

# Key Setup Parameters for Meaningful Vibration Data Analysis

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# Meaningful Vibration Data Analysis

- Lots of tools and techniques available.
- Sometimes can be a bit intimidating and burdensome.
- Need to take away some of the mystery.
- Make the best of the situation.
- Examine scientific terminology and industry jargon.

# Getting Down to Basics

- Vibration is a leading indicator of machinery health.
- Accelerometer is like a doctor's stethoscope.
- Capture the raw data.
- Convert to a "signature" for comparison.
- Know the equipment make-up.
- Watch for patterns, amplitudes, and changes over time.

*(Interpret information relative to PF curve)*

# Predictive Maintenance (PdM)

(an evolution from Breakdown to Preventive)

- 4 Key Elements to the process:
  - Detection
  - Analysis
  - Correction
  - Verification
- *Pinpoint a problem, get to the root cause, take action, and verify effectiveness.*

# DETECTION

- Capture details on equipment and application.
- Choose the right sensor.
- *Set up the right measurement parameters.*
- Obtain good, solid data – also, repeatable.

# ANALYSIS

- Examine trends, changes, patterns, and amplitudes. (*The “Signature”.*)
- Compare to known acceptable standards or baselines.

(Note: *Signature, Spectrum, and FFT (Fast Fourier Transform) are used synonymously.*)

# CORRECTION

- Take actions against offending vibration levels:
  - ✓ Balancing.
  - ✓ Alignment.
  - ✓ Replacing defective bearings.
  - ✓ Tying down loose components.
  - ✓ Avoiding resonance.

*The BIG 5!*

# VERIFICATION

- Perform a “Before and After” assessment.
- *Did the follow-up action make the situation better?*
- If the problem has been addressed, set a new measurement baseline for the future.



# Primary Goals of the PdM Program

- Ensure convenient rework.
- Avoid panic.
- Avoid secondary damage.
- Promote safety.
- Reduce repair time.
- *Avoid any unnecessary downtime.*

# 12 Steps for Success

- **Survey the plant** in terms of critical, essential, balance of plant categories.
- **Choose the machines** to put into the program.
- **Optimize measurements** in terms of parameters and timing.
- **Choose the method** and **educate participants**.
- **Set criteria** (alarms) for assessment.
- **Baseline** the machine under consideration.
- thru 10, Setup, Measure, Store, Present (**detection**).
- Problem assessment (**analysis**).
- Correct the fault (**correction**).

*(After step 12, the process can be re-entered at step 6.)*

# Establishing the Program

- Put equipment into categories of “critical”, “essential”, and “balance of plant”.
- Start with the critical machinery.
- Get into the physical make-up of the equipment and the application.
- Decide the kinds of measurements and sensors to be used.
- Look for vibration presence, patterns, and severity.

# Vibration measurement

- Choose the best location.
- Choose the proper sensor.
- Make the proper placement – firm mounting and direction. (similar to sensitive directional microphone).
- Measure in several axes.
- *Set measurement parameters to get “tell-tale” data.*
- Set alarm limits for proper assessment. (typically “warning”, “alert”, and “danger”).

# Other Key Considerations ...

- Know the make-up of the machine in terms of bearings, gearbox, pulleys, couplings, cooling fans (# of blades) and pumps (# of impellor blades).
- Know the 1X (i.e., running speed) of the machine being measured.
- Know the relative phase readings on key positions of the machine. (*This will show relative motion.*)

# Key Measurement Parameters

- Time or frequency data to be captured.
- Sample time.
- Number of samples.
- Number of averages.
- Frequency range.
- Frequency resolution.

# Data Interpretation

- Examining presence, patterns, and severity will lead to correction.
- There are typically 5 main causes for the vibration:
  - Unbalance.
  - Misalignment.
  - Bearing defects.
  - Looseness.
  - Resonance.

# Getting Good Data

- Avoid the GIGO (garbage in, garbage out) principle.
- Make certain to have a good sensor, cabling, and connections.
- Ensure proper (solid) mounting (no rocking).
- Set up instrument parameters to get the right measurements.
- Make sure that the equipment is running.
- Be sure that it is the right location.
- Recognize “bad” data before moving on.
- Utilize auxiliary tools available to build confidence in the assessment. (*Examples here include bump tests, coastdown, cross-channel phase, and demodulation.*)



# Measurement Considerations

- Right place, right time.
- Minimize outside influences.
- Time or frequency?
- Frequency band,  $F_{min}$  and  $F_{max}$ .
- Resolution.
- Windowing.
- Sampling time.
- Number of samples.
- Number of averages
- Accompanying speed and phase information?
- Additional simultaneous channel?

# Measurement Relationships

- Highest frequency (Fmax)

$$F_{\max} \text{ (Hz)} = \# \text{ of samples} / (2.56 * \text{sample time})$$

(corollary: sample time = # lines of resolution / Fmax (Hz))

- Lines of resolution

$$\# \text{ Lines} = \text{samples} / 2.56$$

(corollary: samples = 2.56 \* # lines)

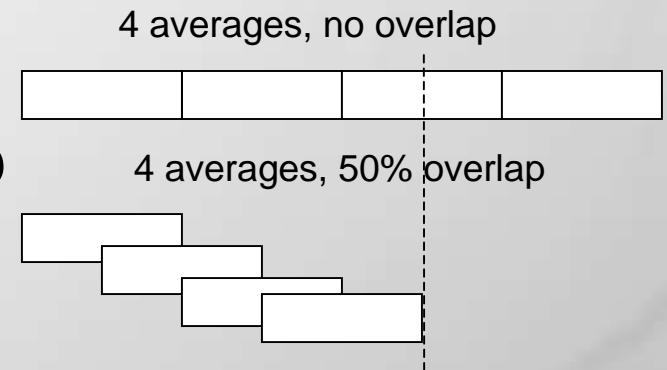
- Time for collection

$$\text{Time} = (\# \text{ averages} * \# \text{ lines}) / F_{\max} \text{ (in Hz)}$$

