ORBIT ANALYSIS

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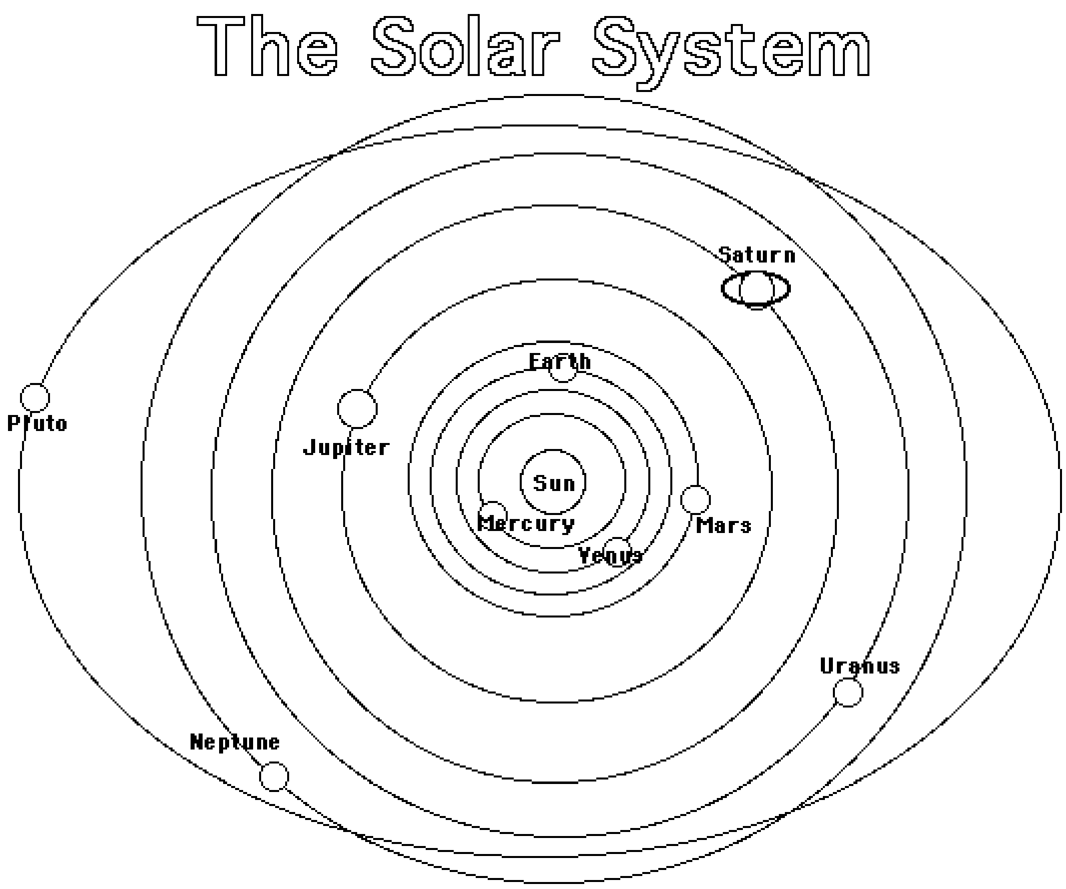
The Concept of Orbits



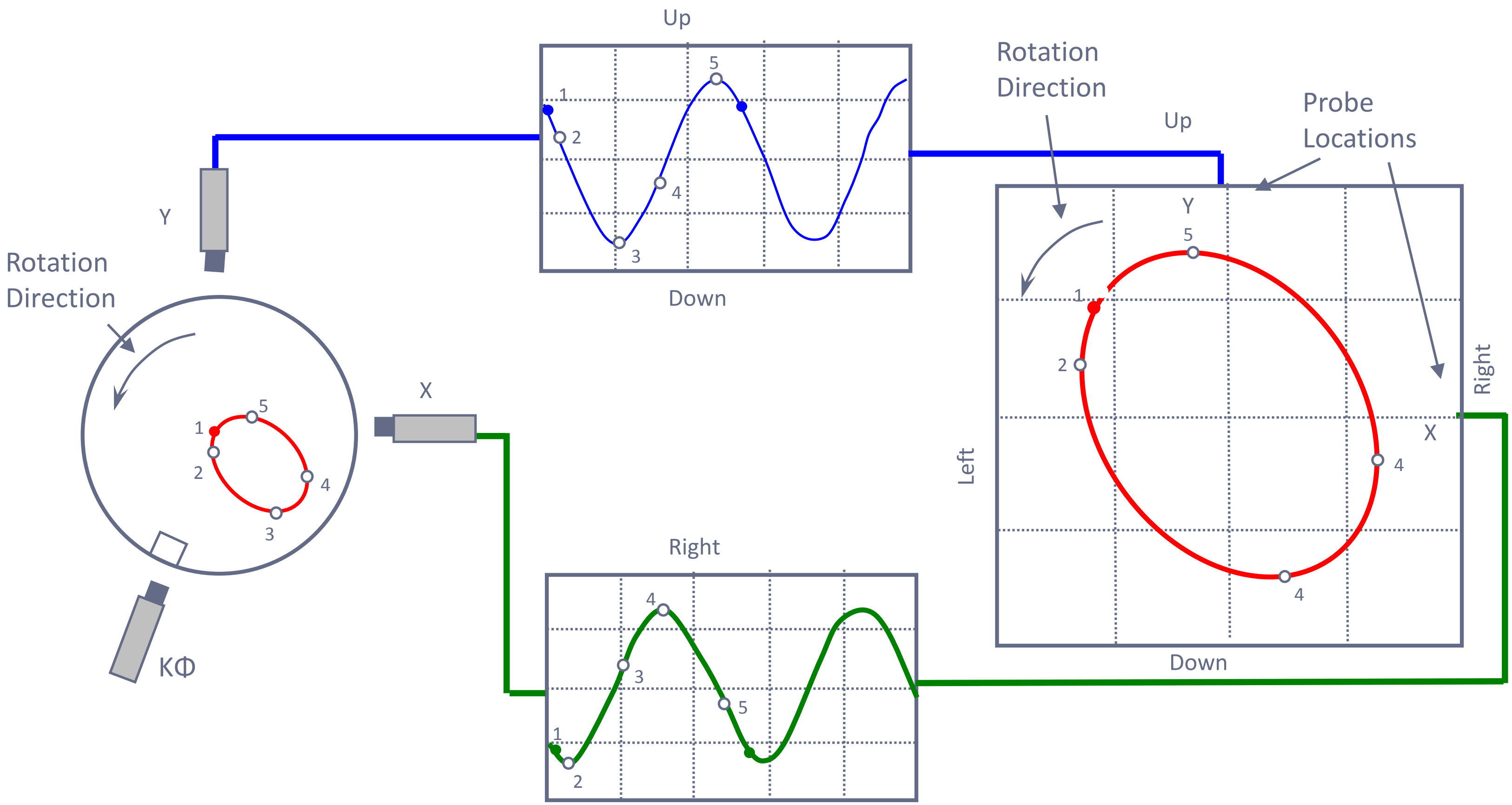
Overview

- Orbit Description
- Orbital Construction
- 1X Orbits
- Phase Reference in Orbits
- Compensation
- Frequency Analysis using Orbits
- Precession in Orbits
- Orbit Shapes
- Pedestal orbits
- Field Data Collection

Orbits

- Orbit Plots show the path a rotor takes as at vibrates during operation
- Orbits are created from the data from two orthogonal (perpendicular) measurements taken simultaneously
- A phase reference on the rotor is used for filtering an orbit to a specific frequency and identifying frequency content from orbit plots
- Orbits may be Direct (unfiltered), 1X or nX
- Like Bode’ or Polar Plots, Orbits may be compensated or un-compensated

Orbit Construction



*Reproduced from Fundamentals of Rotating Machinery Diagnostics by Donald E. Bently and Charles Hatch

