# Administrative

- MATLAB2 due tonight – questions?
  - –Sinc: need logic to handle case of x=0 in sin(x)/x
  - –floats: a == b will fail if a=2, b = 2.000000000001 instead, use abs(a-b) < 1e-6 (or some small #)
- Quiz 1: MATLAB1, MATLAB2, HW
  - Will post HW solution to today's HW after class; will also post a recent year's quiz 1
- I haven't located an extra book to put on hold. Are you all figuring out how to get access to books?

# EE-125:
# Digital Signal Processing

## Lecture 8:
## LTI systems –
## Geometric interpretation of pole/zeros plots

## Group velocity and dispersion

Tufts

# Outline

- Quick review geometric interpretation of pole/zero diagrams – another phase example
- Linear and nonlinear phase systems (5.3)

- Next lecture:
  - Filter design via pole/zero placement (P&M 5.4)

# Geometric interpretation of H(ω)

- The magnitude of H is the *product* of the individual magnitudes:

$$| H(\omega) | = |G| \frac{\prod_{k=1}^{M} |e^{j\omega} - z_k|}{\prod_{k=1}^{N} |e^{j\omega} - p_k|}$$

The individual magnitudes are the distances between the pole or zero and points on the unit circle.

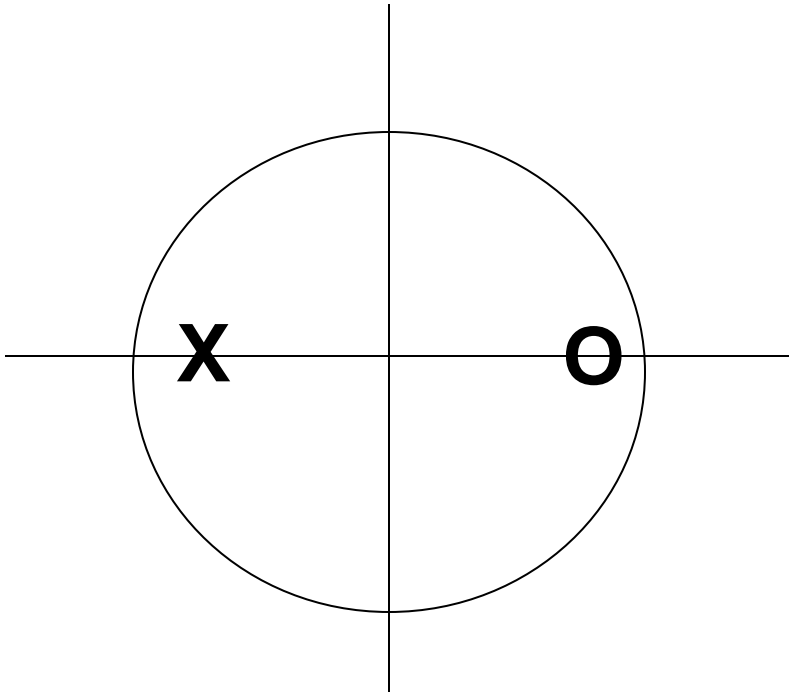
- The phase of H is the *sum* of the individual phases:

$$\angle H(\omega) = \angle G - \omega(N - M) + \sum_{k=1}^{M} \angle \left(e^{j\omega} - z_k\right) - \sum_{k=1}^{N} \angle \left(e^{j\omega} - p_k\right)$$

