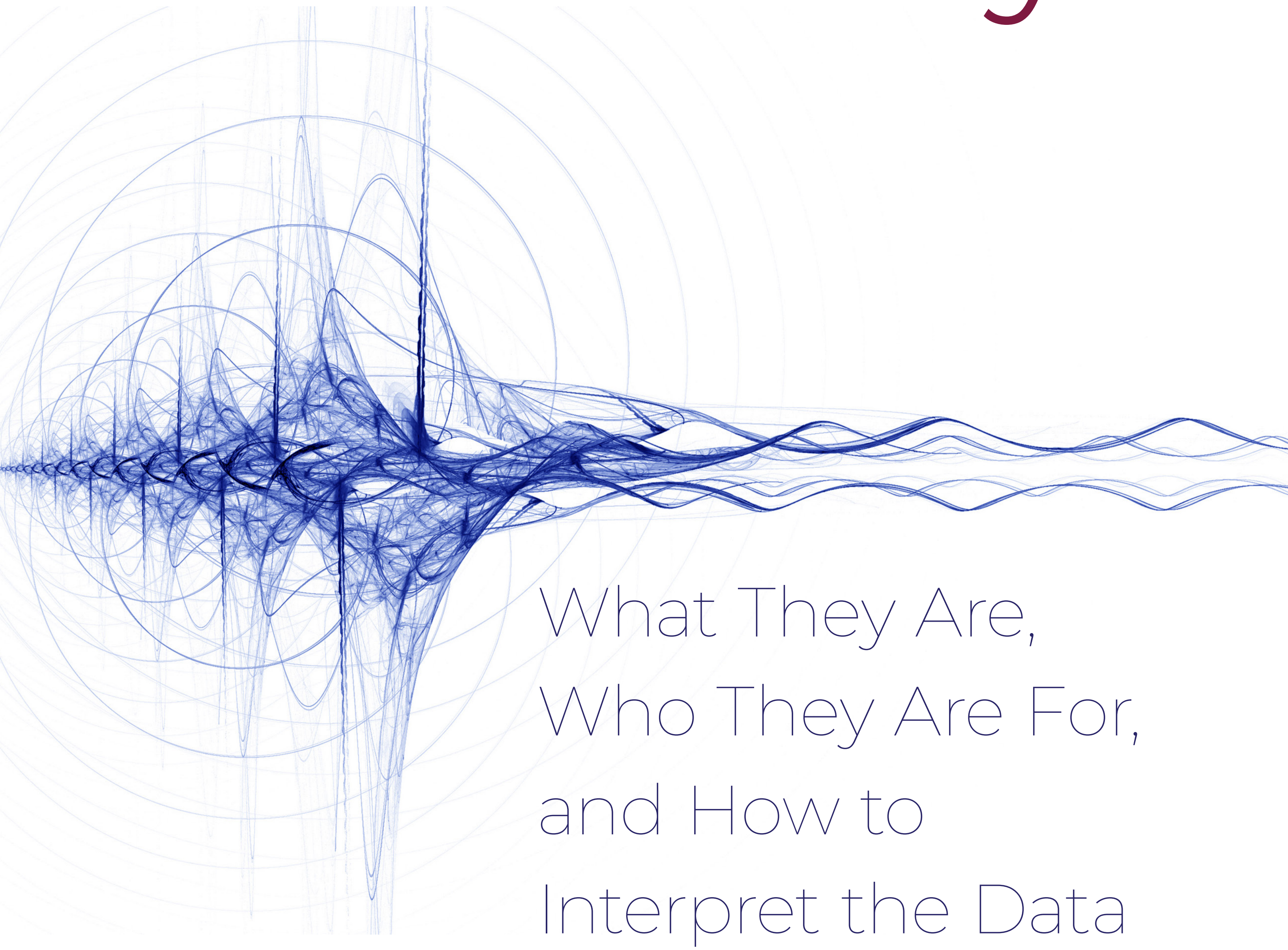
VEC

Site Surveys



What They Are, Who They Are For, and How to Interpret the Data

Mitigation for Precision Instruments

Site Surveys: What They Are and Who They Are For

When university labs or technology companies purchase electron microscopes, semiconductor manufacturing tools, or other high-end equipment, the manufacturers often require site surveys to ensure that their equipment will work to the highest level of performance. This equipment conducts image processing on the micro and nano scales and is vulnerable to the smallest traces of environmental disturbance including vibration, acoustic noise, magnetic fields, or minor variations in temperature.

When these disturbances are present in the local environment, it often can result in edge noise on an electron microscope image or an anomaly in production. Think of it like setting up a camera on a tripod near a speaker at rock and roll concert. When taking a picture with long exposure time, the noise from the speaker will cause the camera to shake, resulting in a blurry image. (Figure 1).

A site survey ensures that your equipment environment is free of such disturbances and can operate at the highest capacity. Thermo Fisher Scientific, Tescan, Zeiss, Nikon, JOEL, Bruker, ASML, Hitachi and many other equipment manufacturers require these surveys to ensure quality results for high-end equipment investments.

Many times, a customer may not fully understand what these surveys are or how to interpret them. A variety of stakeholders may find themselves needing to access and interpret the survey, including:

- OEM/Instrument Manufacturers
- Lab managers
- Facility managers
- Tool owners
- Architectural firms
- General contractors

A location may fail on one or more areas of the survey and stakeholders may not understand what actions are required next. This report from VEC will help you to understand the purpose behind our site surveys, and how to address any potential remediation recommendations.

