Stanford University
Winter 2012-2013

Signal Processing and Linear Systems I

Lecture 1: Course Overview

January 7, 2013

Class Web Site

Everything for the class will be available at

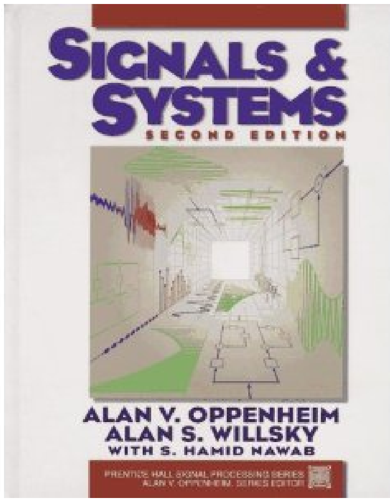
`http://eeclass.stanford.edu/ee102a`

This includes

- Class notes, usually the day before the lecture
- Homework, data sets, labs
- Solutions
- Grades

You need to register with eeclass for access

Textbook



Required Text:
Signals and Systems,2^{nd} Edition
Oppenheim and Willsky
Prentice Hall
ISBN: 0138147574

Labs and Matlab

- Matlab will be an important part of the course
  - Recommend you have a copy for your computer
  - Changes the way you think and work with signals
- Each homework set will have a "lab" component that uses matlab to process and analyze signals.
- Matlab programming will be covered in the weekly session Monday night.

Grading

- 20%Weekly homework assignments, each of which has two components:
  - 10% Problem Sets
  - 10% Matlab Labs
- 30% Midterm examination, in class Friday Feb 15th
- 50% Final examination, Wednesday March 20th, 8:30 AM

You are free to work together on the homework, but write up your own solutions.

Instructor

John Pauly
Research interests in:

- Magnetic Resonance Imaging (MRI)
- Cardiac imaging
- Image guided interventions
- Imaging brain activation

TA's

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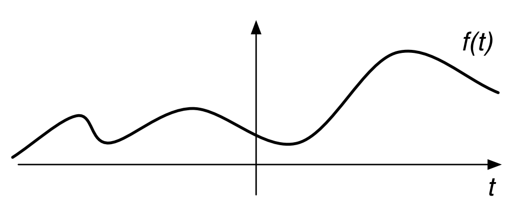
Course Overview

- Time-Series Representation of Signals

  Typically think of a signal as a "time series", or a sequence of values in time

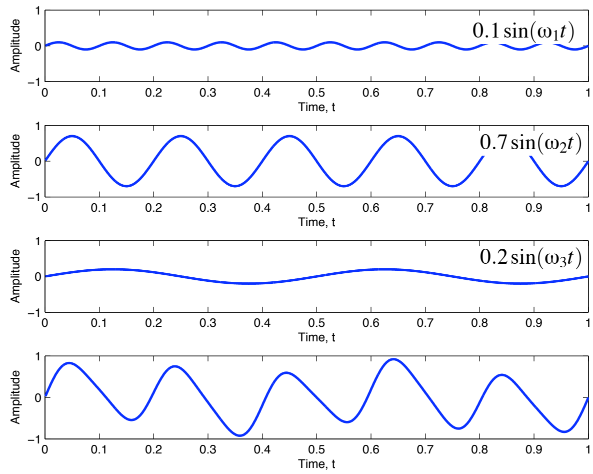


  Useful for saying what is happening at a particular time

  Not so useful for capturing the overall characteristics of the signal.

Idea 1: Frequency Domain Representation of Signals

- Represent signal as a combination of sinusoids



$$f(t) = 0.1\sin(\omega_1 t) + 0.7\sin(\omega_2 t) + 0.2\sin(\omega_3 t)$$

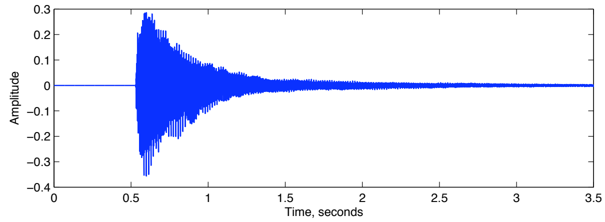
- This example is mostly a sinusoid at frequency ω_2, with small contributions from sinusoids at frequencies ω_1 and ω_3.
  - Very simple representation (for this case).
  - Not immediately obvious what the value is at any particular time.

