Acoustics of Speech and Hearing

Lecture 1-9
Signals & Systems Review
Introduction to Spectrography

Overview

- Review Signals and Systems
- Review Source-Filter Model
- Introduction to Spectrography

Signals and Systems Theory

- Quantitative description of
  - *Signals*, e.g. a sound
  - *Systems*, e.g. a tube
- Used in the course to analyse:
  - Speech Production
  - Instrumentation
  - Hearing

Signals

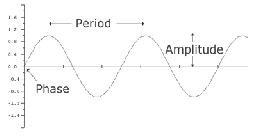
Sound

- Pressure waves
- *Loudness* ➔ amplitude (or intensity)
- *decibel* scale
  - dB = 20 $\log_{10}$ (AmplitudeRatio)
  - If AmplitudeRatio = 2 ➔ +6dB
  - If AmplitudeRatio = 10 ➔ +20dB
- Sound Pressure Level Scale
  - *dBSPL* = 20 $\log_{10}$ (MeasuredAmp/20μPa)

Periodic Signals

- *Pitch* ➔ repetition frequency
- *Sinewaves*

Amplitude

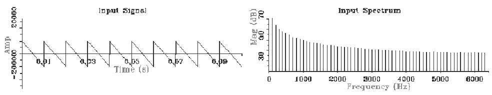


time

- Described by: *Frequency* (or Period), *Amplitude* and *Phase*

Complex periodic signals

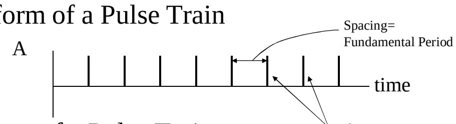
- Principle of *harmonic analysis* and synthesis (Fourier)
  – *Fundamental frequency, Harmonics, Spectrum*



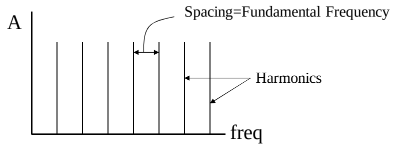
- *Timbre* ➔ relative amplitude of harmonics

Spectrum of Complex Periodic Waveform

- Waveform of a Pulse Train

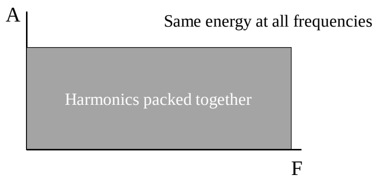


- Spectrum of a Pulse Train



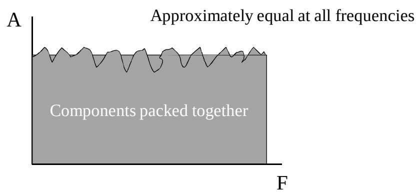
Spectrum of a Pulse

- Spectrum of a single narrow pulse



Spectrum of Noise

- Spectrum of “white” noise



Systems

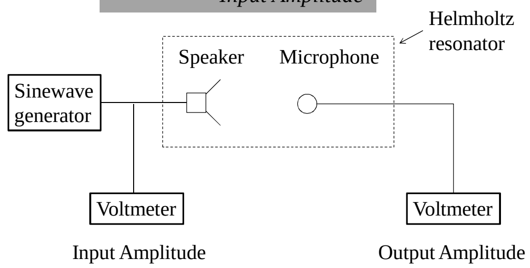
Simple Resonators

- Have single preferred frequency of vibration
  – Pendulum, tuning fork, mass-on-a-spring
  – Acoustic resonator
- *Natural Frequency* & *Damping*
- Response to a pulse = damped sinusoid

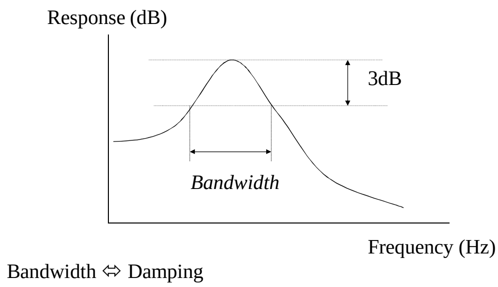
- Response to sinewaves = forced oscillation
  – *Frequency Response Graph*