What is a Site Survey, and Why Do You Need One?

A site survey is a series of precision measurements using calibrated equipment to evaluate a proposed location for the suitability of high-tech manufacturing and analytical equipment. It is designed to determine whether the proposed site is suitable, based on the manufacturer's listed specifications or industry standards.

Figure 1: *Vibration, magnetic fields, and acoustic noise can result in disturbance or edge noise on an electron microscope image.*

Below is a look at some of the potential factors that are typically measured:

Vibration

Vibration is a common problem when it comes to micro or nanoscale imaging and manufacturing. For instance, nearby construction, rotating machinery, or local foot traffic could cause a site to be out of specification. The amplitude of the vibration source, frequency, and distance to the measurement location will determine its impact on survey results. In addition, the stiffness and construction of a building will impact the propagation of vibration through the floor.

Acoustic Noise

Sound waves coming from other locations in the lab may impact the quality of your equipment's imaging. For example, a nearby air conditioning vent may cause image distortion. Vibration sources, such as pumps and compressors, can result in acoustic noise problems as well.

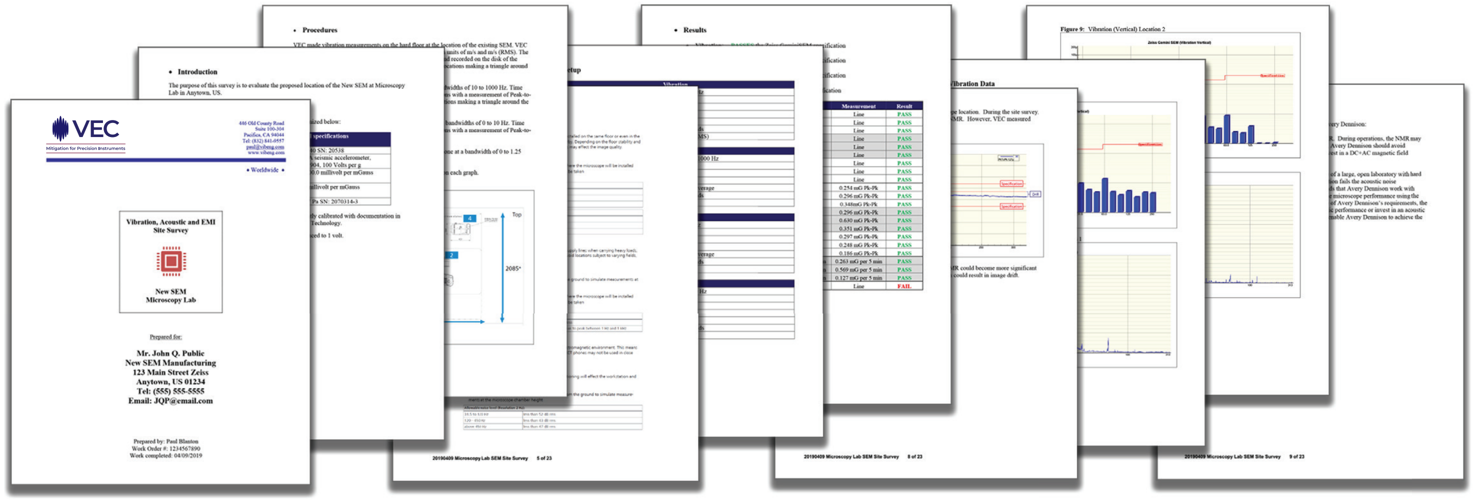
Magnetic Fields

Two types of magnetic fields can impact microscope or tool performance: AC and changes in DC magnetic fields. Nearby power equipment, wiring with high or imbalanced current, or power distribution and transformer stations can result in AC magnetic field issues. Elevators, the movement of metal doors, and nuclear magnetic resonance (NMR) machines are some of the sources that can result in changes in DC magnetic fields.

Each equipment manufacturer will have specific requirements related to vibration, acoustic noise, magnetic field, and other sources.

With these measurements in hand, you will have a deeper understanding of the quality of your proposed site and whether your equipment can live up to the manufacturer's standards within your environment. Failure to meet manufacturer specifications can result in a microscope or imaging tool with lower levels of resolution, higher production anomalies, or a lower throughput than advertised. In other words, you can experience blurry imaging results or reduced production quality.

A VEC site survey report is designed to help you optimize your facility in order to enjoy the highest levels of performance from your equipment. While these reports convey a significant amount of information, VEC presents the data in a method that is designed to be straight forward and highly readable.



What You Get in a VEC Site Survey Report

We set out to create a resource that can guide you in the process of optimizing your environment for the best tool performance. With this in mind, we give you much more than a simple "pass or fail" grade. The report offers several pieces of key information:

Details on the manufacturer's specifications:

This is designed to inform you of what the manufacturer deems the optimal environment for equipment performance. It indicates ideal levels for interference, and how the measurements are to be taken.

Figure 2: The VEC site survey report summarizes your microscope manufacturer's site requirements for best performance, giving us the baseline for determining whether a site meets specification.

