





Prosig Noise & Vibration Blog

Telling you what you need to know about noise & vibration



[Home](#) [Who Are We?](#) [Contact Us](#) [Index](#)

Which Should I Use? Real & imaginary? Or magnitude & phase?

 Adrian Lincoln  May 4, 2011  signal processing  12
Comments

In [one of our recent articles](#) a question was asked regarding the practical use of real & imaginary type plots compared with modulus & phase type plots.

In general, noise or vibration signals are composed of one or more sinusoidal signals which can be quantified in terms of their magnitude (modulus) and phase components. These can be visualised as the result of a spectral transformation in the form of either a real & imaginary plot or a modulus & phase plot. The moduli & phases are directly related to the real & imaginary components. Real & imaginary is one way to visualise a complex number, modulus & phase is another way.

A sinusoidal vibration will have a magnitude which is the amount it is moving up and down. The phase component of the same signal is how much this sinusoid is delayed (in terms of an angle) compared with a reference sinusoid moving with the same frequency. This is an important point; the phase is only relevant if it is relative to a reference.

FREE HANDBOOK DOWNLOAD



**FREE
DOWNLOAD**

Download your free copy of the

Noise & Vibration Measurement Handbook

DOWNLOAD 

Sign up for our newsletter

Don't miss out on new posts & articles

Email Address

Say, for example, a simple, floating (free-free) beam has some form of sinusoidal excitation applied to one end of the beam and accelerometers are used to measure the responses at both ends. When both the phases are the same (at the excitation position and the response position) the ends of the beam will be moving up and down together as shown in Figures 1 and 2.



Figure 1



Figure 2

But when both the phases are not the same, the ends of the beam will be moving up and down at different times and the beam will pitch from side to side, as shown in Figures 3 and 4.



Figure 3

subscribe

Top Posts







-  What Are dB, Noise Floor & Dynamic Range?
-  A Simple Frequency Response Function
-  What Are AC and DC Coupling?
-  10 Sites That Every Engineer Should Know About
-  Converting Acceleration, Velocity & Displacement
-  How To Analyze Noise & Vibration In Rotating Machines



Figure 4

Now, to return to the original question, specifically about real & imaginary numbers:

A Real & Imaginary pair of numbers defines the position of the end point of a straight line drawn from the origin (0,0) of a two dimensional plot; one of the dimensions is the horizontal (real) part and the other dimension is the vertical (imaginary) part. This is known as **rectangular complex data**.

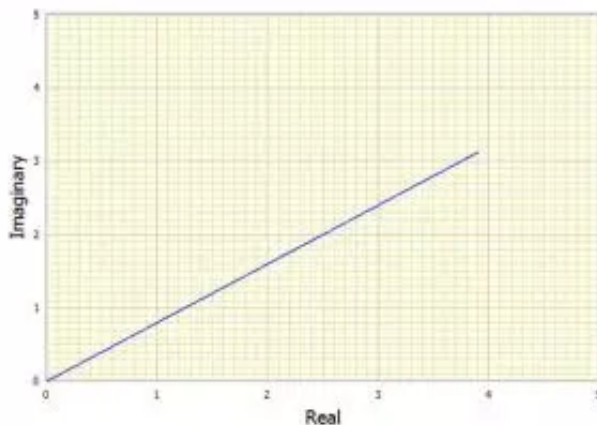


Figure 5: Real & Imaginary plot (rectangular complex)

Real & imaginary data can also be expressed in the form of a pair of modulus & phase numbers, this is also known as **polar complex**. In this form the modulus is the distance from the origin and the phase is the angle that the line makes with the horizontal axis.