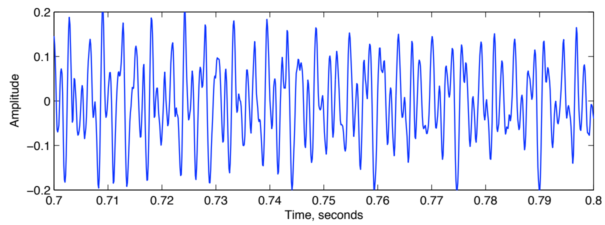
- Why use frequency domain representation?
  - Simpler for many types of signals (AM radio signal, for example)
  - Many systems are easier to analyze from this perspective (Linear Systems).
  - Reveals the fundamental characteristics of a system.

- *Rapidly becomes an alternate way of thinking about the world.*

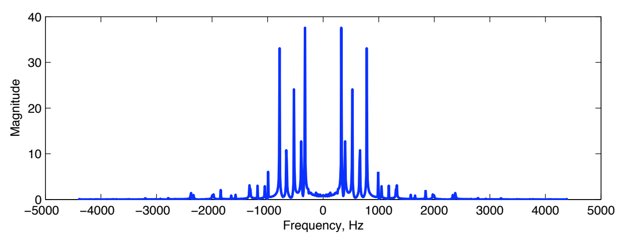
Demonstration: Piano Chord

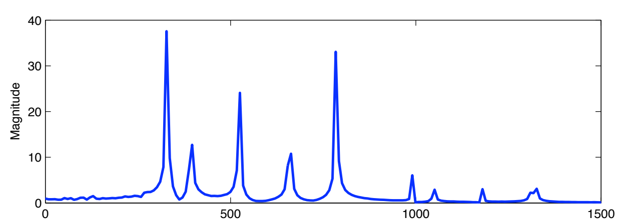
- You are already a highly sophisticated system for performing spectral analysis!
- Listen to the piano chord. You hear several notes being struck, and fading away. This is waveform is plotted below:





- The time series plot shows the time the chord starts, and its decay, but it is difficult tell what the notes are from the waveform.
- If we represent the waveform as a sum of sinusoids at different frequencies, and plot the amplitude at each frequency, the plot is much simpler to understand.

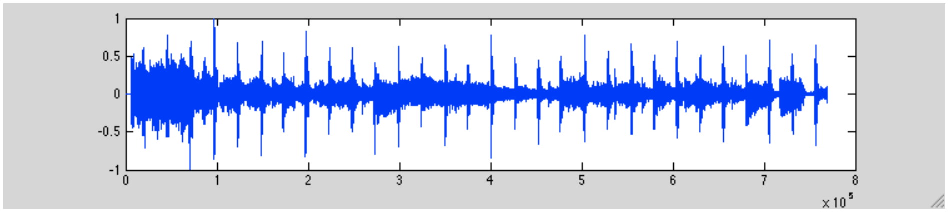




Note: C is 262 Hz, E is 330 Hz, and G is 392 Hz

Application: Audio Compression

Most audio signals are *compressed* by exploiting the time and frequency domain structure of the signals.



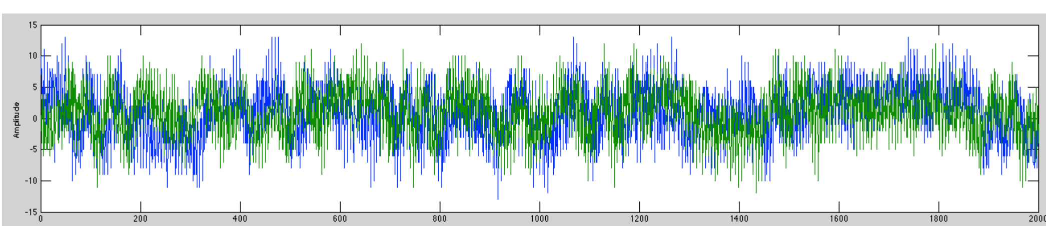
- Raw audio: 44.1 kHz, 16bit, stereo = 1378 kbit/sec
- MP3: 44.1 kHz, 16bit, stereo = 128 kbit/sec
- 10.76 fold!

Even higher compression with images (JPEG normal, ∼22 fold) and video (MPEG4, ∼75 fold).

Application: Communications

Communications systems are best understood from the perspective of the frequency domain.