- **Specifications:**

Vibrations

Vibrations can be caused e.g. by heavy-duty machinery installed on the same floor or even in the same building as well as transport facilities operated nearby. Depending on the floor stability and construction, even walking in the room or in the hallways may effect the image quality.

Requirements for measuring vibrations:

- Three positions should be measured
- The positions need to cover a triangle over the area where the microscope will be installed
- At each position, measurements in X, Y and Z need to be taken
- X is along the front of the microscope

Allowable horizontal vibration values (Resolution 0.5 Hz):	
up to 10 Hz	less than 5 µm/s rms
10 - 60 Hz	less than 10 µm/s rms
above 60 Hz	less than 14 µm/s rms

Allowable vertical vibration values (Resolution 0.5 Hz):	
up to 10 Hz	less than 4 µm/s rms
10 - 60 Hz	less than 14 µm/s rms
above 60 Hz	less than 20 µm/s rms

Magnetic Stray Fields

Magnetic stray fields can be generated by machines, by supply lines when carrying heavy loads, by power distribution panels and transformer stations. Avoid locations subject to varying fields, e.g. close to an elevator.

Requirements for measuring magnetic stray fields:

- Measurements need to be done in in time domain
- The sensor should be a minimum of 1.0-1.5 m from the ground to simulate measurements at the microscope chamber height
- Three positions should be measured
- The positions need to cover a triangle over the area where the microscope will be installed
- At each position, measurements in X, Y and Z need to be taken
- X is along the front of the microscope

Allowable magnetic stray fields (Resolution 1 Hz):	
DC component	0.5 mG (50 nT) / 5 min or less
AC component	less than 1 mG (100 nT) peak to peak between 1 Hz and 1 kHz

Electrical Field

This equipment is designed to operate in a controlled electromagnetic environment. This means that devices with rf transmitters like mobile phones or DECT phones may not be used in close proximity.

Acoustic Noise

Sound waves e.g. vibration of the air caused by air-conditioning will effect the workstation and may cause image distortion.

Requirements for measuring acoustic noise:

- The microphone should be a minimum of 1.0-1.5 m from the ground to simulate measurements at the microscope chamber height

Allowable noise level (Resolution 2 Hz):	
31.5 to 120 Hz	less than 52 dB rms
120 - 450 Hz	less than 43 dB rms
above 450 Hz	less than 47 dB rms

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Methods and Equipment Used to Collect Data:

This information is compiled in the "procedures" and "instrumentation" sections of the site report, and it offers full transparency to our practices so that you can understand the methodology behind our findings.

Summary of Pass/Fail:

At VEC, our site survey reports are compiled to give you the necessary information to understand our 6 test results and the larger context behind the analysis of your proposed location.

Figure 3: The VEC site survey report also provides the methodology for their findings.

- **Instrumentation**

The instrumentation utilized to conduct the testing is itemized below:

Measurement equipment	Technical specifications
Spectrum Analyzer	Data Physics ACE DP-240 SN: 20538
Accelerometer	Wilcoxon Research 731A seismic accelerometer, Serial Number 1934 & 1904, 100 Volts per g
Near DC field (0 – 10 Hz)	MEDA u-Mag #6058, 100.0 millivolt per mGauss
AC Fields (10 – 1000Hz)	MSI Magcheck 95, 1.0 millivolt per mGauss
Microphone	ACO Model: 4212, 3.2V Pa SN: 2070314-3

All instrumentation and the spectrum analyzer are currently calibrated with documentation in place traceable to the National Institute of Standards and Technology.

The analyzer has low range sensitivity to -130 dB referenced to 1 volt.

To do this, we offer a line by line summary of our Pass/Fail section so that you see the specific locations that may require additional work.

Key Results and Supporting Charts:

Site surveys contain several charts that lay out recorded data in multiple formats so you get a complete understanding of the proposed location. This also helps to ensure that your survey is done in unison with the specific manufacturer's listed requirements.

Figure 4: *Summary charts make it easy to quickly digest survey results.*

- **Results**
  - **Vibration**: PASSES the New SEM specification
  - **AC EMI**: PASSES the New SEM specification
  - **DC EMI**: PASSES the New SEM specification
  - **Acoustics:** FAILS the New SEM specification

