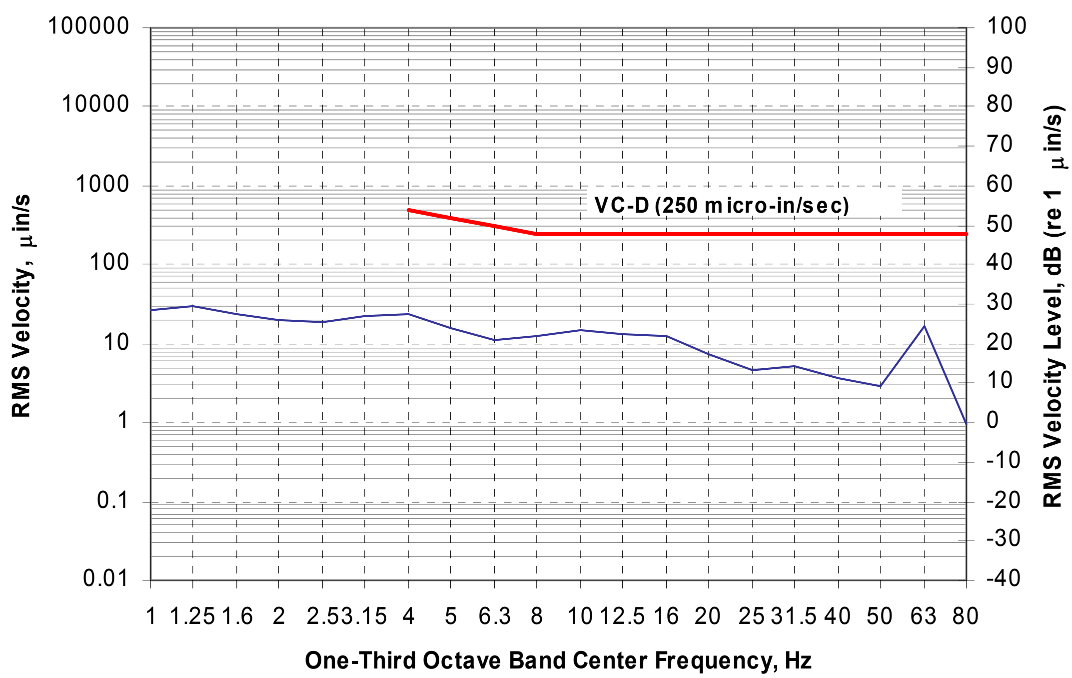
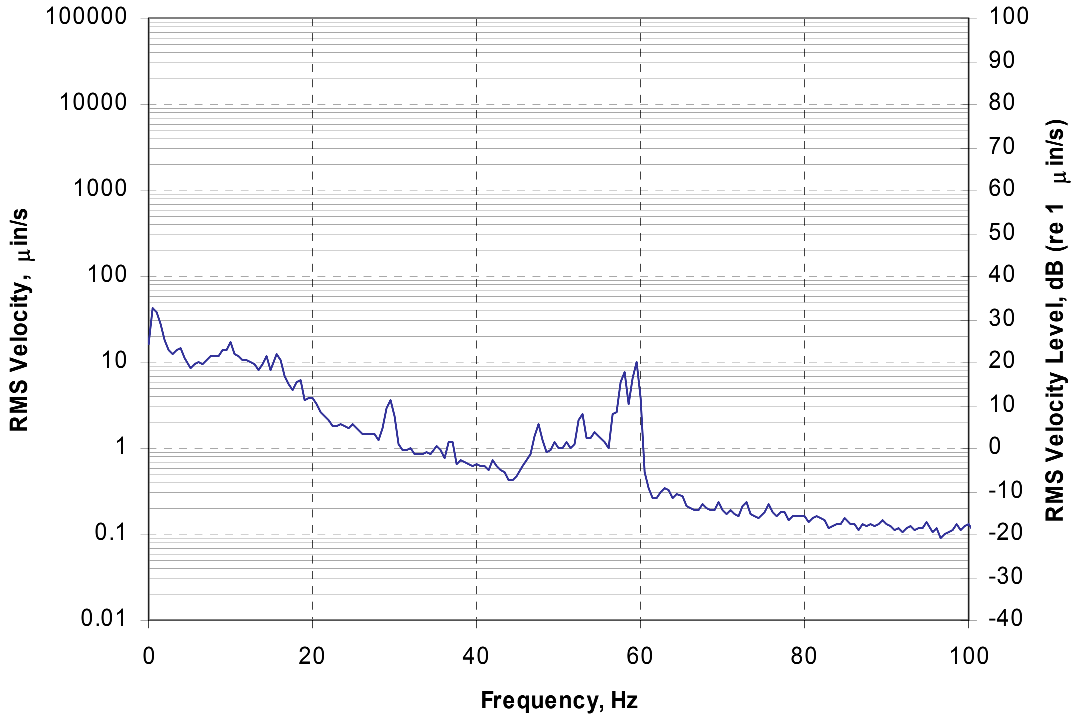


Figure B3: UCSB CNSI Site Study - 10/17/2002
Engineering Science II, JEOL 2010, East-West, Linear Average

a) Narrowband (Bandwidth = 0.75 Hz)



b) One-Third Octave Band

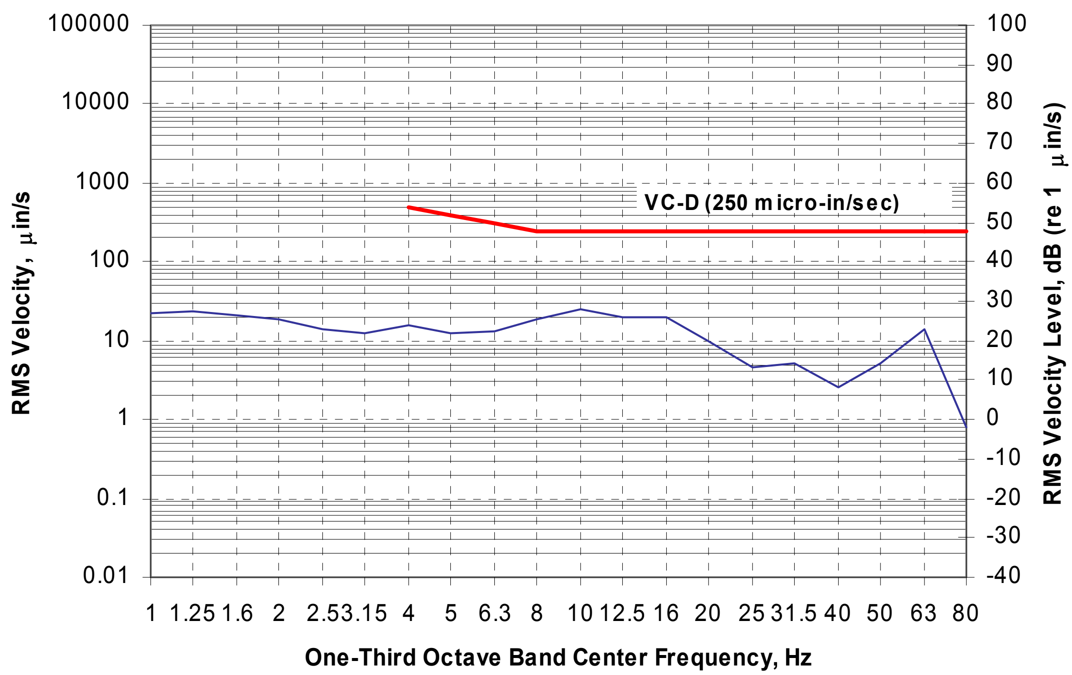
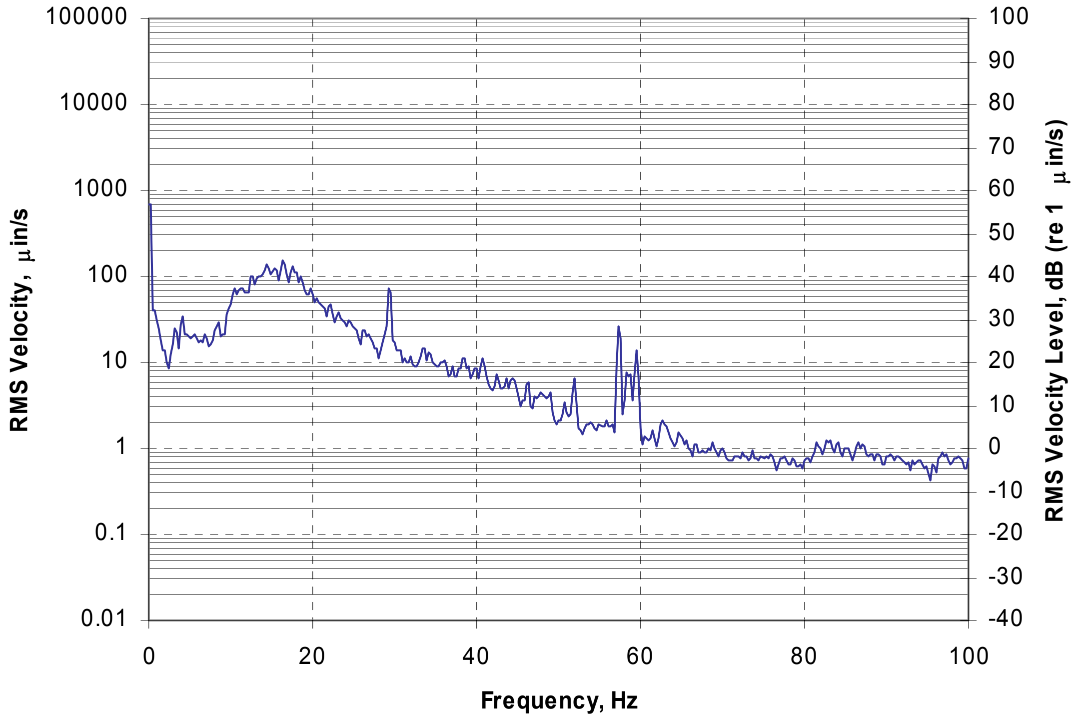


Figure B4: UCSB CNSI Site Study - 10/17/2002
Location 1, Vertical, Linear Average

a) Narrowband (Bandwidth = 0.375 Hz)



b) One-Third Octave Band

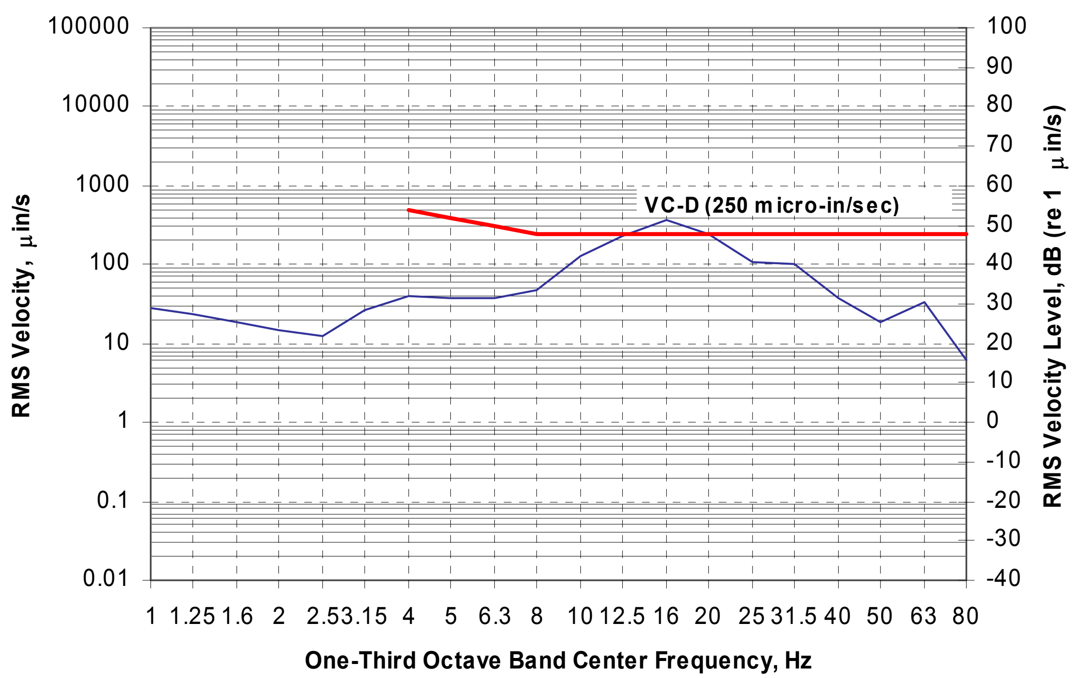
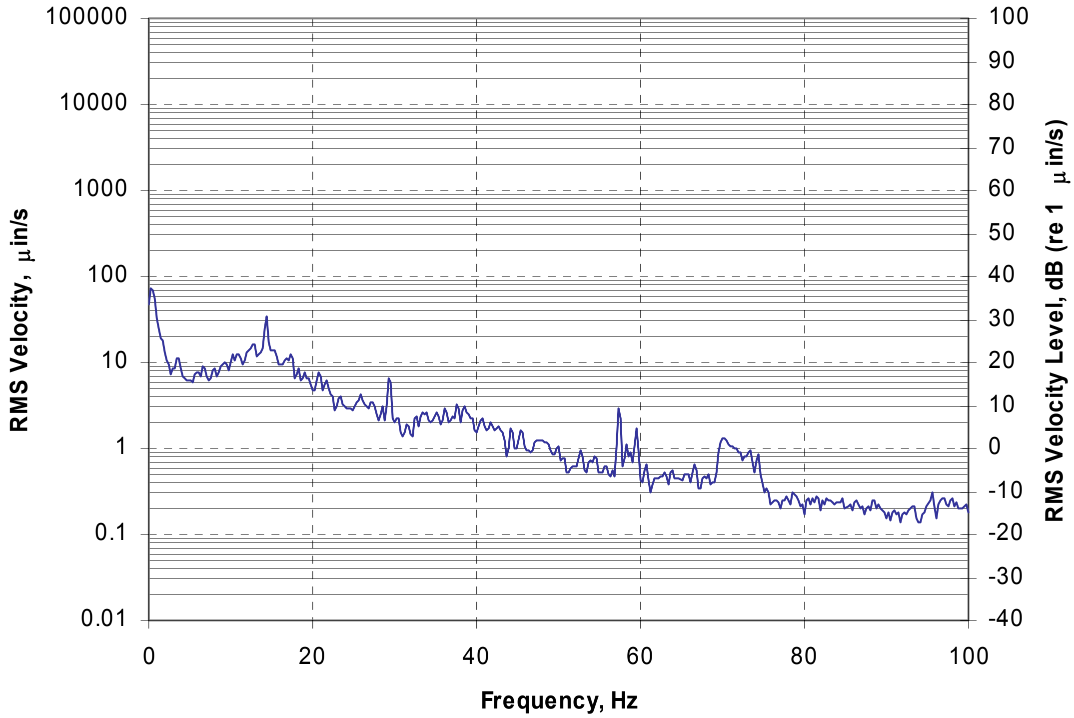


Figure B5: UCSB CNSI Site Study - 10/17/2002
Location 1, North-South, Linear Average

a) Narrowband (Bandwidth = 0.375 Hz)



b) One-Third Octave Band

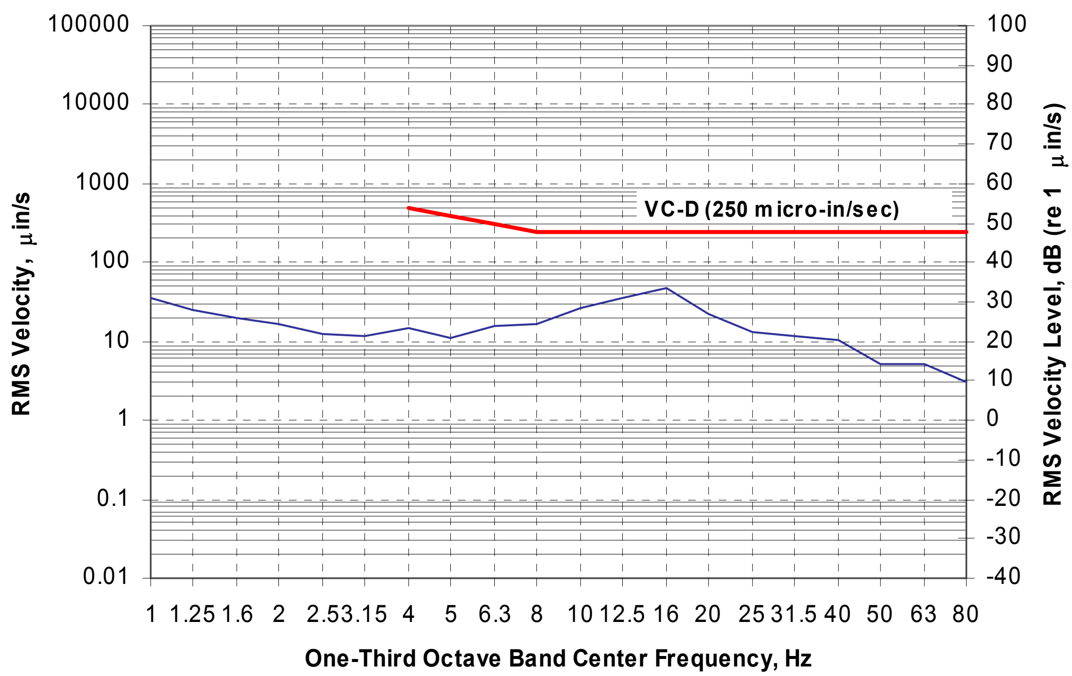
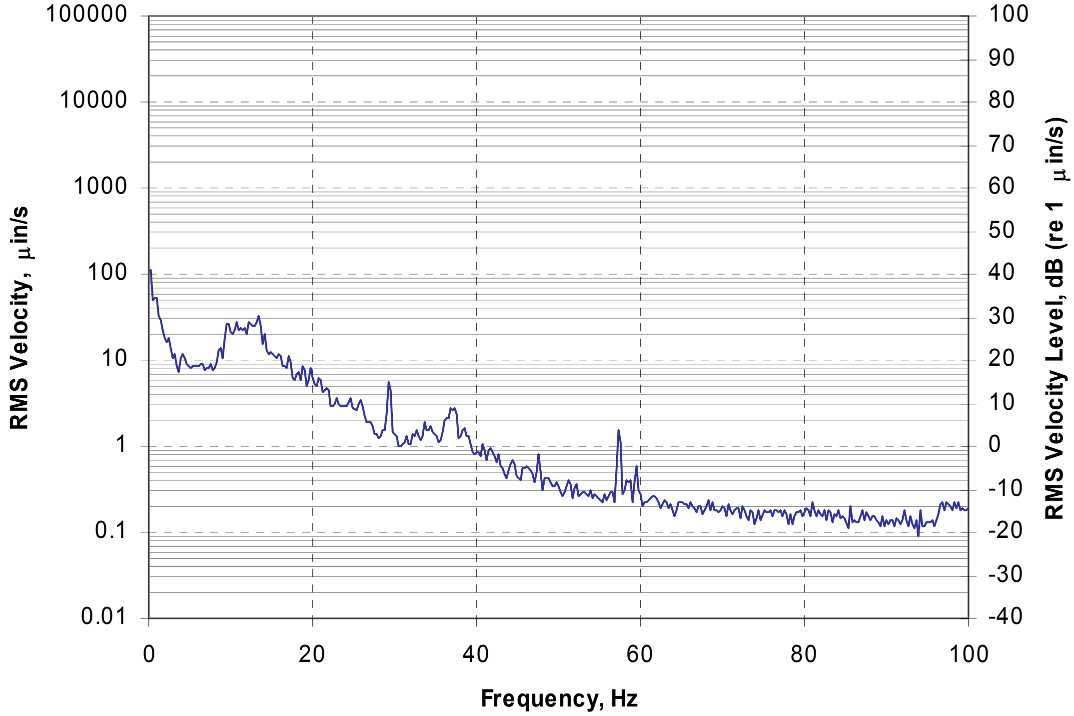


Figure B6: UCSB CNSI Site Study - 10/17/2002
Location 1, East-West, Linear Average

a) Narrowband (Bandwidth = 0.375 Hz)



b) One-Third Octave Band

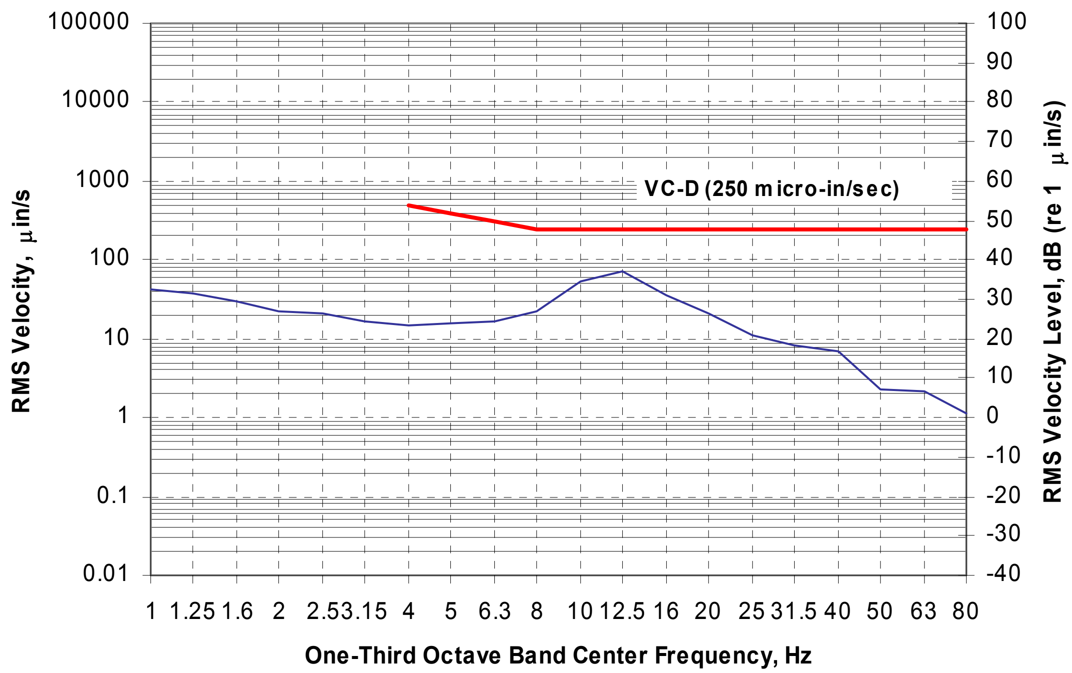
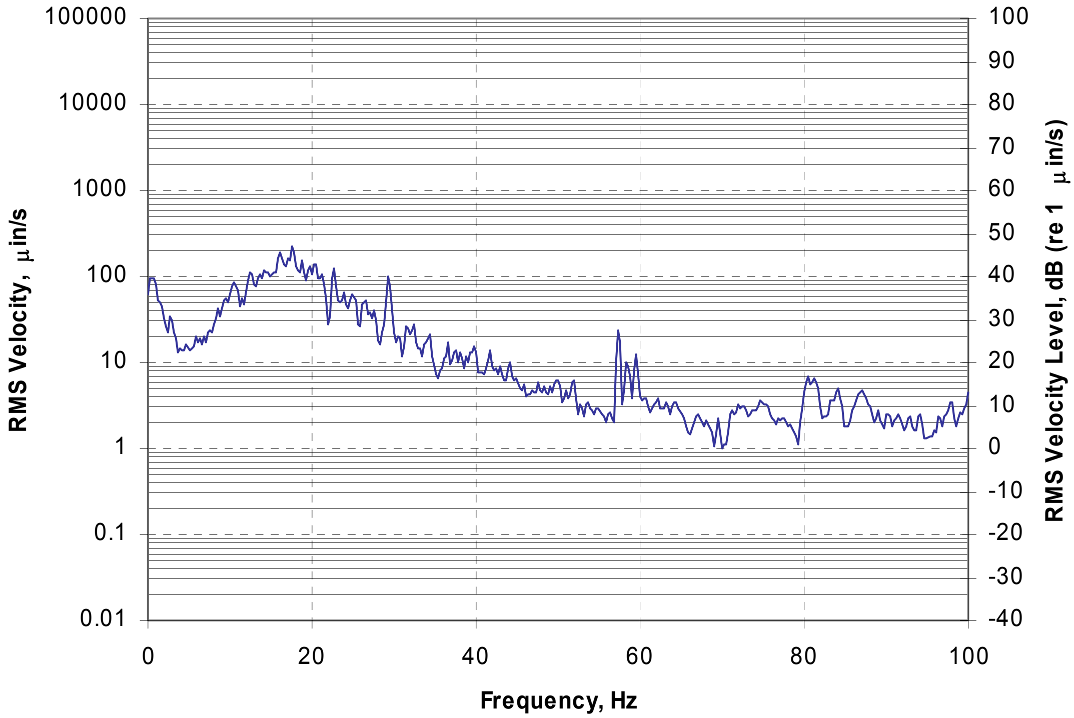