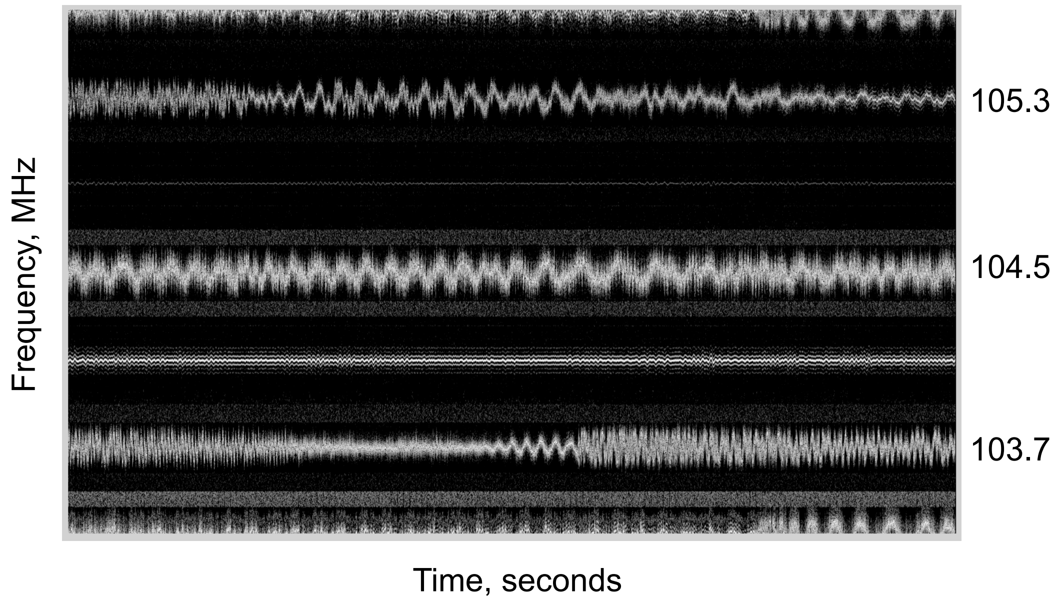
Example:
1ms of FM radio signal, tuned to 104.5 MHz, sampled at 2.4 MHz.



Signal is complex (real and imaginary)

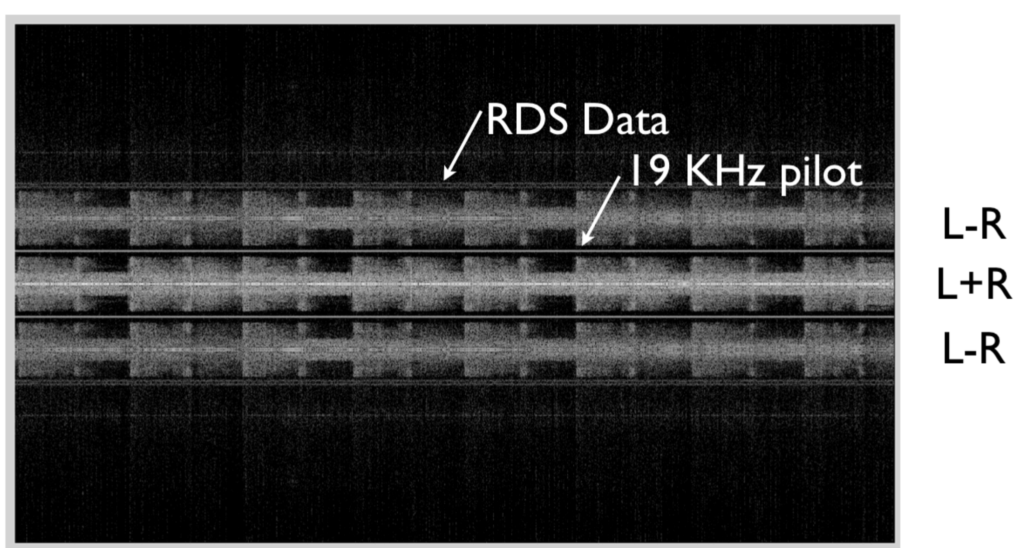
Structure is not obvious, or how to decode it