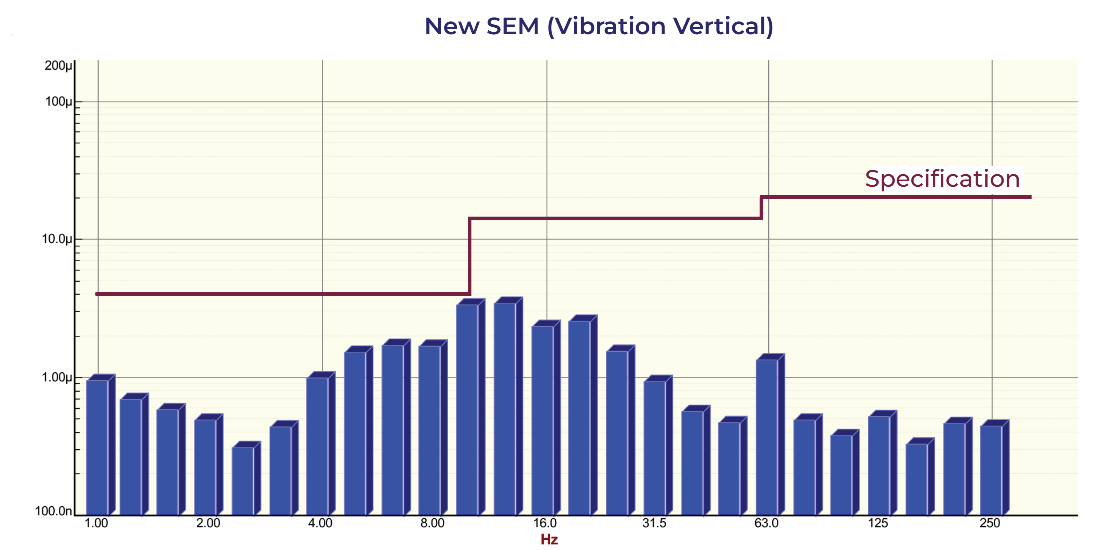
Type	Location	Direction	Specification	Measurement	Result
Vibration	1	Vertical	Line	Line	PASS
		Front-Back	Line	Line	PASS
		Left-Right	Line	Line	PASS
	2	Vertical	Line	Line	PASS
		Front-Back	Line	Line	PASS
		Left-Right	Line	Line	PASS
	3	Vertical	Line	Line	PASS
		Front-Back	Line	Line	PASS
		Left-Right	Line	Line	PASS
AC EMI	1	Vertical	1 mG Pk-Pk	0.254 mG Pk-Pk	PASS
		Front-Back	1 mG Pk-Pk	0.296 mG Pk-Pk	PASS
		Left-Right	1 mG Pk-Pk	0.348mG Pk-Pk	PASS
	2	Vertical	1 mG Pk-Pk	0.296 mG Pk-Pk	PASS
		Front-Back	1 mG Pk-Pk	0.630 mG Pk-Pk	PASS
		Left-Right	1 mG Pk-Pk	0.351 mG Pk-Pk	PASS
	3	Vertical	1 mG Pk-Pk	0.297 mG Pk-Pk	PASS
		Front-Back	1 mG Pk-Pk	0.248 mG Pk-Pk	PASS
		Left-Right	1 mG Pk-Pk	0.186 mG Pk-Pk	PASS
DC EMI	Center of Column	Vertical	0.5 mG per 5 min	0.263 mG per 5 min	PASS
		Front-Back	0.5 mG per 5 min	0.569 mG per 5 min	PASS
		Left-Right	0.5 mG per 5 min	0.127 mG per 5 min	PASS
Acoustics	Center	Omnidirectional	Line	Line	FAIL

Recommendations for Remediation:

When there a failure listed on the report, we offer specific, actionable remediation recommendations so you can take concrete steps to achieve your performance requirements.

- **Vibration Data**

Figure 3: Vibration (Vertical) Location 1



Result – **PASS**

Figure 4: Vibration (Vertical – Narrow Band) Location 1

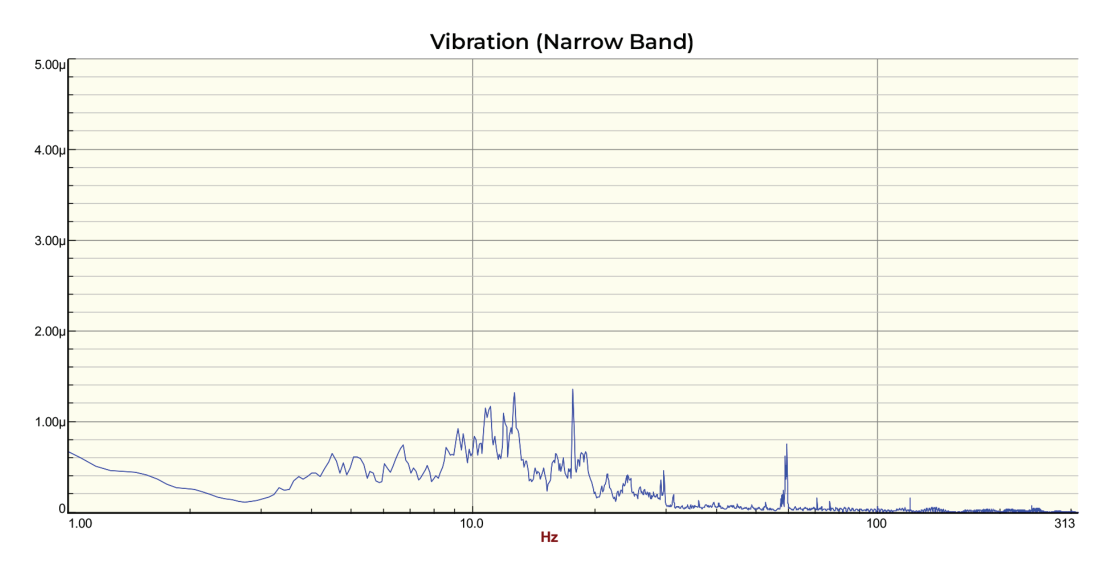


Figure 5: *Data is compared to the specification for the microscope or tool.*

- **Recommendations:**

VEC has the following recommendations for New SEM Company and Microscopy Lab:

Magnetic Field: The location is within 30 feet of an NMR. During operations, the NMR may cause image disturbances and drift. If this is problematic, Microscopy Lab should avoid conducting imaging while the NMR is in operations or invest in a DC+AC magnetic field cancellation system such as the Spicer Consulting SC-24.