Figure B7: UCSB CNSI Site Study - 10/17/2002
Location 1, Vertical, Peak Hold

a) Narrowband (Bandwidth = 0.375 Hz)



b) One-Third Octave Band

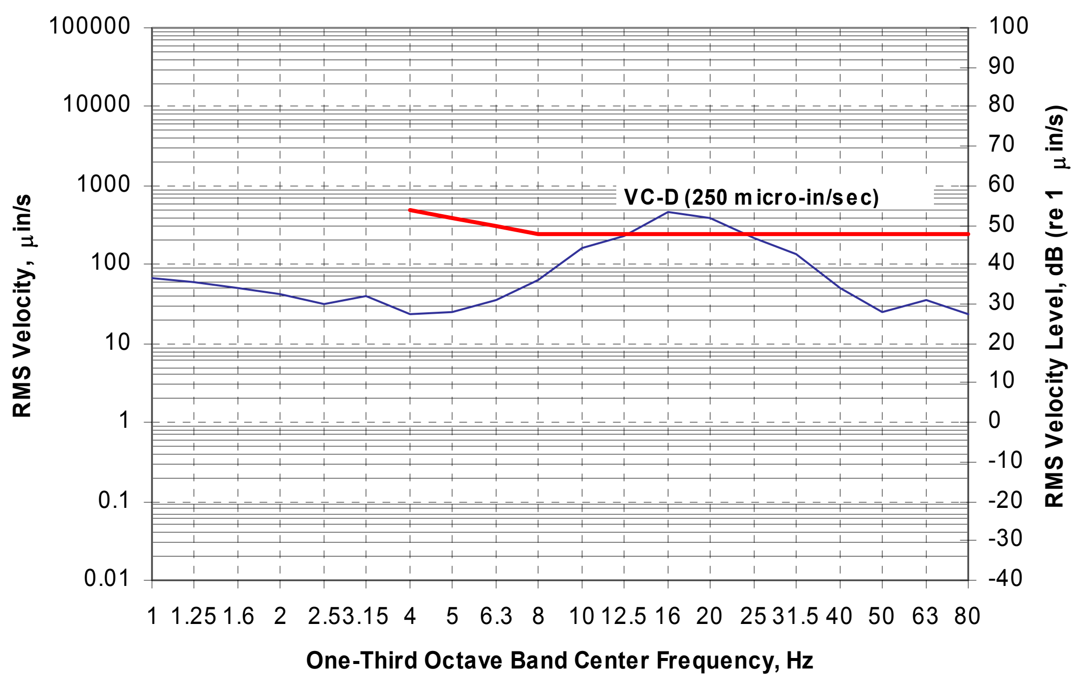
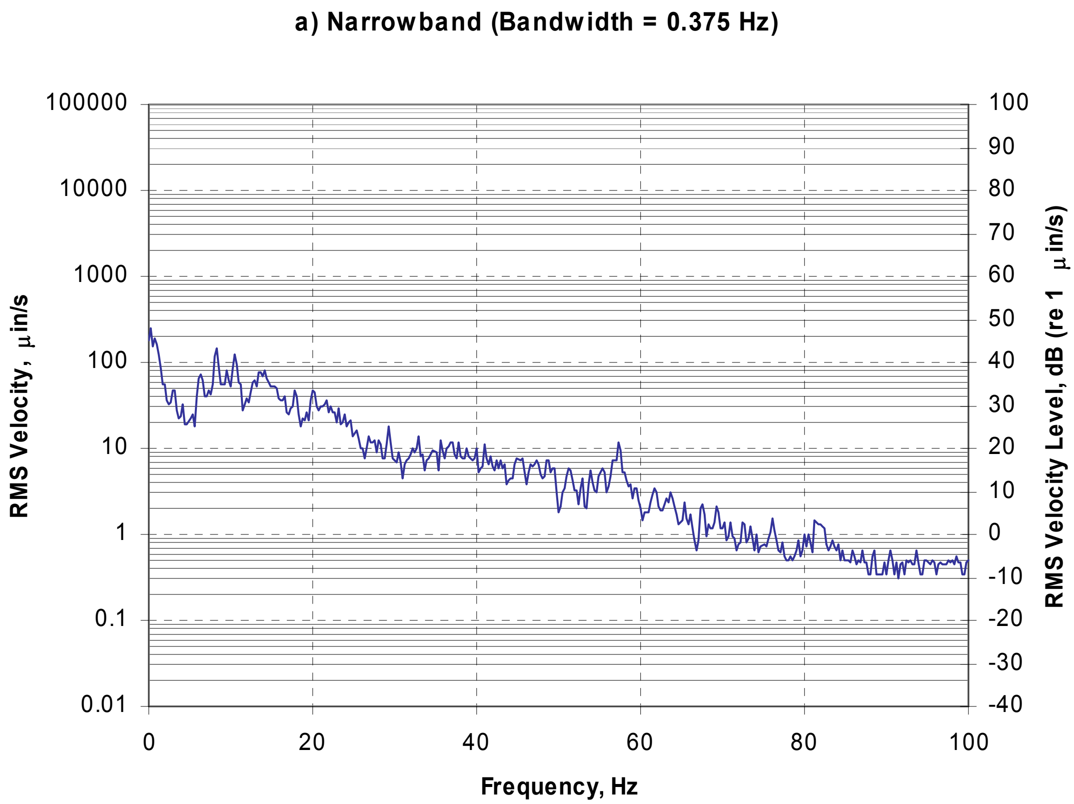


Figure B8: UCSB CNSI Site Study - 10/17/2002
Location 1, North-South, Peak Hold



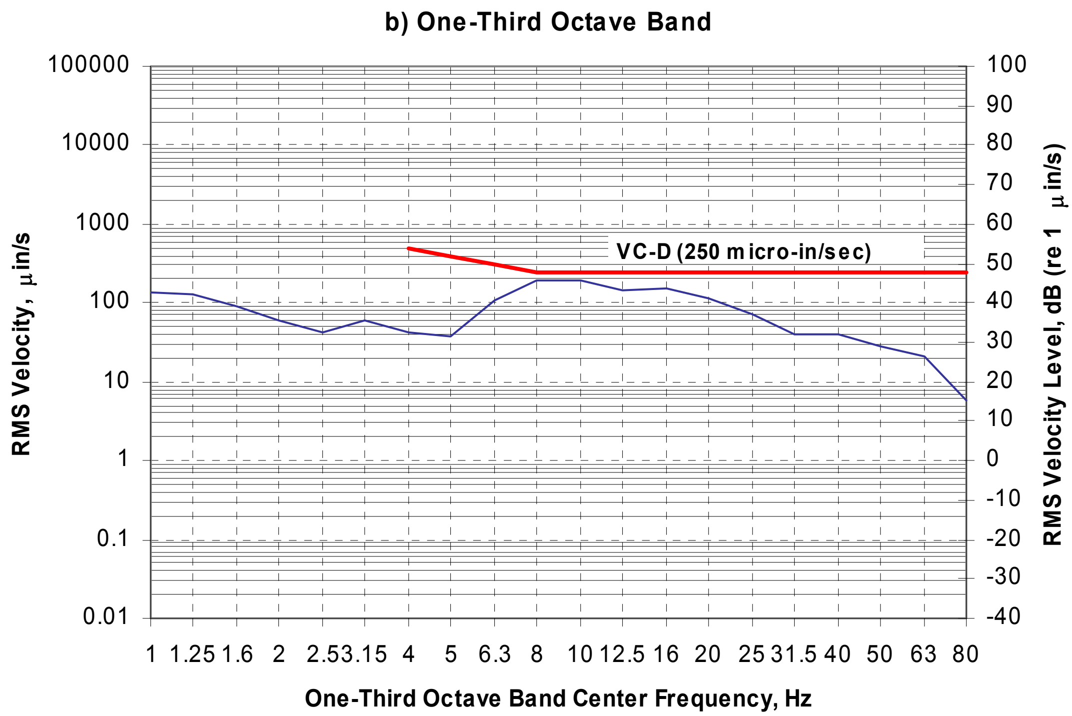
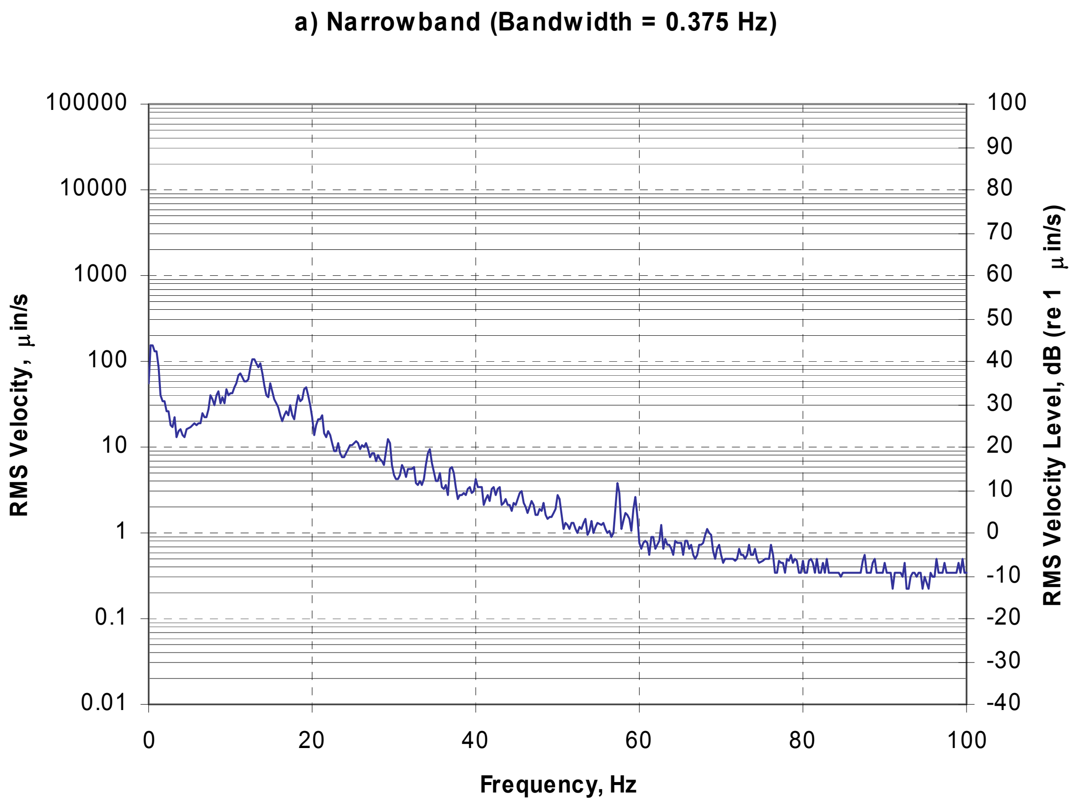


Figure B9: UCSB CNSI Site Study - 10/17/2002
Location 1, East-West, Peak Hold



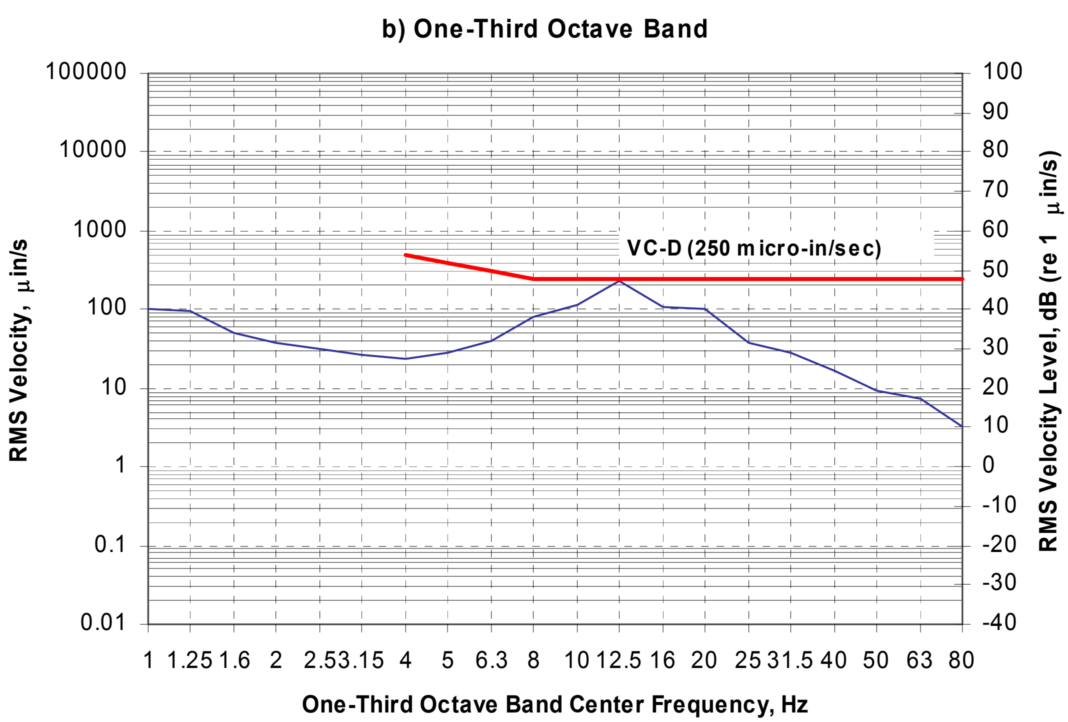
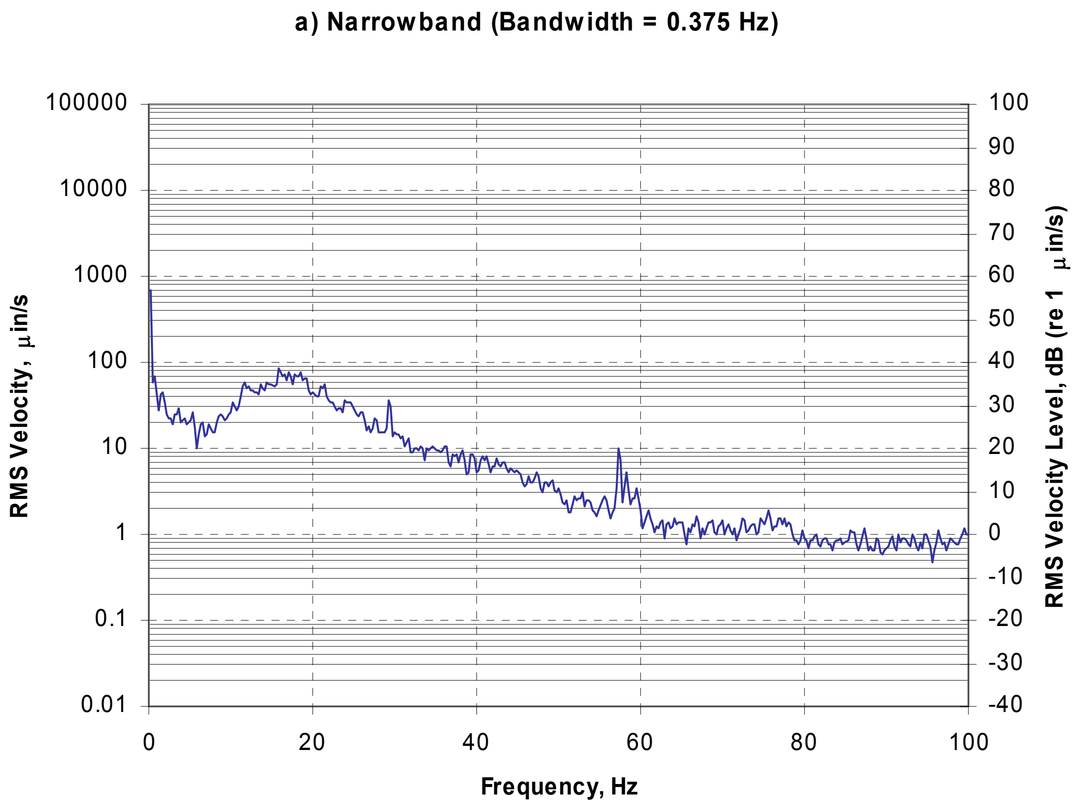


Figure B10: UCSB CNSI Site Study - 10/17/2002
Location 2, Vertical, Linear Average



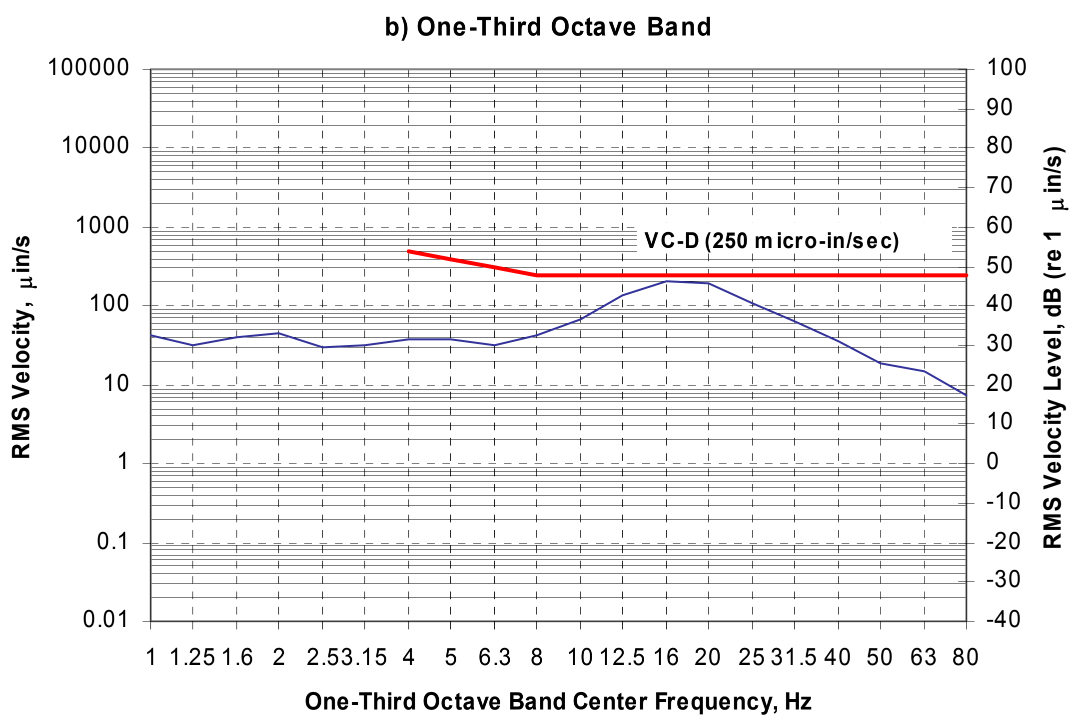
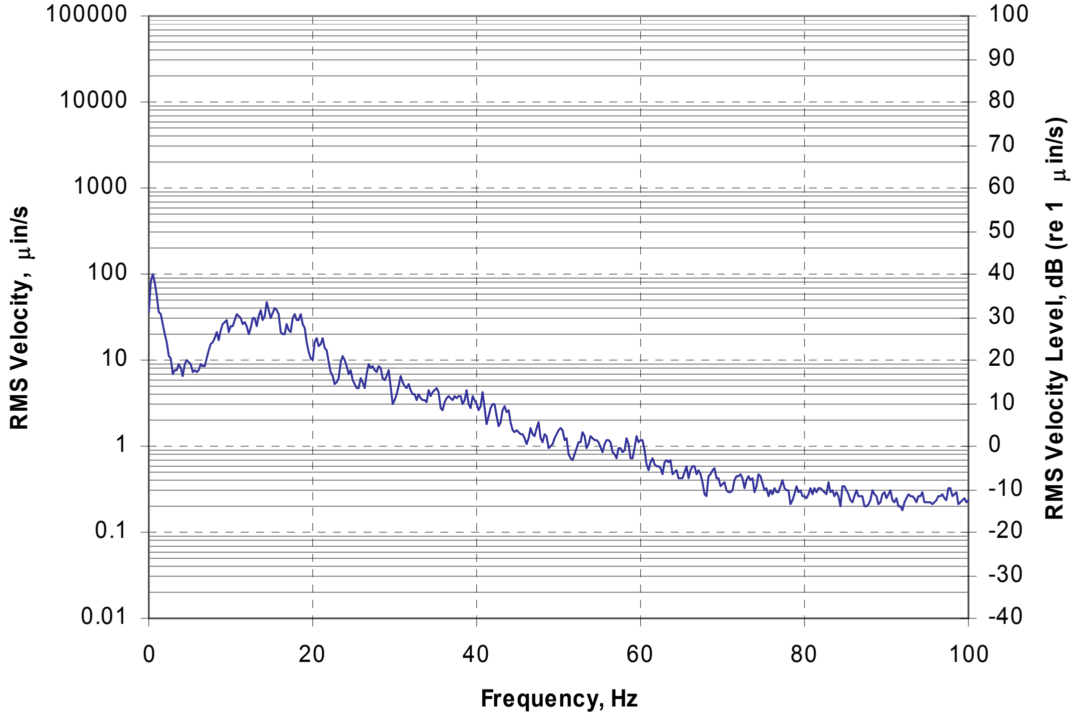


Figure B11: UCSB CNSI Site Study - 10/17/2002
Location 2, North-South, Linear Average

a) Narrowband (Bandwidth = 0.375 Hz)



b) One-Third Octave Band

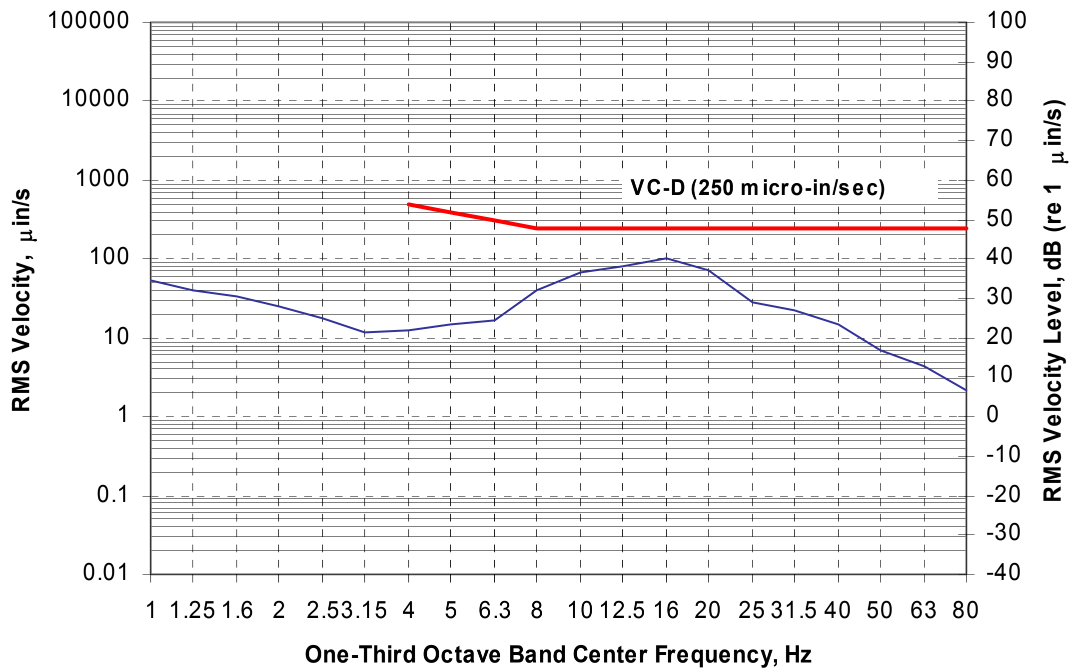
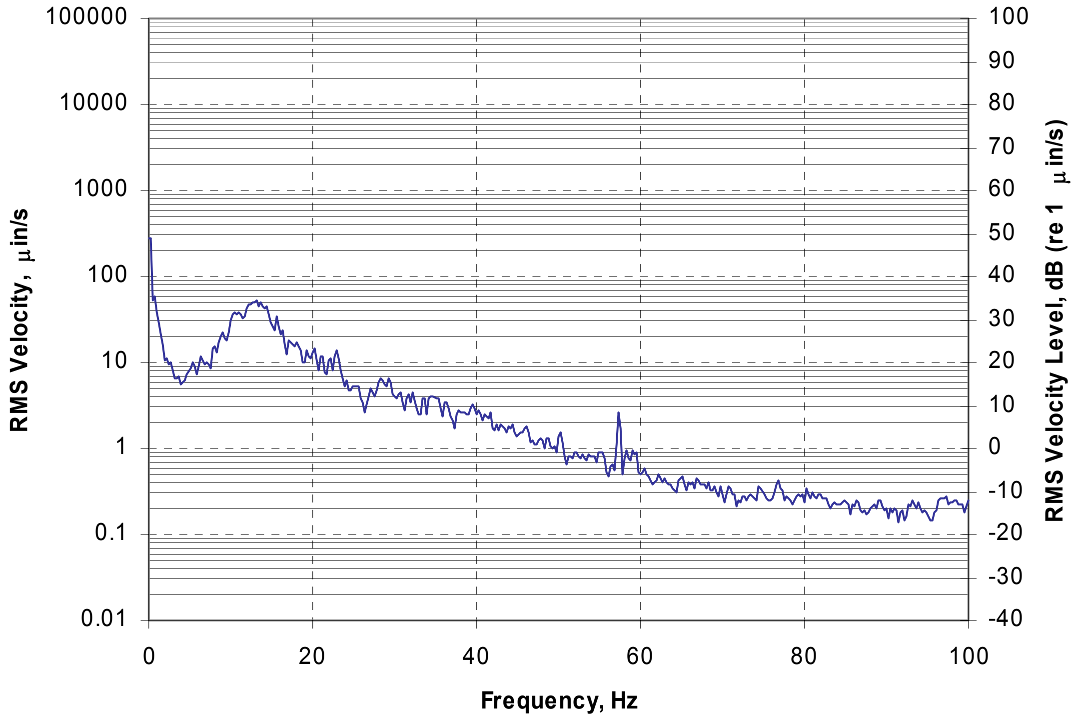


Figure B12: UCSB CNSI Site Study - 10/17/2002
Location 2, East-West, Linear Average



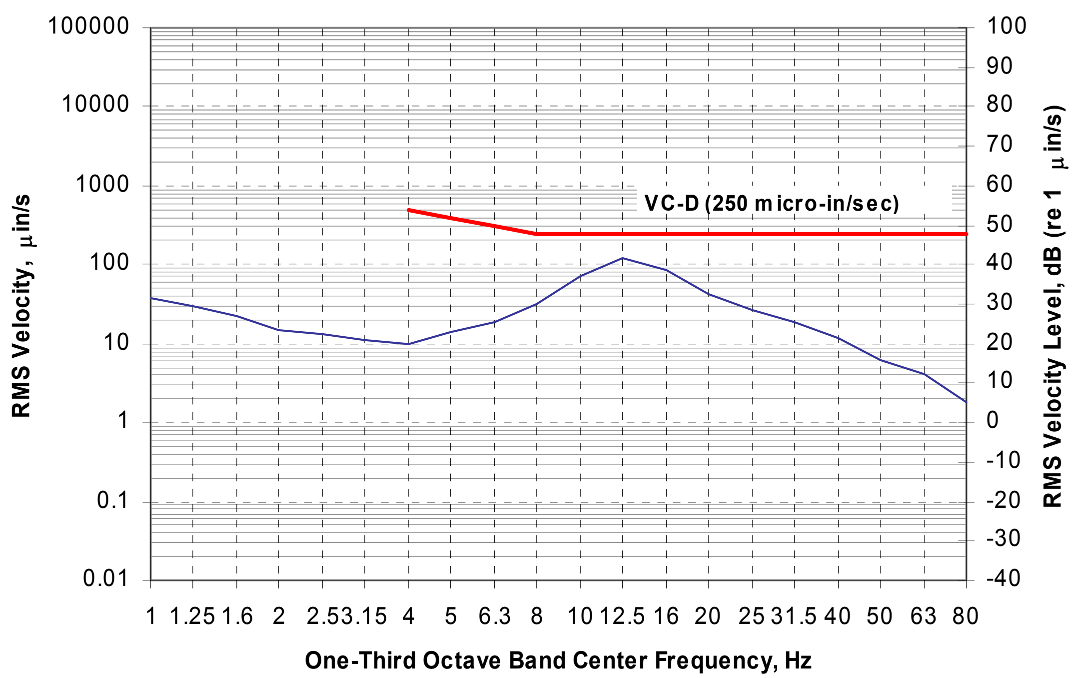
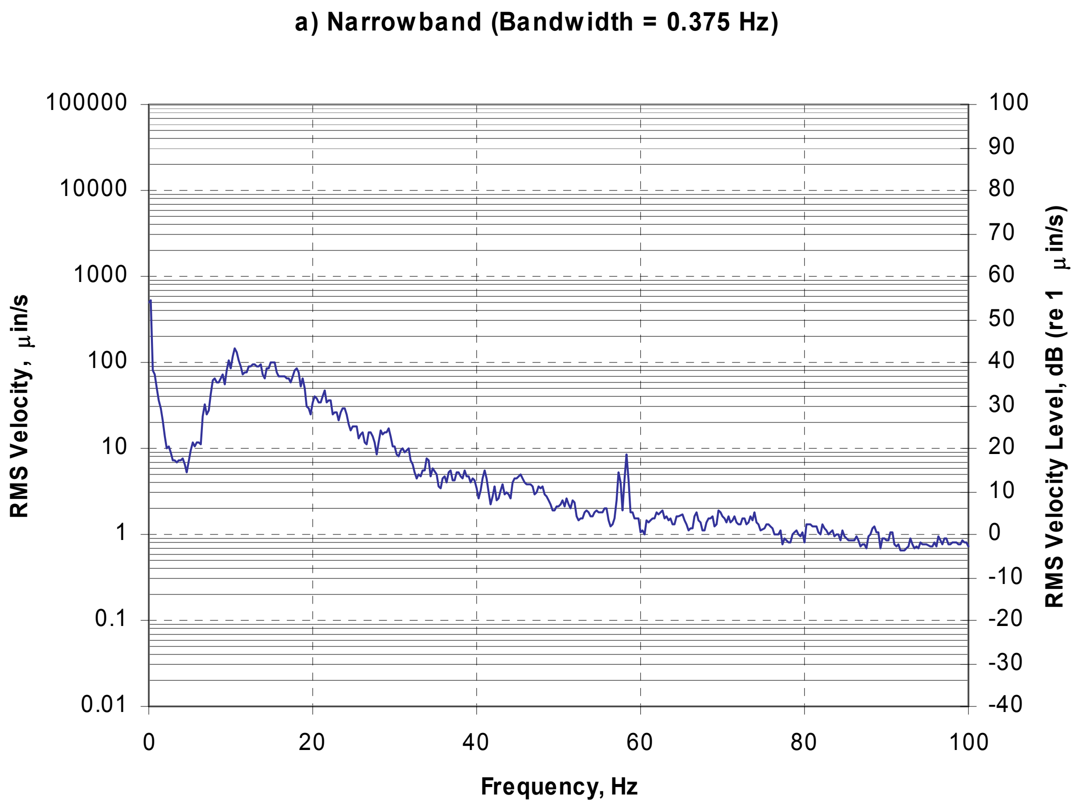