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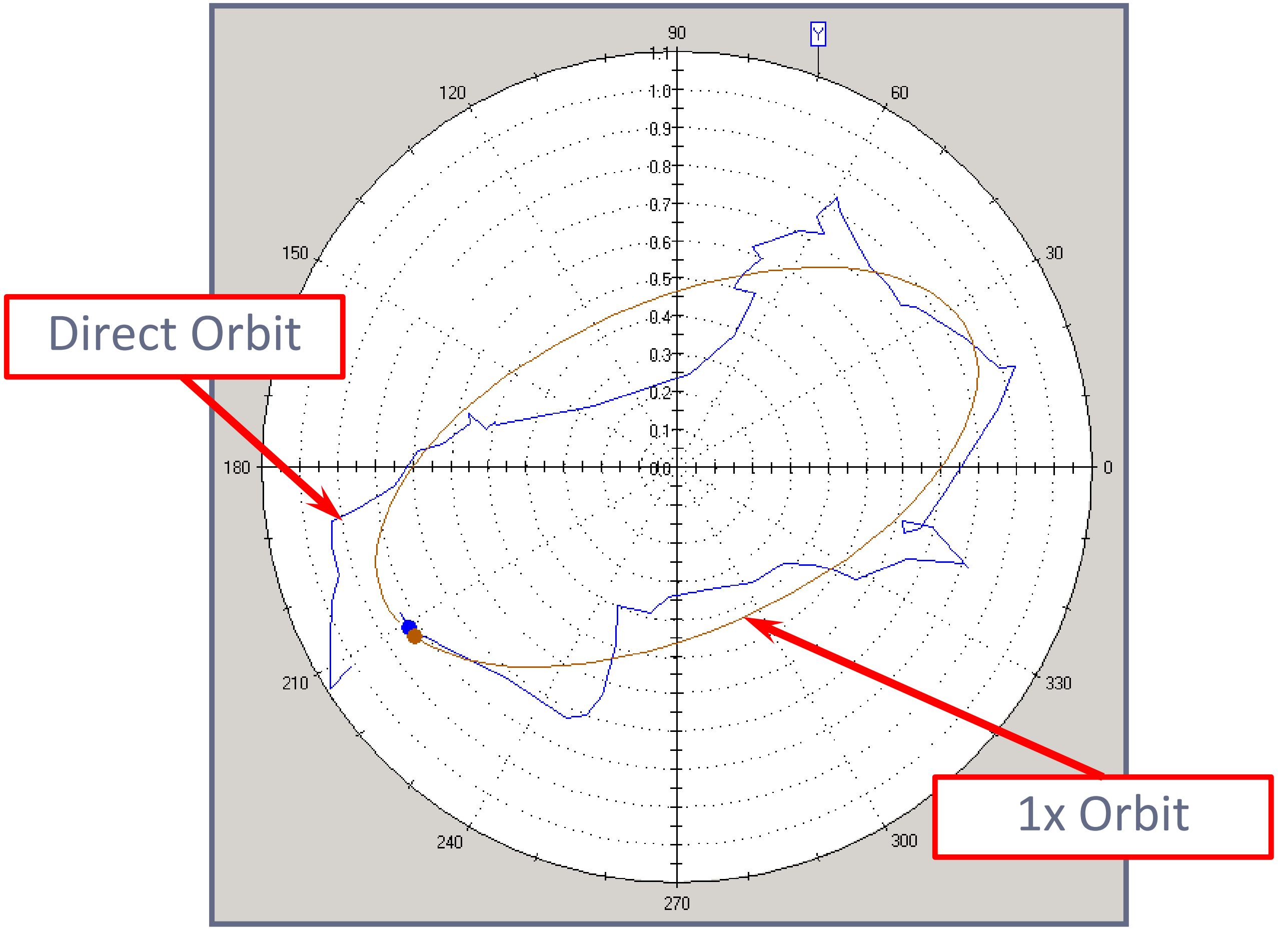
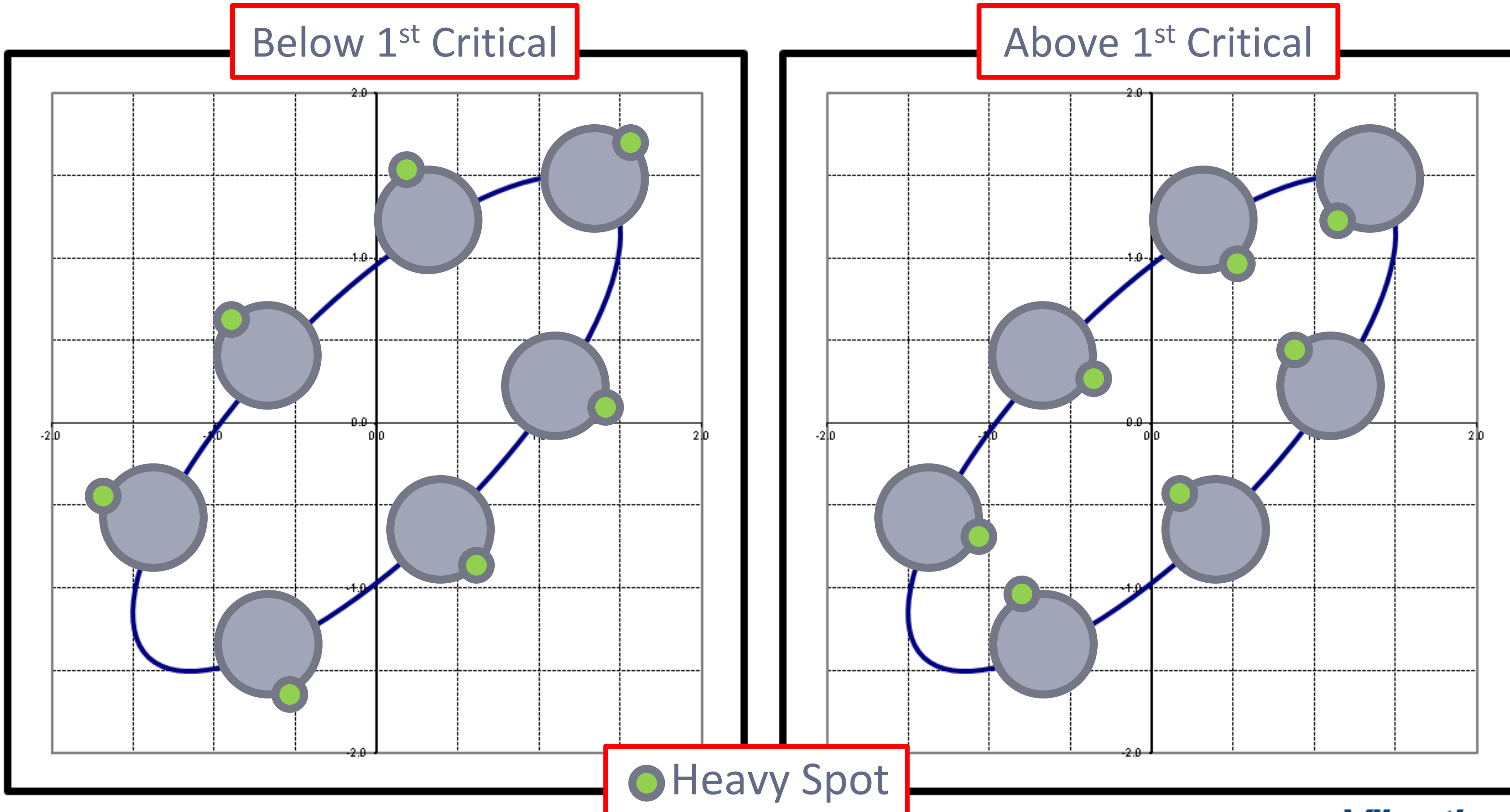
Sample Orbits