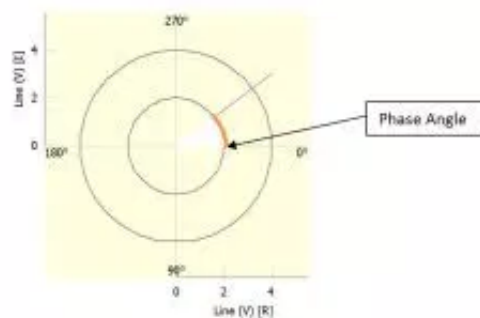


Figure 6: Modulus and Phase plot (polar complex)

Essentially they are two different representations of the same data. Figures 7 and 8 show a frequency spectrum first in rectangular complex form and then in polar complex form respectively.

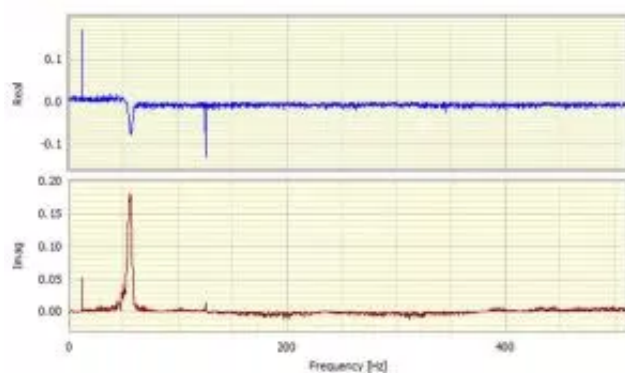


Figure 7: Real & Imaginary (rectangular complex)

The output of a Fast Fourier Transform (FFT) analysis of a time signal is a spectrum of complex (real & imaginary) numbers. However, the human mind better understands and can visualise more easily a complex frequency spectrum when the data is displayed in the form of a modulus & phase plot as shown in Figure 8.

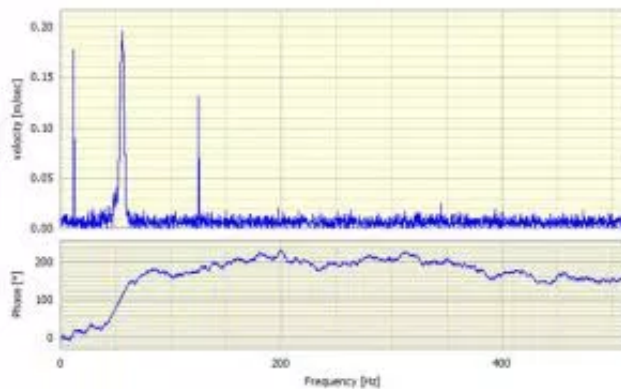


Figure 8: Modulus & phase (polar complex)

The same complex data can also be shown in two other ways: either by plotting the real spectrum versus the imaginary spectrum or the modulus spectrum versus the phase spectrum. This type of plot is commonly known as a **Nyquist plot** as shown in Figure 9 below. This combines the magnitude (modulus) and angle (phase) information into a single plot.

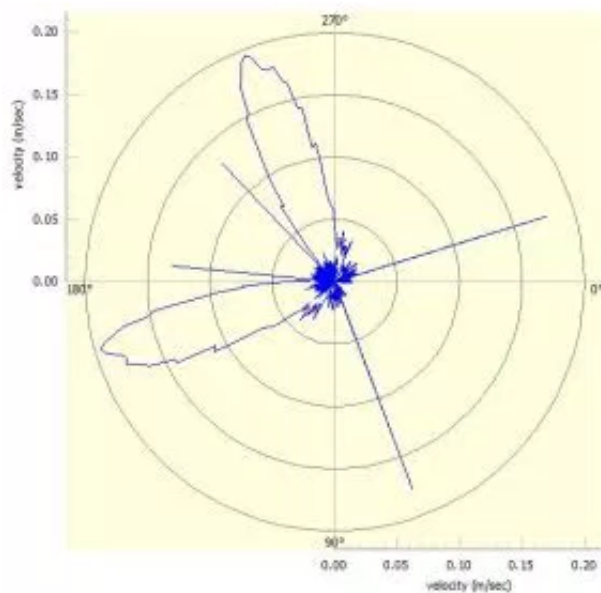


Figure 9: Modulus & phase as a Nyquist plot (polar complex)

The data at each point of Nyquist plot corresponds to the complex amplitude at a particular frequency. Usually the data being displayed would be some sort of frequency response function

which depicts how the response at a particular point varies in both amplitude and phase with changing frequency.