Figure B13: UCSB CNSI Site Study - 10/17/2002
Location 3, Vertical, Linear Average



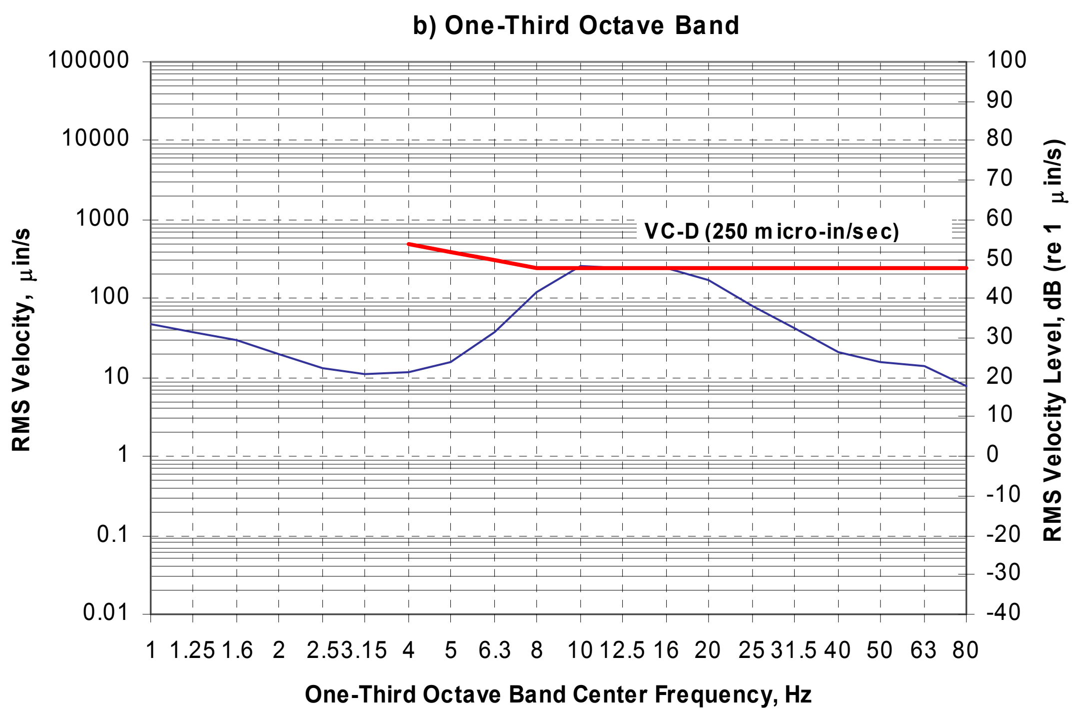
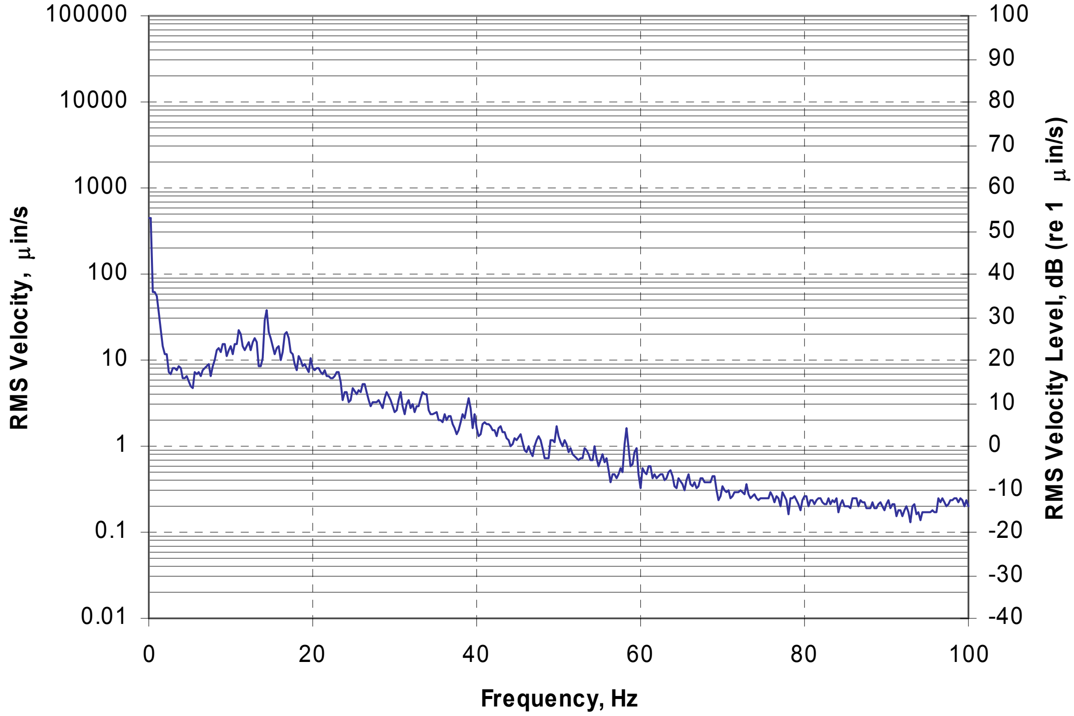


Figure B14: UCSB CNSI Site Study - 10/17/2002
Location 3, North-South, Linear Average

a) Narrowband (Bandwidth = 0.375 Hz)



b) One-Third Octave Band

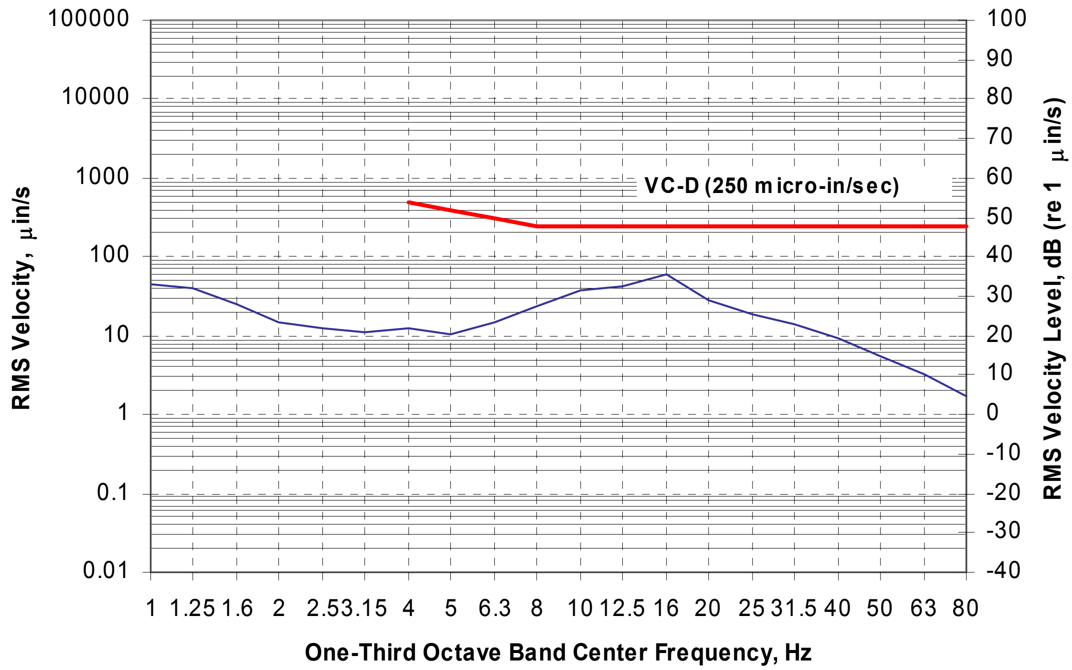
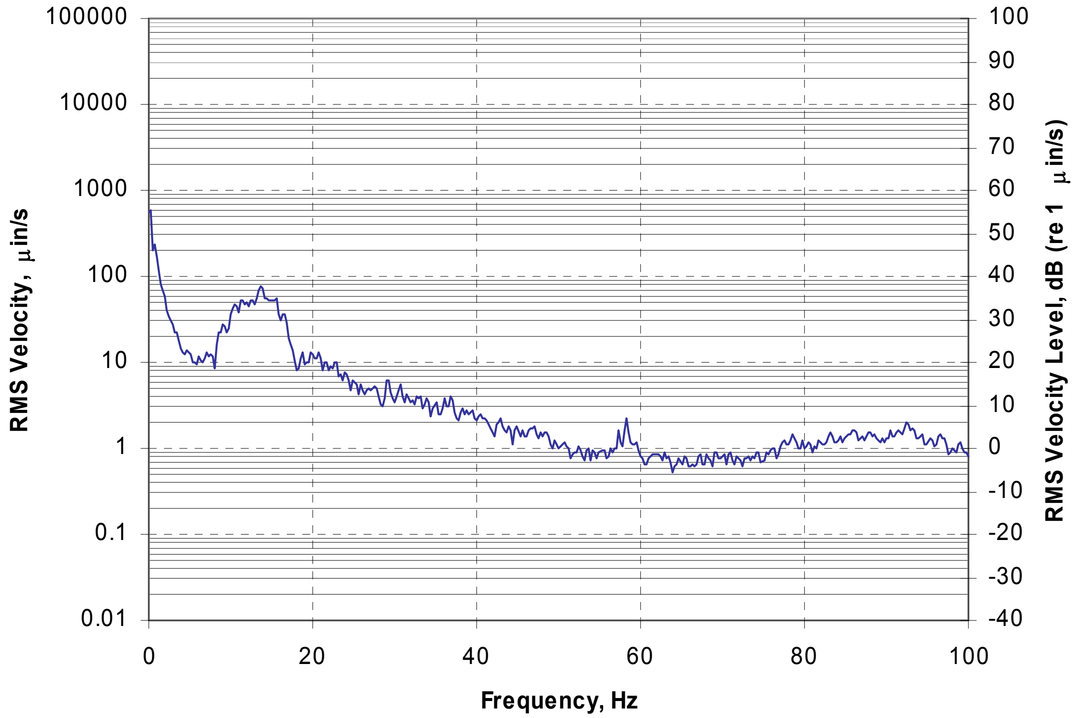


Figure B15: UCSB CNSI Site Study - 10/17/2002
Location 3, East-West, Linear Average

a) Narrowband (Bandwidth = 0.375 Hz)



b) One-Third Octave Band

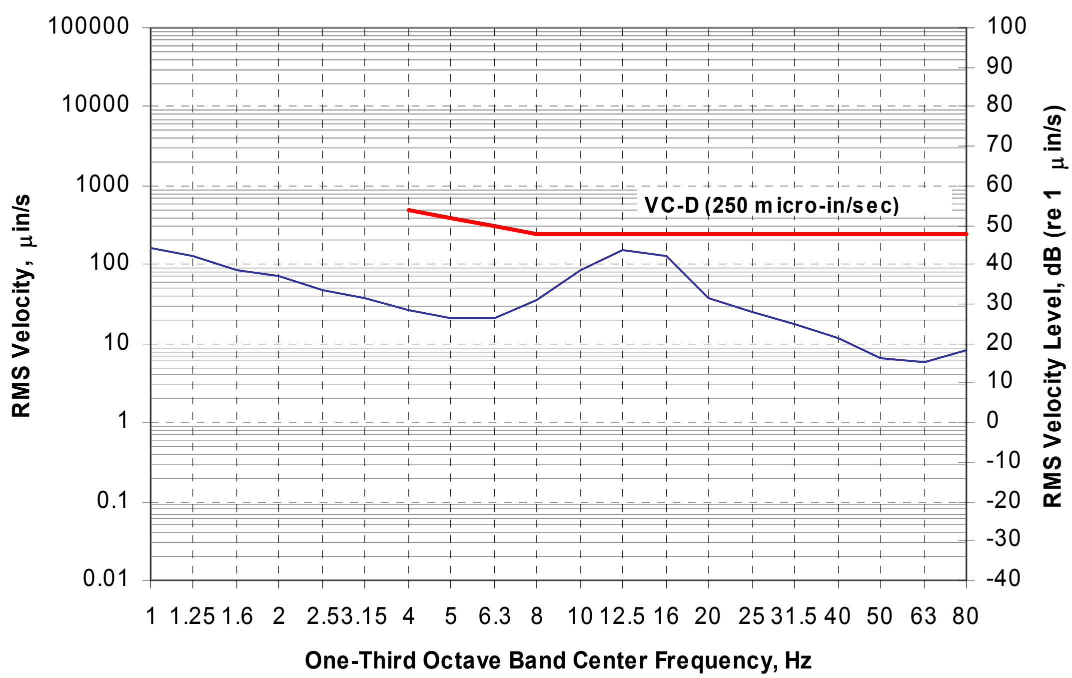
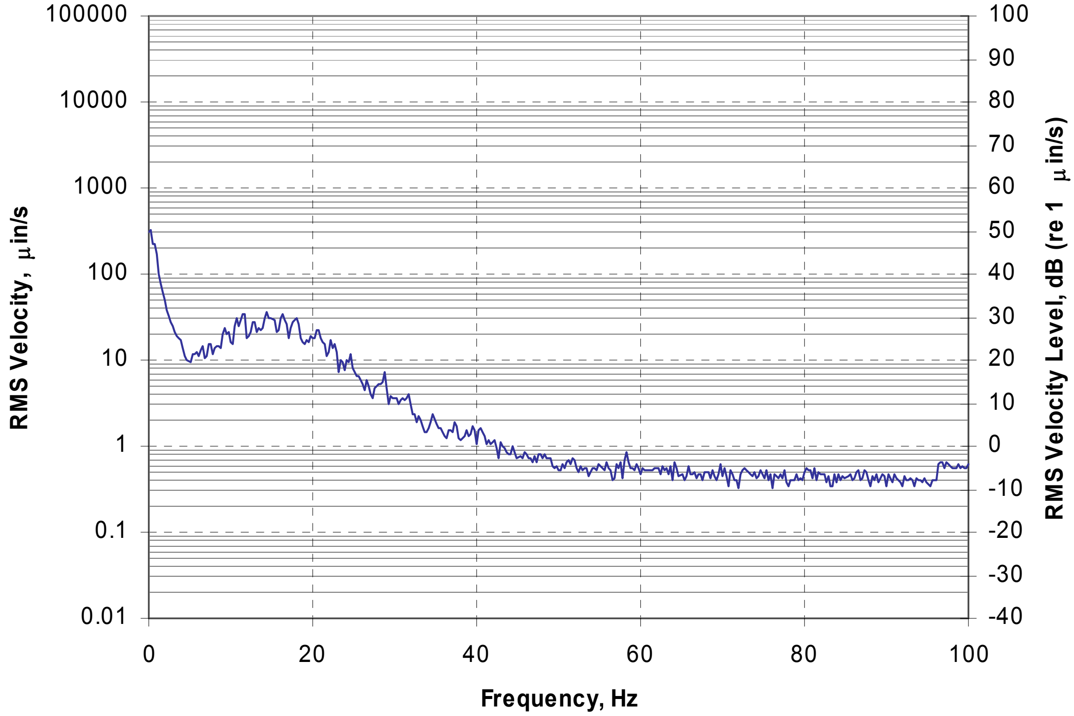


Figure B16: UCSB CNSI Site Study - 10/17/2002
Location 4, Vertical, Linear Average

a) Narrowband (Bandwidth = 0.375 Hz)



b) One-Third Octave Band

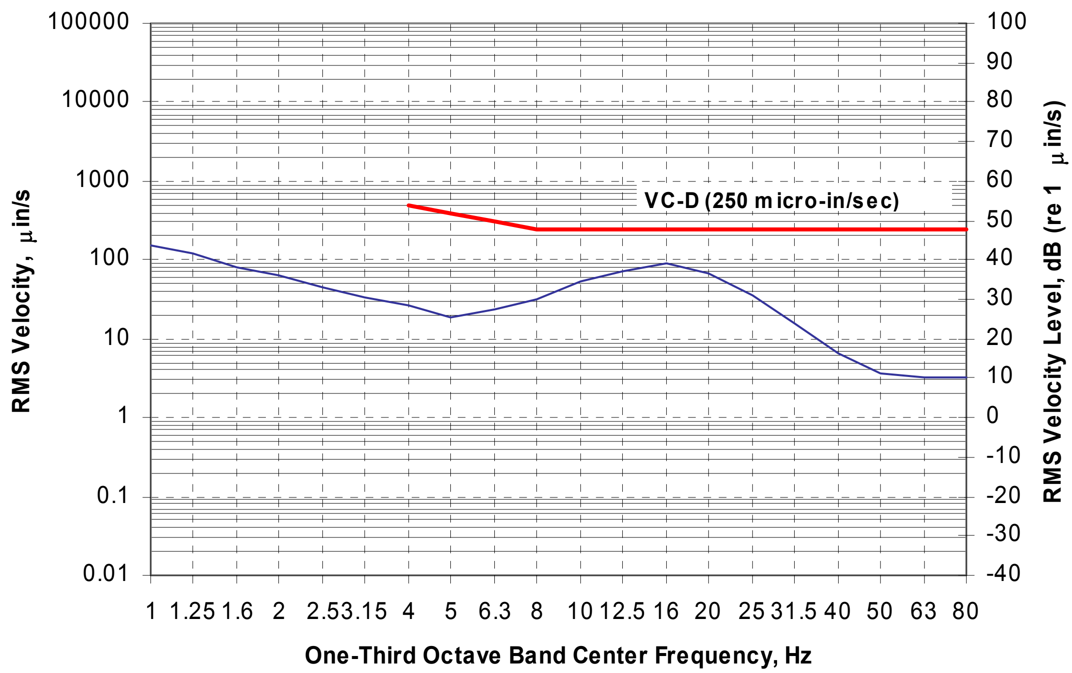
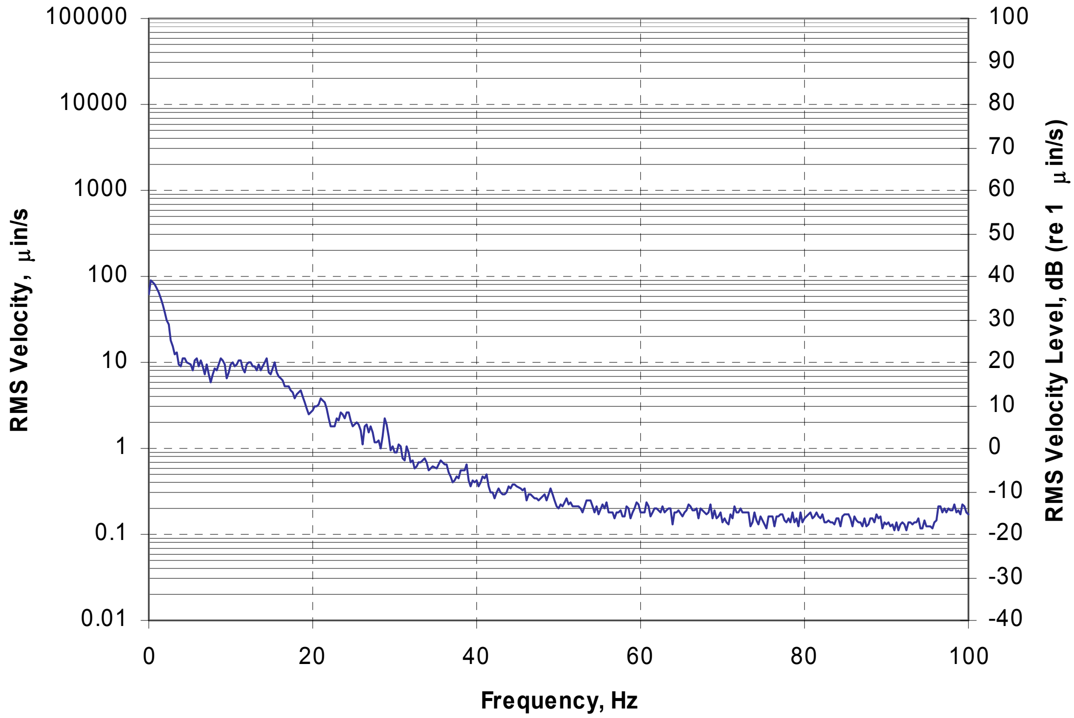


Figure B17: UCSB CNSI Site Study - 10/17/2002
Location 4, North-South, Linear Average

a) Narrowband (Bandwidth = 0.375 Hz)



b) One-Third Octave Band

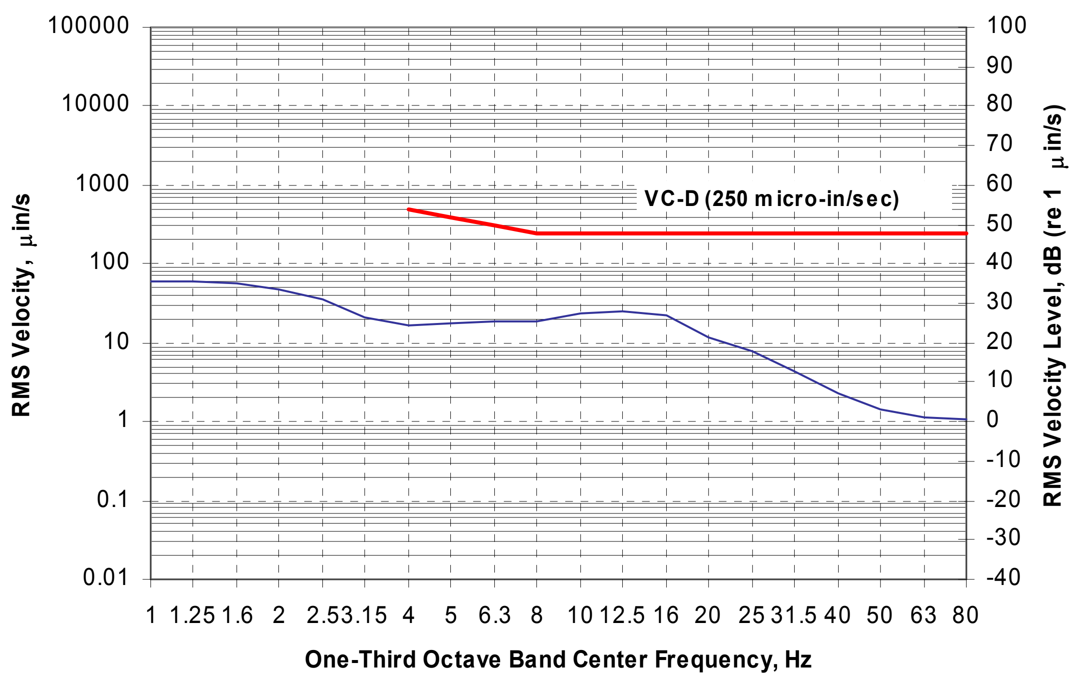
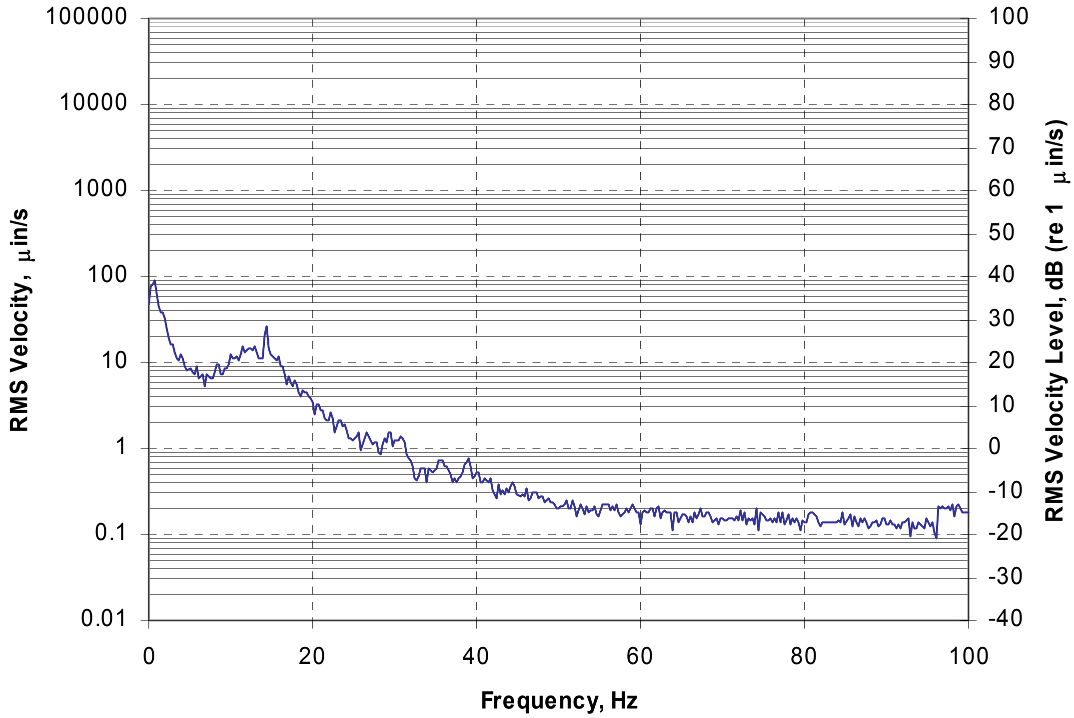