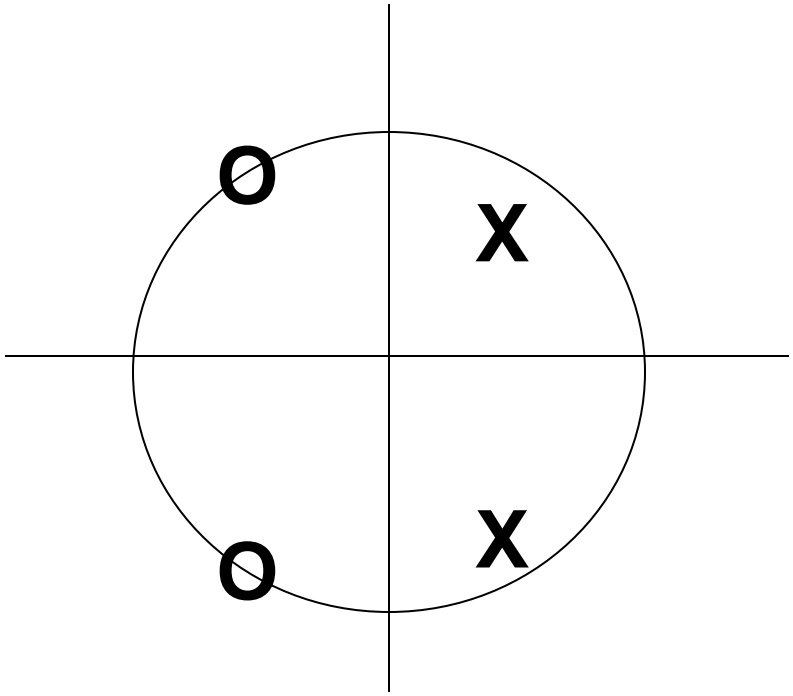
The individual phases are the angles between each pole or zero and points on the unit circle

# Think about rough sketch of magnitude

Magnitude ONLY



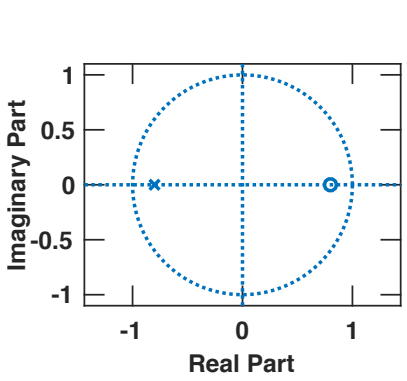

Magnitude ONLY

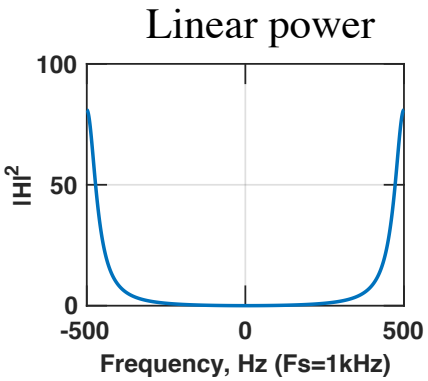


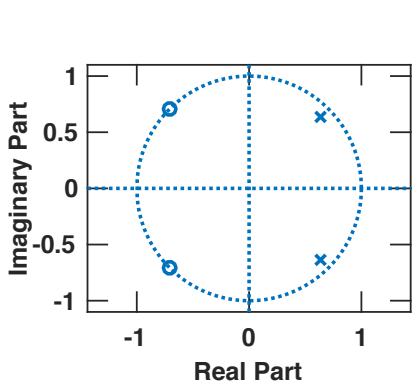

1) Are these FIR or IIR?

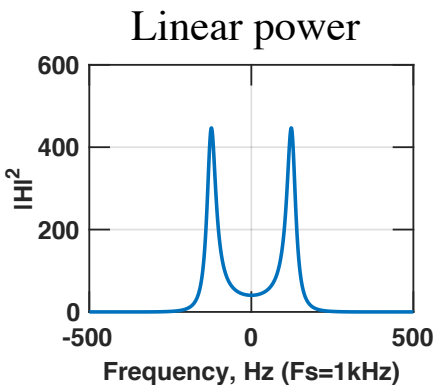
2) If these systems are stable, what else can you say about them?

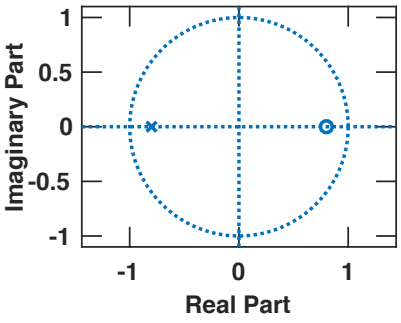
# Calculated values (putting x/o at 0.8, except for zeros on unit circle)