- Frequency resolution

$$\text{Resolution} = F_{\max} / \# \text{ lines}$$

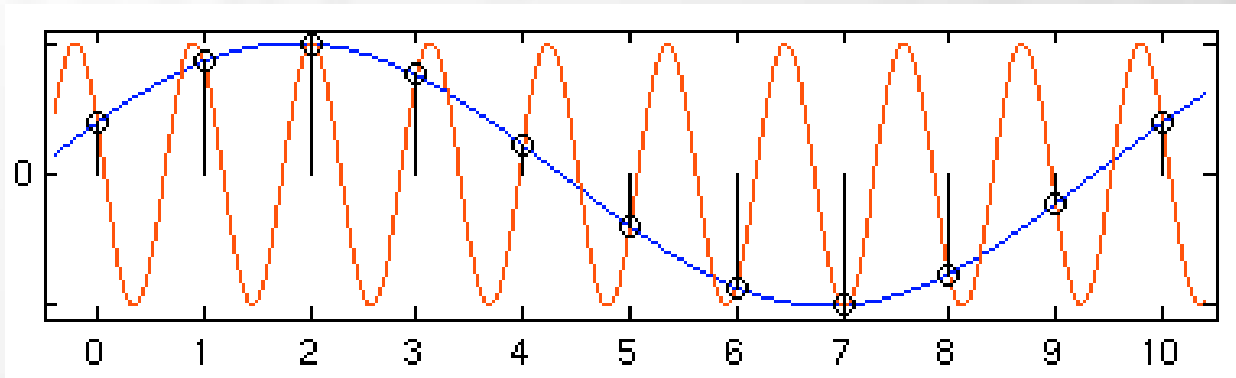
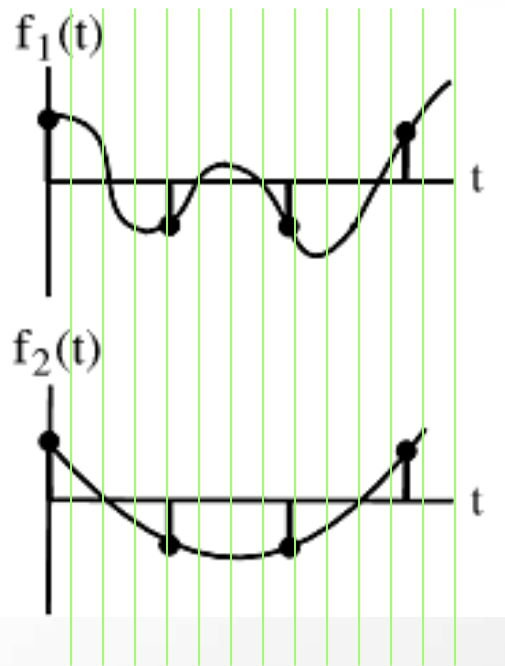
(Keep in mind the specifications for the sensor and instrumentation.)



# Measurement Considerations

- Shannon (Nyquist) Sampling Theorem: Sampled signal can be completely reproduced if sampling frequency is at least twice the highest frequency content. (We use the factor 2.56 in digitizing.)
- Any attempt to do less results in “aliasing”.
- There is an inverse relationship between time sample and highest frequency content.
- More samples, less time results in higher frequency.

# Digital Sampling... Example



Two very different signals with same sampling.

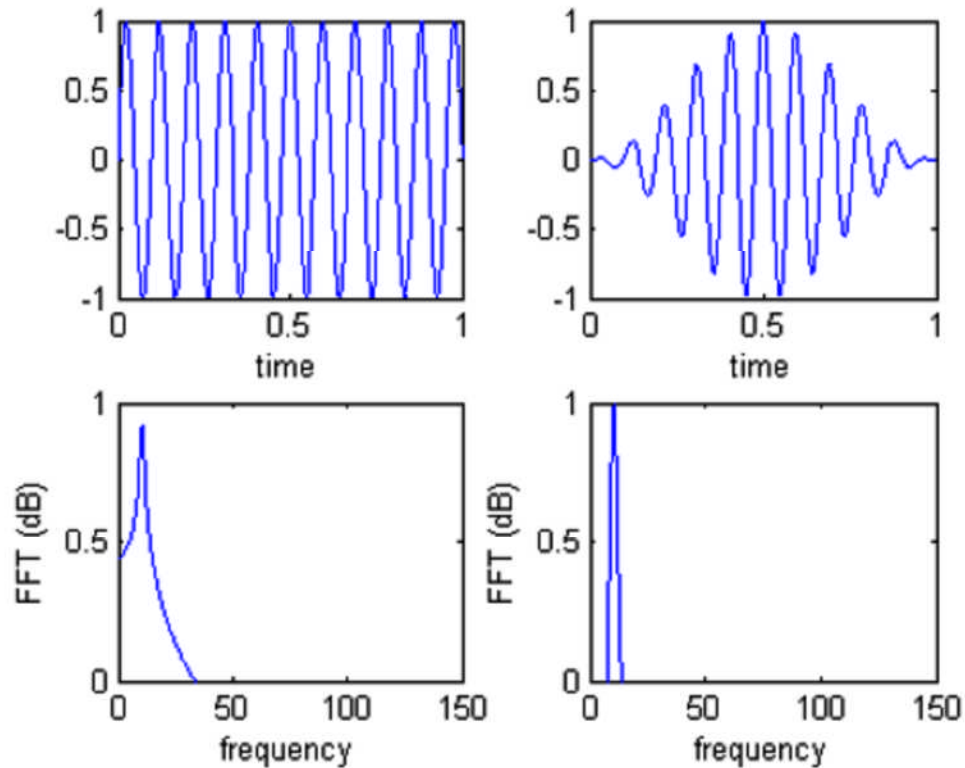
The more samples, the better reconstruction.

2.56X is a nice sampling factor in digitizing.

# Further considerations

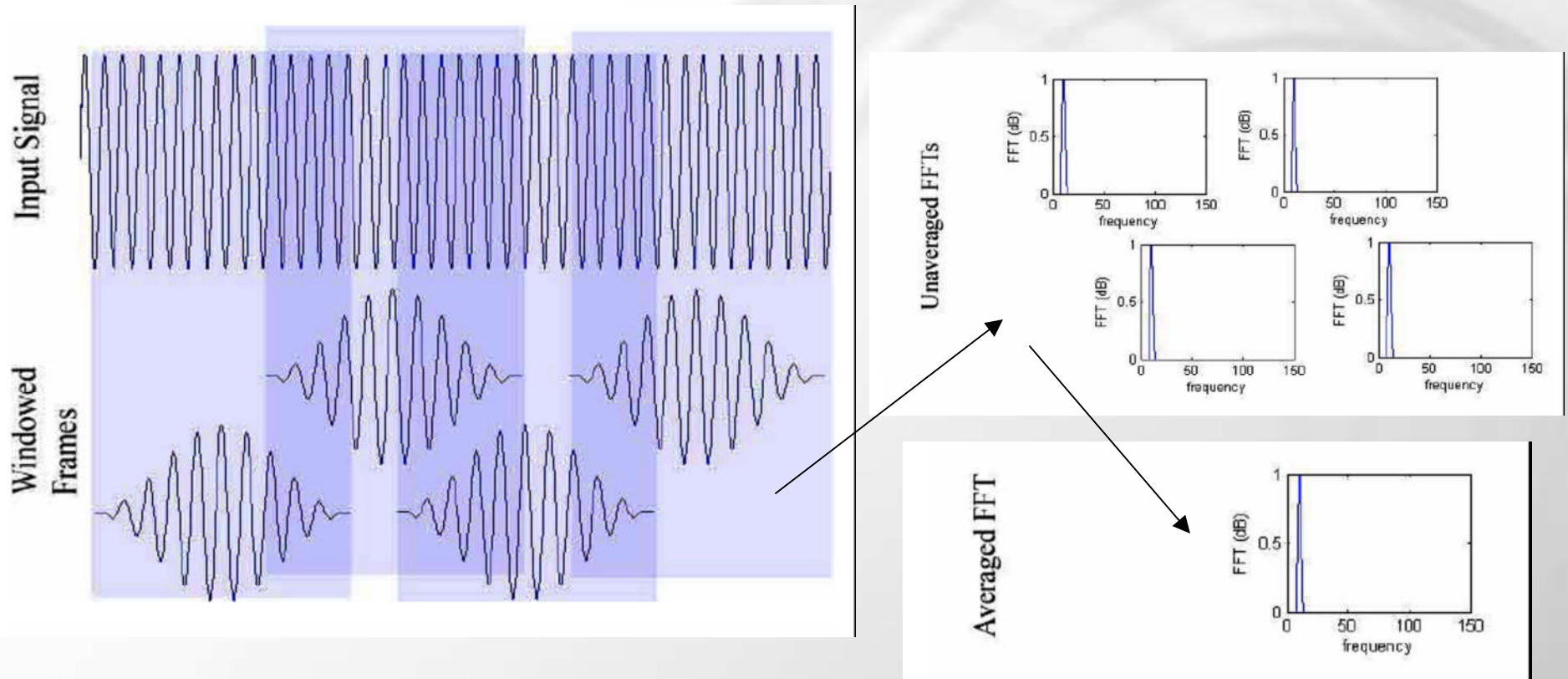
- Product(s) specifications and limitations.
- Measurement capture.
- Measurement processing.
- Measurement unit (acceleration, velocity, displacement).
- Measurement scaling (rms, average, peak, pk-pk).