Acoustic Noise: The microscope location is in the middle of a large, open laboratory with hard floors and noisy air handlers nearby. As a result, the location fails the acoustic noise specification across all frequency bands. VEC recommends that Microscopy Lab work with New SEM Company to understand the impact of this acoustic noise on the microscope performance using the edge analysis tool. If the resulting performance is outside of Microscopy Lab's requirements, the microscope should be moved to a room with better acoustic performance or invest in an acoustic enclosure. Most manufacturer's acoustic enclosures will enable Microscopy Lab to achieve the New SEM Company specification.

Figure 6: *VEC provides detailed recommendations based on the collected data.*

The Many Types of Data and How to Interpret Them

Frequency Domain vs. Time Domain

In the site survey, we typically present data in the frequency domain by applying the Fast Fourier Transform (FFT) to the time domain data (Figure 7).

The frequency domain allows VEC to identify the individual frequency components of vibration, acoustic noise, magnetic fields, and other signals, which VEC can correlate to sources within a facility. This can give you an idea of where your interference originates and what might be needed to remediate the problem.

Another purpose of the charts is to compare collected environmental data regarding vibration, acoustic noise, magnetic field levels, and other factors against the manufacturer specifications. VEC's charts show how you perform against the tool specification along each measurement dimension.

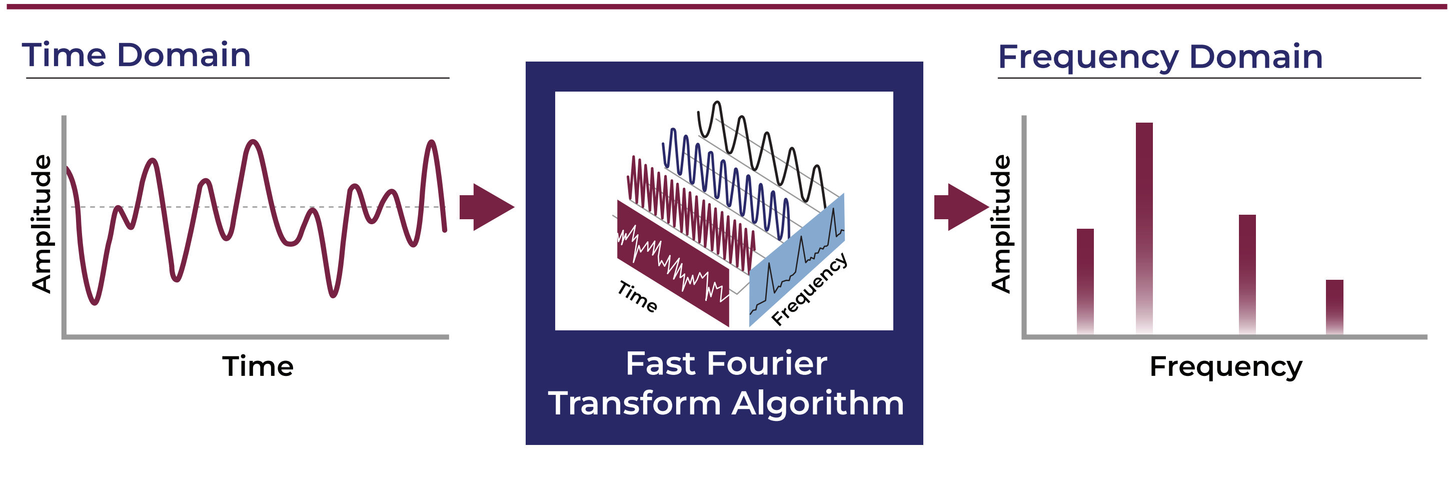
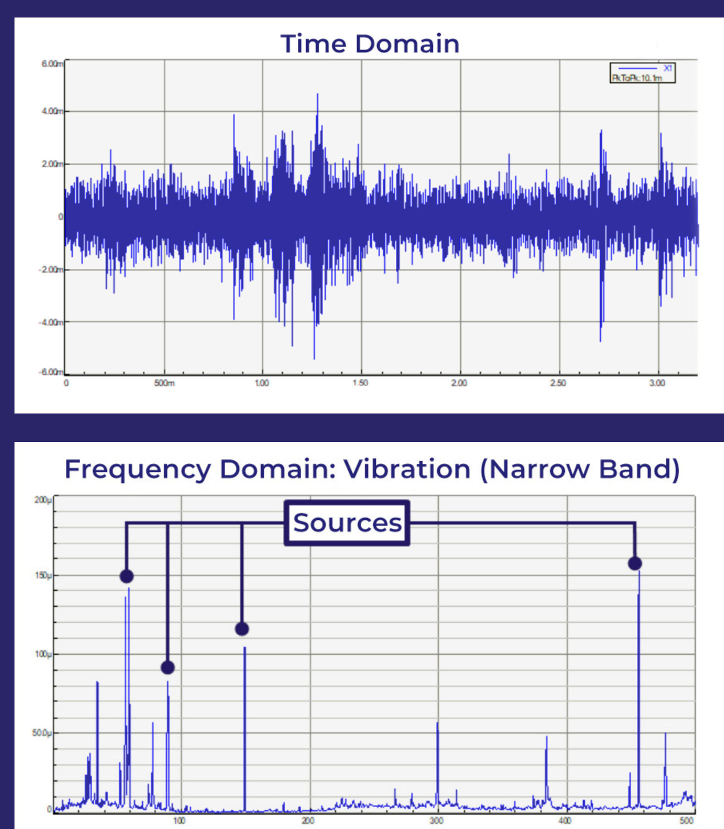


Figure 7: *The Fast Fourier Transform algorithm converts a signal from the time domain into the frequency domain.*

As shown in Figure 9, it is rare to hear a pure tone or have a single source of vibration. Typically, multiple sources of vibration, acoustic noise, and magnetic field exist, and it can be overwhelming to try to determine which of the many nearby sources negatively impact your site.