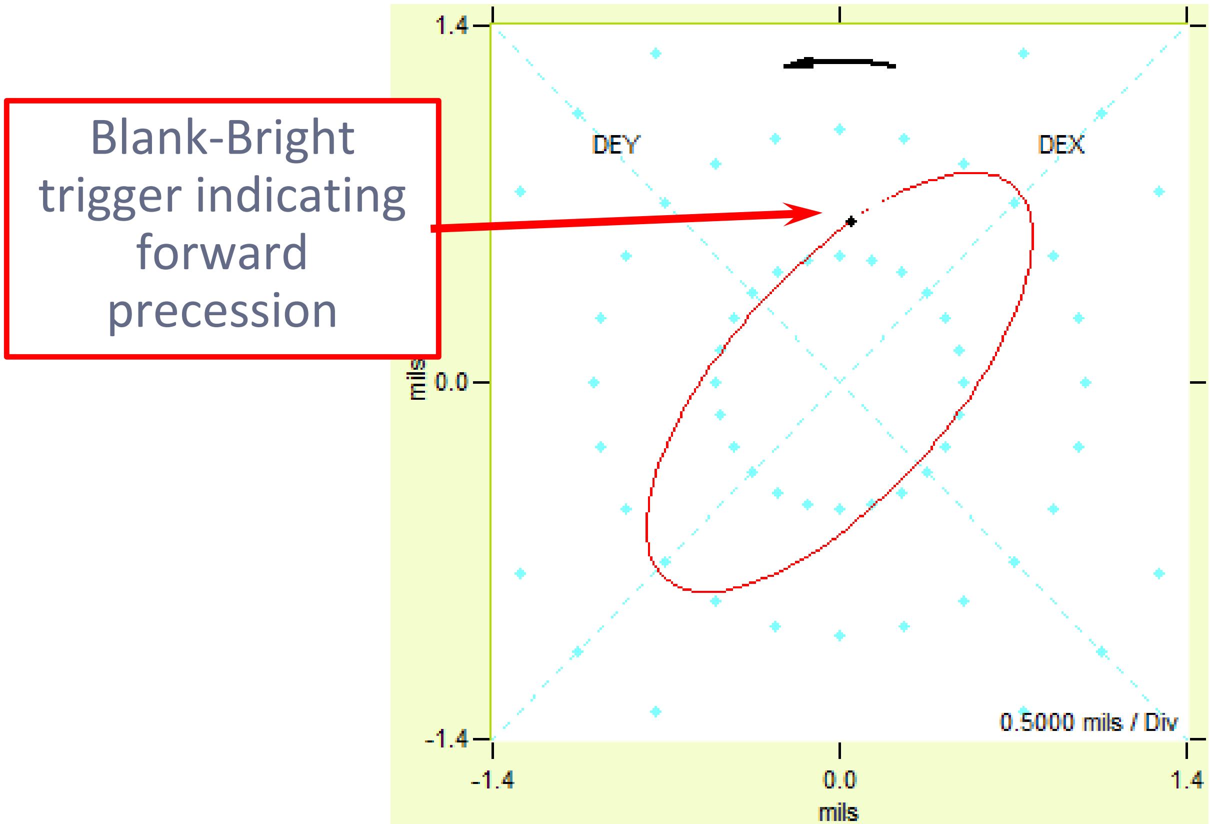
The 1X Orbit Due to Imbalance

- Well below the critical speed, the high spot is in phase with the heavy spot and both are on the “outside” of the orbit path
- Above the first critical speed, the heavy spot is on the “inside” of the orbit path. The high spot, by definition, remains on the “outside”



Orbit Phase Reference

- The location of the rotor when the phase reference trigger fires is indicated by the blank-bright mark on the orbit plot

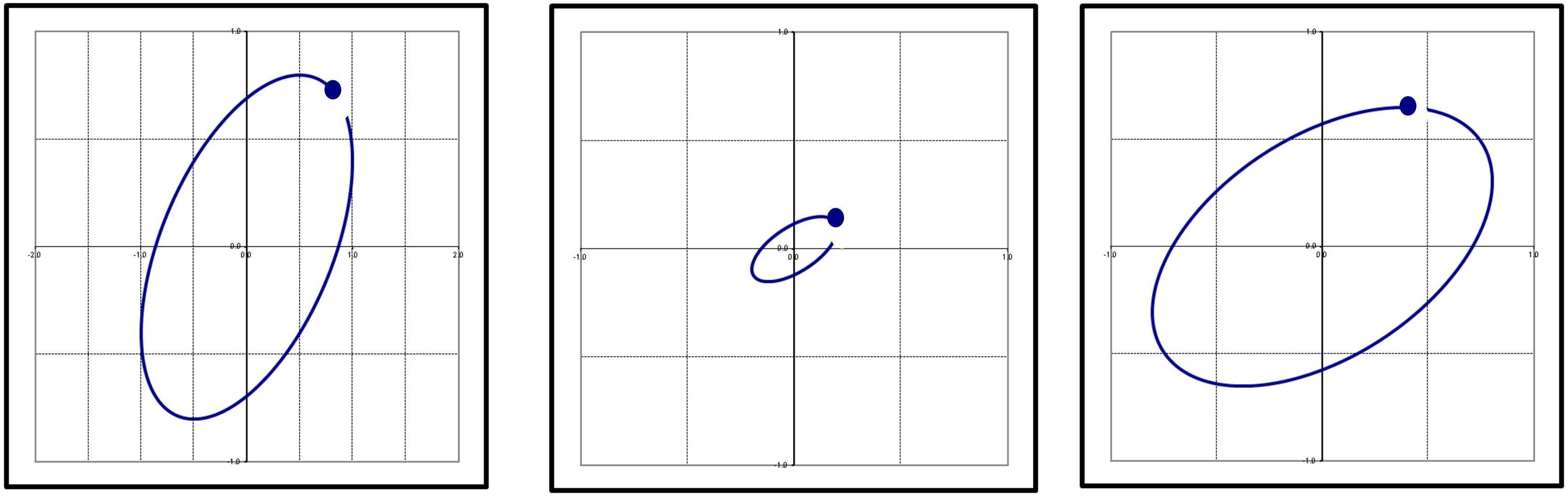


- The blank-bright orientation is the standard convention based on the use of the z-axis input for the trigger on an oscilloscope and a negative trigger pulse

Orbit Vector Compensation

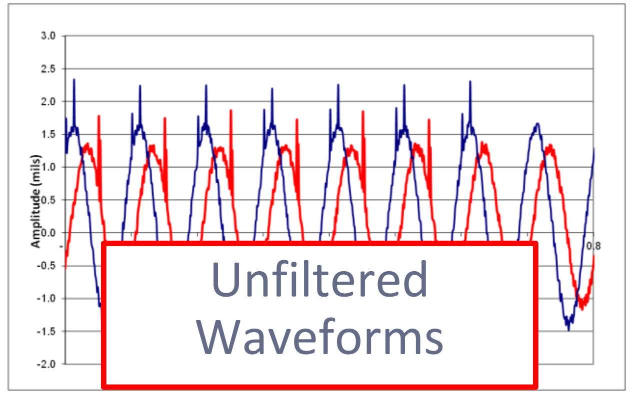
- Compensation allows us to remove any unwanted information from an orbit plot mathematically.
- Filtered 1X orbits can be vector compensated to subtract out the slow roll runout vectors from each probe

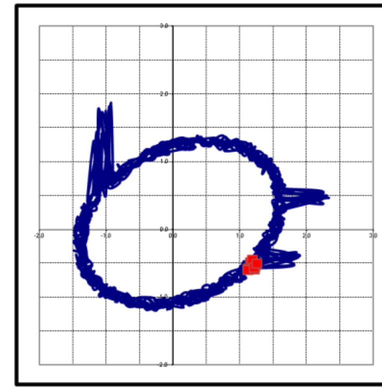
1X Orbit – 1X Slow Roll Vector Orbit = 1X Compensated Orbit



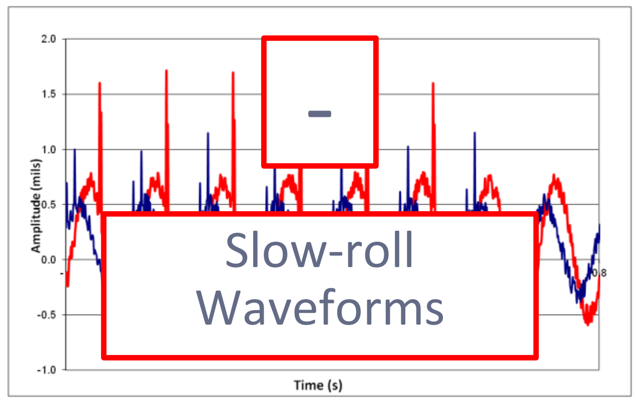
Orbit Waveform Compensation

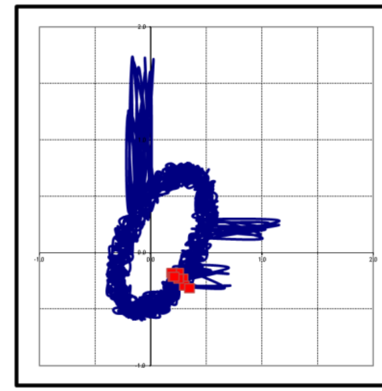
Waveform compensation can be used to eliminate "glitch" in orbit data caused by surface defects on probe target areas