# Windowing for sampling



Comparison of non-periodic sine wave and FFT with leakage (left) to windowed sine wave and FFT showing no leakage (right).

# Overlapping Averages



Overlap processing shortens the acquisition time by recovering a portion of each previous frame that otherwise is lost due to the effect of the FFT window,

# Example – at instrument side

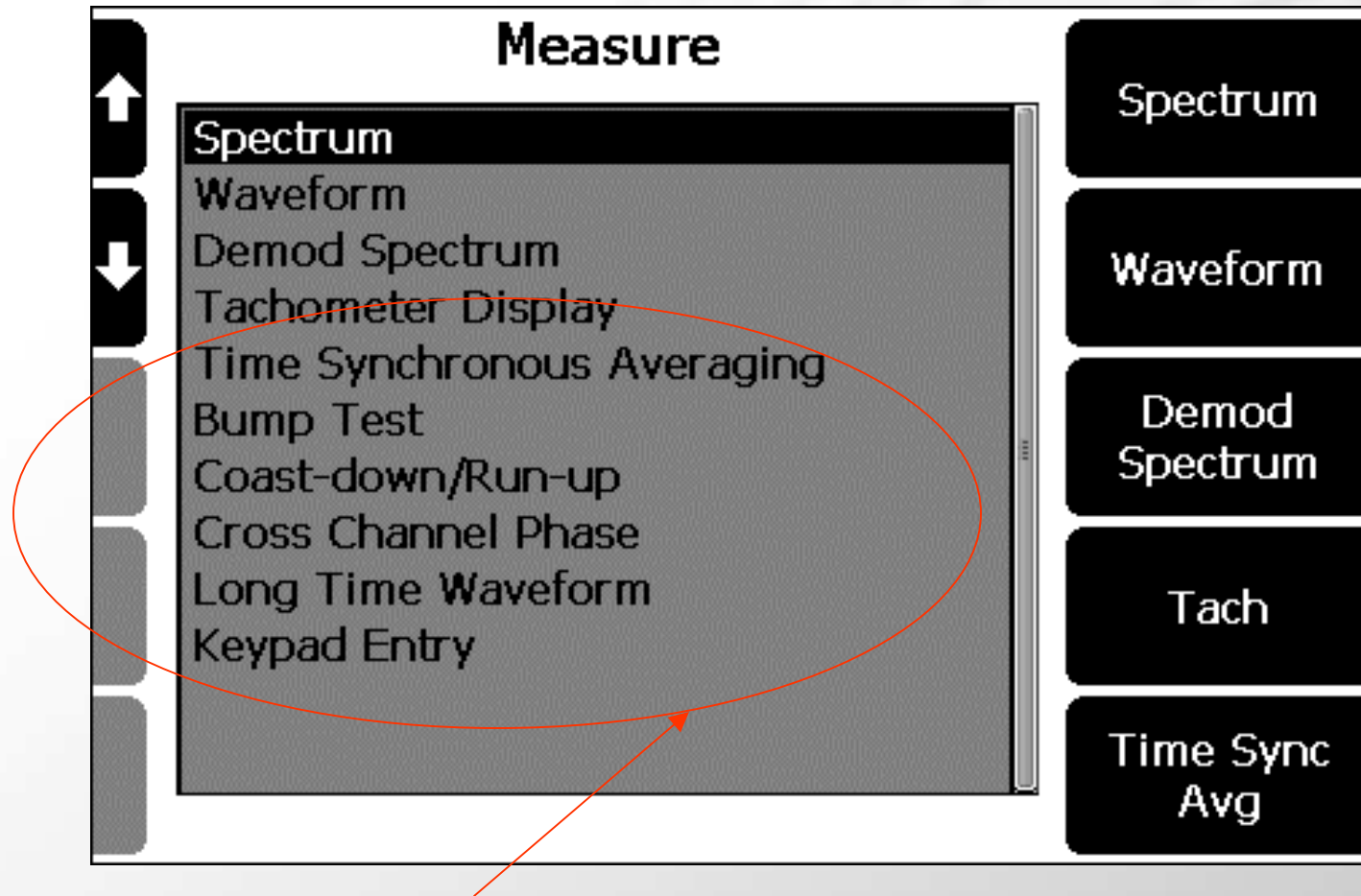
Sensor		
Name	Accel 100mV/g	100
Type	Accel.	mV/g
Voltage Rng and Coupling	AC +/- 8V	
Settling	3 s	ON
Auto Settling	ON	CHECK

Key settings to address



# Example – at instrument side

Most commonly used  
On routine data collection



Advanced analysis

# FFT (Spectrum) Measurement

## Typical Settings Menu

Spectrum		
<small>ALT</small> Number of Averages	4	Velocity
<small>ALT</small> Average Type	Linear	60 kCPM
<small>ALT</small> Average Overlap	50%	800
<small>ALT</small> Window	Hanning	60 CPM
<small>ALT</small> Sensor Setup	CH1: Accel 100mV/	OFF
		<small>ALT</small> Store Units
		<small>ALT</small> Fmax
		<small>ALT</small> Spectral Lines
		<small>ALT</small> Fmin
		<small>ALT</small> Tach Trigger