Figure B18: UCSB CNSI Site Study - 10/17/2002
Location 4, East-West, Linear Average

a) Narrowband (Bandwidth = 0.375 Hz)



b) One-Third Octave Band

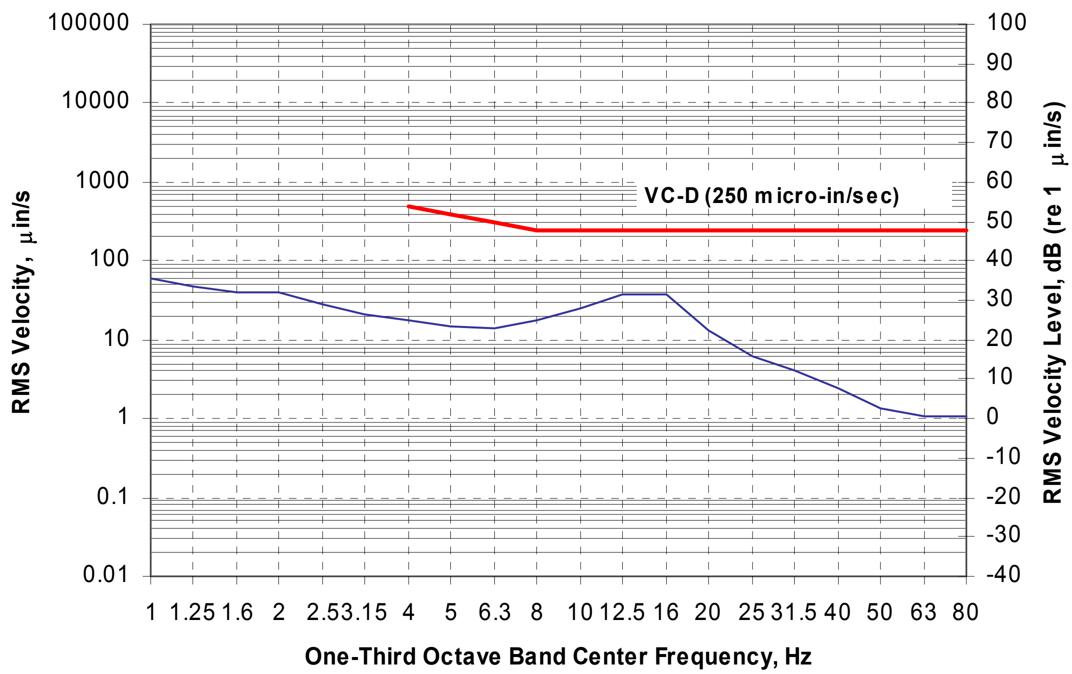
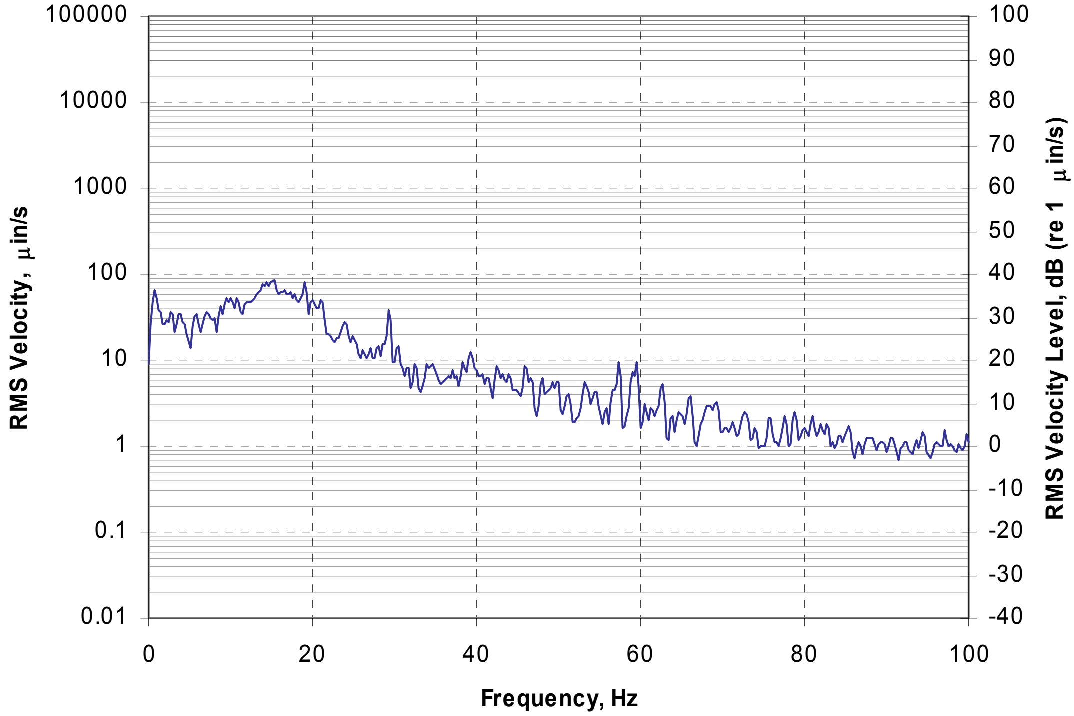


Figure B19: UCSB CNSI Site Study - 10/17/2002
Location 5, Vertical, Linear Average

a) Narrowband (Bandwidth = 0.375 Hz)



b) One-Third Octave Band

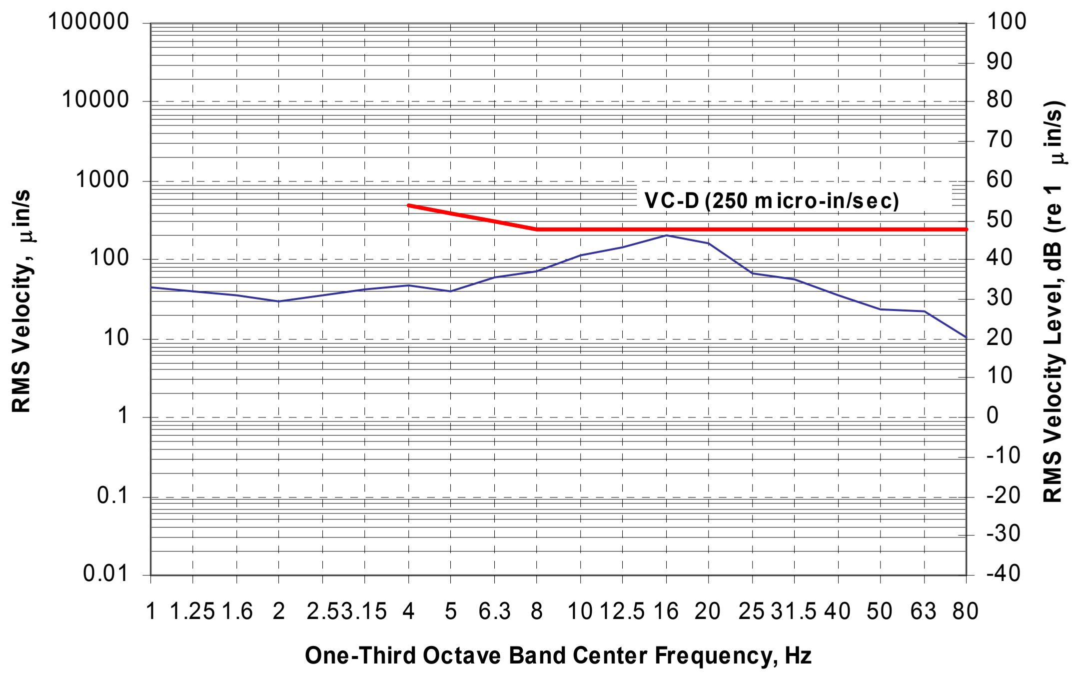
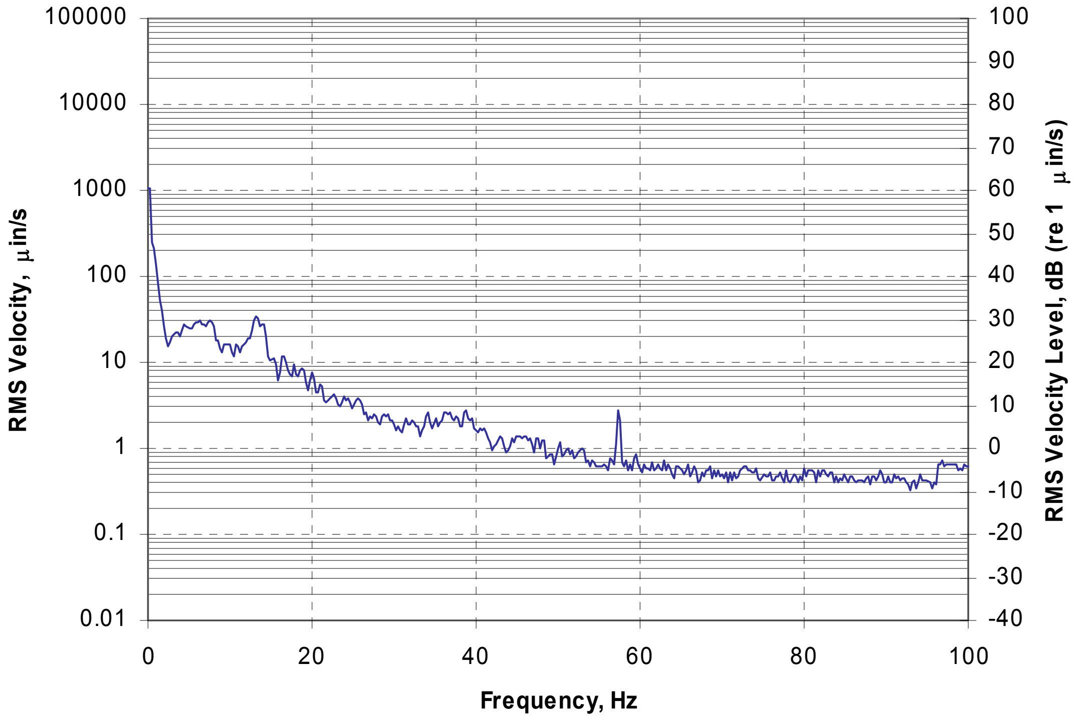


Figure B20: UCSB CNSI Site Study - 10/17/2002
Location 5, North-South, Linear Average

a) Narrowband (Bandwidth = 0.375 Hz)



b) One-Third Octave Band

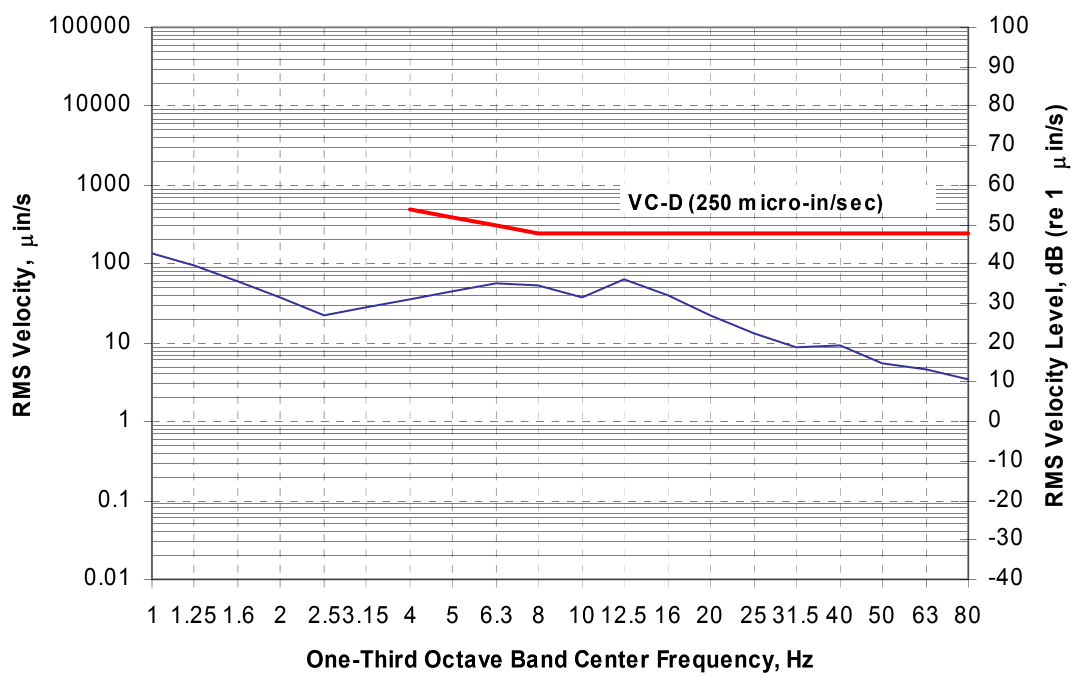
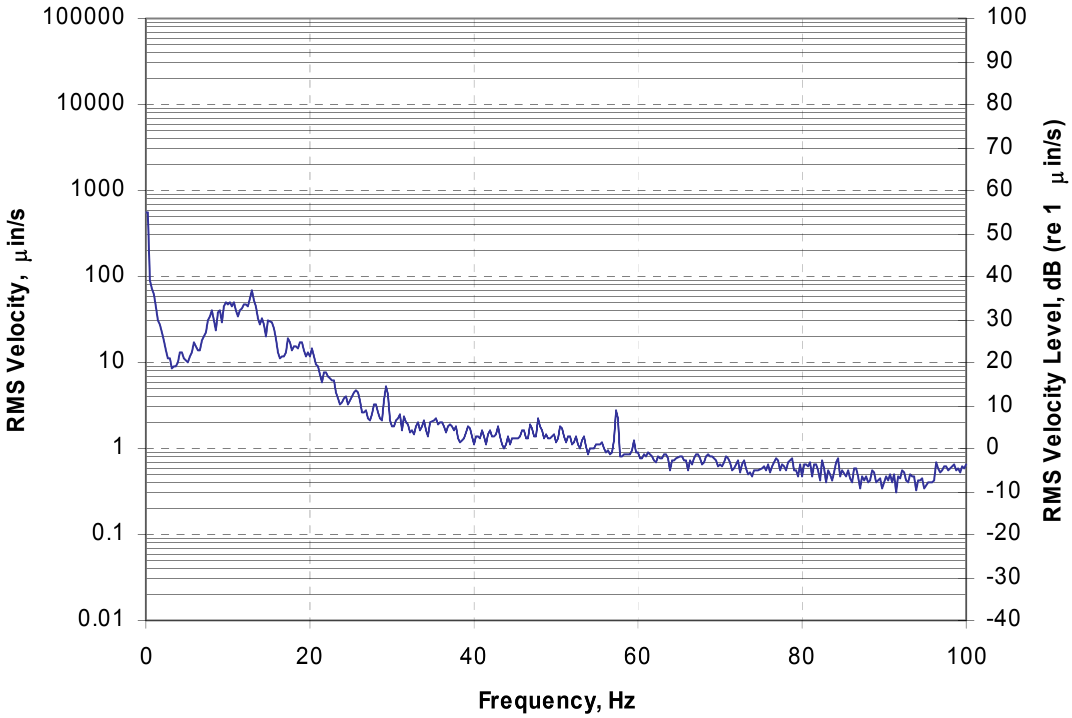


Figure B21: UCSB CNSI Site Study - 10/17/2002
Location 5, East-West, Linear Average

a) Narrowband (Bandwidth = 0.375 Hz)



b) One-Third Octave Band

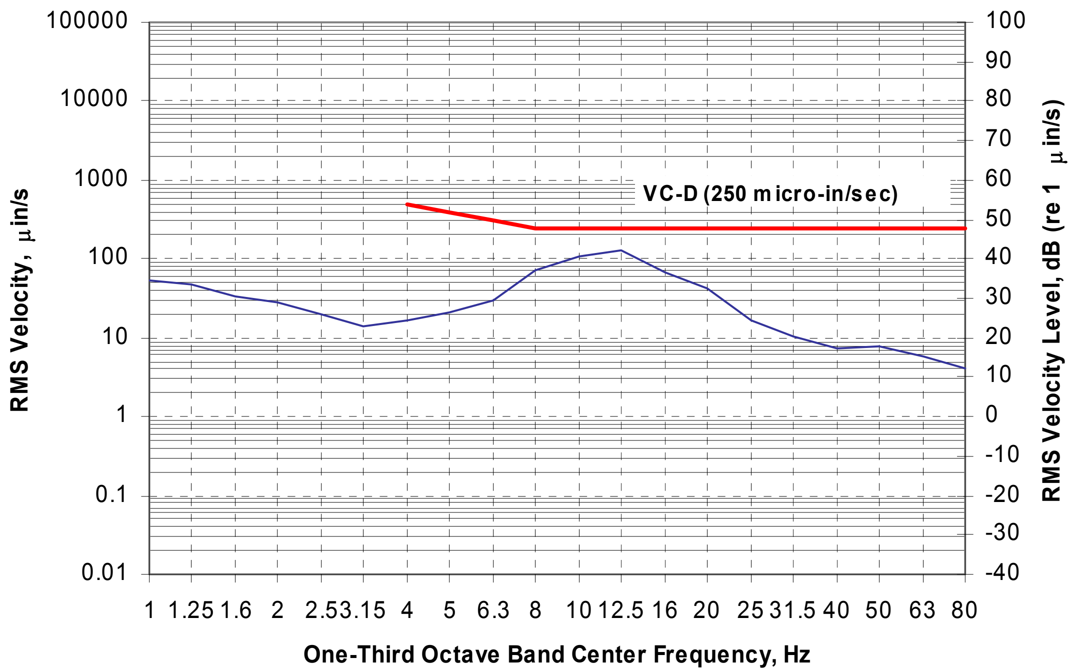
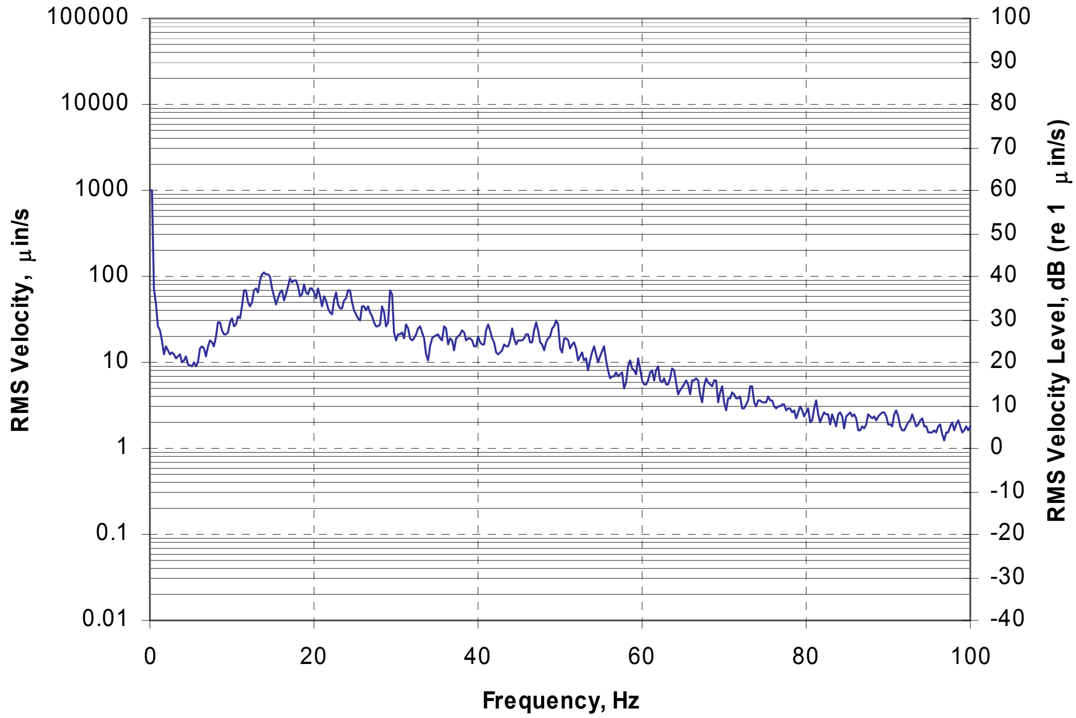


Figure B22: UCSB CNSI Site Study - 10/17/2002
Location 6, Vertical, Linear Average

a) Narrowband (Bandwidth = 0.375 Hz)



b) One-Third Octave Band

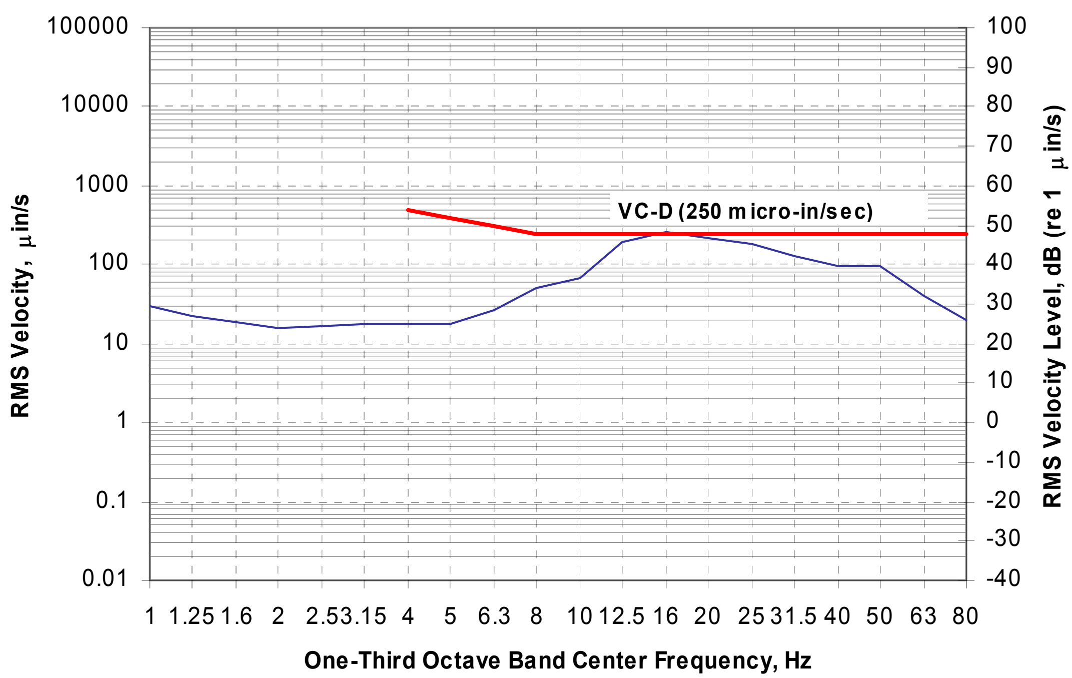
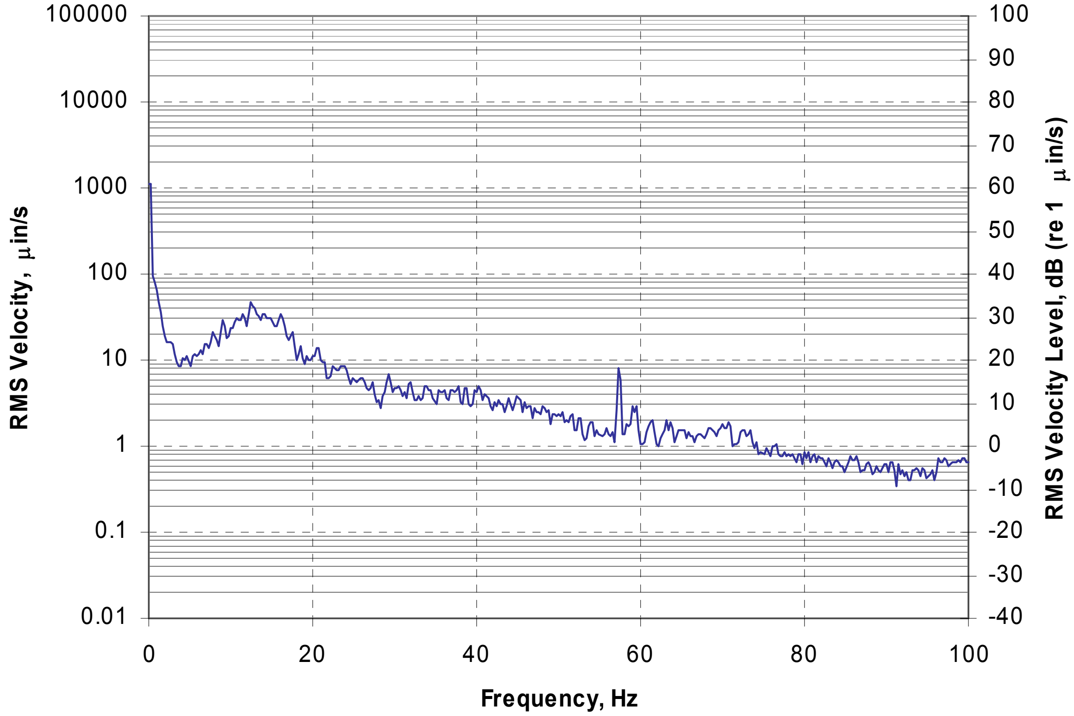