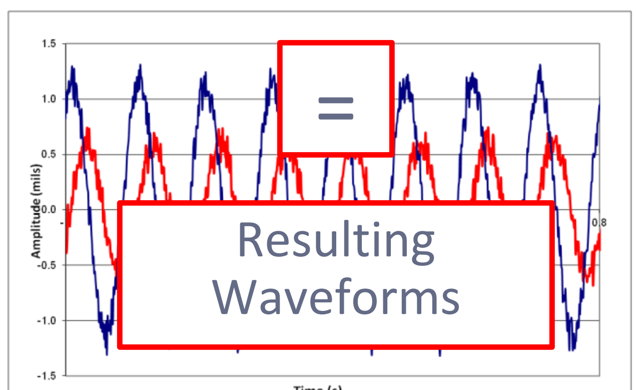


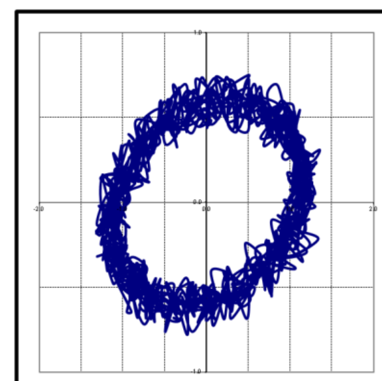
A slow-roll waveform is digitally subtracted from vibration waveform data using the trigger as a reference





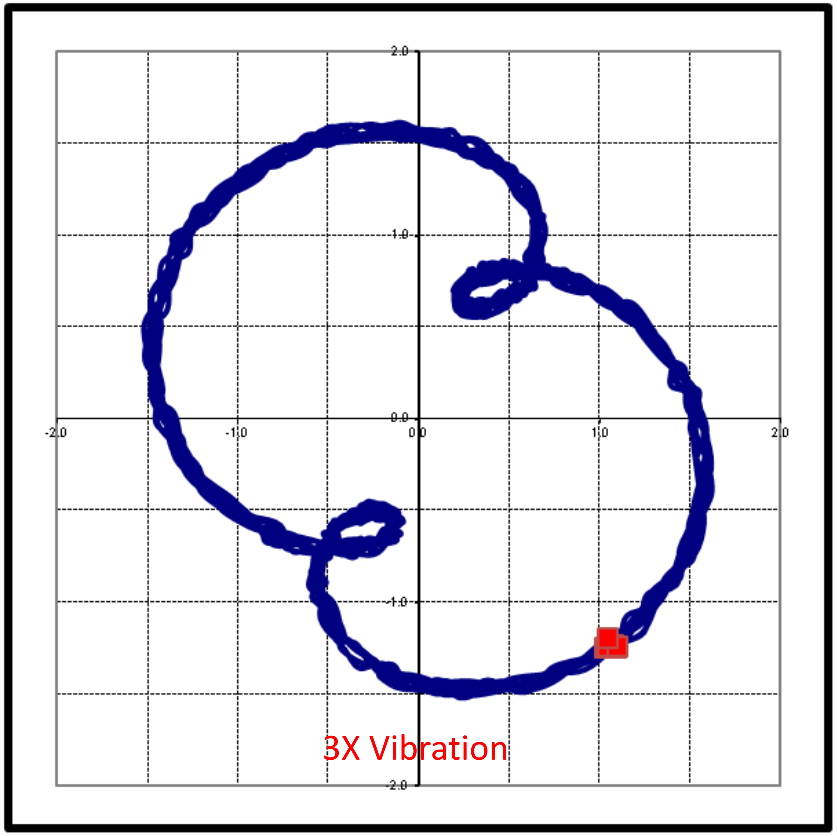
The resulting waveform includes actual shaft vibration and any noise in the signal

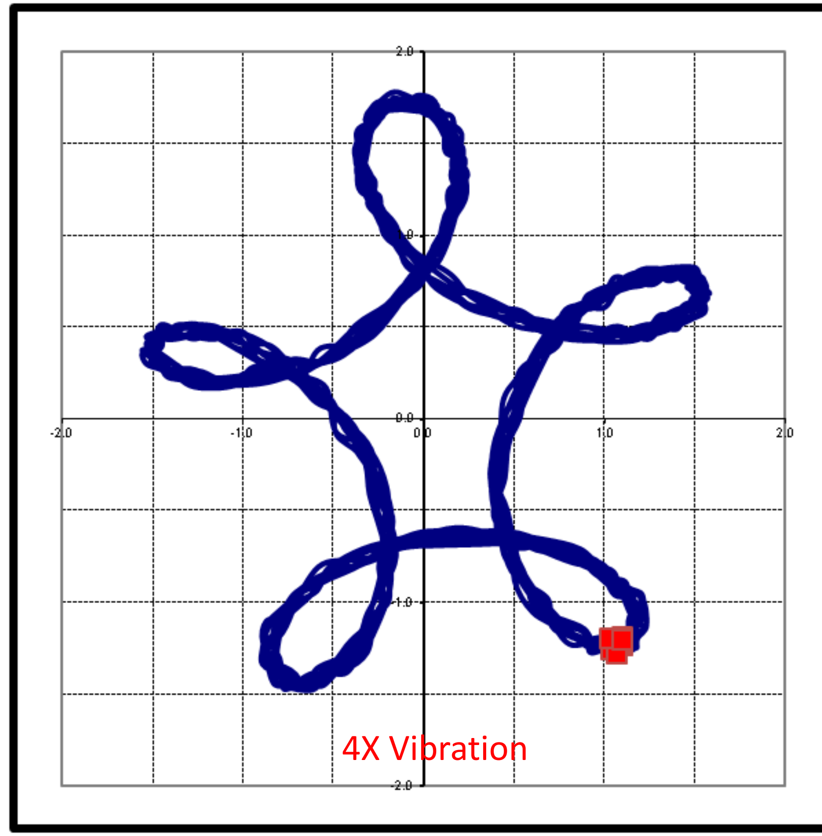




Orbit Plots – Loop Rules

- Loop rules can be used to determine vibration frequency when only one timing mark is present.





$$\text{Vibration Frequency} = \frac{\text{\# of Loops} \pm 1}{\text{Number Rotations}}$$

No. Rotations = No. Timing Marks

Internal:Add External: Subtract

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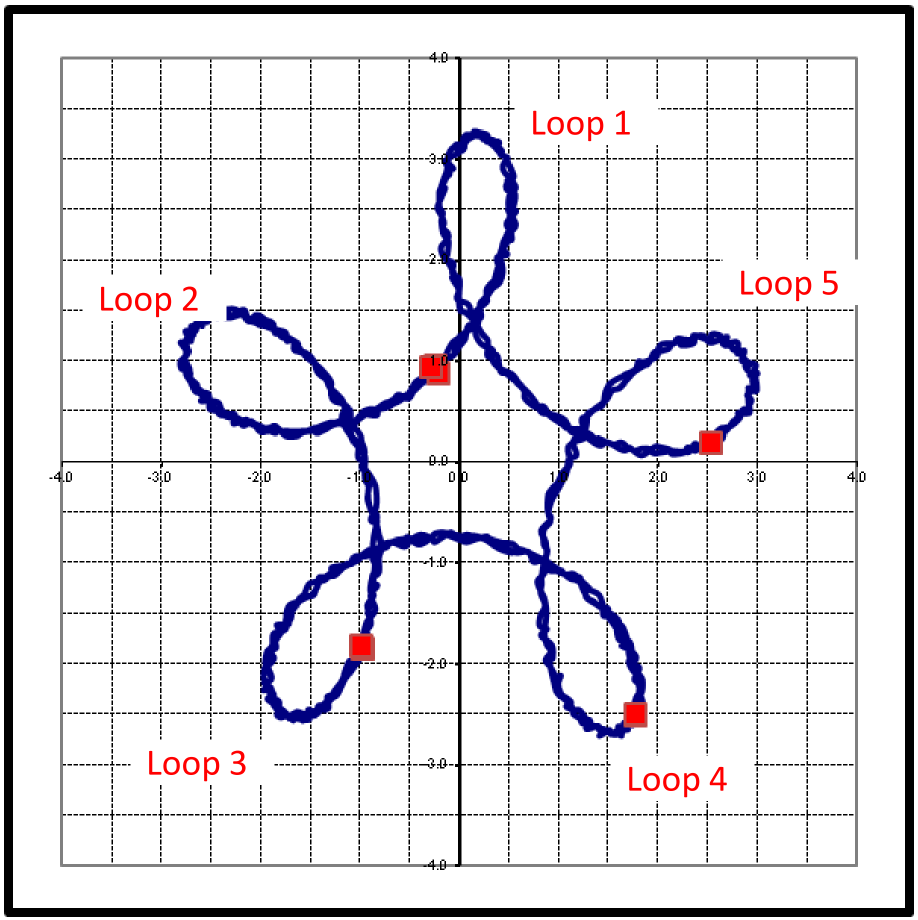
Orbit Analysis – Frequency Content

- Multiple timing marks indicate sub-synchronous vibration
- Frequency ratio can be determined by inspection