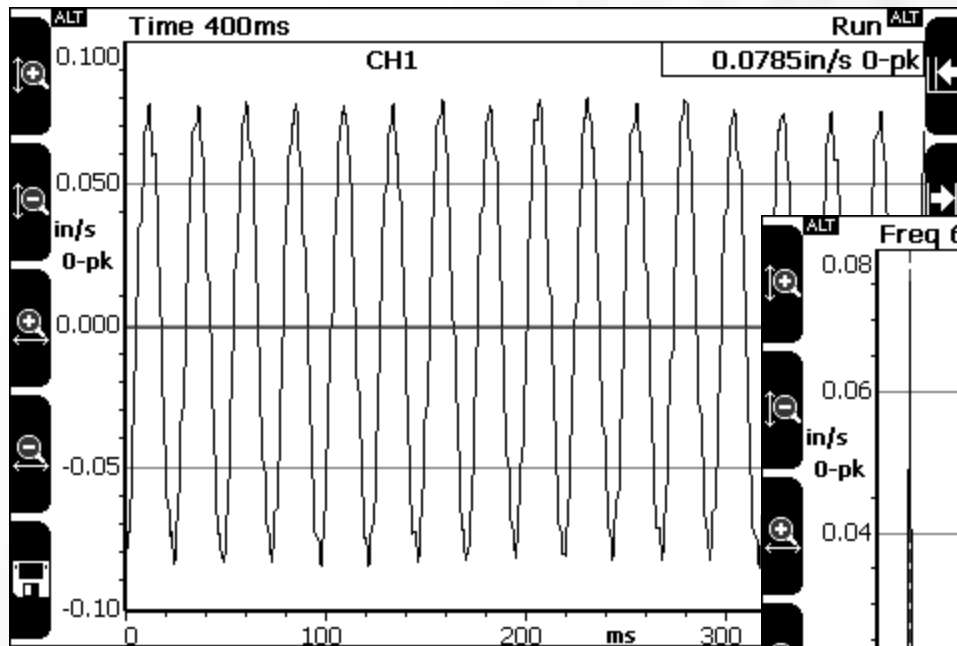
# TWF (Time Waveform) Measurement

## Typical Settings Menu

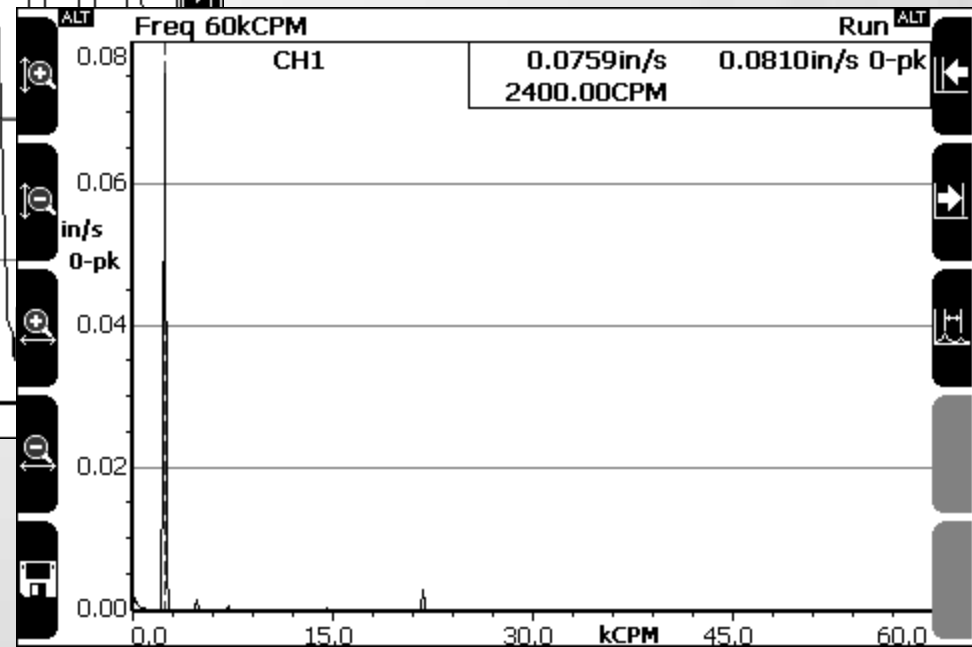
Waveform		
<small>ALT</small> Number of Averages	1	Velocity
<small>ALT</small> Average Type	Linear	60 kCPM
		1024
		400ms
<small>ALT</small> Sensor Setup	CH1: Accel 100mV/	OFF
		<small>ALT</small> Store Units
		<small>ALT</small> Equivalent Fmax
		<small>ALT</small> Number of Samples
		<small>ALT</small> Duration
		<small>ALT</small> Tach Trigger