Figure B23: UCSB CNSI Site Study - 10/17/2002
Location 6, North-South, Linear Average

a) Narrowband (Bandwidth = 0.375 Hz)



b) One-Third Octave Band

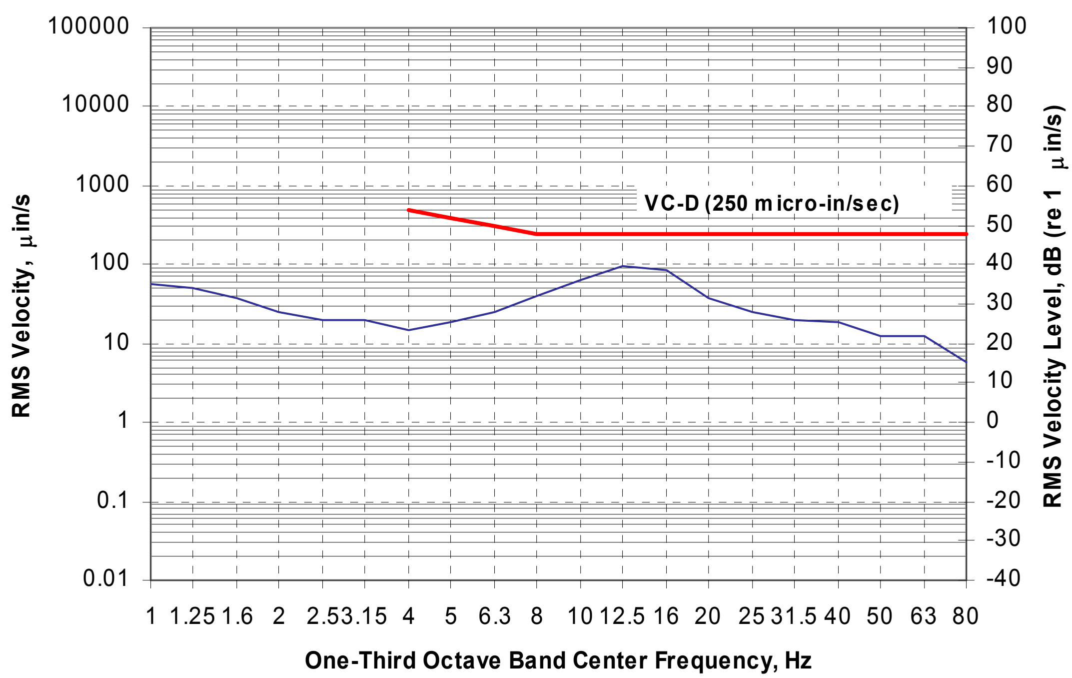
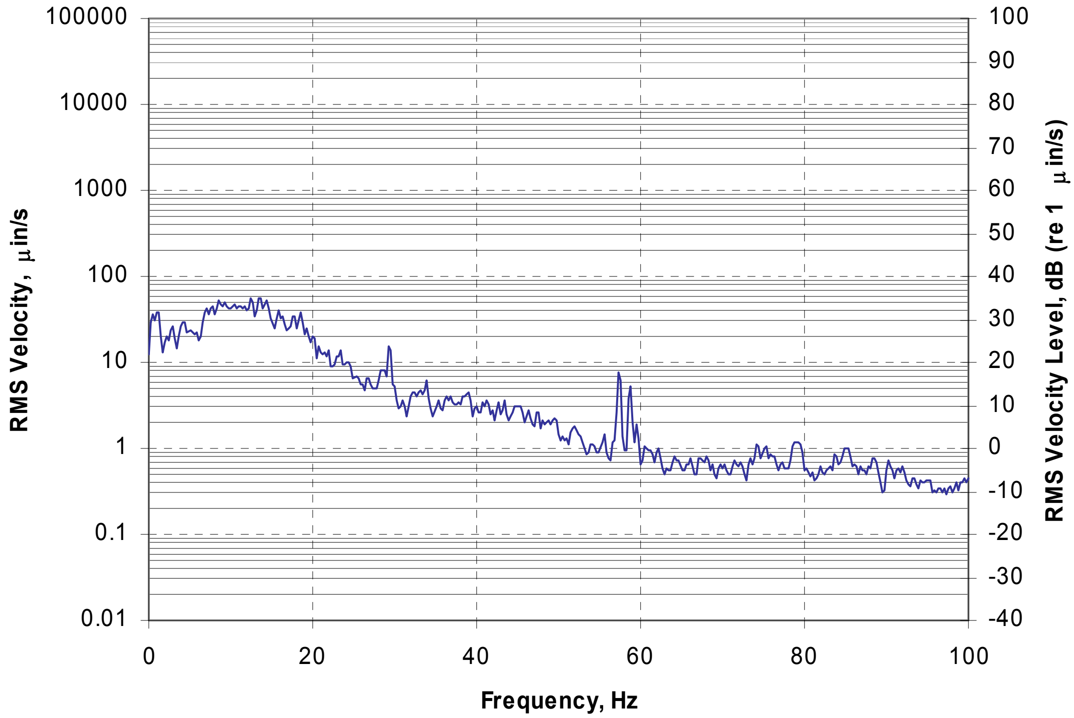


Figure B24: UCSB CNSI Site Study - 10/17/2002
Location 6, East-West, Linear Average

a) Narrowband (Bandwidth = 0.375 Hz)



b) One-Third Octave Band

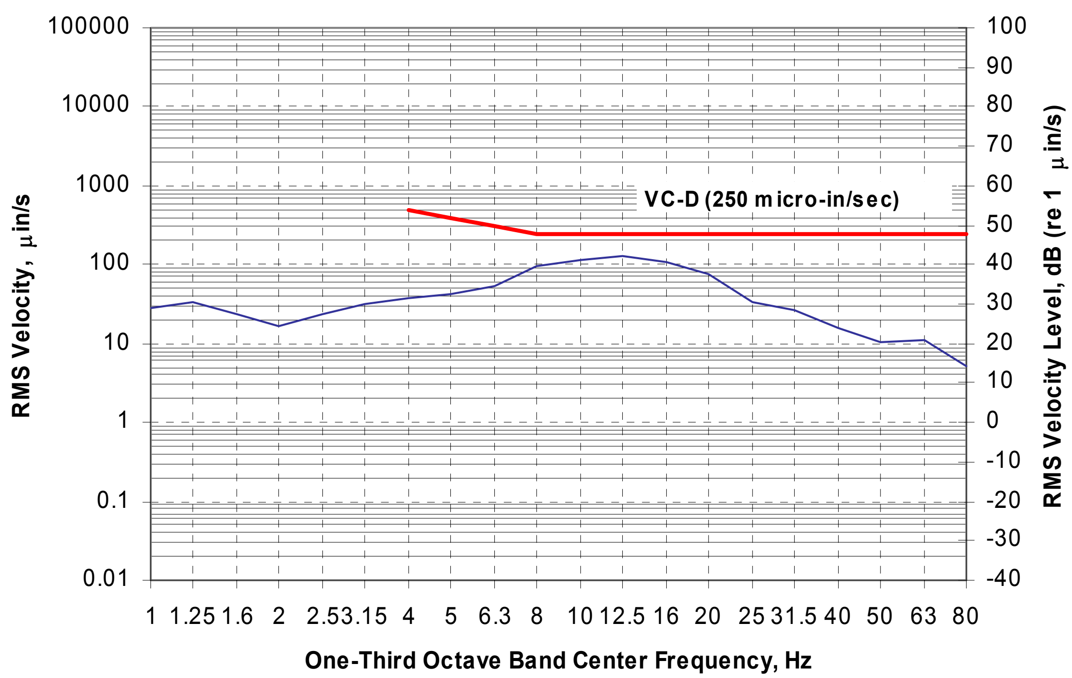
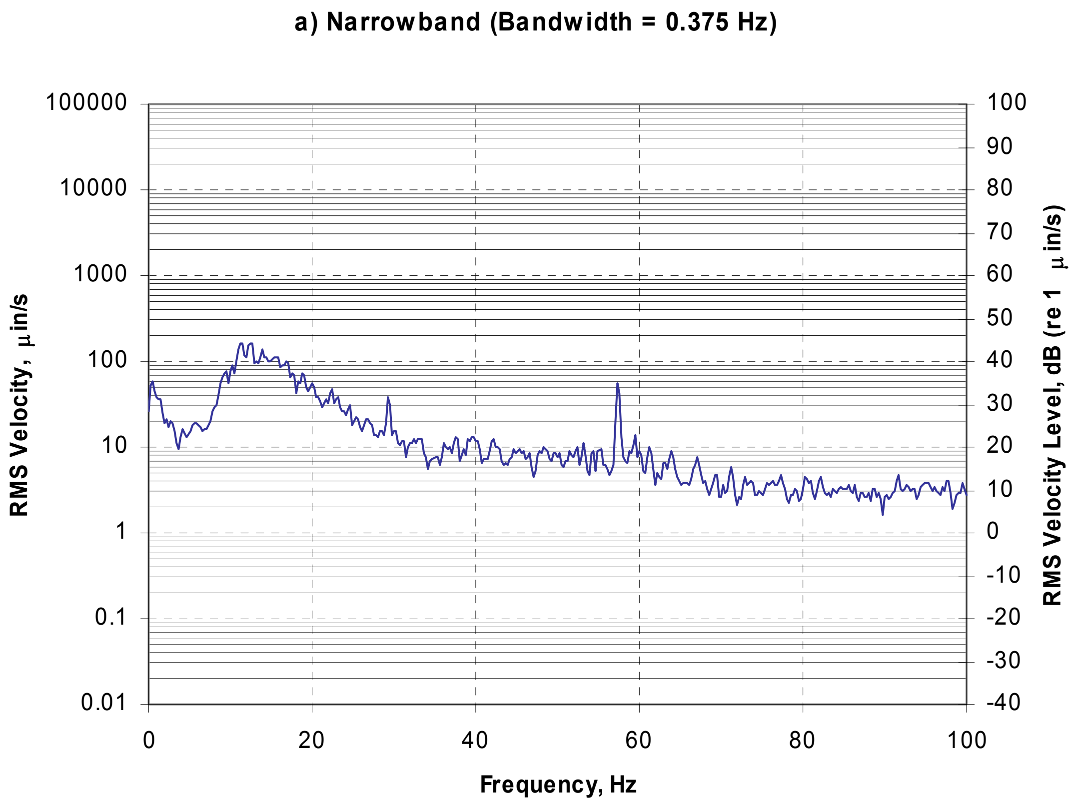


Figure B25: UCSB CNSI Site Study - 10/17/2002
Location 7, Vertical, Linear Average



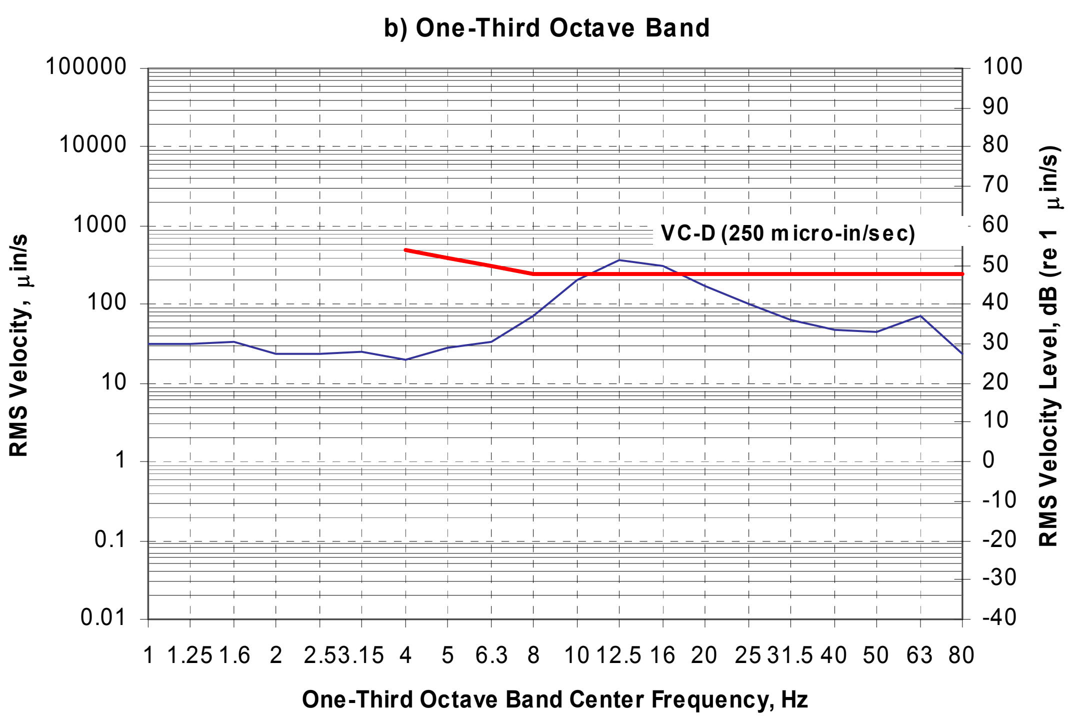
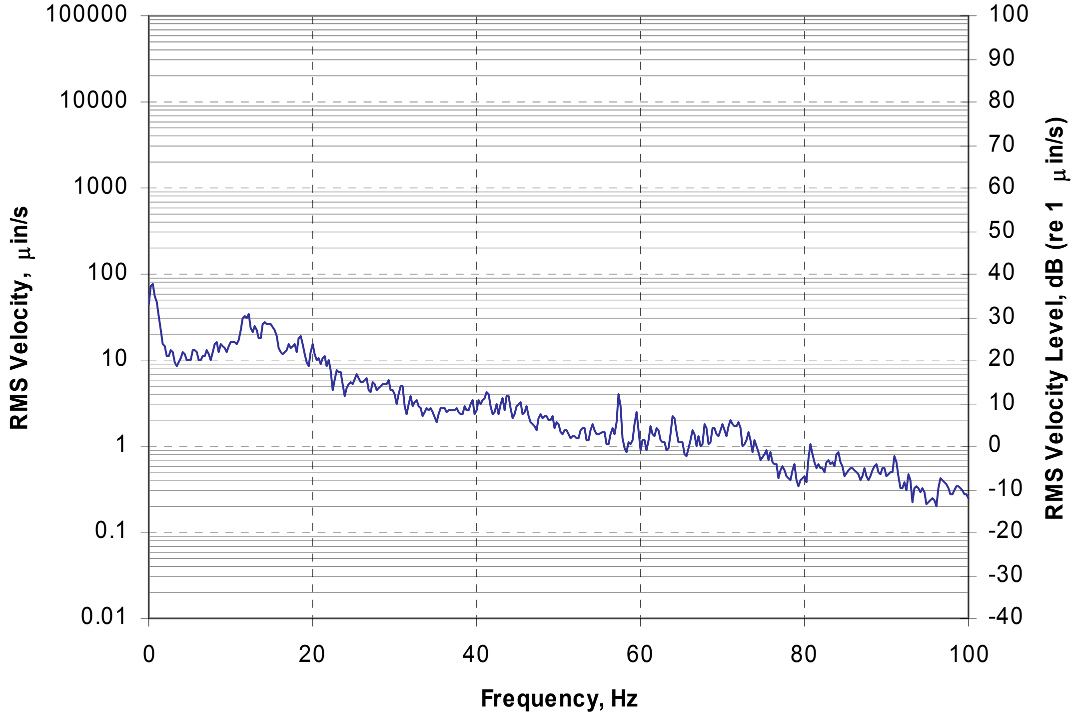


Figure B26: UCSB CNSI Site Study - 10/17/2002
Location 7, North-South, Linear Average

a) Narrowband (Bandwidth = 0.375 Hz)



b) One-Third Octave Band

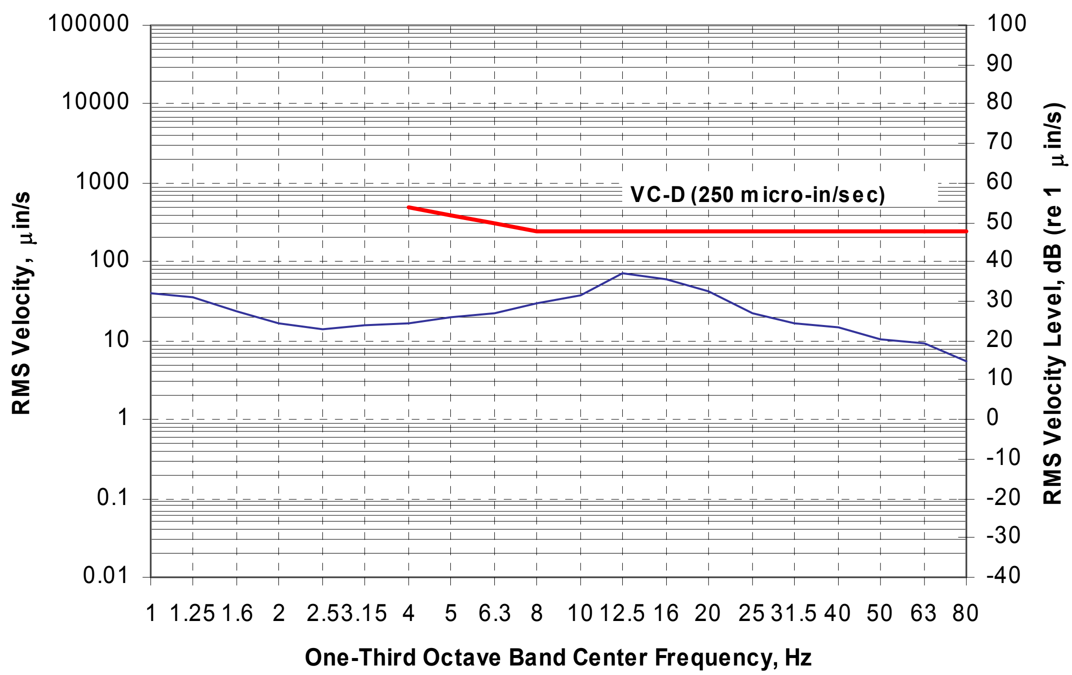
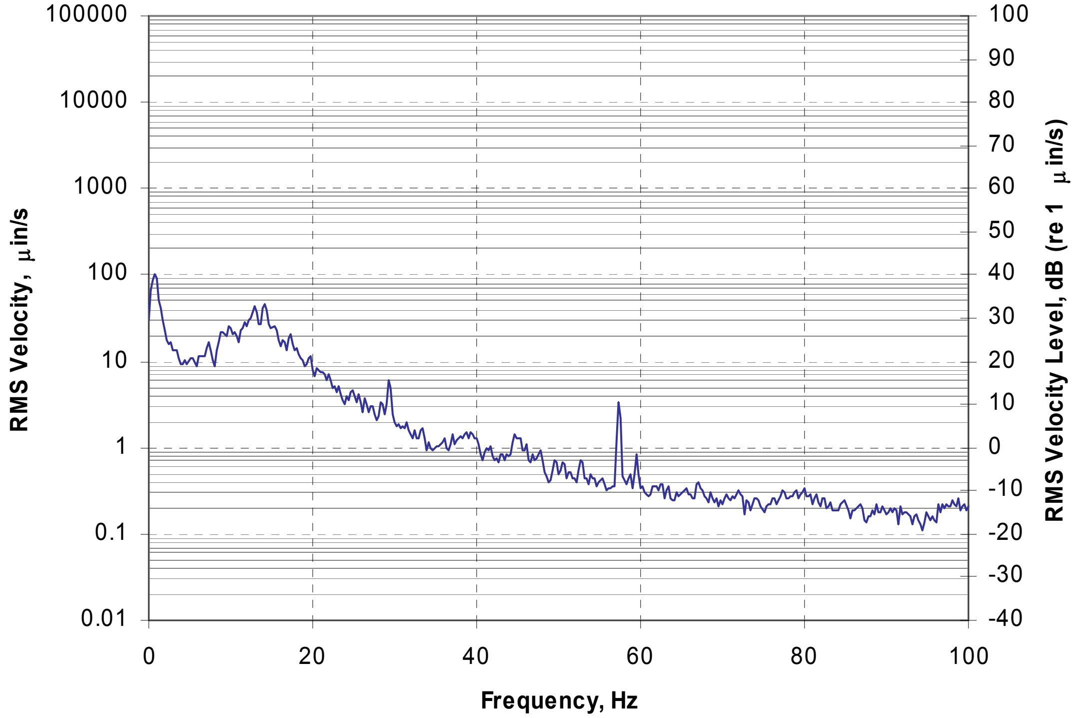


Figure B27: UCSB CNSI Site Study - 10/17/2002
Location 7, East-West, Linear Average

a) Narrowband (Bandwidth = 0.375 Hz)



b) One-Third Octave Band

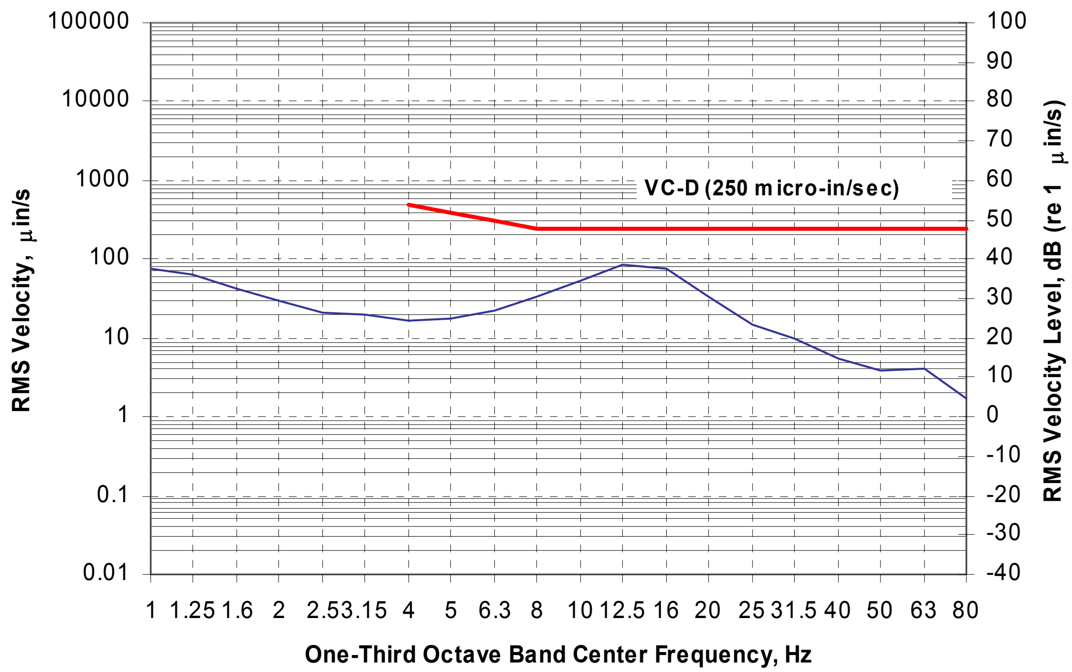
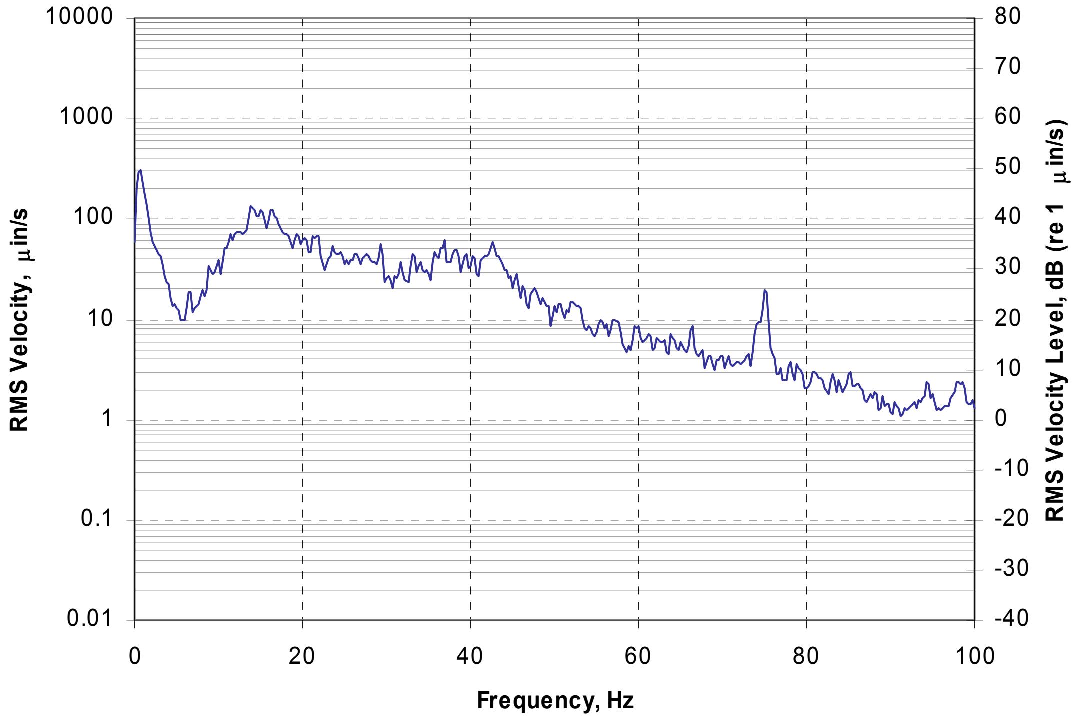


Figure B28: UCSB CNSI Site Study - 10/17/2002
Location 8, Vertical, Linear Average

a) Narrowband (Bandwidth = 0.375 Hz)



b) One-Third Octave Band

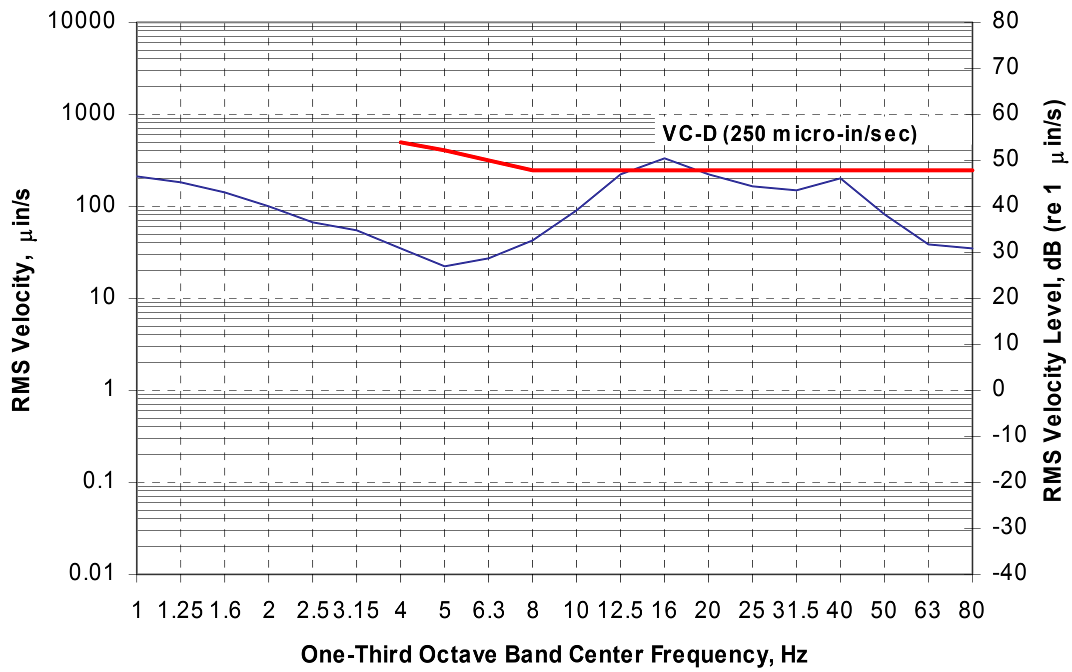
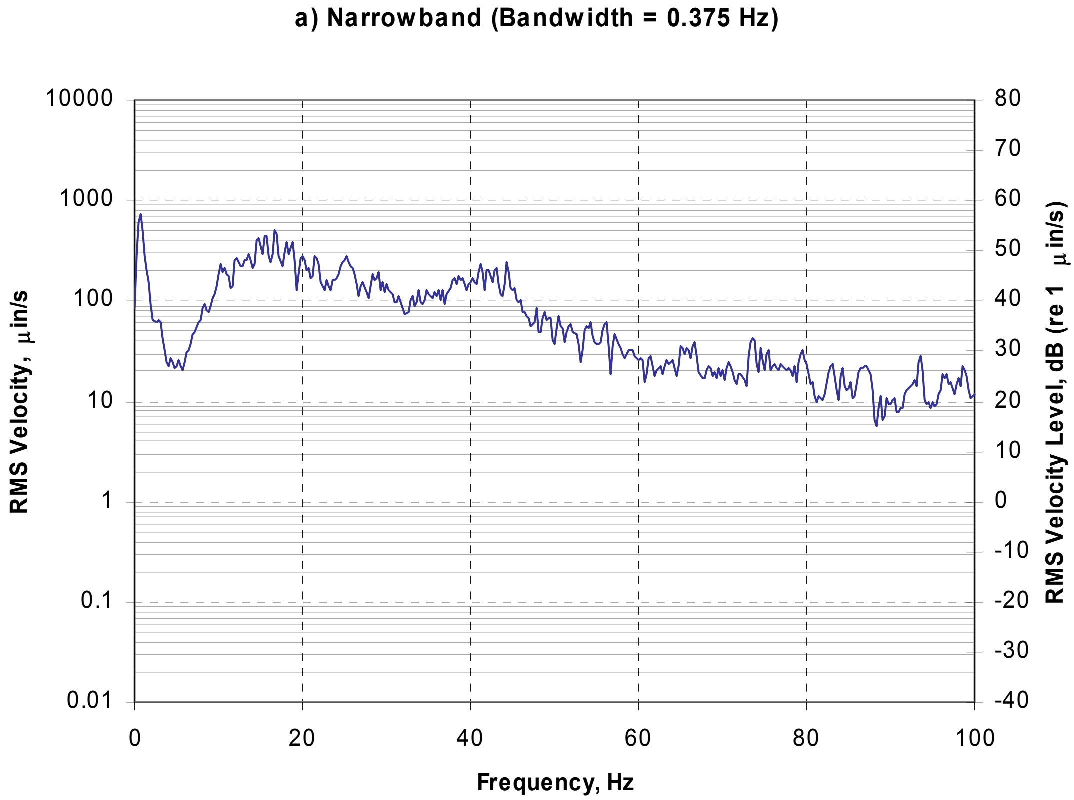