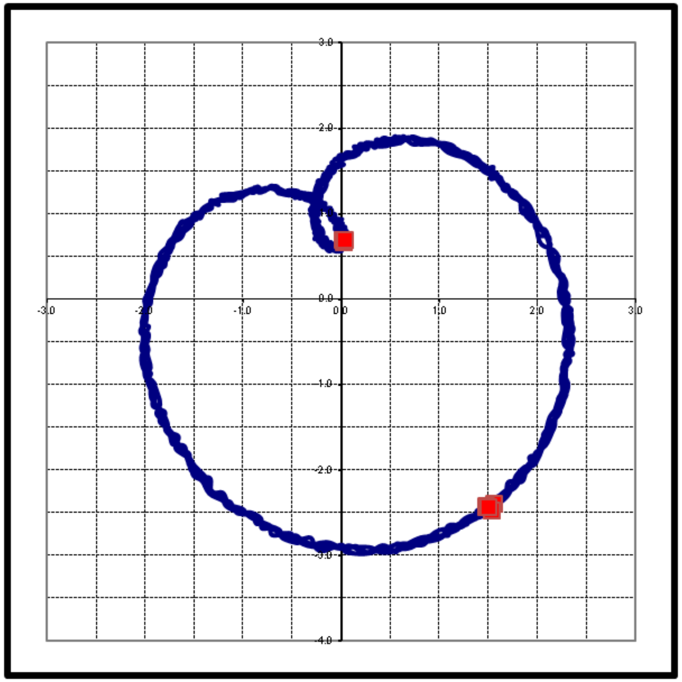
1/4X Vibration

Orbit Loops

- Loops indicate the presence of non-synchronous vibration
- External loops are caused by dominant forward precession of the non-synchronous components
- Internal loops are caused by dominant reverse precession of the non-synchronous components