# Measurements at Instrument

Time Waveform

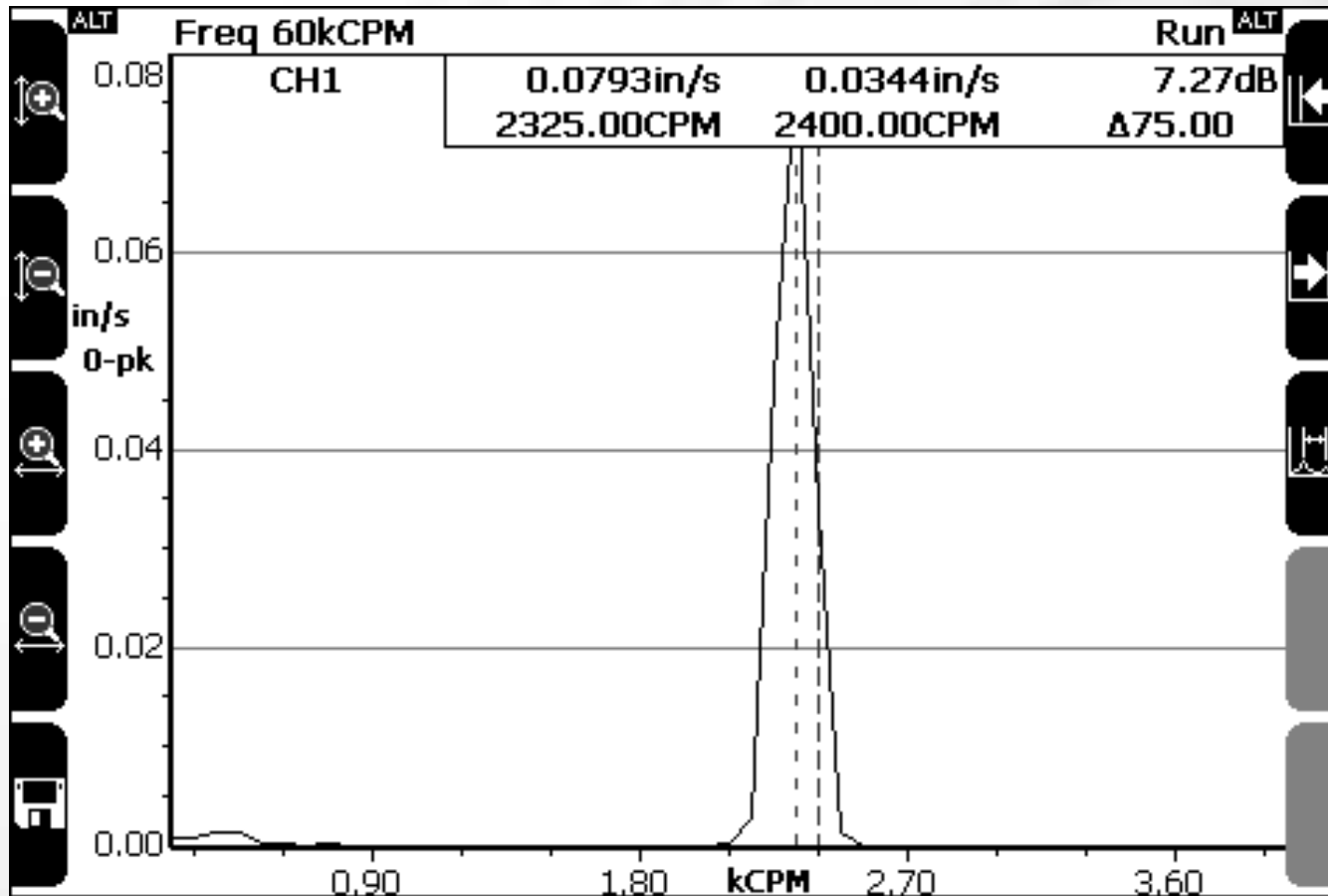


FFT



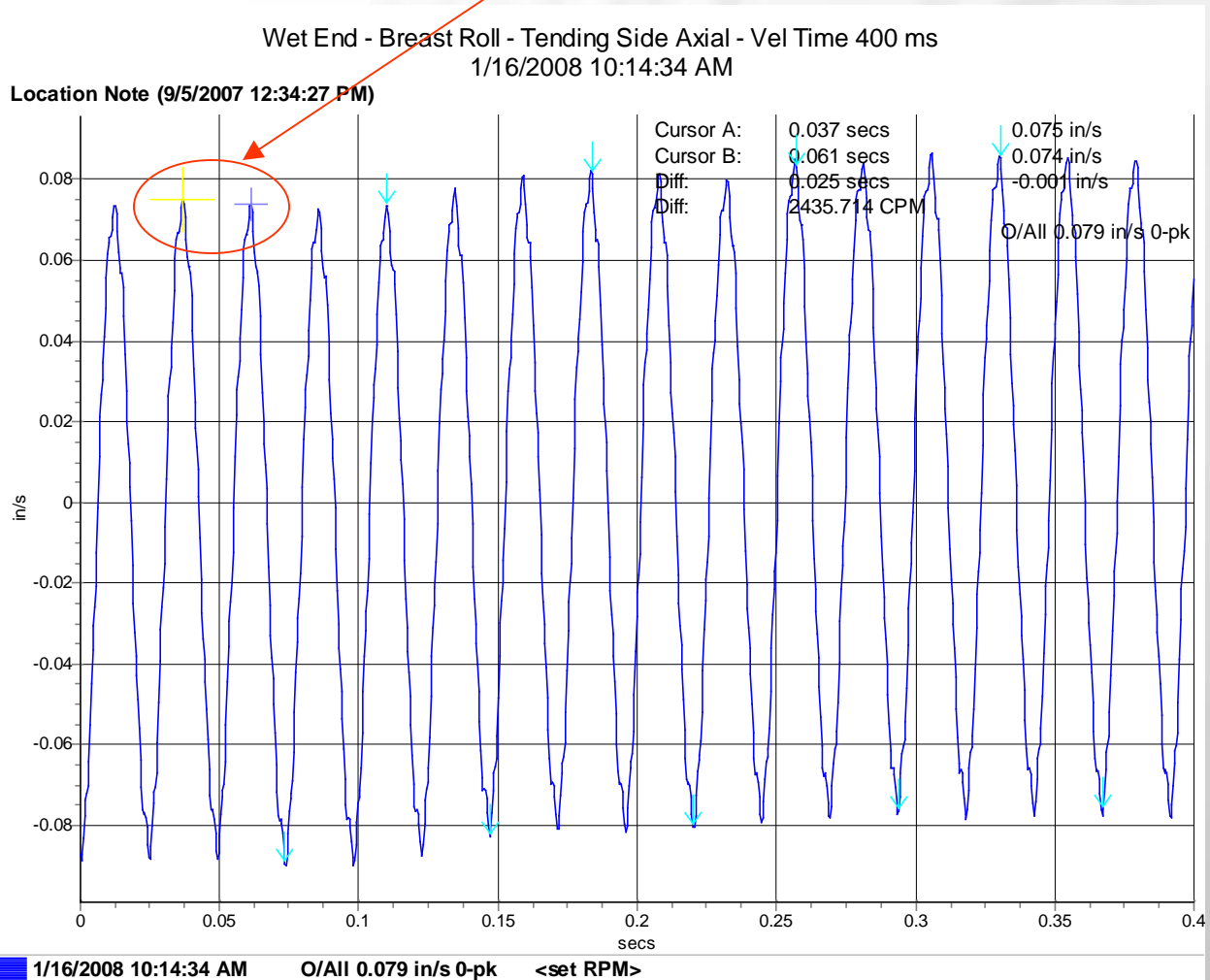
# Zoomed FFT on Instrument

Shows more precise frequency and resolution



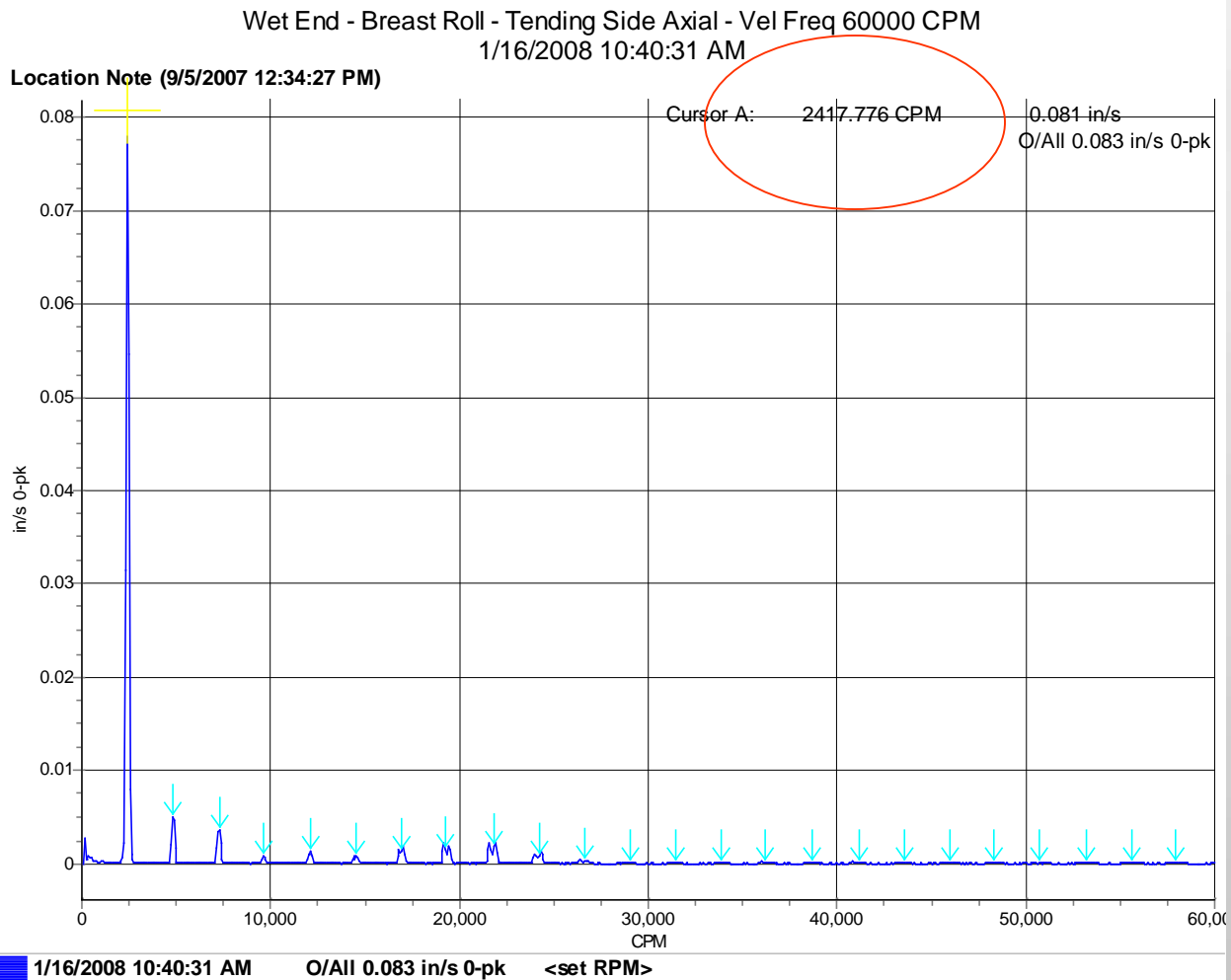
# Viewed at PC

Note delta cursors to determine approximate frequency



# Viewed at PC

## Interpolated running frequency



# Setup Parameters - TWF

Edit Paramset / Schedule Entry

Select Parameter Set: Vel Time 400 ms

Description:

Domain:  Frequency  Time  Demodulation

Measurement Units: Velocity (in/s 0-pk)

**Warning: These settings are not supported by all vb instruments. See the Applicable vb Instrument tab for details.**

Read RPM from Tach  
 Tach Triggered (time synchronous) Default RPM:   
 Ask user for RPM when measurement is taken  
 Record this schedule entry when performing a Route.

Parameters Channel/Sensor **Applicable vb Instrument** Baseline Overall RMS

Items marked with a \* are not supported by all instruments:

Number of samples:   
Duration:  ms  
Equivalent FMax:

Estimated Recording Time: 0.4 seconds

OK Cancel Help

Note the settings and calculated equivalent Fmax value and estimated time.



# Setup Parameters - FFT

The screenshot shows a software dialog box titled "Edit Paramset / Schedule Entry". The "Select Parameter Set" dropdown is set to "Vel Freq 60000 CPM". The "Domain" is set to "Frequency". The "Measurement Units" are "Velocity (in/s 0-pk)". A warning message states: "Warning: These settings are not supported by all vb instruments. See the Applicable vb Instrument tab for details." Below this, there are several checkboxes: "Read RPM from Tach" (checked), "Record Phase Data (requires Tach)" (unchecked), "Ask user for RPM when measurement is taken" (unchecked), and "Record this schedule entry when performing a Route" (unchecked). The "Default RPM" is set to 0. The "Parameters" tab is selected, showing a list of parameters: "Fmin: 60 CPM", "Fmax: 60000 CPM", "Lines: 800", "Average type: Linear", and "Number of averages: 4". The "Estimated Recording Time" is displayed as "2 seconds". At the bottom are "OK", "Cancel", and "Help" buttons.

Select Parameter Set: Vel Freq 60000 CPM

Description:

Domain:  Frequency  Time  Demodulation

Measurement Units: Velocity (in/s 0-pk)

**Warning: These settings are not supported by all vb instruments. See the Applicable vb Instrument tab for details.**

Read RPM from Tach  
 Record Phase Data (requires Tach) Default RPM: 0  
 Ask user for RPM when measurement is taken  
 Record this schedule entry when performing a Route.

Parameters Channel/Sensor Applicable vb Instrument Baseline Overall RMS FFT Options

Items marked with a \* are not supported by all instruments:

Fmin: 60 CPM  
Fmax: 60000 CPM  
Lines: 800

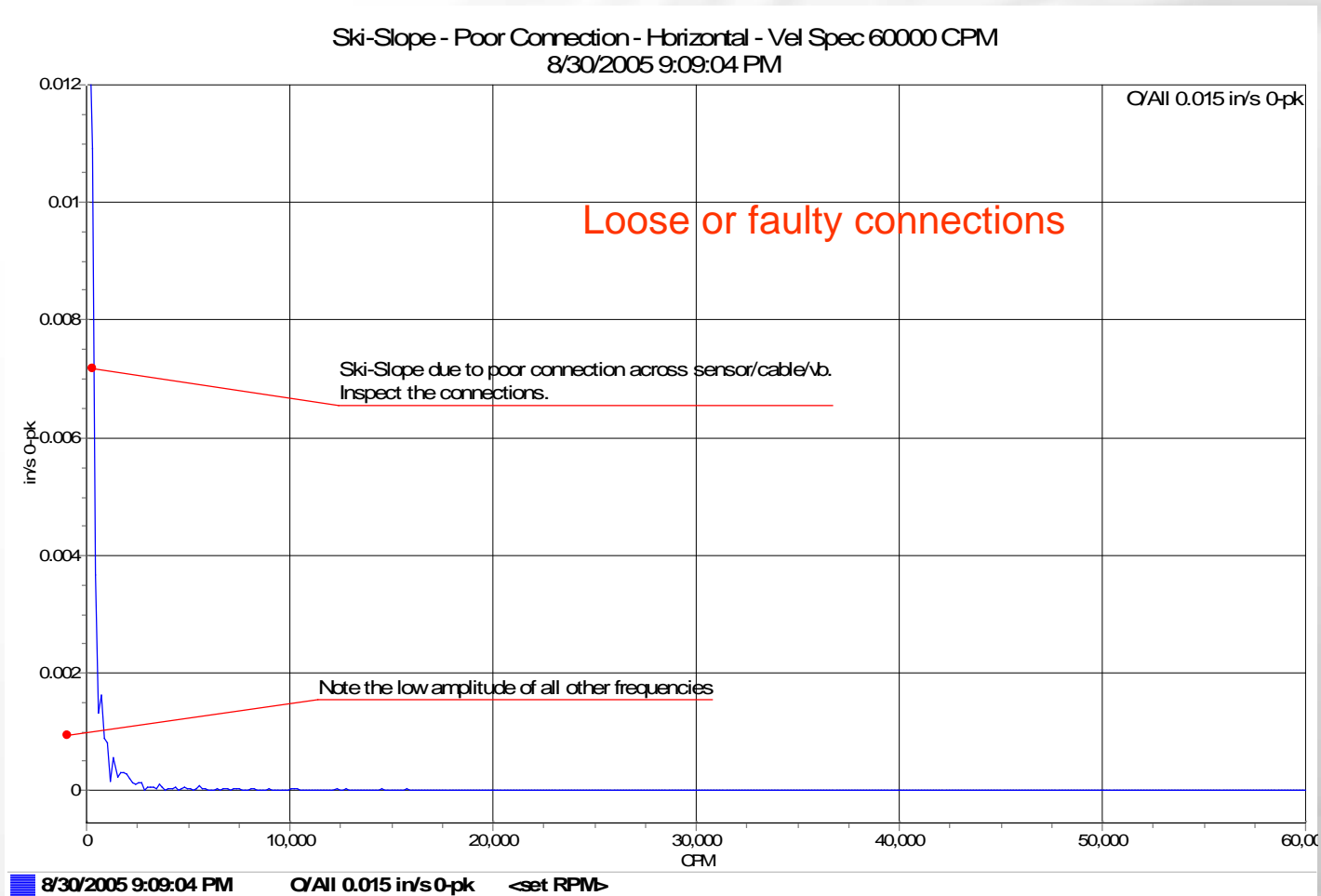
Average type: Linear  
Number of averages: 4

