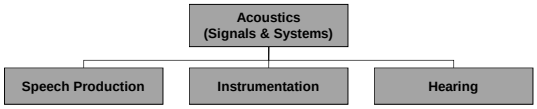
Acoustics of Speech and Hearing

Lecture 5
Frequency Response

Acoustics



- Week 2 – waveform, decibel
- Week 3 – period, frequency, sinewave
- Week 4 – fundamental frequency, harmonic, spectrum
- Week 5 – frequency response

Signals Review

- Classification
  - Simple & complex periodic waveforms
  - Impulsive & noise aperiodic waveforms
- Spectral analysis
  - Complex periodic waveforms analysed into a sum of harmonics (sinewaves at multiples of fundamental frequency)
  - Spectrum shows which sinewaves to add together to make waveform

Signals Review

- Loudness
  - related logarithmically to intensity
- Pitch
  - related to fundamental frequency
- Timbre
  - related to amplitude of harmonics
    (for complex periodic waveforms)

Overview

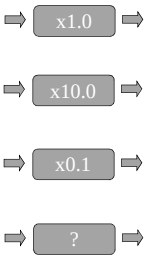
- Signals and systems
- How can we measure systems?
- Frequency response graph
- Frequency response of a simple resonator

Signals & Systems

- Signal
  - physical form of a waveform
  - e.g. sound, electrical current, radio wave
- System
  - a channel that changes a signal that passes through it
  - e.g. a telephone connection, a room, a vocal tract

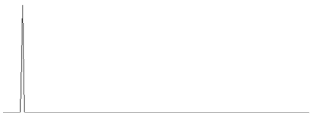
Simple Systems

- A piece of wire
  - does nothing!
- An amplifier
  - increases amplitude
- An attenuator
  - decreases amplitude
- BUT A simple resonator
  - does what to a signal?



Pulse into Simple Resonator

- Input Signal (Pulse)



- Output Signal (Damped Sinusoid)

Sinewaves into Simple Resonator

Response to Sinusoids

Description	Input	Output
Sinewave below natural frequency		
Sinewave at natural frequency		
Sinewave above natural frequency		

Define "Response"

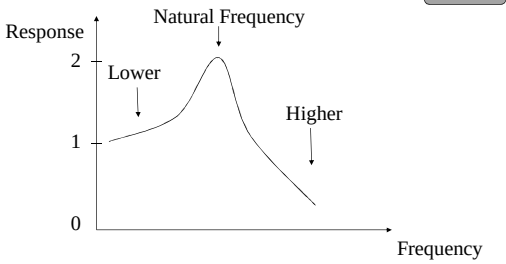
- Mathematical expression of change of amplitude

$$\text{Response} = \frac{\text{Output Amplitude}}{\text{Input Amplitude}}$$

- Usually expressed in decibels

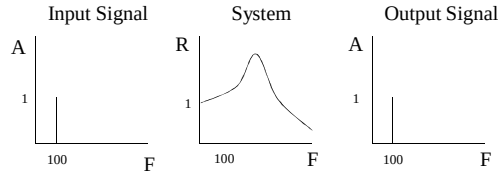
$$\text{Response (dB)} = 20\log_{10}\left(\frac{\text{Output Amplitude}}{\text{Input Amplitude}}\right)$$

Simple Resonator Response



Frequency Response Graph

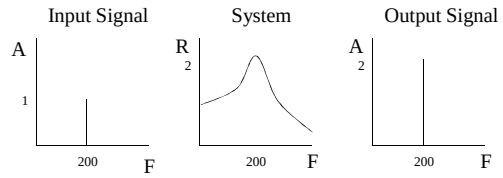
Frequency Domain Description



Output = Input × Response

Frequency Response Graph

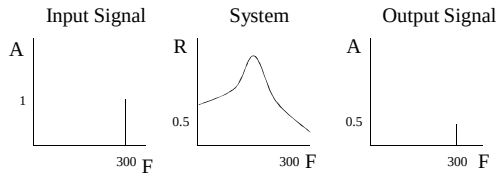
Frequency Domain Description



Output = Input × Response

Frequency Response Graph

Frequency Domain Description



Output = Input × Response

Frequency Response Graph

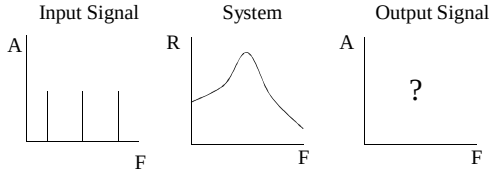
- Shows how *response* of a system to sinewaves varies as a function of frequency
- But can use to characterise how a system changes **any** signal **since any signal can be considered a sum of sinewaves**!

Output amplitude = Input amplitude × Response

Output spectrum = Input spectrum × Frequency response

Frequency Response Graph

Frequency Domain Description

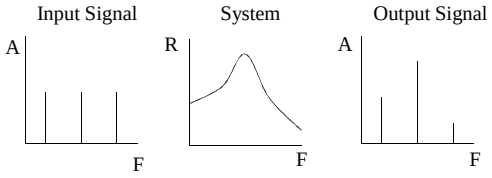


Input × Response = Output

⇨ Frequency Response ⇨

Frequency Response Graph

Frequency Domain Description



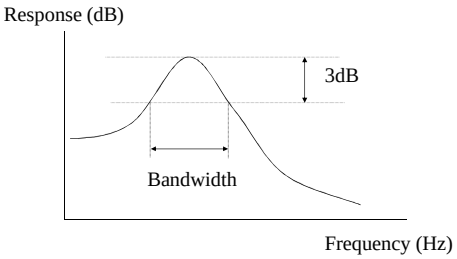
Input × Response = Output

⇨ Frequency Response ⇨

What about Damping?

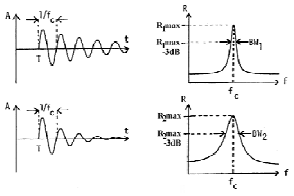
- We can measure the resonant frequency from the frequency response graph
  - as frequency of peak
- In fact we can also measure the amount of damping
  - as "peakiness" of peak
- Measure of "peakiness" is called **Bandwidth**

Bandwidth



Bandwidth & Damping

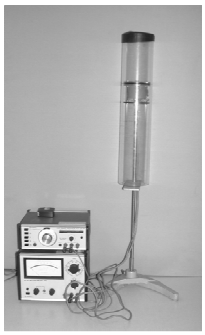
- Two ways of describing the same thing:
  - **Narrow** Bandwidth = **Low** Damping
  - **Wide** Bandwidth = **High** Damping



Summary

- Systems are channels that change signals that pass through them
- Response is an expression of the change in amplitude caused by system
- A **frequency response graph** shows how the system response varies with frequency (of sinewave input signals)
- A simple resonator has parameters of resonant frequency and bandwidth

Lab Experiment



- Measure the frequency response of the acoustic resonator for two lengths
- Increase damping and measure the effect of damping on the frequency response