Figure B29: UCSB CNSI Site Study - 10/17/2002
Location 8, Vertical, Peak Hold



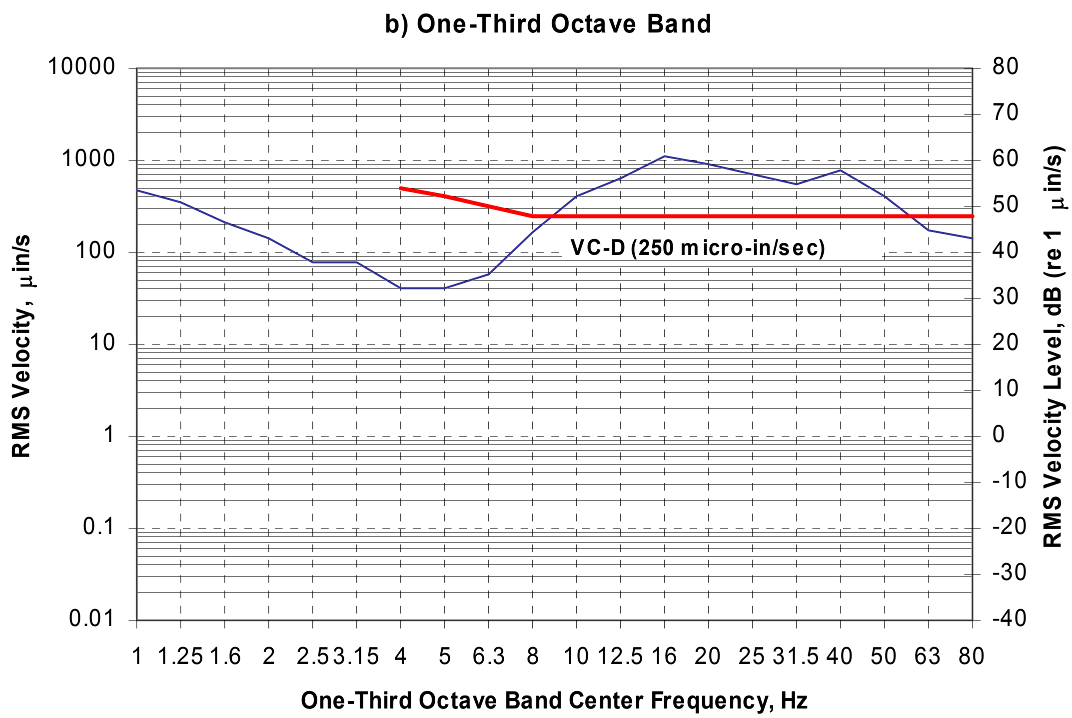
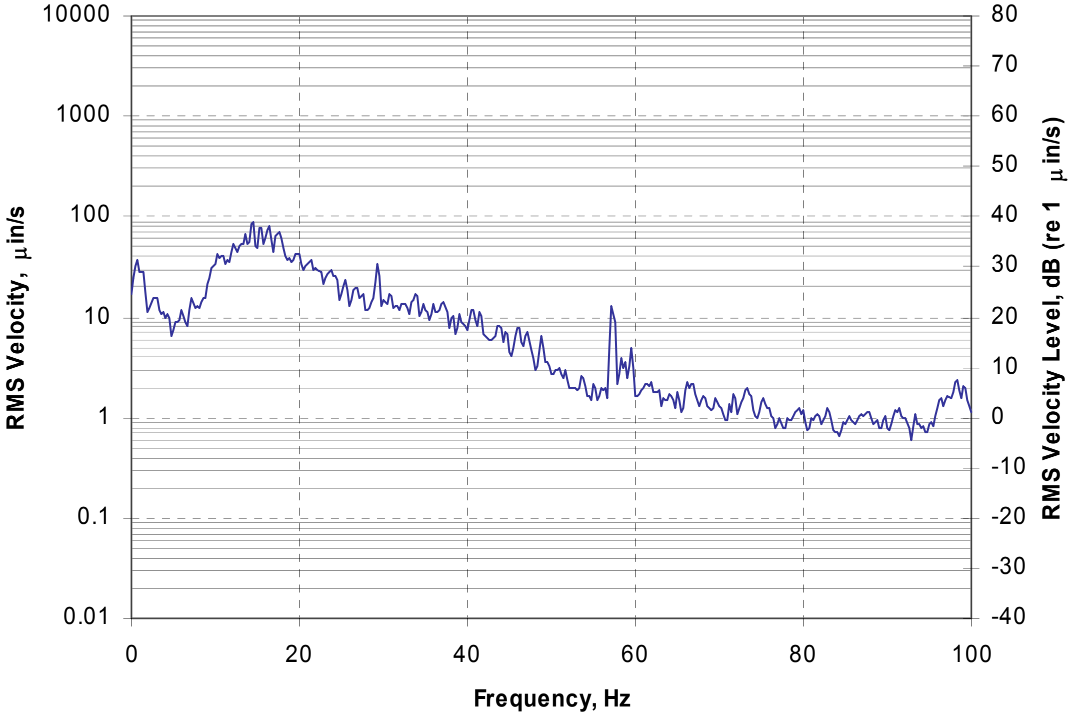


Figure B30: UCSB CNSI Site Study - 10/17/2002
Location 9, Vertical, Linear Average

a) Narrowband (Bandwidth = 0.375 Hz)



b) One-Third Octave Band

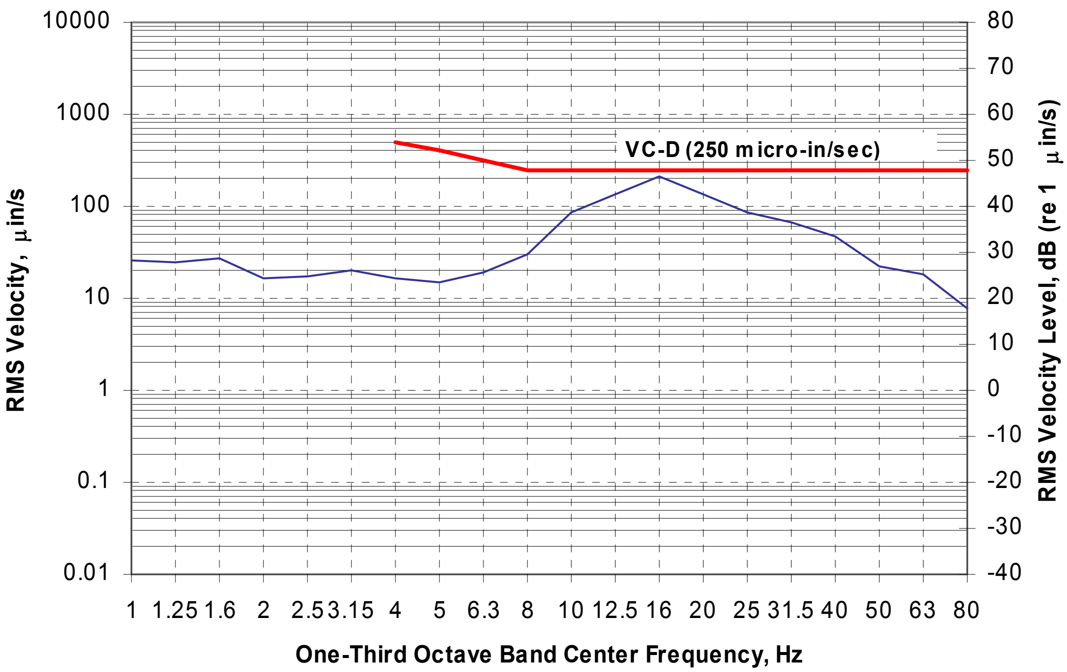
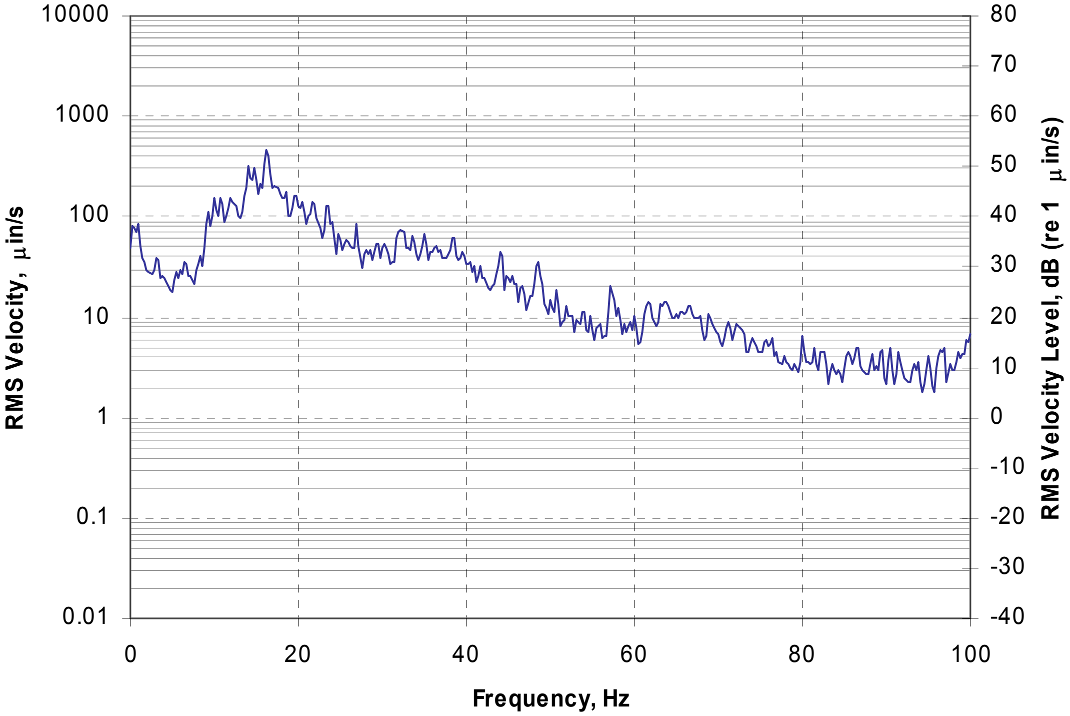


Figure B31: UCSB CNSI Site Study - 10/17/2002
Location 9, Vertical, Peak Hold

a) Narrowband (Bandwidth = 0.375 Hz)



b) One-Third Octave Band

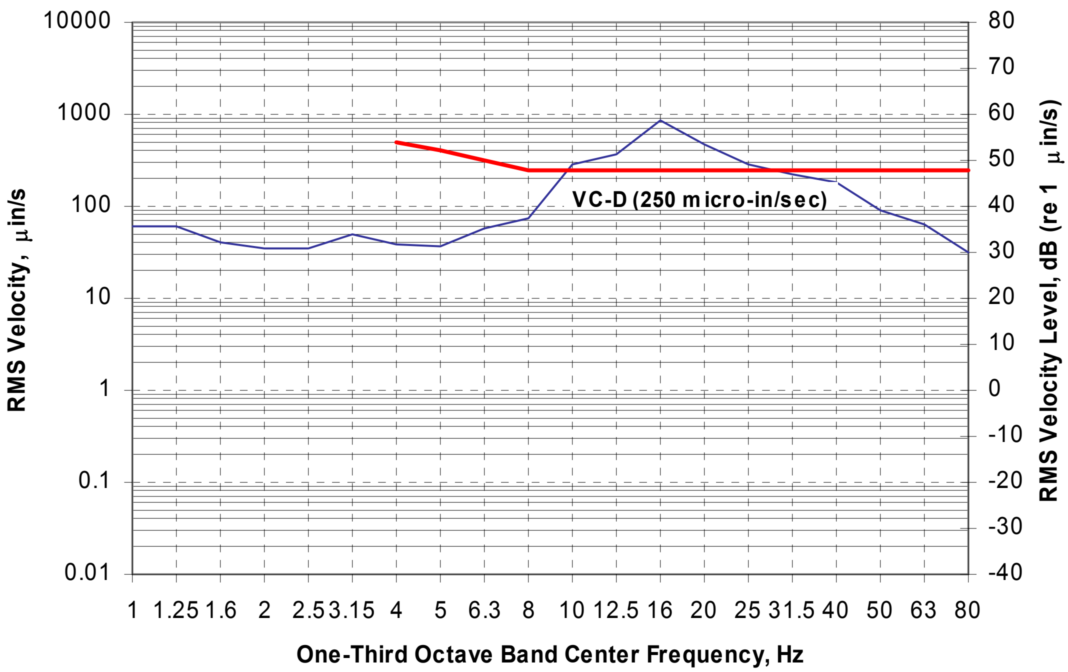


Figure B32: UCSB CNSI Site Study - 10/17/2002
Location 10, Vertical, Linear Average

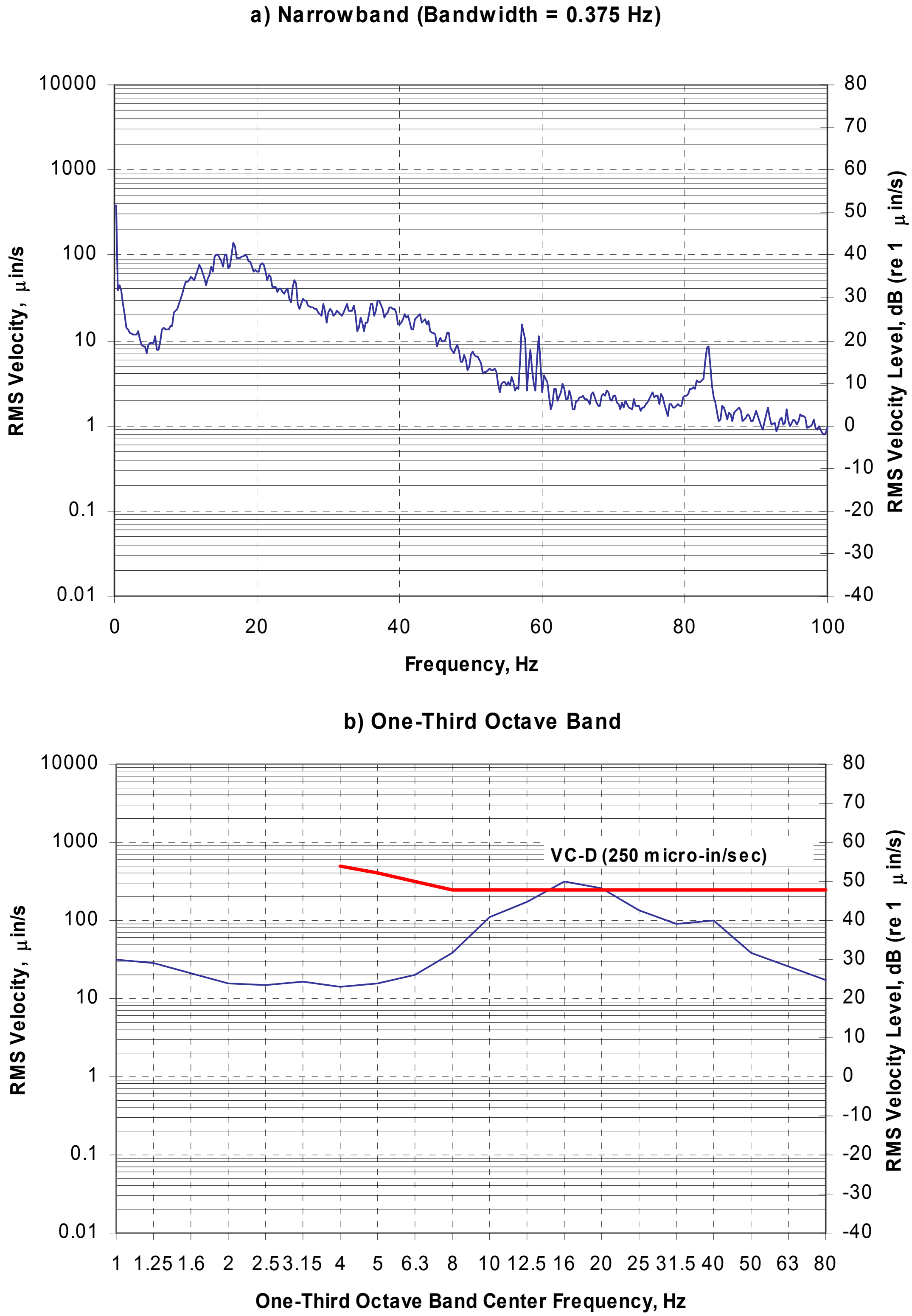
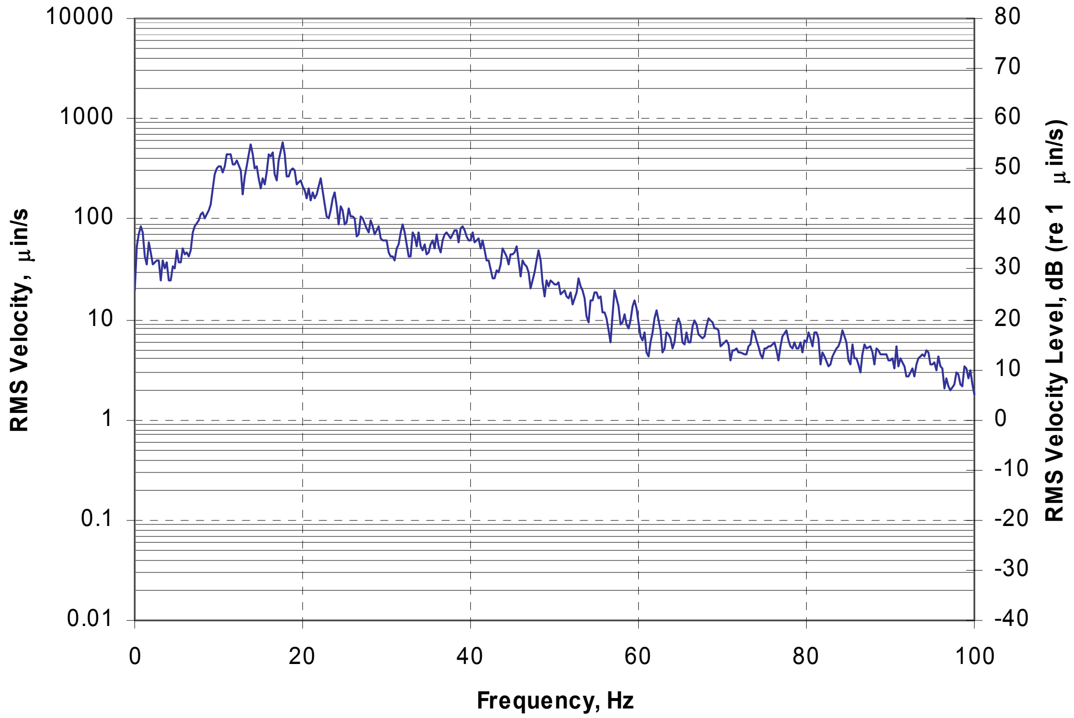


Figure B33: UCSB CNSI Site Study - 10/17/2002
Location 10, Vertical, Peak Hold

a) Narrowband (Bandwidth = 0.375 Hz)



b) One-Third Octave Band

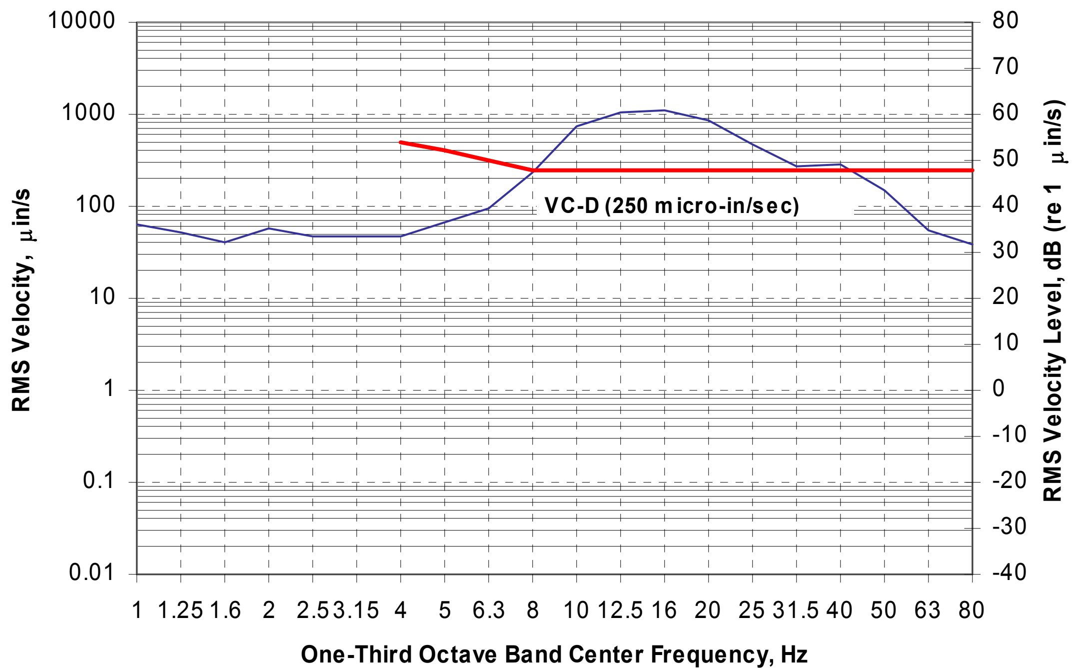
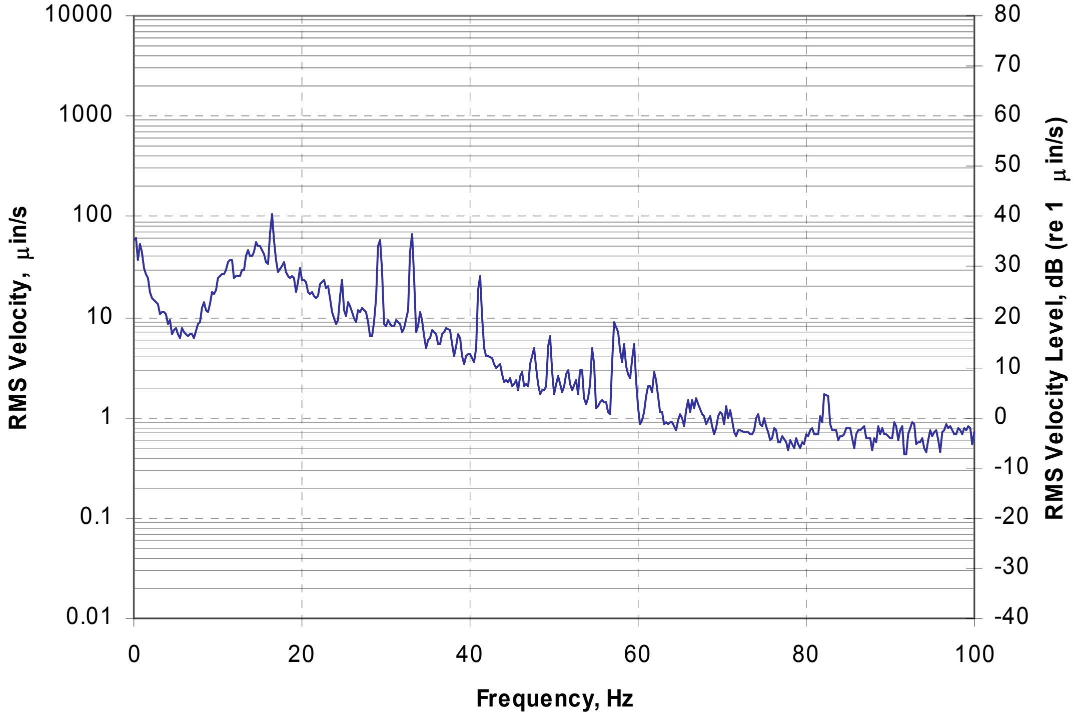