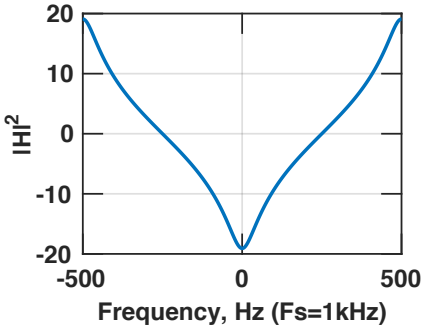


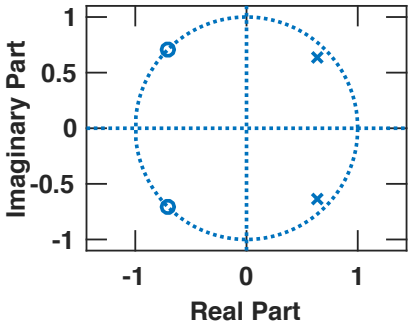



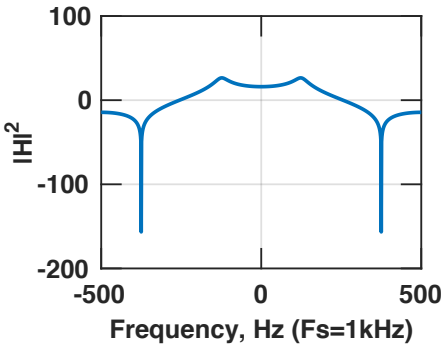



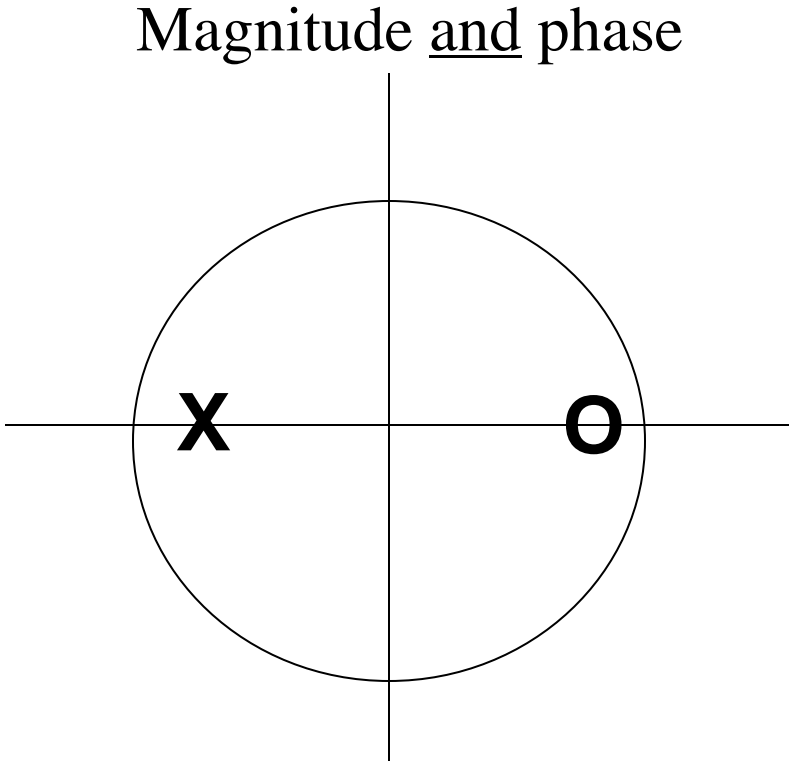




Usually more informative to plot magnitude responses or powers in dB

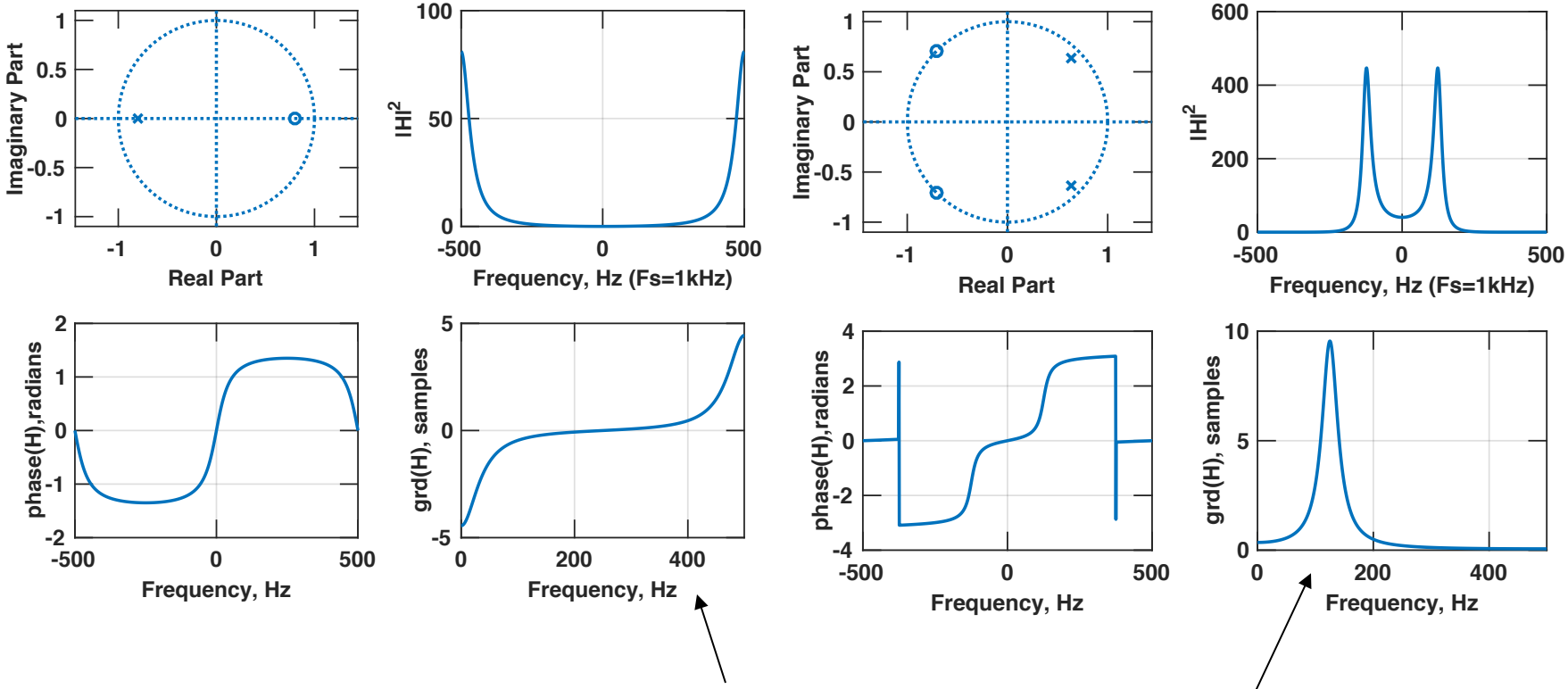
Power,dB = $10*\log10(|X(\omega)|^2) = 20*\log10(|X(\omega)|)$

Tufts

# Do on board: roughly sketch phase response



# Calculated values (putting x/o at 0.8, except for zeros on unit circle)




Ignore these two plots for now

# Outline

- Geometric interpretation of pole/zero diagrams
- Linear and nonlinear phase systems
- Next lecture:
  - Filter design via pole/zero placement (P&M 5.4)

Video covering (basically) same material as today:
https://youtu.be/hri7c5bm-_c (_c, not 'space' c)

A few differences:
- writes $H(e^{j\omega})$ instead of $H(\omega)$

# Dispersion in natural systems

- Water waves (physics -> low freq are fastest)