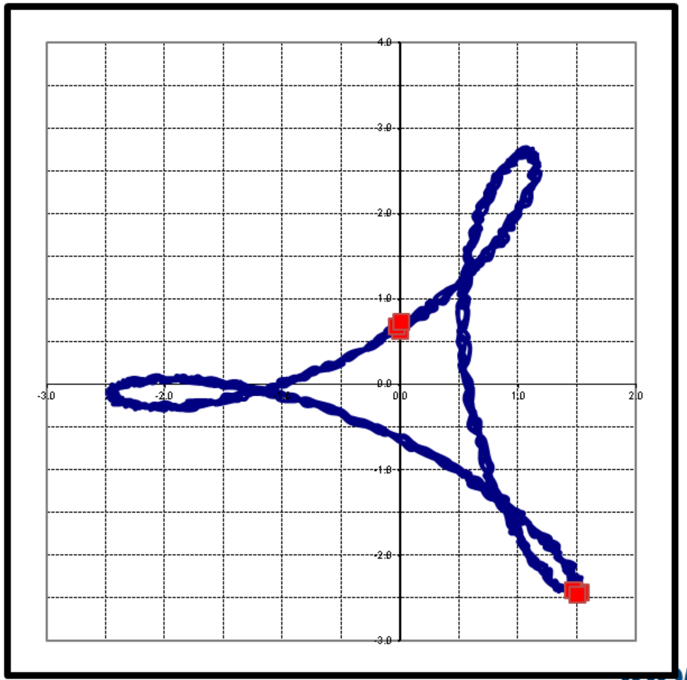
1X and 1/2X

Forward Precession



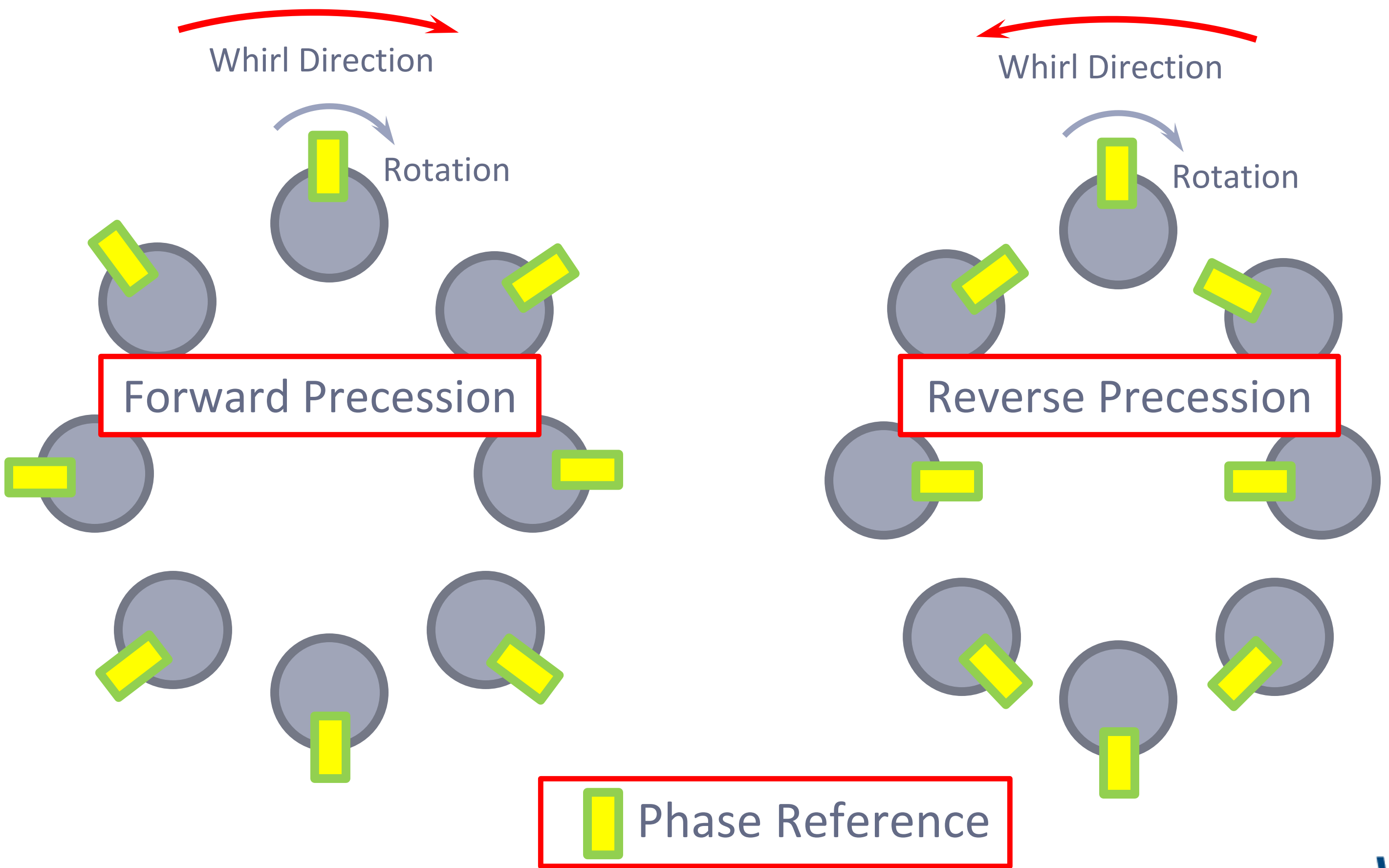
1X and 1/2X

Reverse Precession



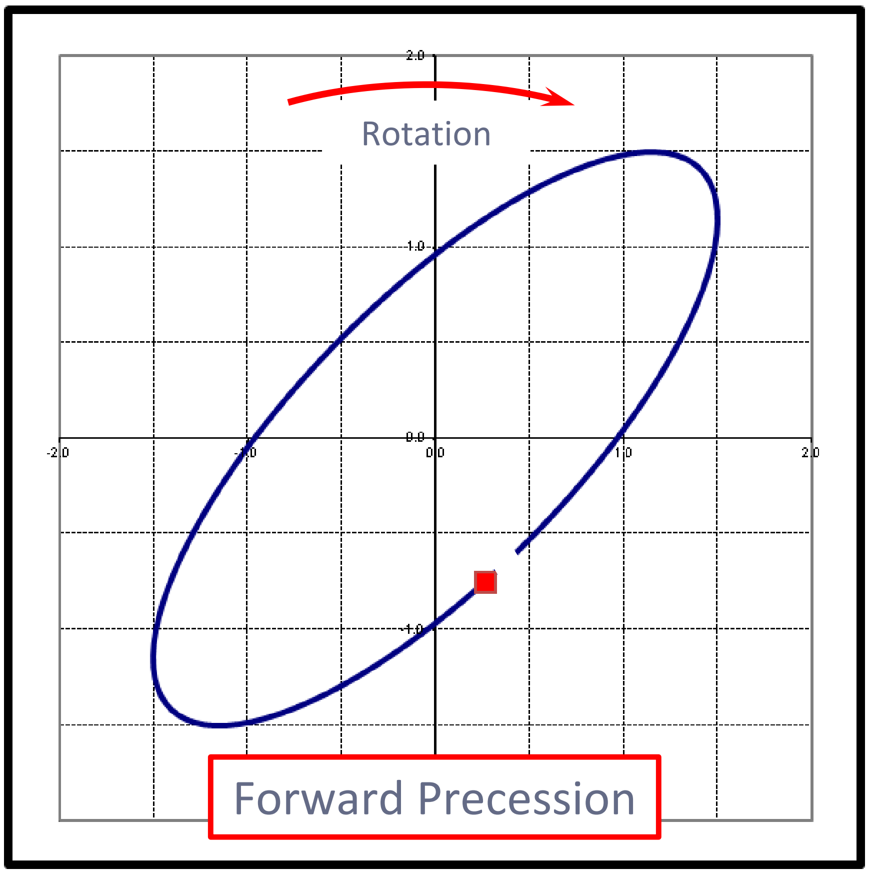
Forward and Reverse Precession

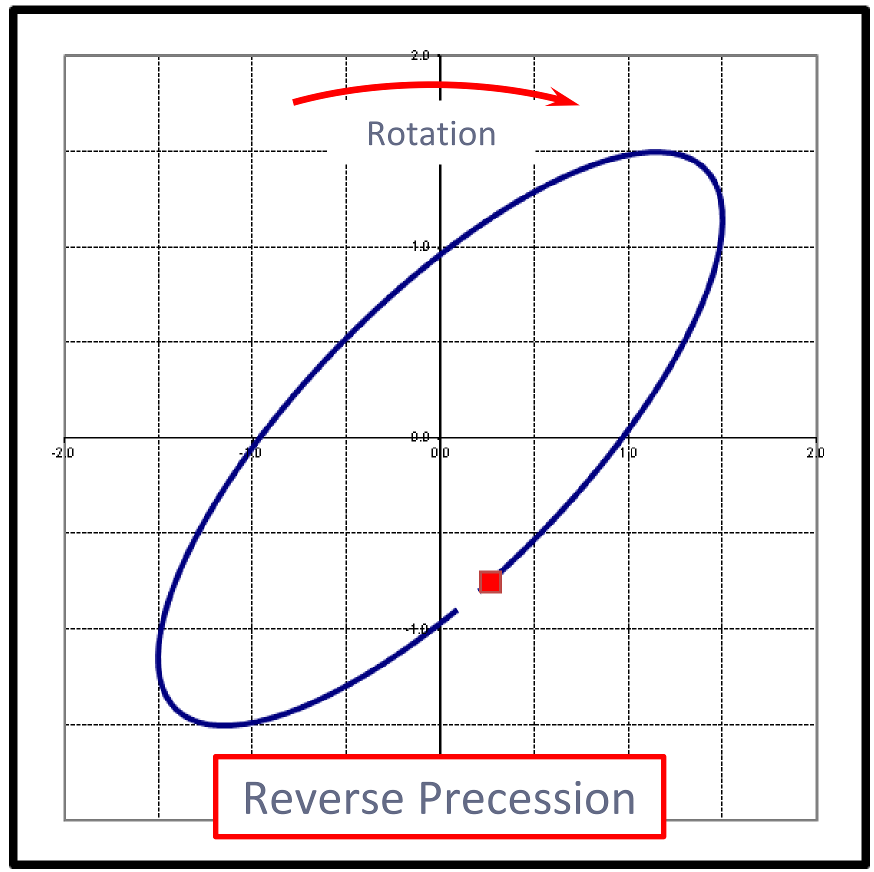
- Forward precession is the most common vibration observed. The shaft is whirling in the same direction as rotation.
- Reverse precession happens with the shaft is whirling in the opposite direction from rotation. This can happen during rubs or between split critical speeds.



Precession from Phase Reference

- The normal "Blank-Bright" convention indicates forward precession
- "Bright-Blank" phase marks indicate reverse precession
- Always check probe orientation and rotation direction!

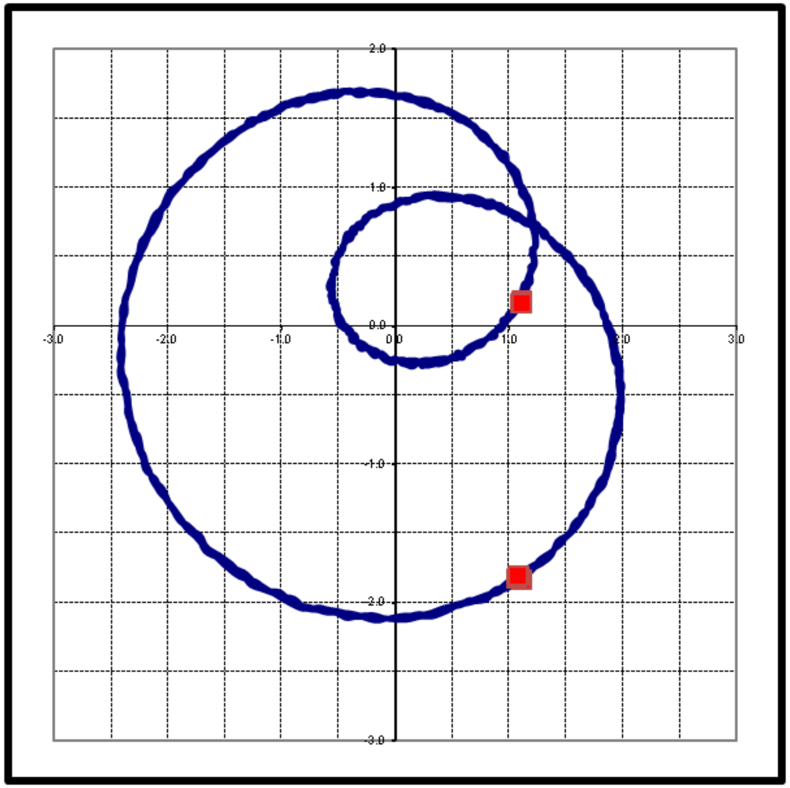




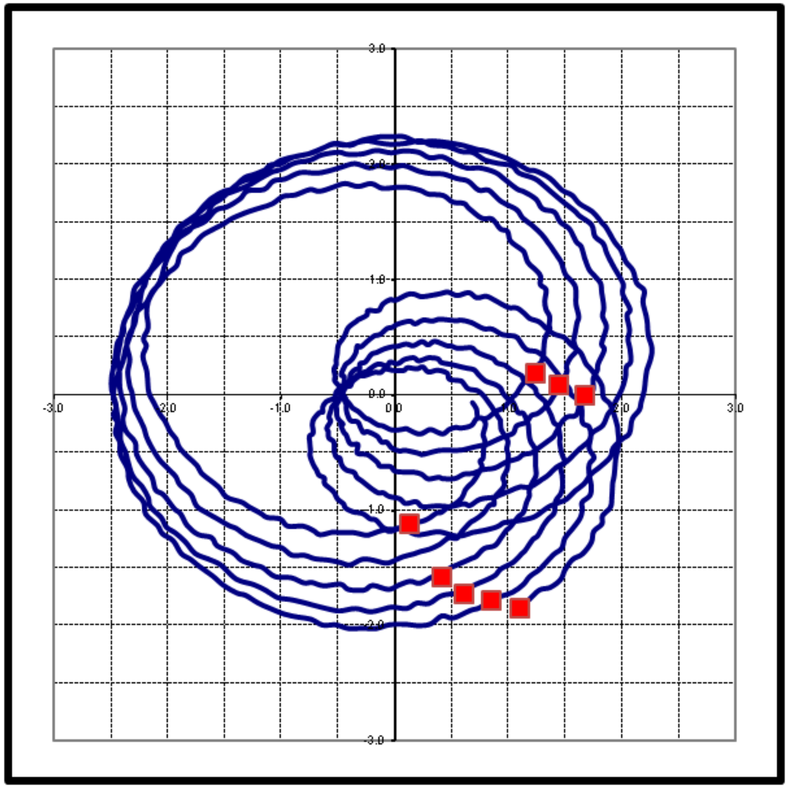
Orbit Analysis – Non-integer Components

- Shapes of orbits with non-integer multiples or sub-multiple components will be similar to exact integers but will be "skewed"
- The location of the phase reference mark will "rotate" along the orbit path