Figure 8: *Sample time domain data and the corresponding frequency domain data.*



One thing you can do is look at the frequency of nearby sources. Using this methodology, we identify the vibration frequency associated with different sources and compare these to the baseline data collected.

For example, we determined that the equipment in Figure 10 has a primary vibration frequency at 56.7 Hz. When we measure this in conjunction with the baseline vibration level, we can decide if this source will be problematic at the proposed tool or microscope location.

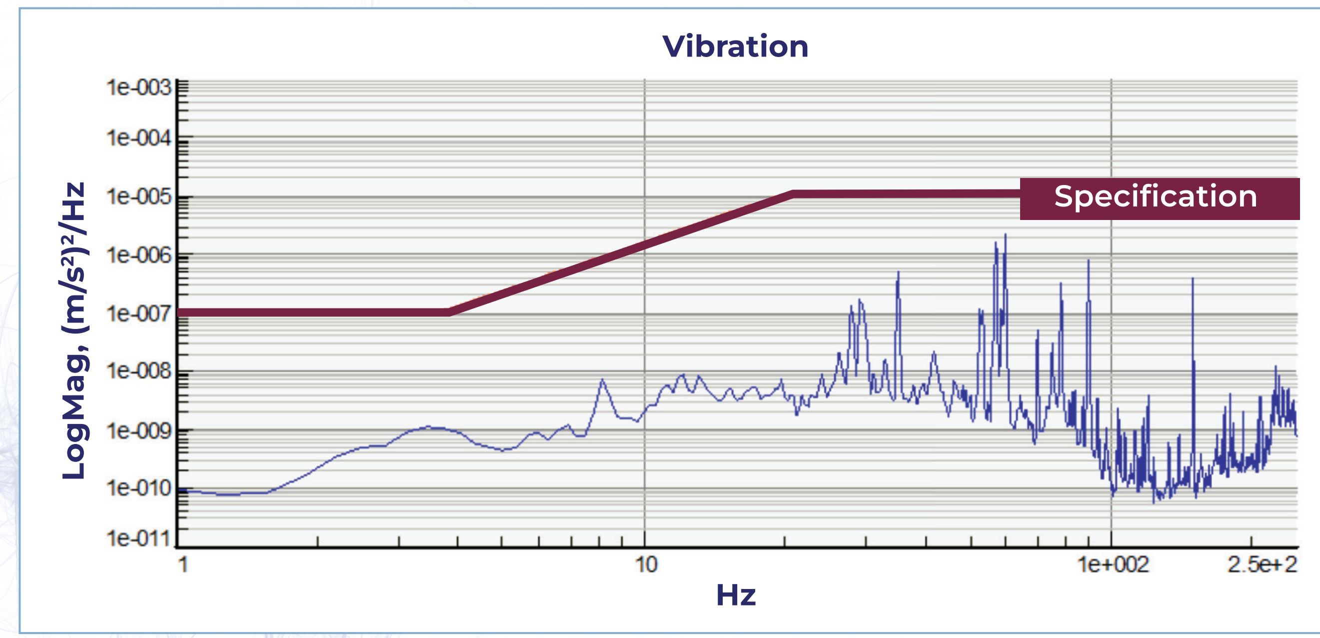


Figure 9: *Sample vibration data showing data collected compared to the tool specification.*

Types of FFT Averaging (Stable Averaging, Peak–Hold)

An FFT takes a continuous time domain signal and looks at it in small digestible snapshots called windows. In each window, the FFT determines how much of that signal to assign to a particular frequency bin. For instance, if part of a vibration time domain signal is at 45Hz, then the FFT would determine the amplitude of the 45Hz component and assign it to a 45Hz bin. It does this for each frequency displayed on the FFT.