Estimated Recording Time: 2 seconds

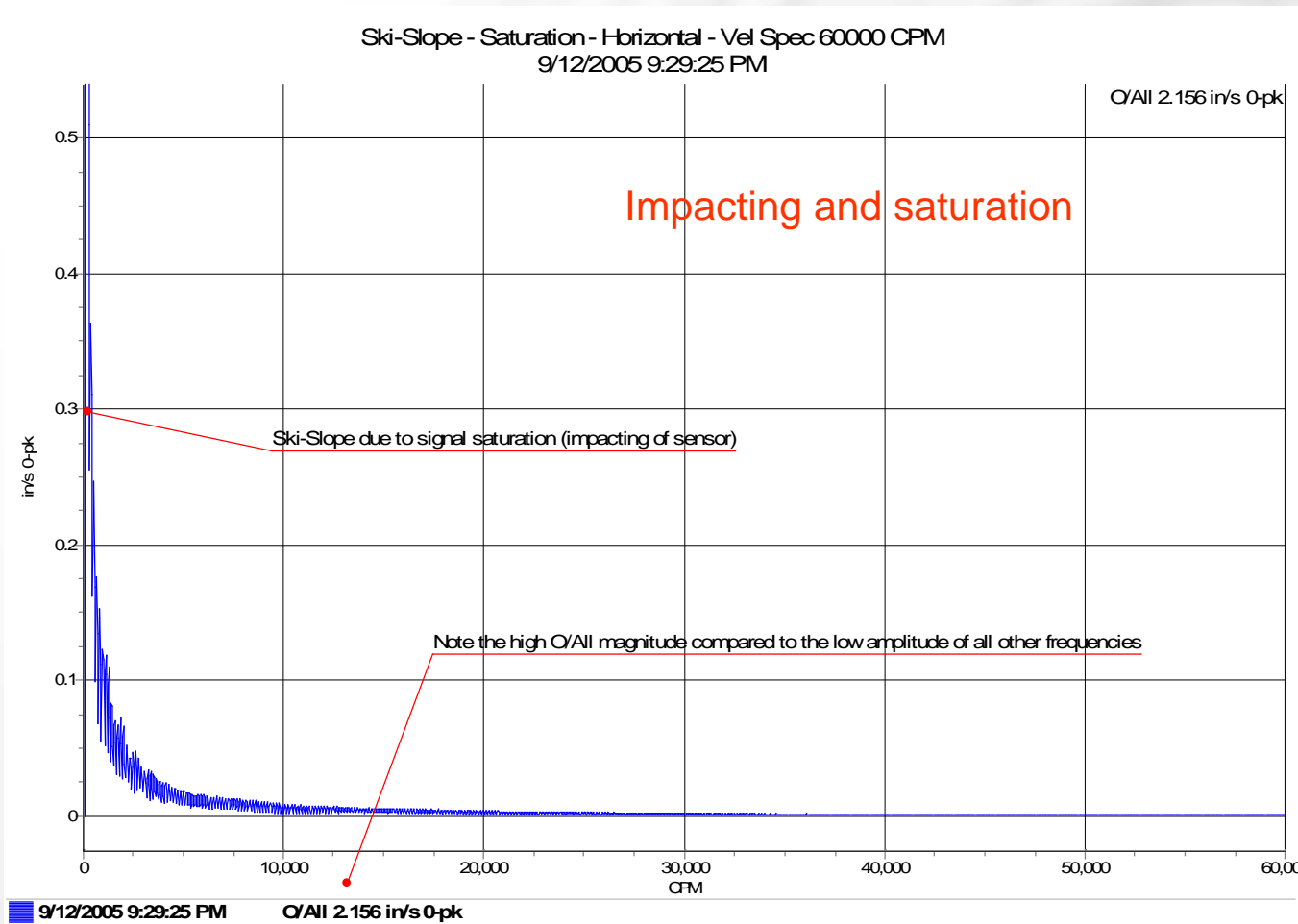
OK Cancel Help

Note the settings and estimated time.