1X and 1/2X



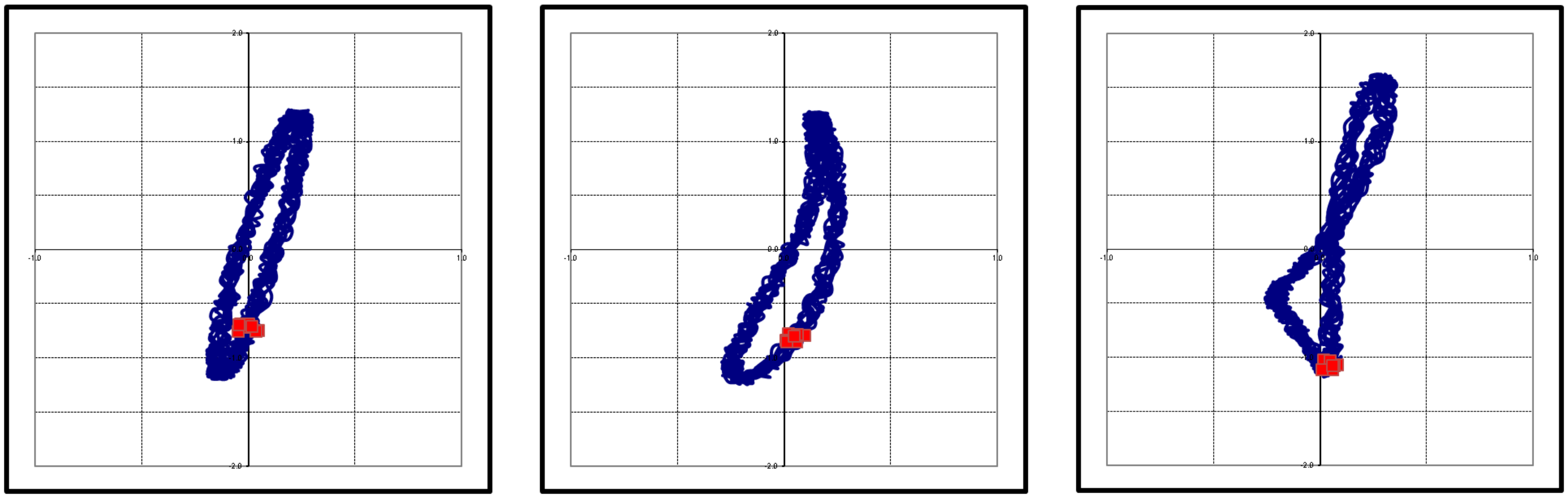
1X and 0.48X



Orbit Shapes

- The shape of the orbit can be used to evaluate any restrictions to motion that influence machine vibration.

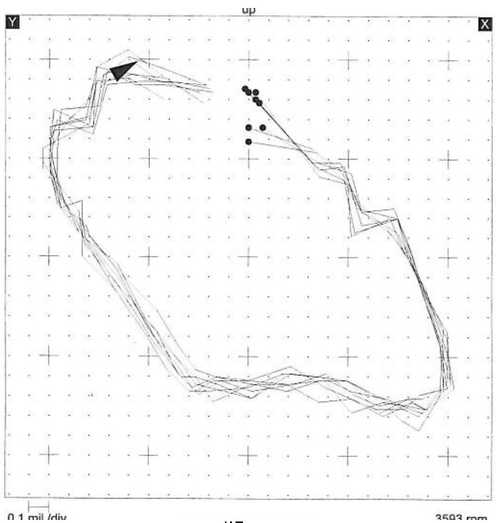
Misalignment

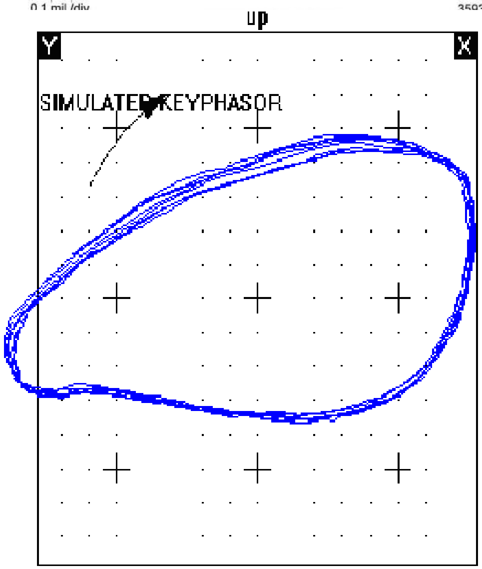


Increasing Severity →

Orbit Shapes

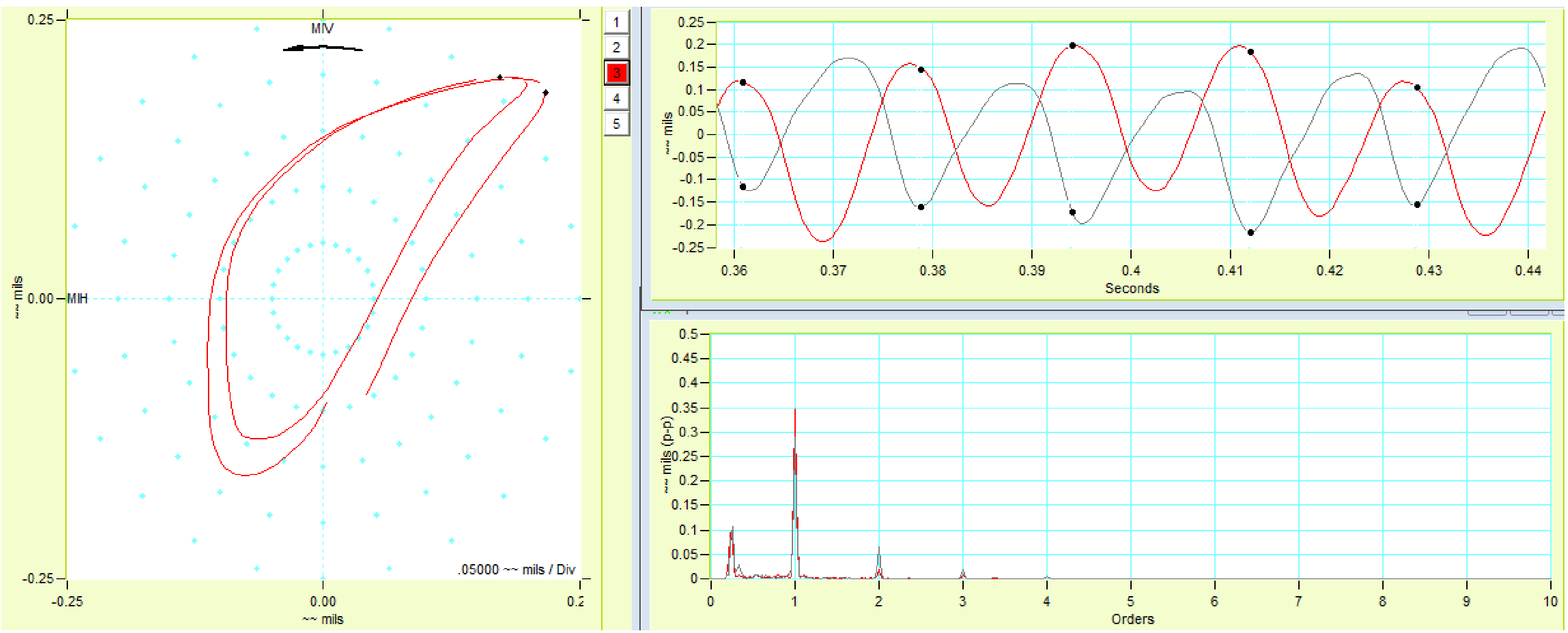
- Physical restraints internal to the machine can restrict shaft motion in the bearings. This can be identified using unfiltered orbits.





Pedestal Orbits

- Orbits can be generated from pedestal measurements when accelerometers are installed on a bearing housing.
- Pedestal orbits often contain frequency content associated with housing vibration that may or may not be present if measuring shaft vibration directly.