Measuring Frequency Response

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

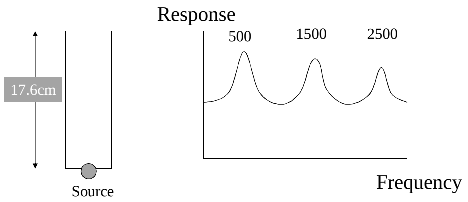


Simple Resonator Frequency Response



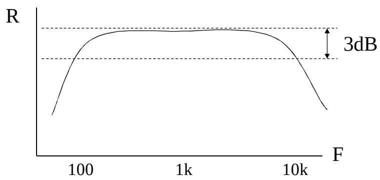
Vocal Tract Filter

- Consider as combination of simple resonators
  - *Formants*



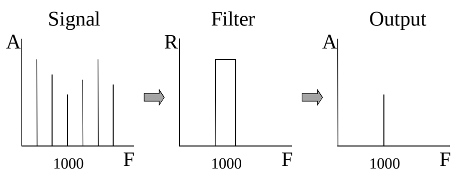
Audio Recorder Response

- Ideal frequency response of audio system is flat
- Typical response has broad range of frequencies where response does not vary by more than 3dB

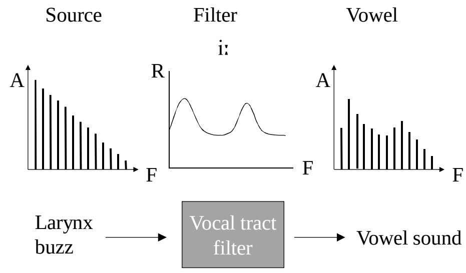


Analysis of Signals

- Narrow *band-pass filter* for spectral analysis



Source Filter Model



Independence of Source and Filter

Spectrography

Introduction to Spectrography

- If the characteristics of a signal do not change with time, then we can describe them adequately with a spectrum
- However many interesting signals *change quality* in time (speech, for example!)
- Need to study how the spectrum of a signal changes with time

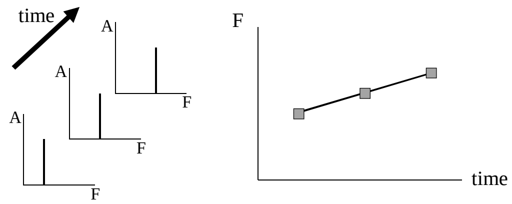
Static and Dynamic Signals

- **Static:** A monophthongal vowel on a constant pitch can be described by any single spectrum
  - just like a single snapshot picture of a stationary object
- **Dynamic:** A vowel that changes in quality or changes in pitch has a spectrum that changes with time
  - just like a movie is needed to show a moving object

Spectrography

- Adds a "time" dimension to a spectrum analysis

e.g. a single sinewave increasing in frequency

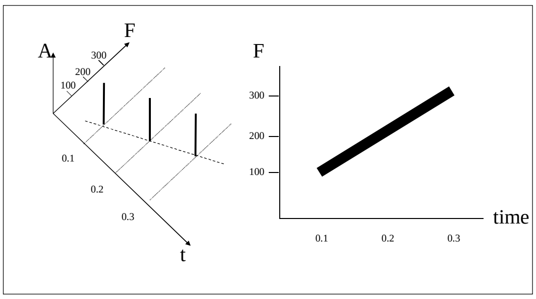


Spectrogram

- Is a graph of the frequency content of a signal plotted as a function of time
- **Time** is along the horizontal axis
- **Frequency** is along the vertical axis
- **Amplitude** of any component present in the signal at any given time and frequency is displayed on a grey-scale (white=low, black=high)

low  high

Spectrography



Summary

- Spectrogram is to Spectrum as Movie is to Snapshot
- Spectrogram is like a series of spectrum snapshots
- Amplitude compressed into coloured scale like a relief map
- More next week!

Programme Today

- Recordings (10.30-12.30, 2.00-4.00)
  - See timetable for your own recording time
  - Research Laboratory, CH Basement
  - Please be punctual
  - Check through reading materials in handbook in advance
- ~~Test~~ Quiz (1.00-1.45)
  - Room B02, CH