# Examples of Field Problems

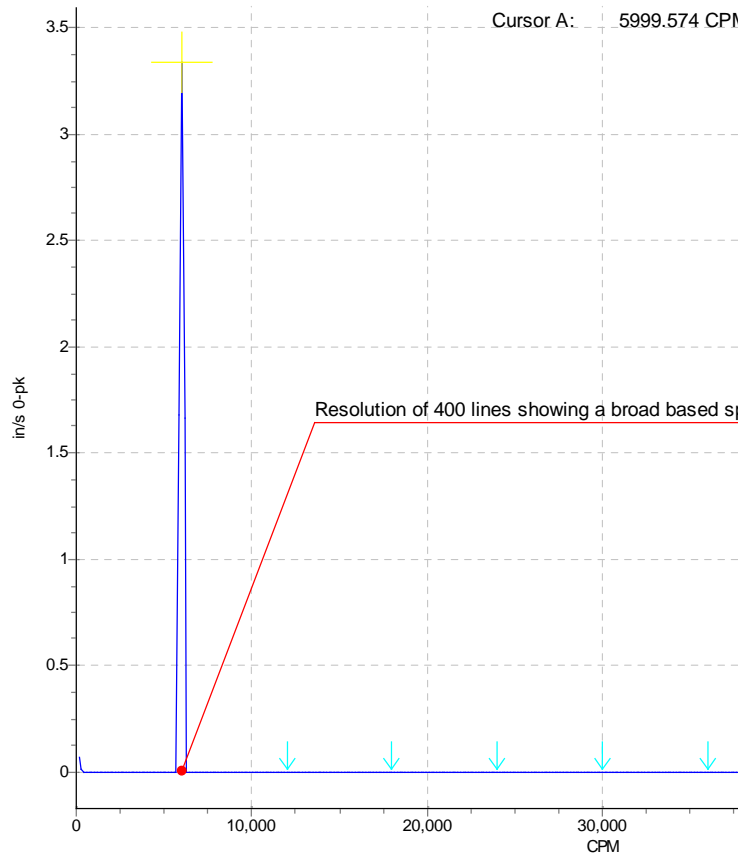


# Examples of Field Problems



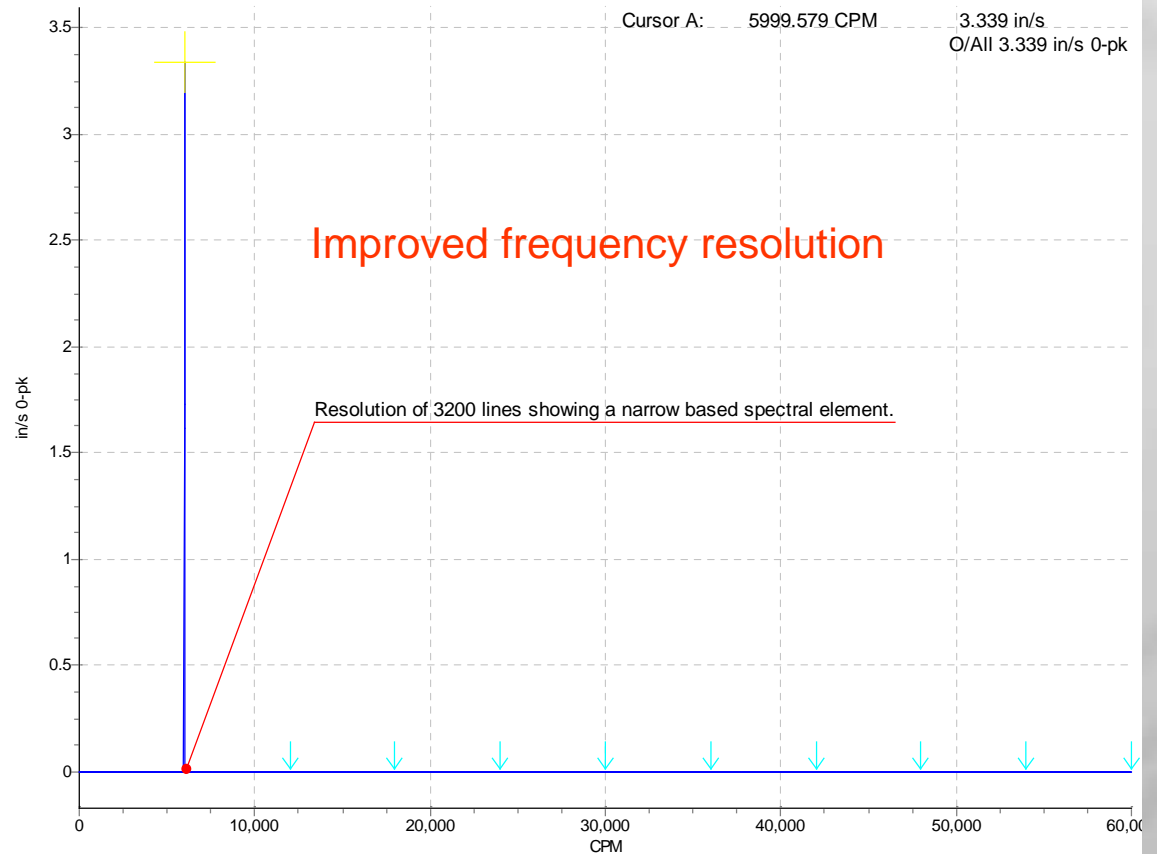
# Example of Setup Issues

Resolution - Low - Horizontal - Vel Freq 60000 CPM  
7/24/2005 6:31:06 PM



7/24/2005 6:31:06 PM O/All 3.34 in/s 0-pk 5999.574 RPM

Resolution - High - Horizontal - Vel Freq 60000 CPM  
7/24/2005 6:31:17 PM

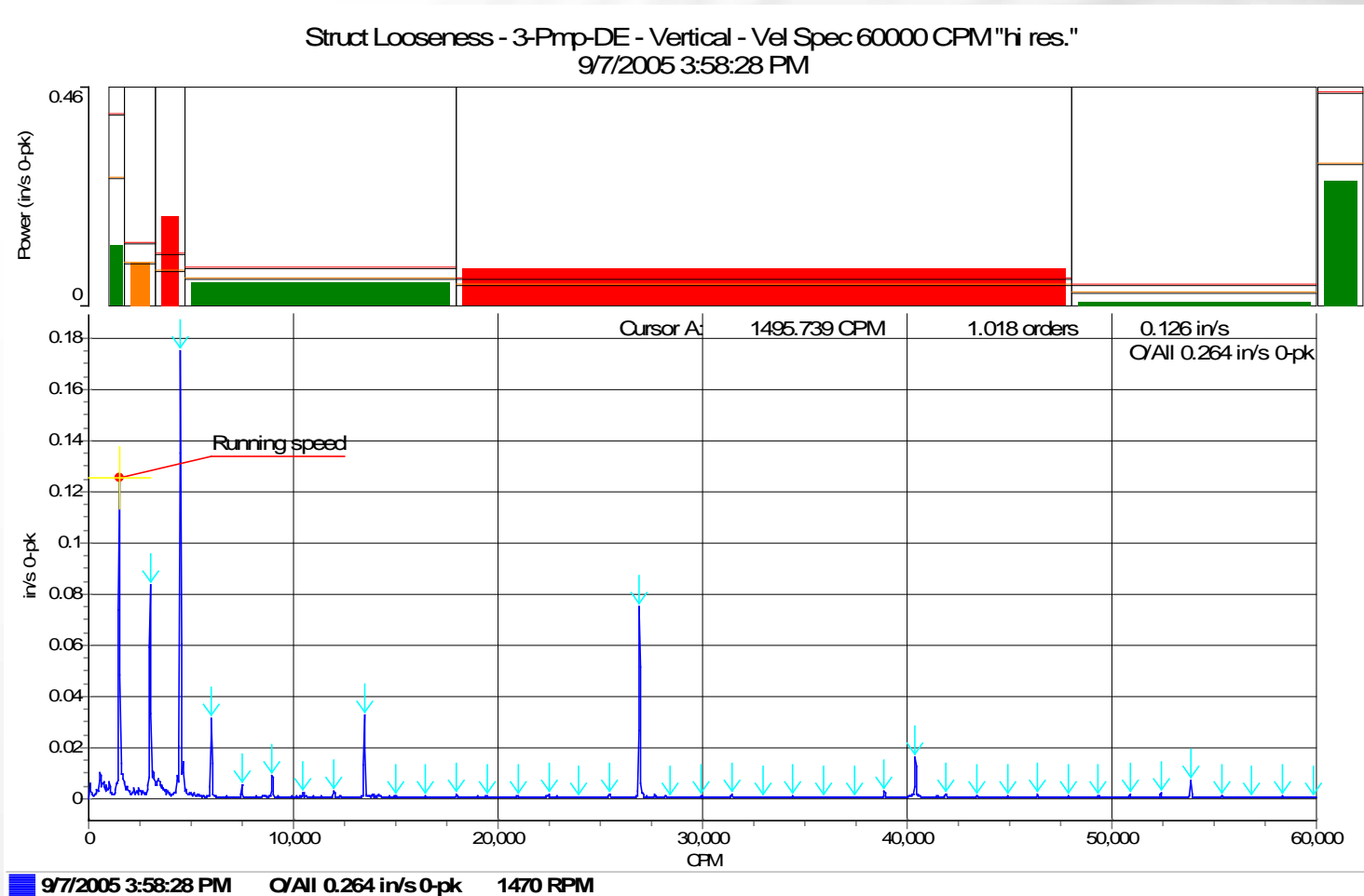


Improved frequency resolution

Resolution of 3200 lines showing a narrow based spectral element.

7/24/2005 6:31:17 PM O/All 3.339 in/s 0-pk <set RPM>

# Example of Good Data for Analysis



# Summary – Key Considerations

- Know the equipment and application.
- Recognize changing conditions.
- Choose the best shot at capturing the event.
- Choose the best sensor for the job.
- Choose the best location for the measurement.
- Make appropriate settings for the measurement.
- Capture good quality data.
- Transform data to information.
- Identify tell-tale signs of trouble.
- Decide a course of action.

# Concluding Remarks

- Vibration is a primary measurement for an effective PdM program.
- Education and experience in the technology and techniques are essential for success.
- Get management 'buy-in' on the process.
- Know the equipment in terms of physical make-up and intended operation.
- Know standards for acceptable operation.
- Know the tell-tale signs for potential problems.
- Know the tools available for the program.
- Perform the proper setup for acquiring data.
- Be confident in assessing the situation.
- Have confidence in making the call for action.

# Questions and/or Comments?

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