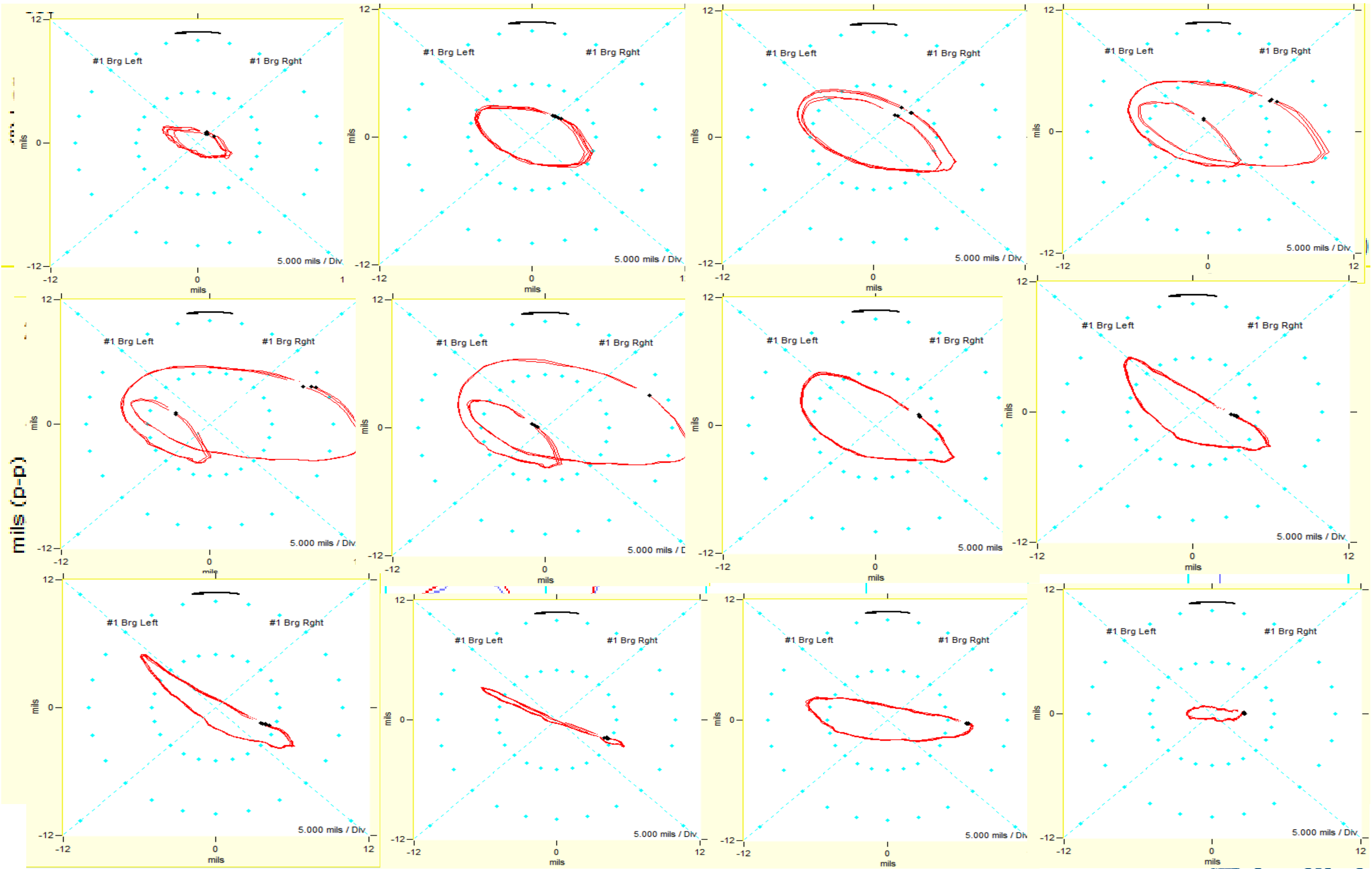


Field Data Collection

- Avoid pitfalls during data collection:
  - Verify collection parameters are adequate for the application (Fmax, No. of lines, etc.)
  - Verify probe orientation. Does your collector setup match physical location of probes? Are your cables crossed?
  - Check for the correct rotation direction.
  - Is your phase reference a positive or negative trigger?
    - A proximity probe looking at a keyway will produce a negative trigger.
    - A key will produce a positive trigger.
    - Most laser tachometers are selectable.

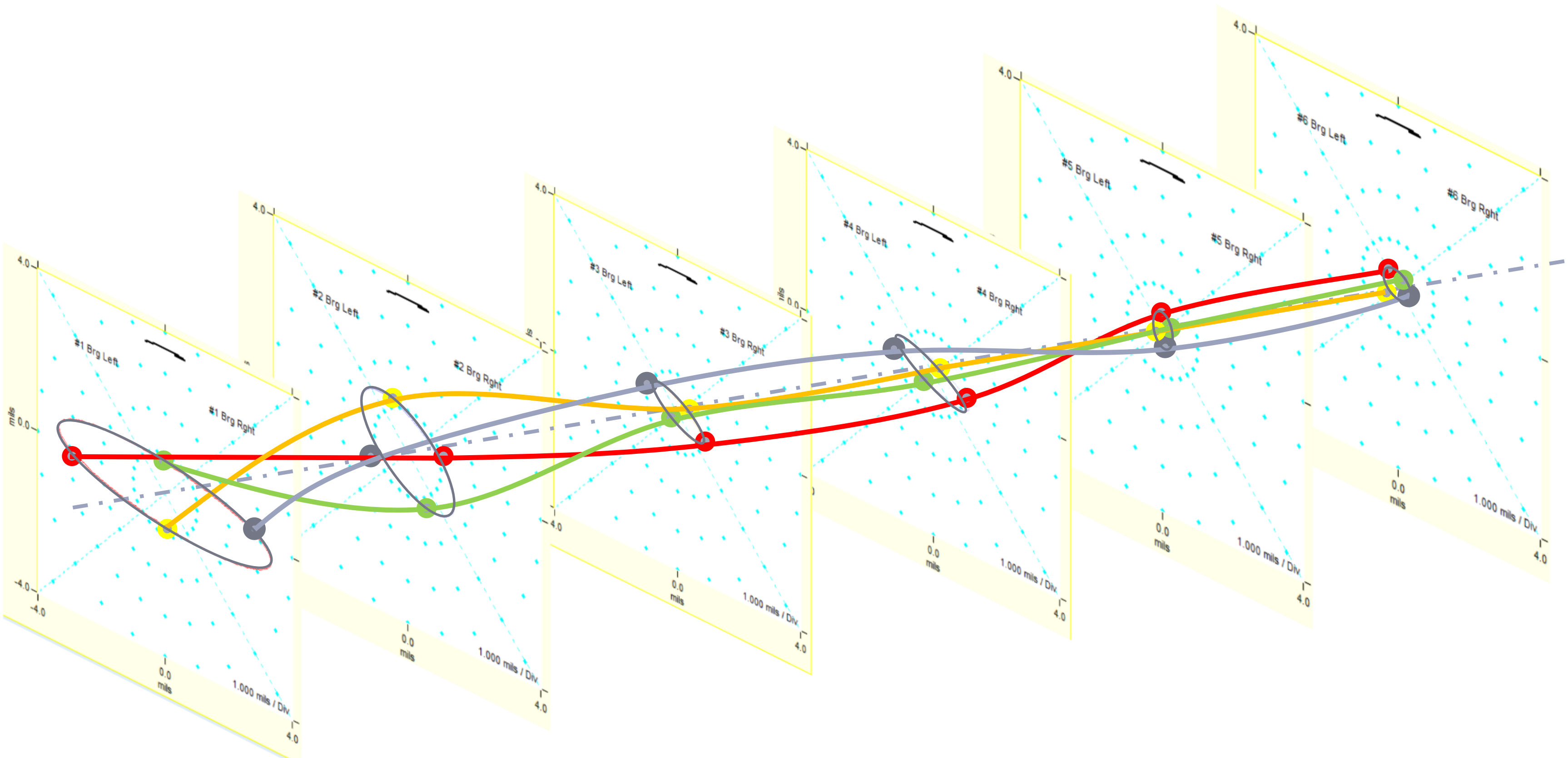
Field Data

- Many software packages will allow the analyst to view orbits to identify times, speeds, or loads where significant events occur.



Field Data – Operating Deflection Shapes

- 1X orbits can be used to estimate a rotor operating deflection shape when X-Y measurements are available at multiple axial locations



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Closing

- Orbit analysis is another useful tool to keep in your Analyst Toolbox
  - Use both Direct and Filtered (1X) orbits
  - Evaluate affect of vector or waveform compensation on orbit plots
  - Review frequency content apparent in orbits
  - Evaluate the shape of the orbit and what may be influencing this
  - Look for changes in orbit plots caused by time/speed/load changes

- Like any other analysis method, good conclusions can only be made from good data