Figure B34: UCSB CNSI Site Study - 10/17/2002
Location 11, Vertical, Linear Average

a) Narrowband (Bandwidth = 0.375 Hz)



b) One-Third Octave Band

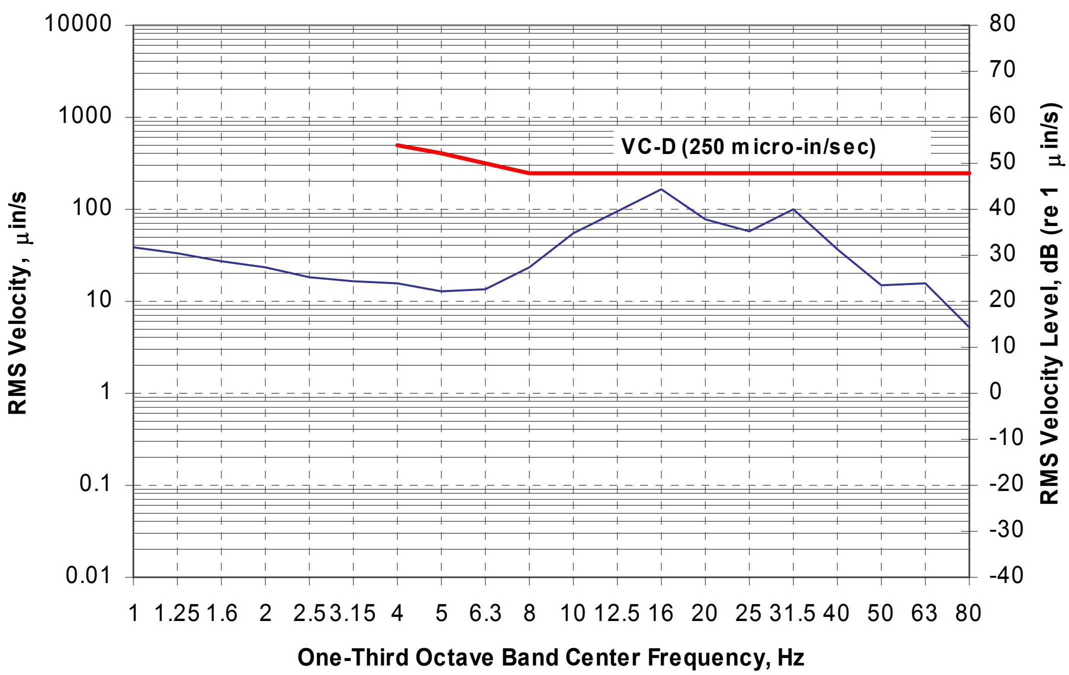
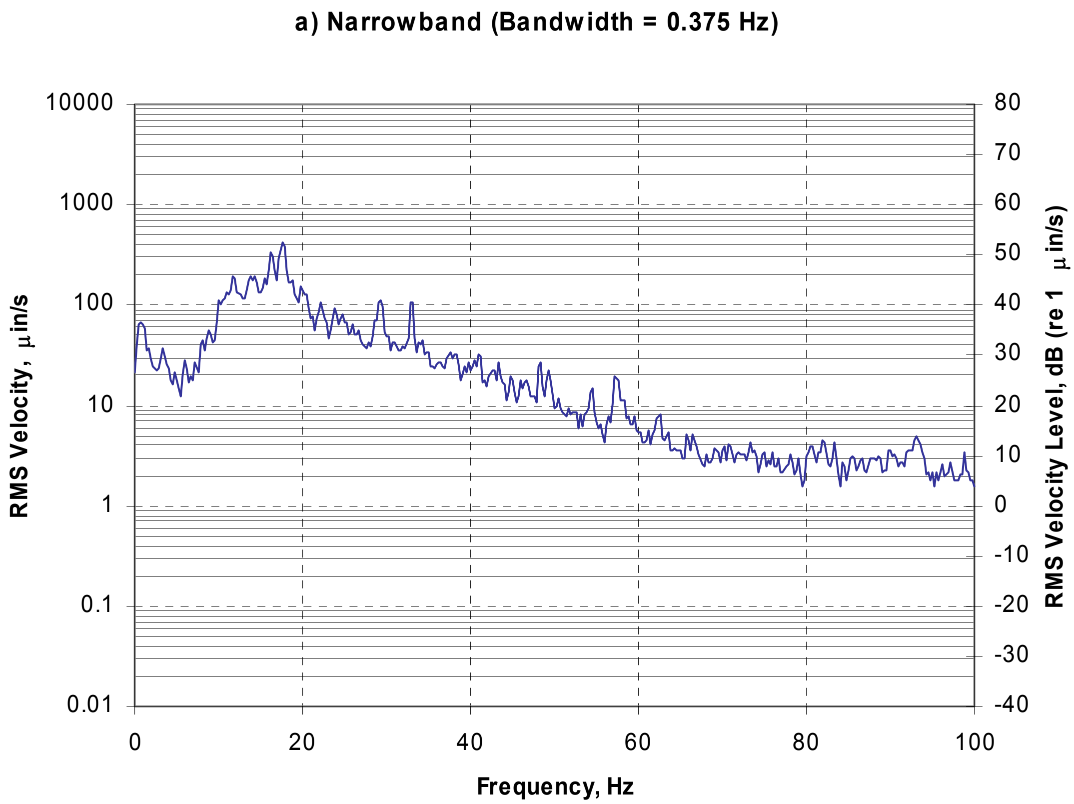


Figure B35: UCSB CNSI Site Study - 10/17/2002
Location 11, Vertical, Peak Hold



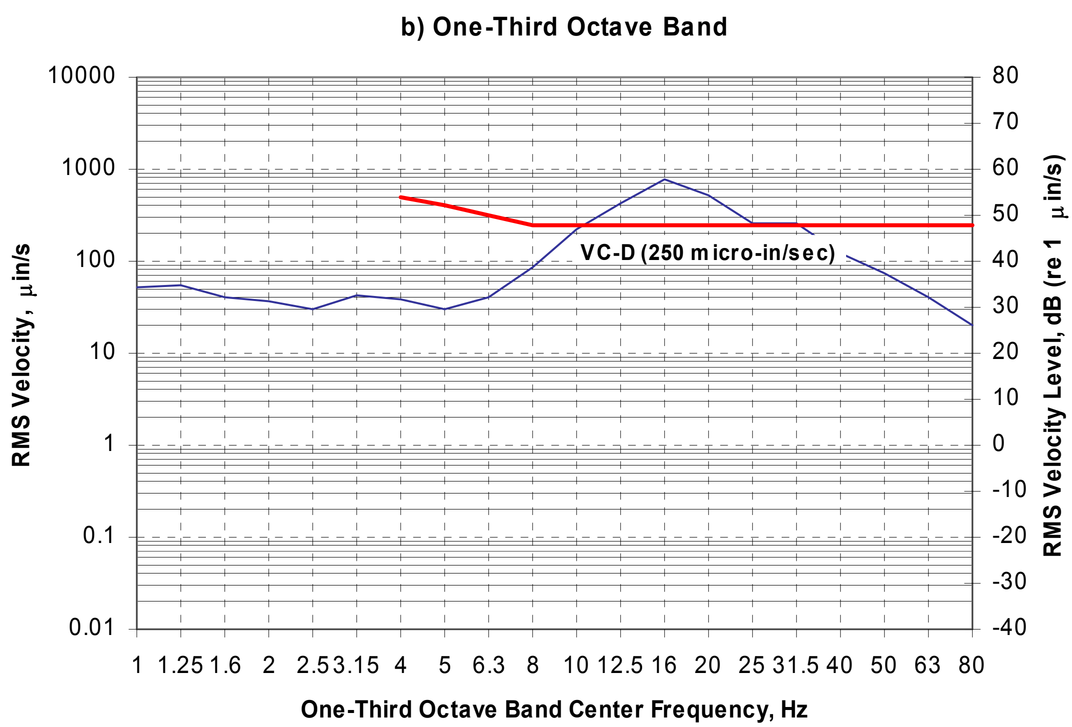


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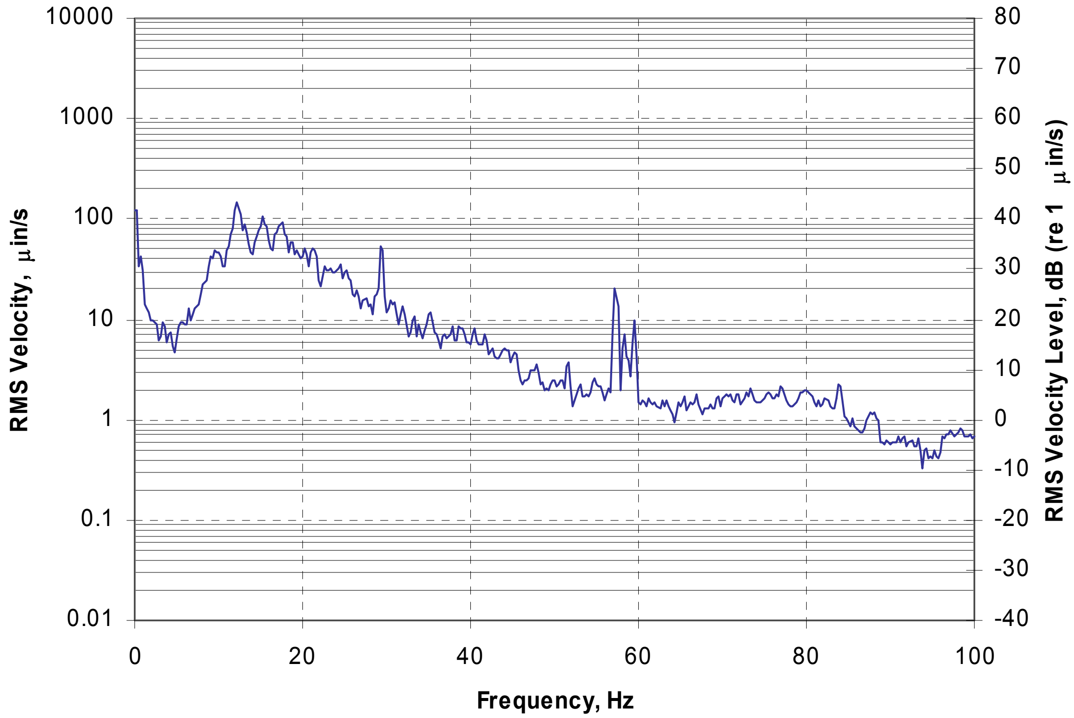
Figure B36: UCSB CNSI Site Study - 10/17/2002
Location 12, Vertical, Linear Average

a) Narrowband (Bandwidth = 0.375 Hz)



b) One-Third Octave Band

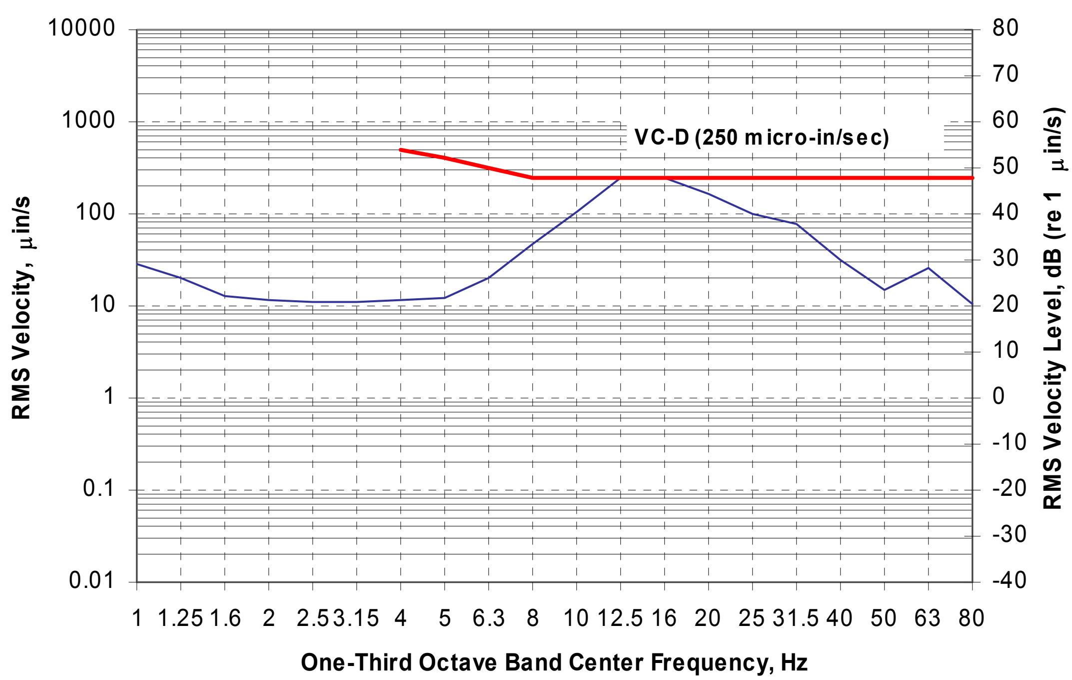
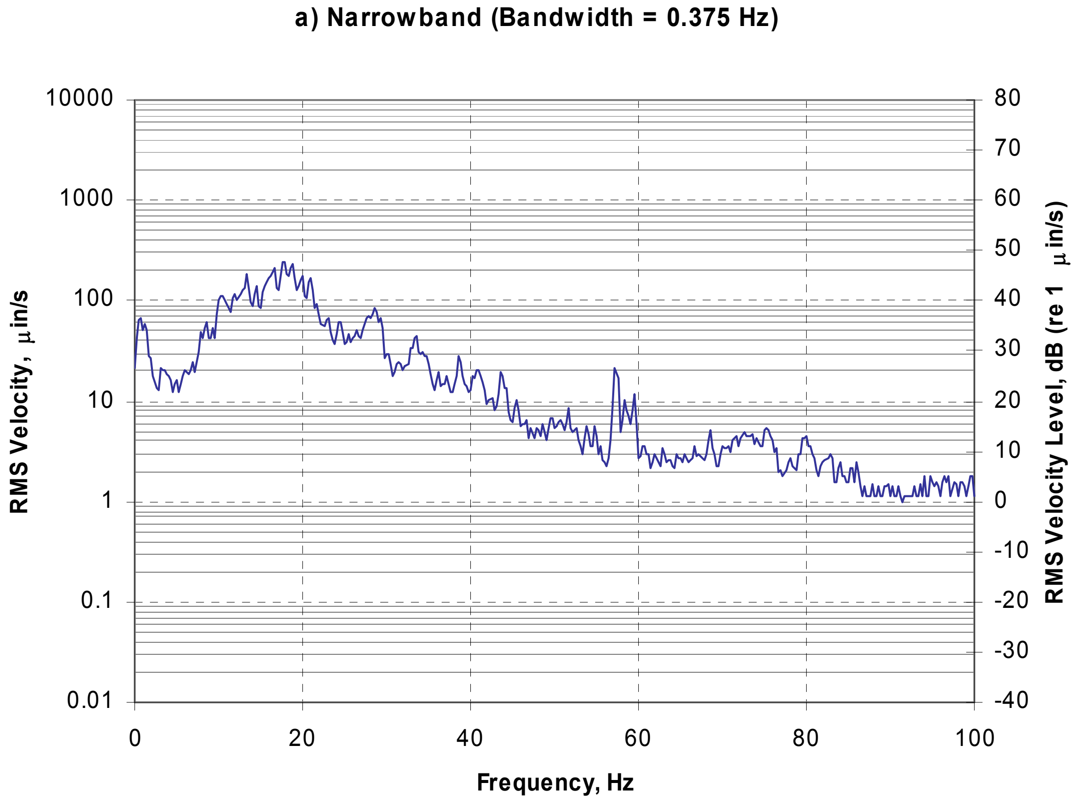


Figure B37: UCSB CNSI Site Study - 10/17/2002
Location 12, Vertical, Peak Hold



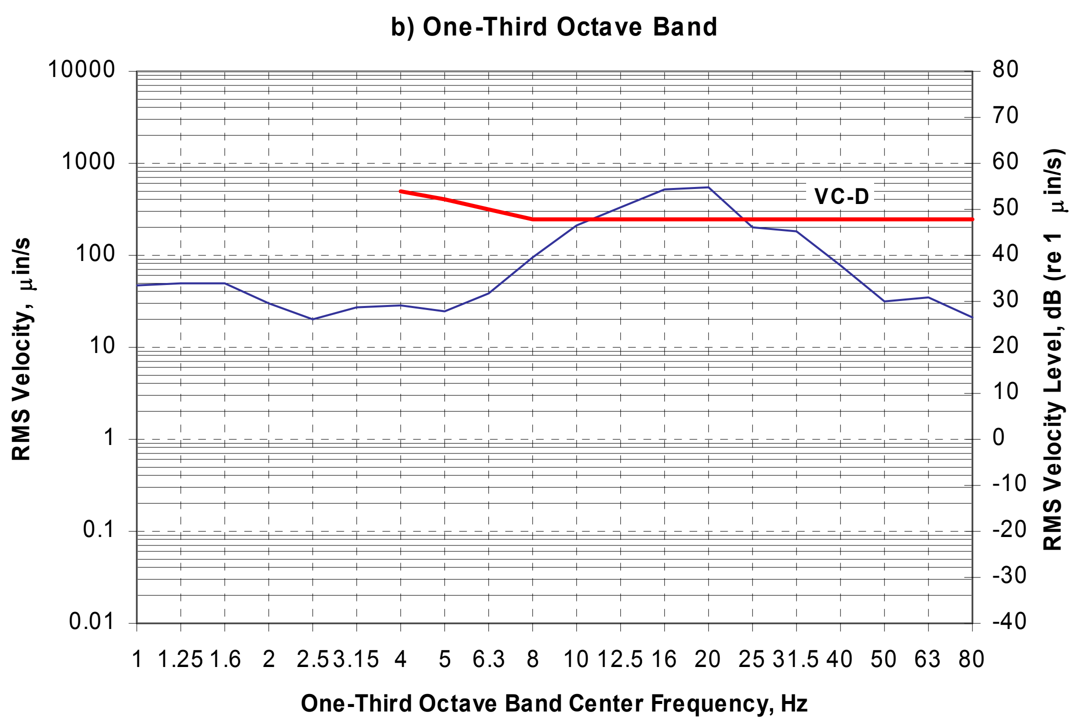
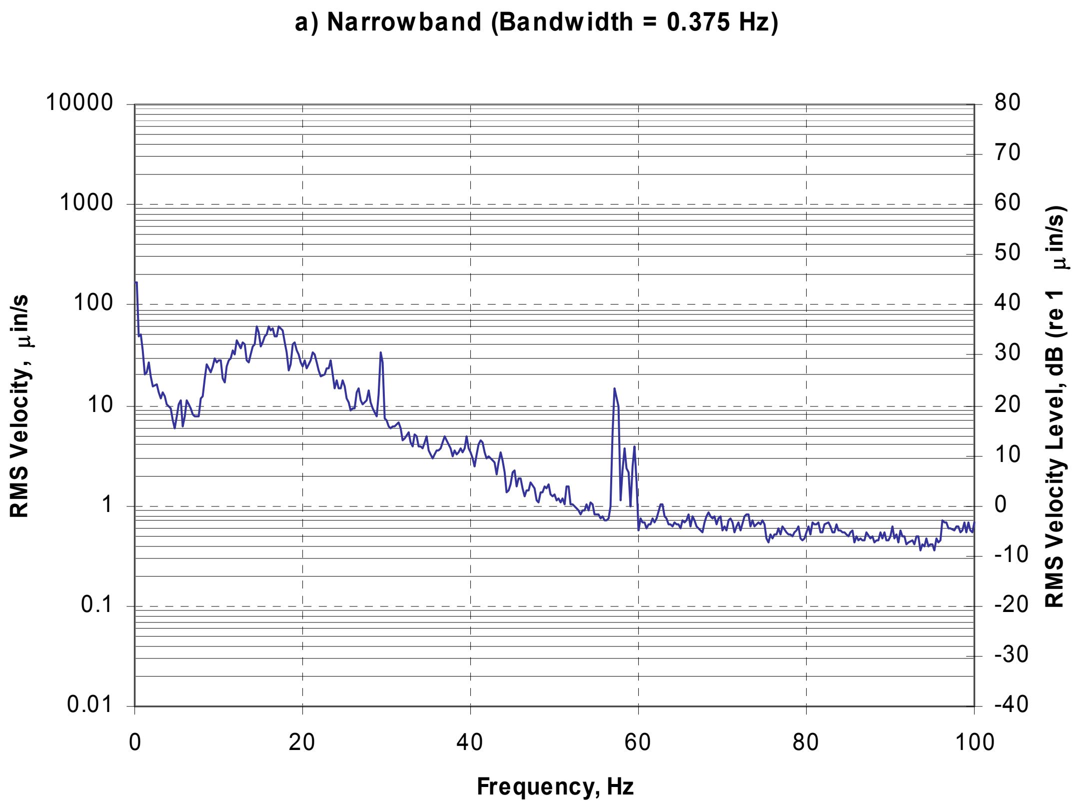


Figure B38: UCSB CNSI Site Study - 10/17/2002
Location 13, Vertical, Linear Average



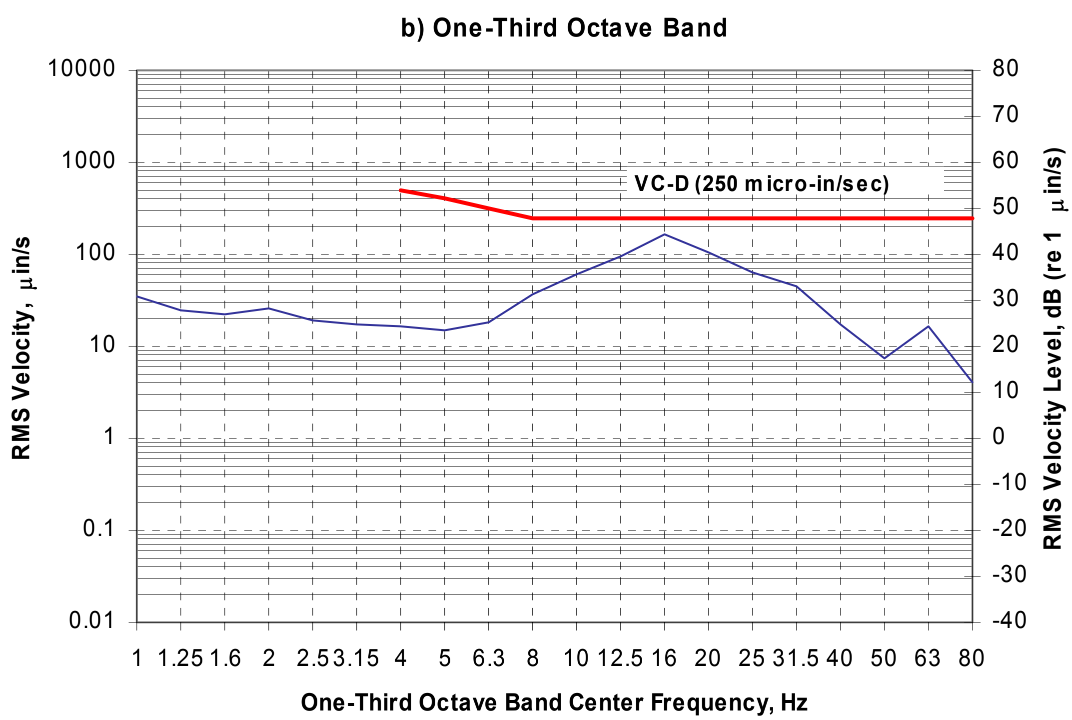
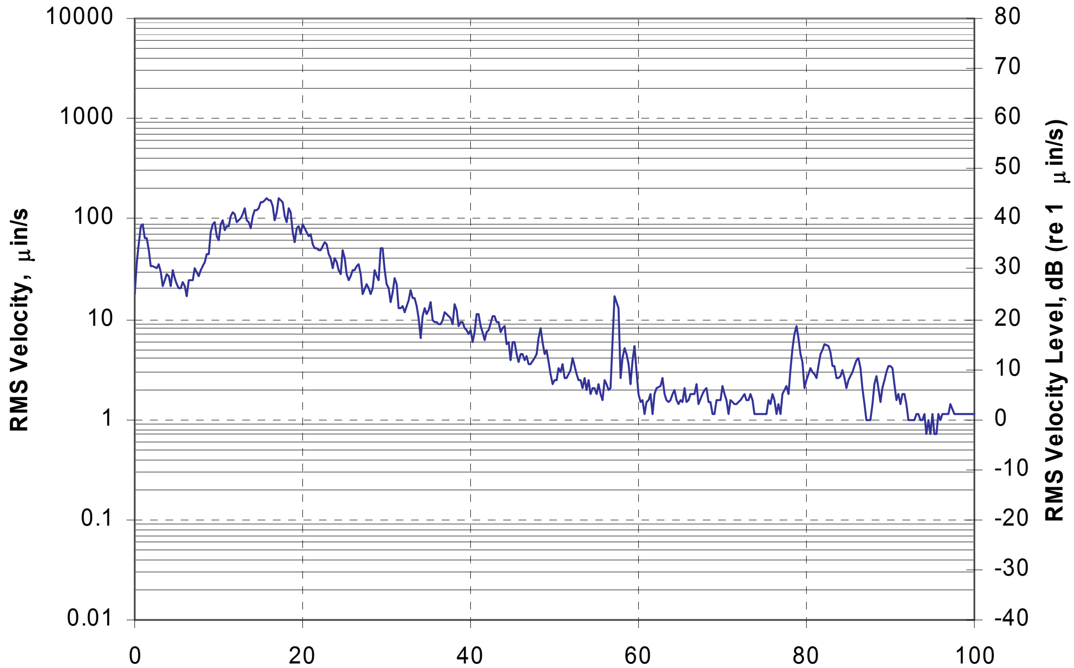
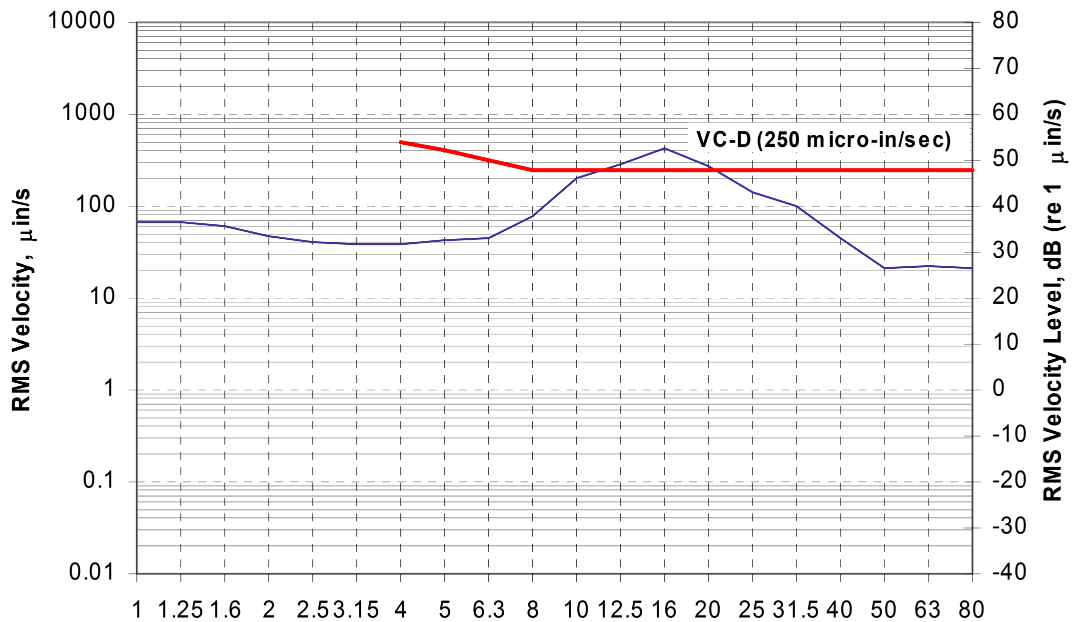


Figure B39: UCSB CNSI Site Study - 10/17/2002
Location 13, Vertical, Peak Hold

a) Narrowband (Bandwidth = 0.375 Hz)