https://youtu.be/T9QwiBFN9gI

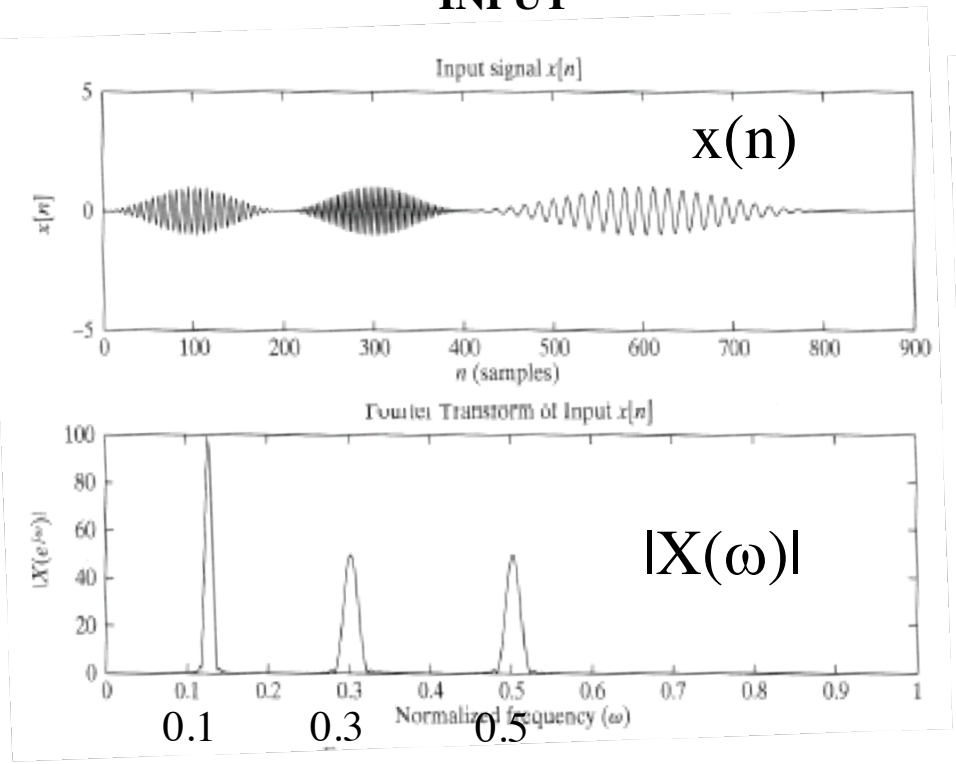
- Ice cracking sounds (physics -> high freq are fastest)

http://silentlistening.wordpress.com/2008/05/09/dispersion-of-sound-waves-in-ice-sheets/

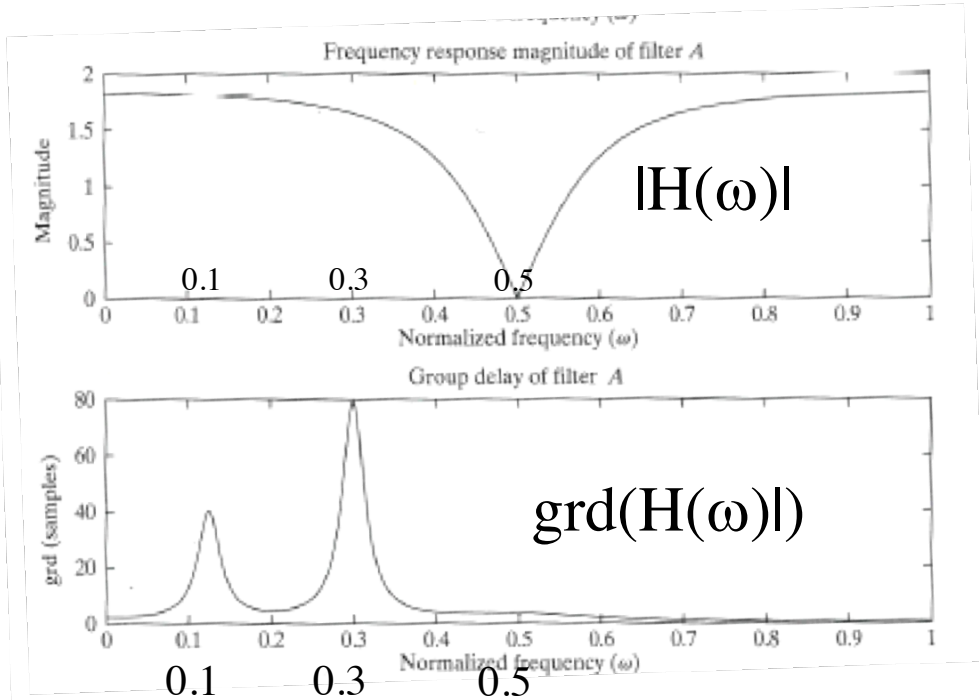
# Water wave dispersion (from https://youtu.be/lWi_KpBy8kU)

# In-class problem – given this input and this system, sketch output

**INPUT**




**SYSTEM FREQ RESPONSE**




Which input pulses survive? All, none, or just some?
How are the surviving pulses (if any) delayed?

Tufts