FM signal in the frequency domain



Time-frequency plot, or *spectrogram*

FM signal after detection

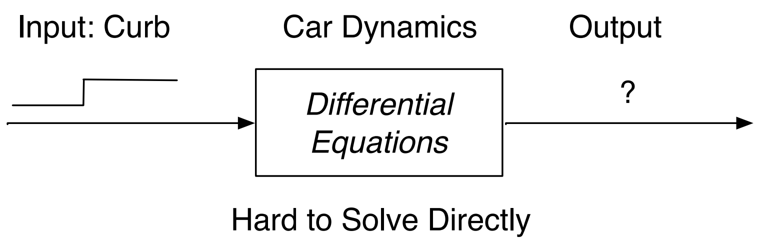


+/- 200 kHz centered on 104.5 MHz

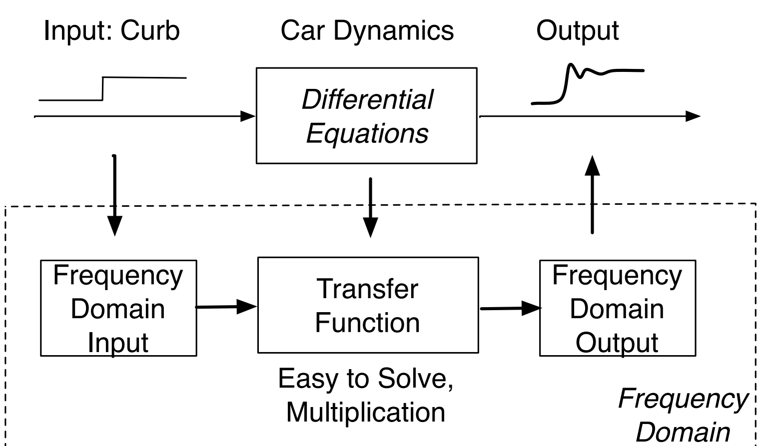
Idea 2: Linear Systems are Easy to Analyze for Sinusoids

Many real-world systems are linear, or can be modeled as linear (we won't know exactly what this means until next week).

Example: We want to predict what will happen when we drive a car over a curb. The curb can be modelled as a "step" input. The dynamics of the car are governed by a set of differential equations, which are hard to solve for an arbitrary input (this is a linear system).



After transforming the input and the differential equations into the frequency domain,

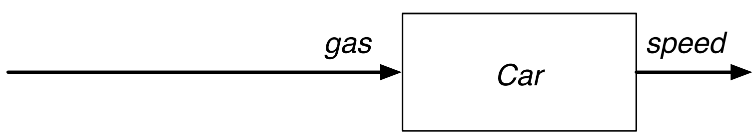


Solving for the frequency domain output is easy. The time domain output is found by the inverse transform. We can predict what happens to the system.

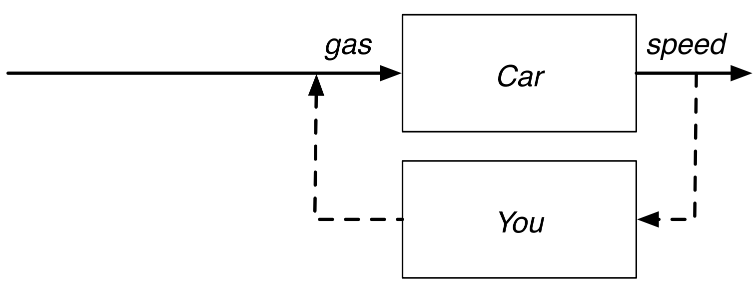
Idea 3: Frequency Domain Lets You Control Linear Systems

- Often we want a system to do something in particular automatically
  - Airplane to fly level
  - Car to go at constant speed
  - Room to remain at a constant temperature
- This is not as trivial as you might think!

Example: Controlling a car's speed. Applying more gas causes the car to speed up

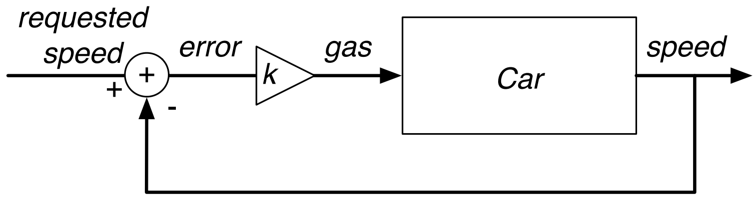


Normally you "close the loop"



How can you do this automatically?

Use feedback by comparing the measured speed to the requested speed:



This can easily do something you don't want or expect, and oscillate out of control.

Frequency domain analysis explains why, and tells you how to design the system to do what you want.

Course Outline

- It is useful to represent signals as sums of sinusoids (the frequency domain)
- Linear systems are easy to analyze in the frequency domain
- We can use this perspective to design controllers for linear systems

Next time: What sort of signals and systems are we talking about?