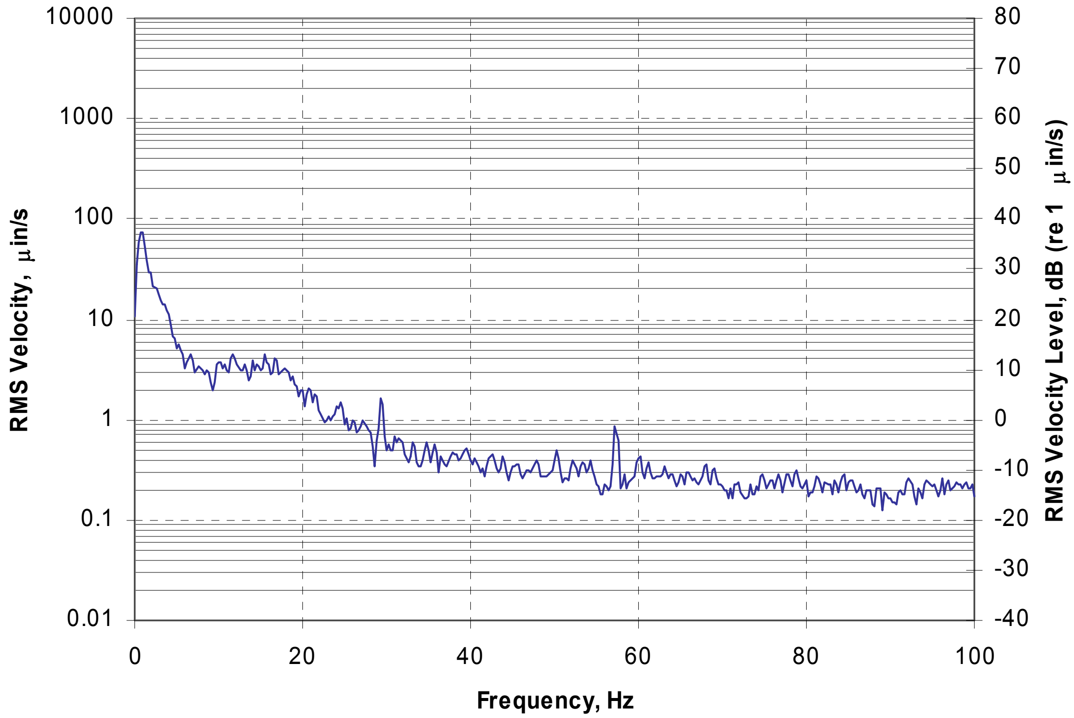
b) One-Third Octave Band



One-Third Octave Band Center Frequency, Hz

Figure B40: UCSB CNSI Site Study - 10/17/2002
Location 14, Vertical, Linear Average

a) Narrowband (Bandwidth = 0.375 Hz)



b) One-Third Octave Band

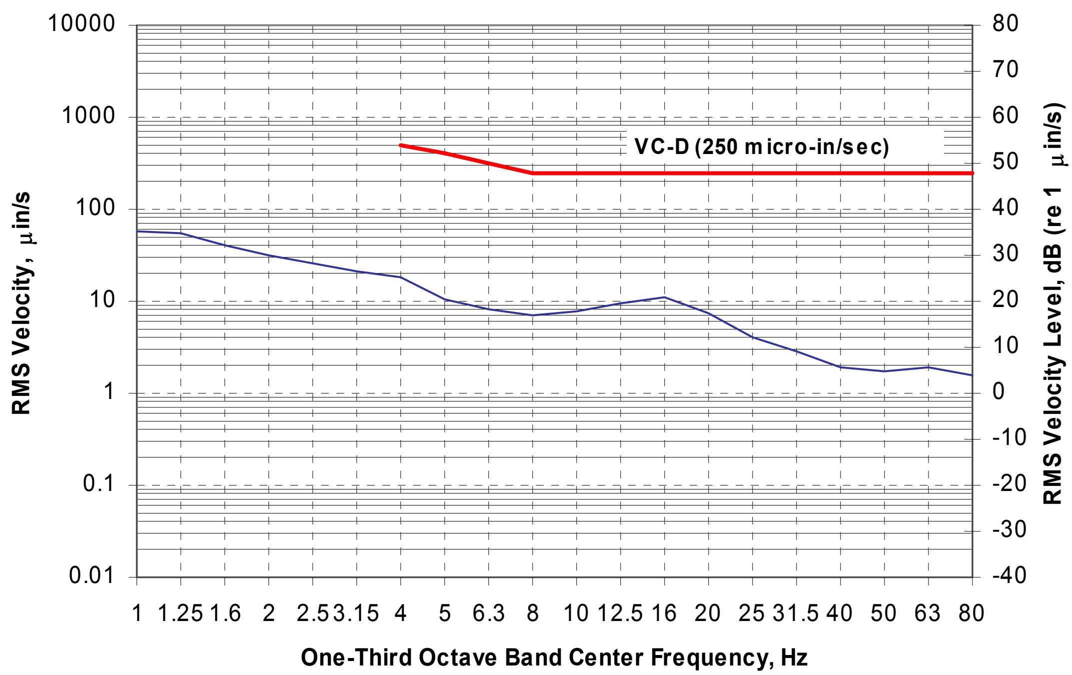
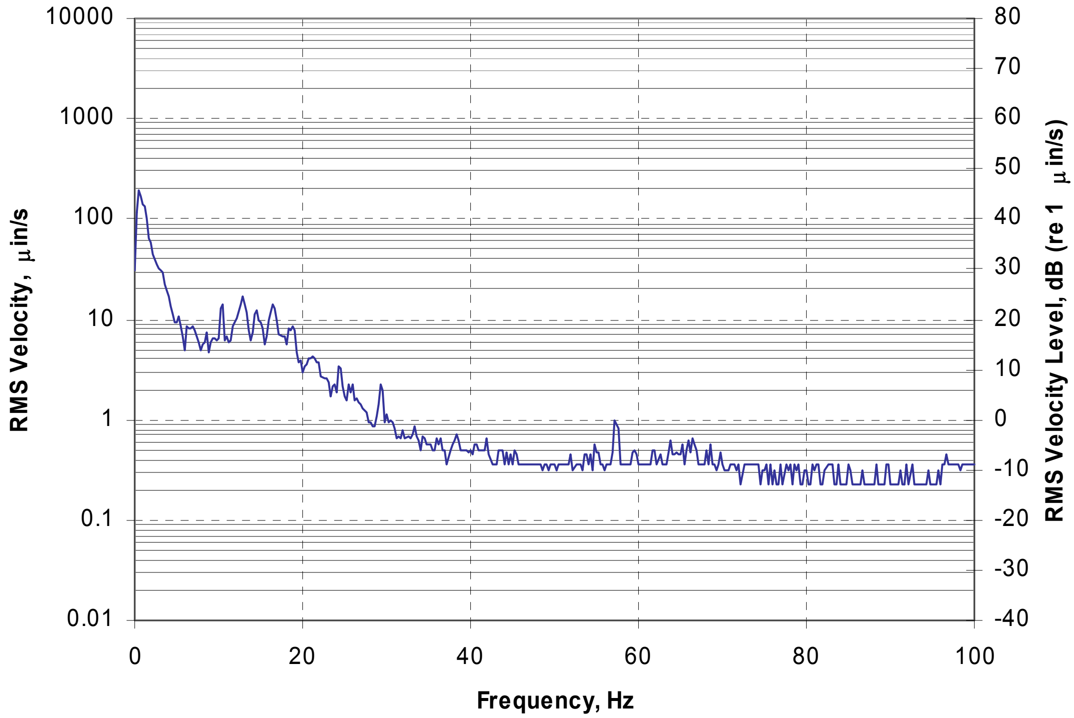


Figure B41: UCSB CNSI Site Study - 10/17/2002
Location 14, Vertical, Peak Hold

a) Narrowband (Bandwidth = 0.375 Hz)



b) One-Third Octave Band

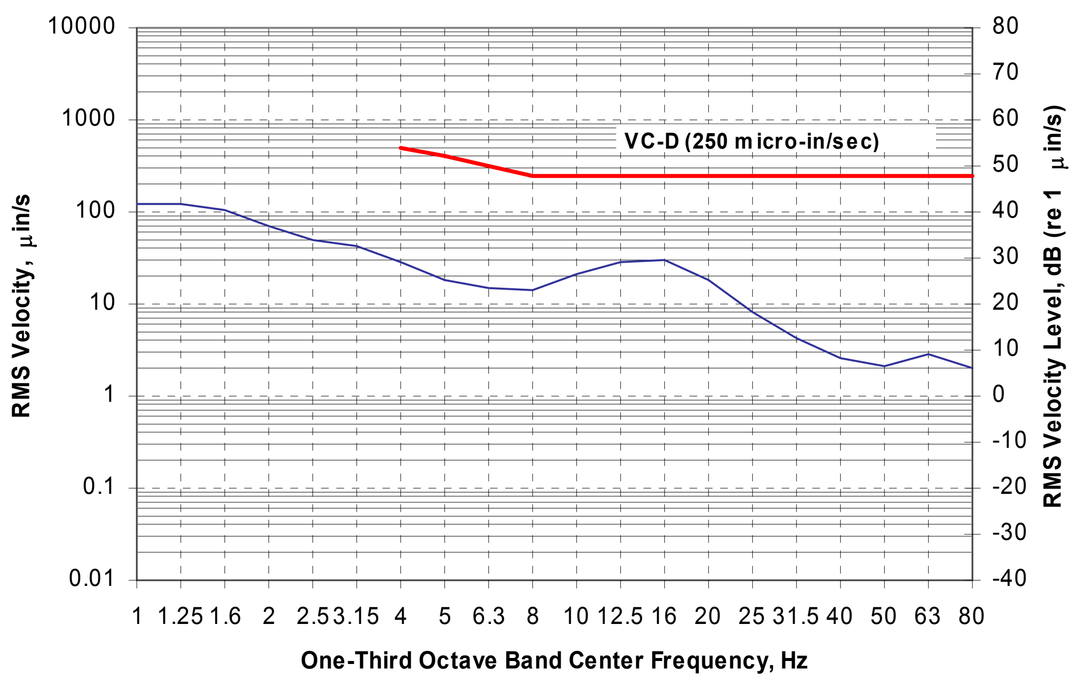
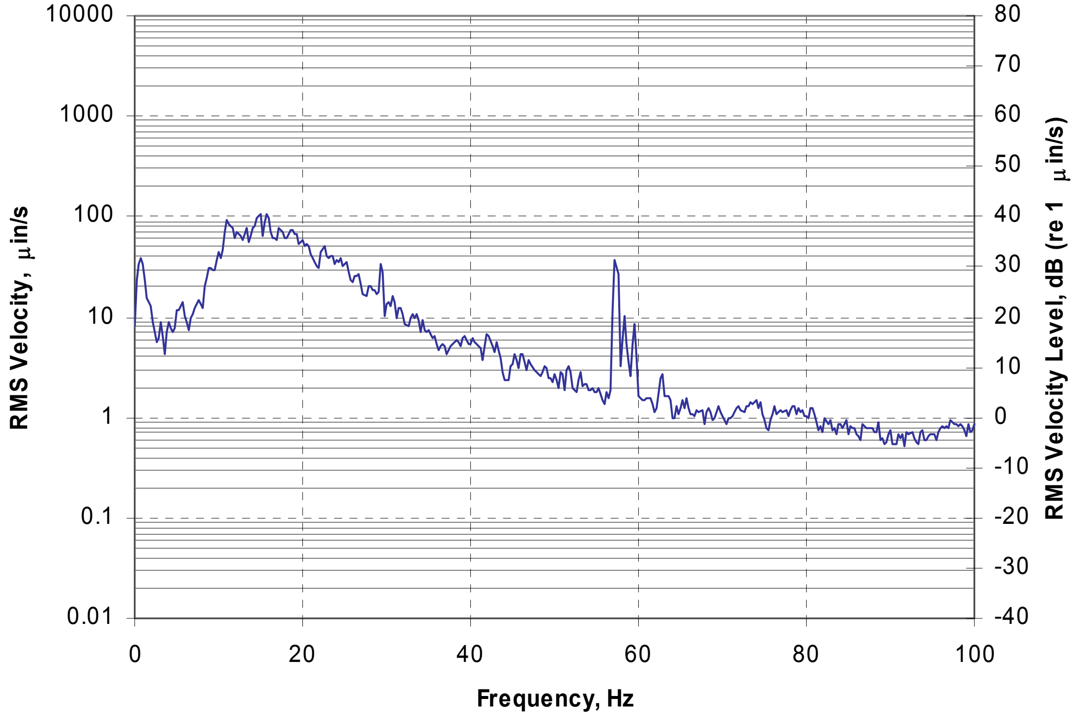


Figure B42: UCSB CNSI Site Study - 10/17/2002
Location 15, Vertical, Linear Average

a) Narrowband (Bandwidth = 0.375 Hz)



b) One-Third Octave Band

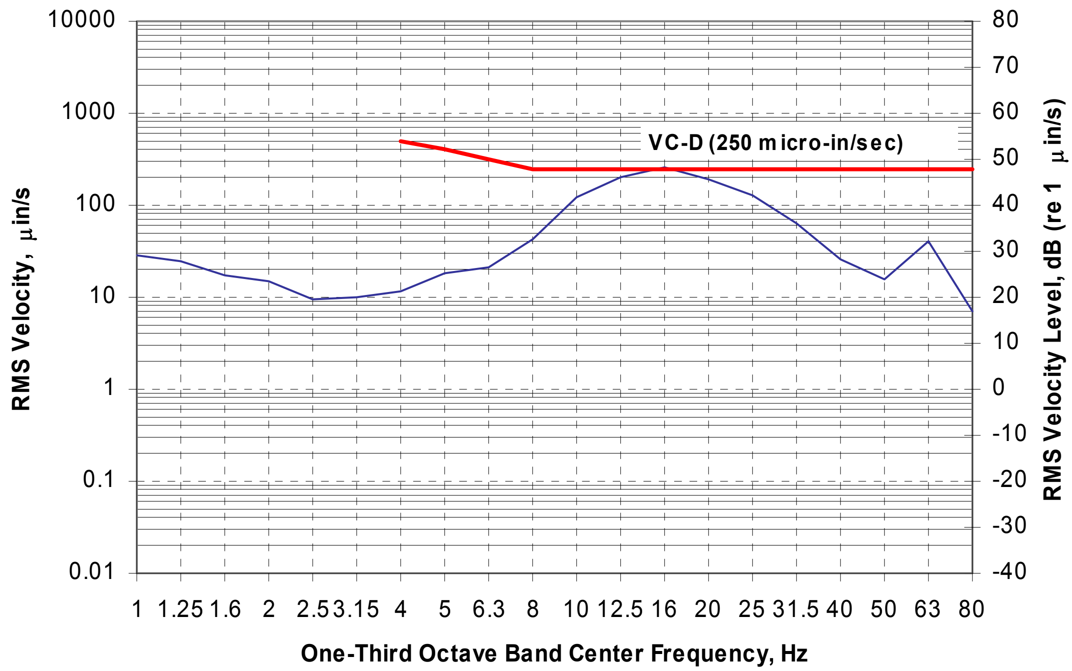
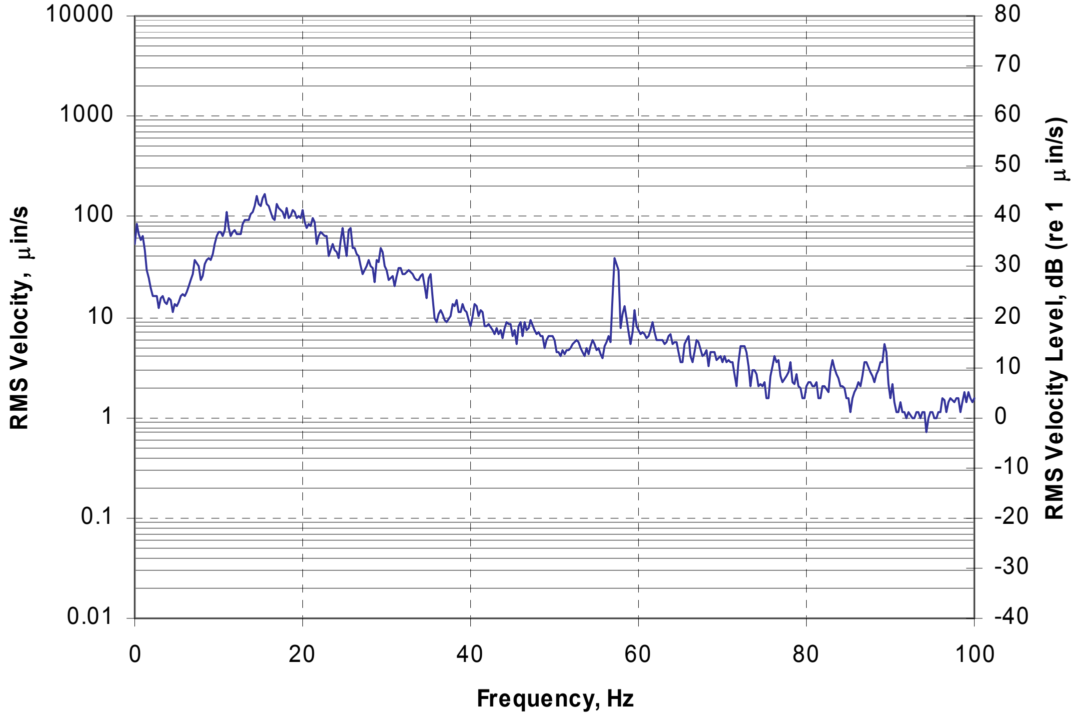


Figure B43: UCSB CNSI Site Study - 10/17/2002
Location 15, Vertical, Peak Hold

a) Narrowband (Bandwidth = 0.375 Hz)



b) One-Third Octave Band

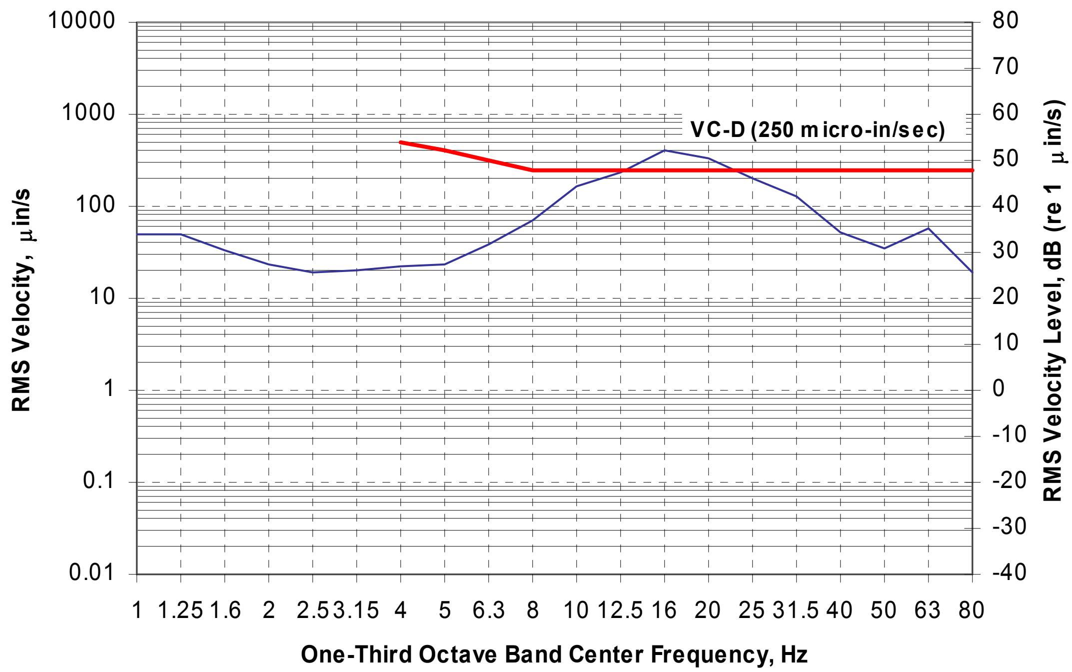
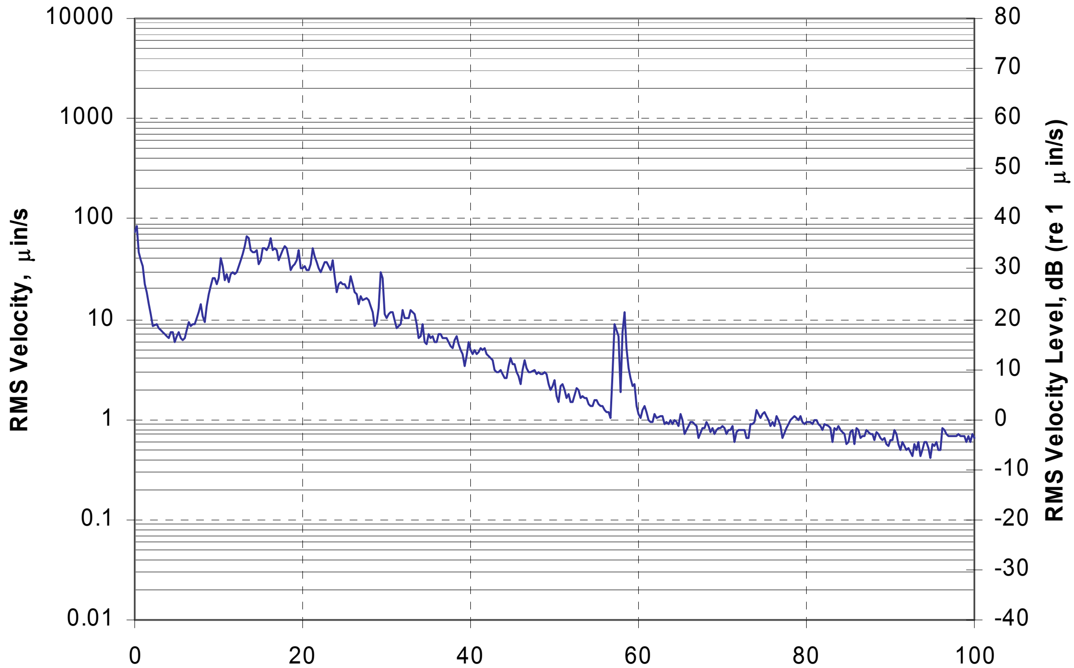


Figure B44: UCSB CNSI Site Study - 10/17/2002
Location 16, Vertical, Linear Average

a) Narrowband (Bandwidth = 0.375 Hz)



b) One-Third Octave Band

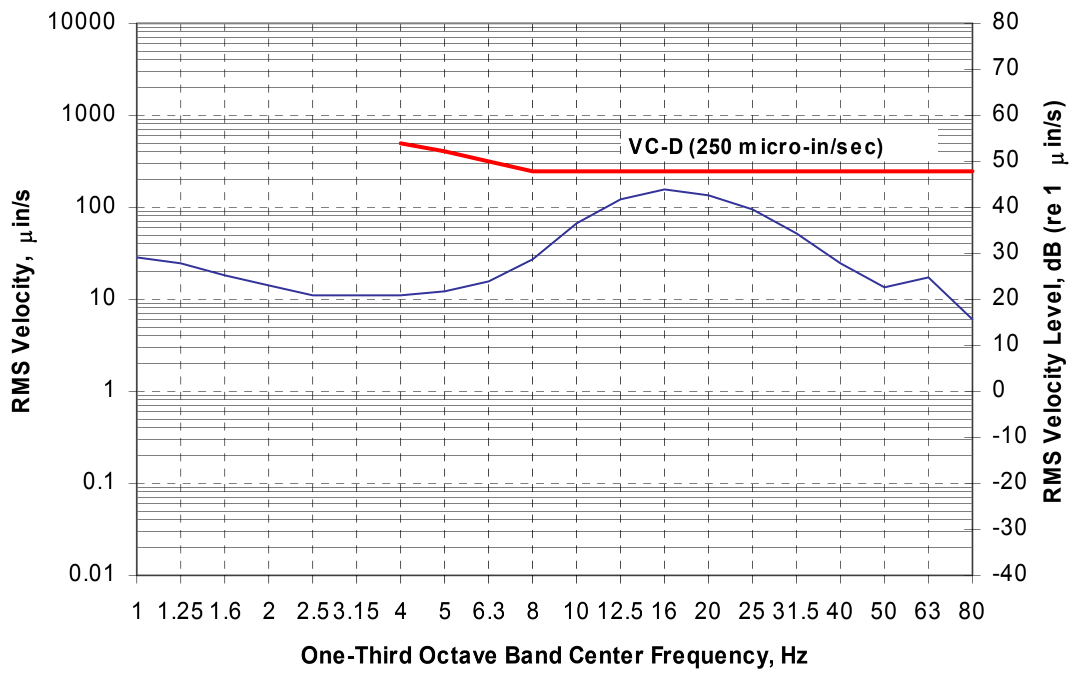
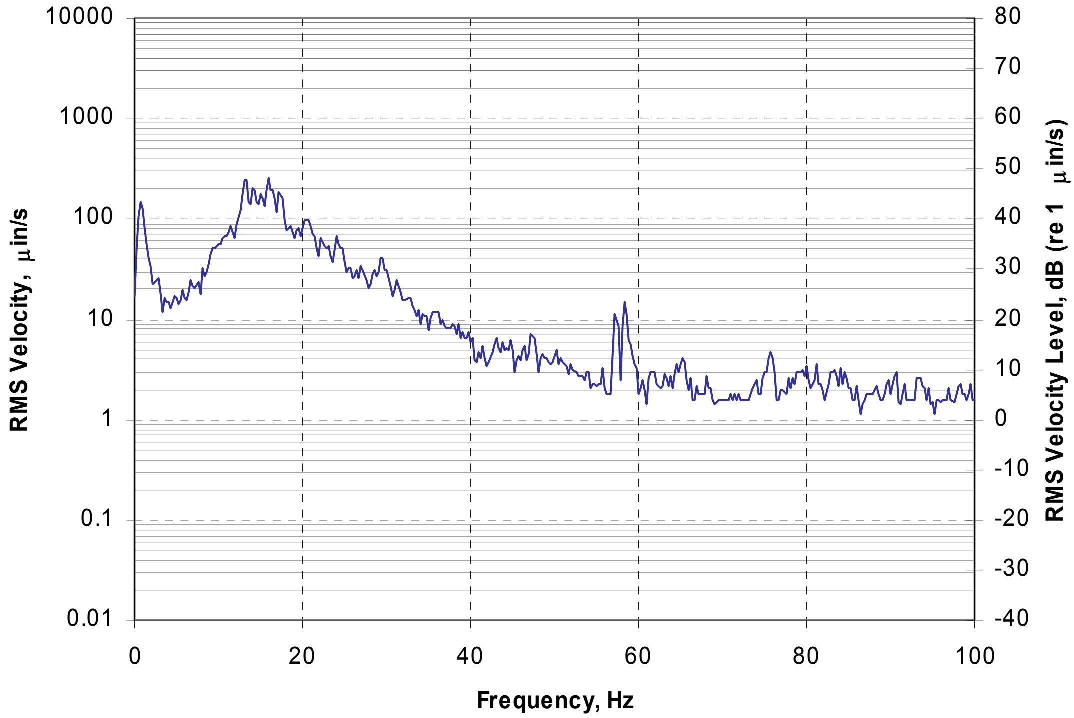


Figure B45: UCSB CNSI Site Study - 10/17/2002
Location 16, Vertical, Peak Hold

a) Narrowband (Bandwidth = 0.375 Hz)



b) One-Third Octave Band