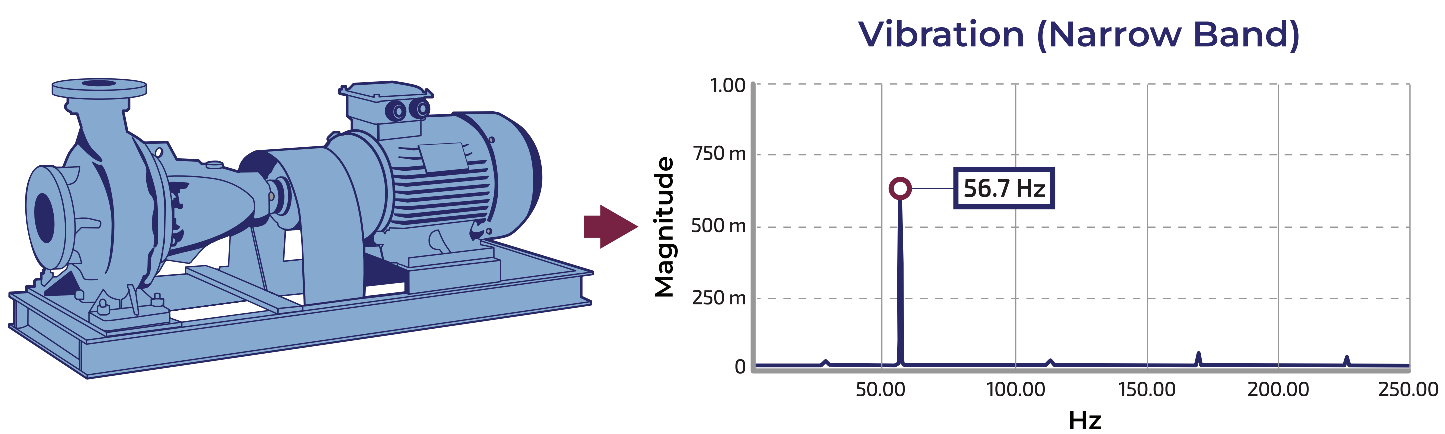


Figure 10: *A vibration frequency of the pump is clearly visible in the frequency domain data.*

The Types of Data Found in a Typical Site Survey

There is, however, some error in an FFT, which means that variation exists from one FFT to another. This error is accounted for using averaging. There are many types of averaging, but two types are the most common.

- **Stable averaging** takes the average value in each unique frequency bin to create an average FFT. For each new window, the values of each new bin are averaged with the values of the prior FFTs in each respective bin. Take a look at the example Figure 11. In bin 2, the value in window 1 is 4, the value in window 2 is 4, and the value in window 3 is 5. Using stable averaging, the end result is (4+4+5)/3 = 4.3. The advantage of stable averaging is that provides the most accurate representation of actual amplitude in each bin assuming that the baseline time domain signal is stable.
- **Peak–hold** takes the maximum value in each frequency bin. So, for each new window, the value in each bin is compared with the prior data. The highest value is kept. In another example from Figure 11, for Bin 2, the largest value in each of the three windows is 5, so the result at the end of the three sample windows is 5.

Zero-to-Peak vs. Peak-to-Peak vs. RMS

These forms can be used to determine the value of the amplitude of a time and domain signal.

- **Zero-to-Peak** is the distance from the X-axis to the top of the peak.
- **Peak-to-Peak** is the distance from the top to the bottom of the wave.
- **RMS** is the zero to peak value divided by the square root of two. In electronics, the RMS value is the equivalent DC voltage of an AC source.