If a flexible structure is excited by a sinusoidal input force then in general the response in the time domain at any position will not be in phase with the excitation as shown in Figure 10 below.

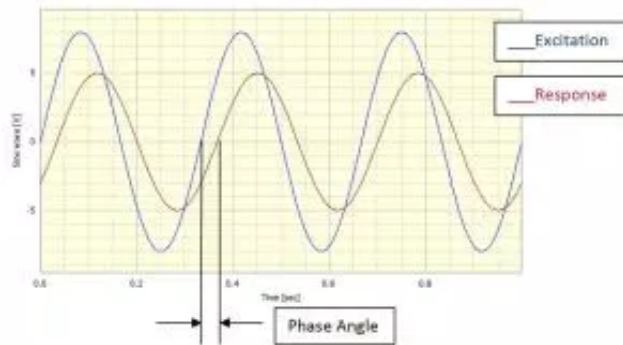


Figure 10: Phase Delay between Excitation and Response

From the time histories of the Excitation and Response the delay between the two signals can clearly be seen as both a time shift and a phase angle shift. In mathematical terms the response R_n at a single frequency f_n can be expressed as

$$R_n = A_n \sin(2\pi f_n + \phi_n)$$

The frequency response at all frequencies from zero to half the sampling rate can be represented by a modulus spectrum of A_n values and a phase angle spectrum of ϕ_n values.

Normally, in noise and vibration work, we would use the modulus & phase form of presenting data. So what is the practical application of using the real & imaginary form? A good example would be modal analysis. Modal resonances usually appear as circles when a **Frequency Response Function (FRF)** is plotted in real versus imaginary form or as clearly defined peaks when the FRF is plotted as a modulus spectrum. However, in some situations when there are two or more resonance frequencies close together the two peaks can merge into a single peak thereby giving the impression that there is just a single modal resonance when in fact there are

multiple resonances. By viewing an FRF as a Nyquist plot it is often easier to discern the presence of additional modes.

In our experience the modulus & phase form of display is by far the most widely used, and often the phase is not displayed at all. There are, however, cases where a real versus imaginary type of display shows phenomena that may be missed by the modulus & phase type of display.



Bio



Latest Posts



Adrian Lincoln

Signal Processing Technology Manager at **Prosig**

Adrian Lincoln is Signal Processing Technology Manager at Prosig Ltd and has responsibilities for signal processing applications, training and consultancy. He was formerly a Research Fellow at the Institute of Sound & Vibration Research (ISVR) at Southampton University. He is a Chartered Engineer and member of the British Computer Society and Institute of Mechanical Engineers.

Share:



29



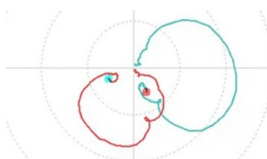
3



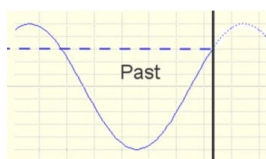
2



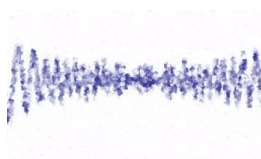
Related



Understanding
Phase



Negative
Frequencies -



Order Tracking,
Frequency and

Measurements**What Are They?****Hertz**

In "signal
processing"

In "signal
processing"

In "signal
processing"

✦ [accelerometer](#), [accelerometers](#), [complex](#), [imaginary](#),
[imaginary components](#), [magnitude](#), [modulus](#), [Nyquist](#), [phase](#),
[phase components](#), [phase type](#), [polar](#), [real](#), [sinusoid](#), [sinusoidal](#)
[excitation](#), [sinusoidal signals](#), [vibration signals](#)

← Visit Prosig at 2011 SAE Noise & Vibration Conference

New version out now - DATS V7.0.19 Released →

12 thoughts on "Which Should I Use? Real & imaginary? Or magnitude & phase?"

