1 Preamble

- Signal below is complex-periodic with a fundamental frequency and harmonics
  - A line spectrum
  - Smooth envelope with no sharp prominences
- Sounds similar to a "buzz"
- Produced by vibration of vocal folds during, e.g., vowel production

2 Preamble

- The sound wave will be altered or "reinforced" by a process called resonance, or filtering, to produce the various vowels of the language
  - /i/ as in beat
  - /u/ as in boot
  - and so forth

3 The Principle of Resonance

- Periodic force (me) is applied to an elastic system (mass-spring system)
- System is forced to vibrate at frequency of applied force, not at f_{nat} of the system
- The closer the frequency of the applied force to the natural frequency (f_{nat}) of the system, the greater the amplitude of vibration

4 RESONANCE AND FILTER CURVES

- Does Not represent a sound wave spectrum
- The curve describes a frequency-selective elastic system
- The curve is called:
  - Resonance curve
  - Filter curve
  - System transfer function
  - Amplitude response
  - "Frequency Response"

5 RESONANCE AND FILTER CURVES

- Note the natural frequency at 0 dB
- What happens above & below the natural frequency?
  - ☑ Amplitudes are diminished (attenuated) for frequencies remote from f_{nat}
- The resonator, or filter, is a frequency-selective system

6 Summary

- Mass and stiffness of elastic system determine its natural, or resonant, frequency
- Elastic system is forced to vibrate at frequency of applied force
- Amplitude of vibration of elastic system is greatest when driving frequency equals natural frequency of system

7 ACOUSTIC IMPEDANCE & RESONANCE

- Two components of impedance (Z):
  - Energy dissipating - Resistance (R)
  - Energy storage - Reactance (X)
- The magnitude of resistance (R) is independent of frequency

- ♦ Thus, R does not contribute to determination of f_{nat}
- ● What components of Z, therefore, determine f_{nat}?
  - ☑ X_m (mass reactance)
  - ☑ X_c (compliant reactance)

8 Effects of Impedance on Resonance Curve

- ● Shape of resonance curve, & location in frequency domain, determined by <u>impedance</u> (Z) of system: R, X_m, & X_c
- ♦ Below f_c : <u>compliance dominant</u>
- ♦ Above f_c : <u>mass dominant</u>
- ♦ Progressive increase of <u>resistance</u>, not just impedance
- ♦ Is natural frequency affected? ☑ No

9 Effects of Impedance on Resonance Curve

- ● As R increases from B to C to D:
  - ♦ More energy is dissipated
  - ♦ Damping increases
  - ♦ System becomes more <u>broadly</u> <u>tuned</u>

10 Admittance

- ● <u>Impedance</u> emphasizes opposition to motion; opposition to transfer of energy
- ● <u>Admittance</u> refers to the inverse; energy accepted, or admitted, to a system

11 System Tuning

- ● The figure compares two resonant systems (not signals)
- ● Narrow tuning at left
- ● <u>Good generator</u> of sound: Why?
  - ♦ lower resistance
  - ♦ less damping
  - ♦ longer free vibrations at f_{nat}

12 System Tuning

- ● Broad tuning at right
- ● <u>Good receiver</u> of sound: Why?
  - ♦ higher resistance
  - ♦ more damping
  - ♦ brief free vibrations
  - ♦ can be forced to vibrate with maximum amplitude over a wide range of frequencies

13 Impedance Matching

- ● Apply vibrating force (driver) to elastic system (load)
  - ♦ Power transferred to system
  - ♦ System forced to vibrate
- ● Maximum power transfer occurs when Z of driver = Z of load
- ● Sounding board of a piano

- Air cavity above the vocal folds
    - Do <u>not</u> amplify sound
    - Zs are matched
    - <u>Maximum</u> transfer of power

14 **FREQUENCY-SELECTIVE SYSTEMS: FILTERS**

- A: Amplitude spectrum of input signal
- B: System transfer function (resonance, or filter, curve)
- C: Amplitude spectrum of output signal

15 **FREQUENCY-SELECTIVE SYSTEMS: FILTERS**

- A: Amplitude spectrum of input signal -- white noise
- B: Transfer function of system
- C: Amplitude spectrum of output signal
    - Frequency-limited (band-limited) white noise

16 **PARAMETERS OF A FILTER**

- Five parameters of filter curves
- 1. Center (natural) frequency, f_c
- 2. Upper cutoff frequency, f_U
- 3. Lower cutoff frequency, f_L
- 4. Bandwidth, Δf
- 5. Attenuation (rejection) rate

17 **Attenuation Rate In dB/octave**

- Filter A: 10 dB / octave
- Filter B: 15 dB / octave
- Attenuation rate quantifies the *selectivity* of a filter