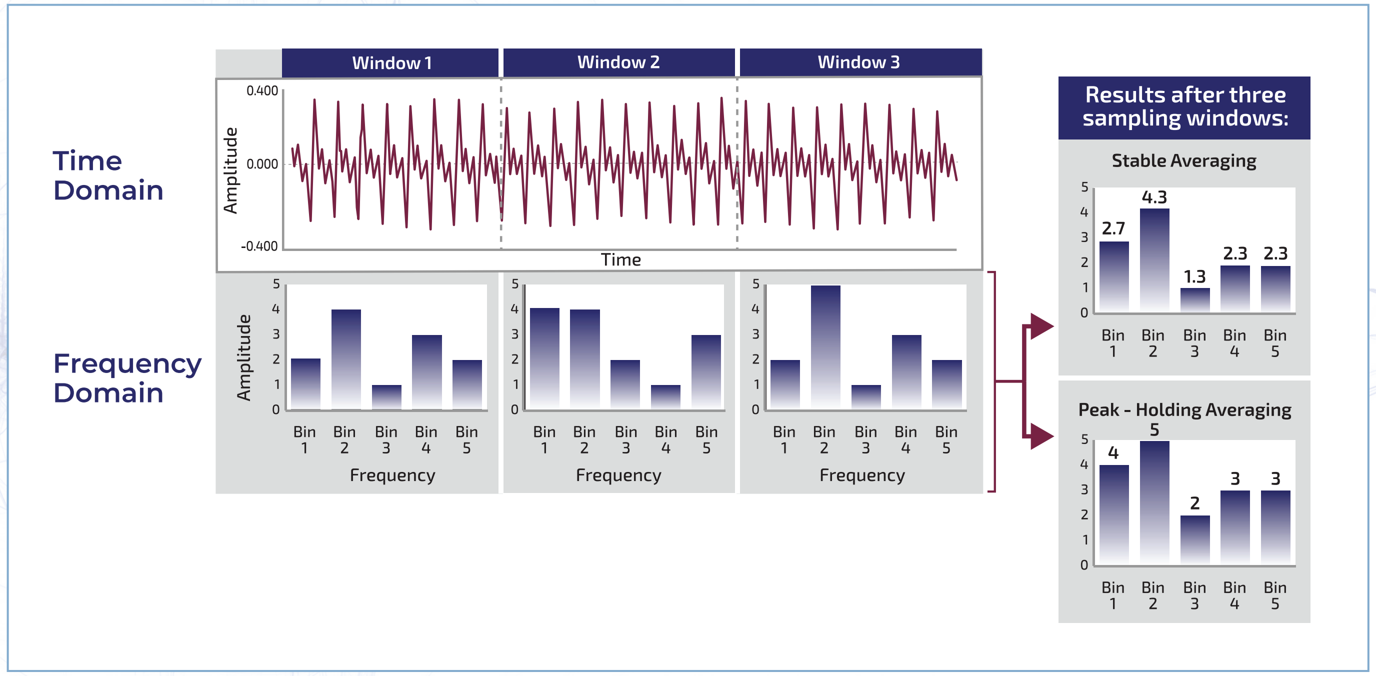


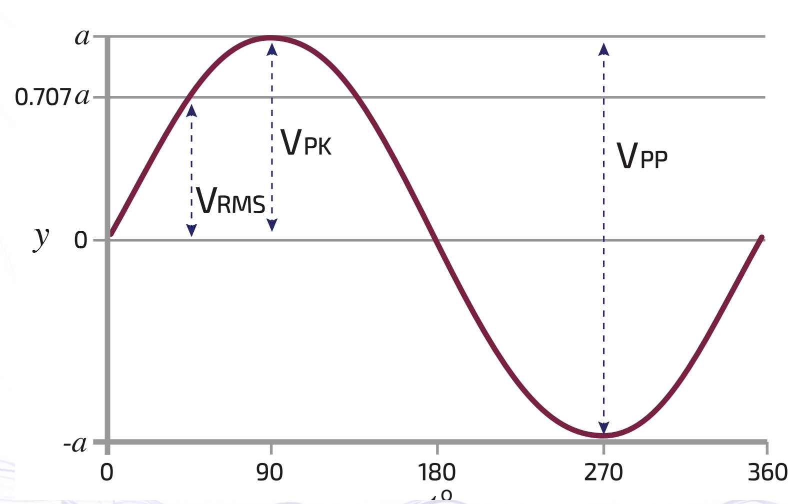
Figure 11: *Peak-Hold Averaging will always result in higher result than Stable Averaging.*

So if an AC power supply has a value of 120 volts RMS, it has the same is electric potential energy as a DC power supply of 120 volts.

Narrow Band vs. 1/3 Octave

Narrow band data is the raw data output from an FFT. Its resolution depends on the inputs to the FFT algorithm. The 1/3 Octave is a way to aggregate a bandwidth of frequencies into a single predefined bucket. Using 1/3 Octave bands allows for the aggregation of sources at similar frequencies into the same bin.

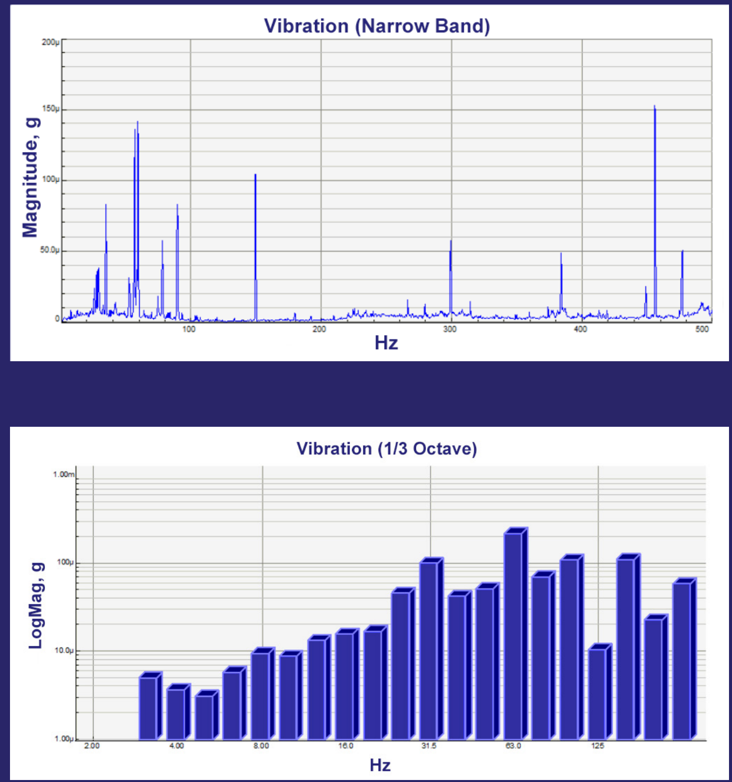
__Figure 12:__ Zero-to-Peak, Peak-to-Peak, and RMS on a sine wave or time domain signal



This is advantageous when assessing whether vibration or acoustic noise will excite a resonance in a tool, microscope, or structure. Narrow band data has more frequency information, so it provides a higher resolution picture of what is going on. Figure 13 illustrates what this might look like.

How you collect data for a site survey and the choices that you make dramatically impact the final result, whether you pass or fail, and ultimately how much capital is required to mitigate any identified problems. When it comes to a site survey for an important piece of scientific equipment, it's critical that you go with a company you can trust.

__Figure 13:__ The 1/3 Octave chart aggregates data in similar frequencies using the standard 1/3 Octave bands.



Why a VEC Site Survey Report is Different

At VEC, these site surveys are our core business. We conduct hundreds of surveys every year, and we are experts at collecting high quality data and interpreting the meaning. We give so much more than a Pass or Fail result.

We provide specific, actionable recommendations designed to optimize your site, and thereby your tool performance.

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