1.



Roman Vinokur

May 19, 2011 at 6:46 pm

"In our experience the modulus & phase form of display is by far the most widely used, and often the phase is not displayed at all."

Agree.

The phase may be important in experimental modal analysis while using two or more accelerometers. In particular, the phase difference can describe the vibration mode if the modulus measurements are similar.

"There are, however, cases where a real versus imaginary type of display shows phenomena that may be missed by the modulus & phase type of display."

Such cases should be rare. The real physical information is given the modulus and phase.

 Reply

2.

**Prasad**

July 10, 2011 at 6:08 pm

Hello Adrian,

Can you explain in detail how to read the Nyquist plot.

 Reply

3.

**J. Mark Wolf**

July 13, 2011 at 12:32 pm

One common application for the magnitude and phase approach is balancing airplane propellers and helicopter rotors. Where, of course, the only frequency of interest is the fundamental frequency of rotation. Everything above this threshold is typically filtered out.

I've had a great deal of difficulty in finding learning material on the web, describing this balancing process, and the attendant DFT process for identifying the magnitude and location of the "heavy spot".

Can you recommend a source of information, for the layman, of the basic process and technology used in balancing such rotating machinery?

 Reply

4.

**Peter M**

July 13, 2011 at 11:17 pm

Honestly, dude, if you do not understand that concept you should be kept very far away from all important machinery. (leave it to smart people to do)

 Reply

5.

**Philippe Hamsand**


July 14, 2011 at 6:51 am

My personal experience is that the best approach to understand the FRFs is to go back to the basics. The FRF can show displacement, velocity and acceleration. They are all related but shifted in phase. Whether to watch imaginary part or real part depends what you are using and what are you expecting from the analysis. But if you forget the analysis itself and go back to mathematics and the basic rules and reasons for usage of the complex numbers in analysis then everything will be clear.

Regarding Prasad's question of Nyquist plot (which I generally don't use other than in teaching the basics) I really recommend the following book: ISBN-13: 978-0470746448 Anders Brandt, Noise and Vibration Analysis: Signal Analysis and Experimental Procedures

I need help with procedures where a linear system is connected to non-linear. The linear system is defined by its FRF and the non-linear is assumed to be SDOF with non-linear spring and viscous damper as well as frictional damping. Maybe I should mention that I work with silicone rubber based tuned mass dampers for automotive industry and experience Fletcher-Gent (amplitude dependency) effect in the rubber.

↳ Reply

6.  **Prasad**
July 14, 2011 at 5:02 pm
Philippe,

Thank you very much for the info.

↳ Reply

7.  **Chris Mason**
July 15, 2011 at 6:57 am

Peter M

Honestly, dude, if you do not understand that concept you should be kept very far away from all important machinery.

(leave it to smart people to do)

Peter, I'm sure your comment was intended to be tongue in cheek, but please remember that a lot of people come here to learn and we all have to start somewhere. I remember a time when even I wasn't a genius. 😊

↳ Reply

8.

**ravi**

February 16, 2013 at 5:22 am

wonderful explanations. thanks.

↳ Reply

9.

**balaji**

January 6, 2015 at 8:41 pm

Can you explain real & imaginary axis concept by simulation

↳ Reply

A.

**Chris Mason**

January 7, 2015 at 7:11 am

Hello balaji

There is a good explanation of complex numbers on Wikipedia here...

http://en.wikipedia.org/wiki/Complex_number

I hope that helps you.

↳ Reply

10.

**balaji**

January 13, 2015 at 7:57 pm

is there any animation video clip of real & imaginary frequency

↳ Reply

A.

**Chris Mason**

January 14, 2015 at 8:53 am

Hi balaji

Try using Google or another search engine to search for something like "**complex numbers frequency animation**". You will find many results for what you are looking for.

[↩ Reply](#)

Leave a Reply