

Lecture 2:

Links and Signaling

CSE 123: Computer Networks
Stefan Savage





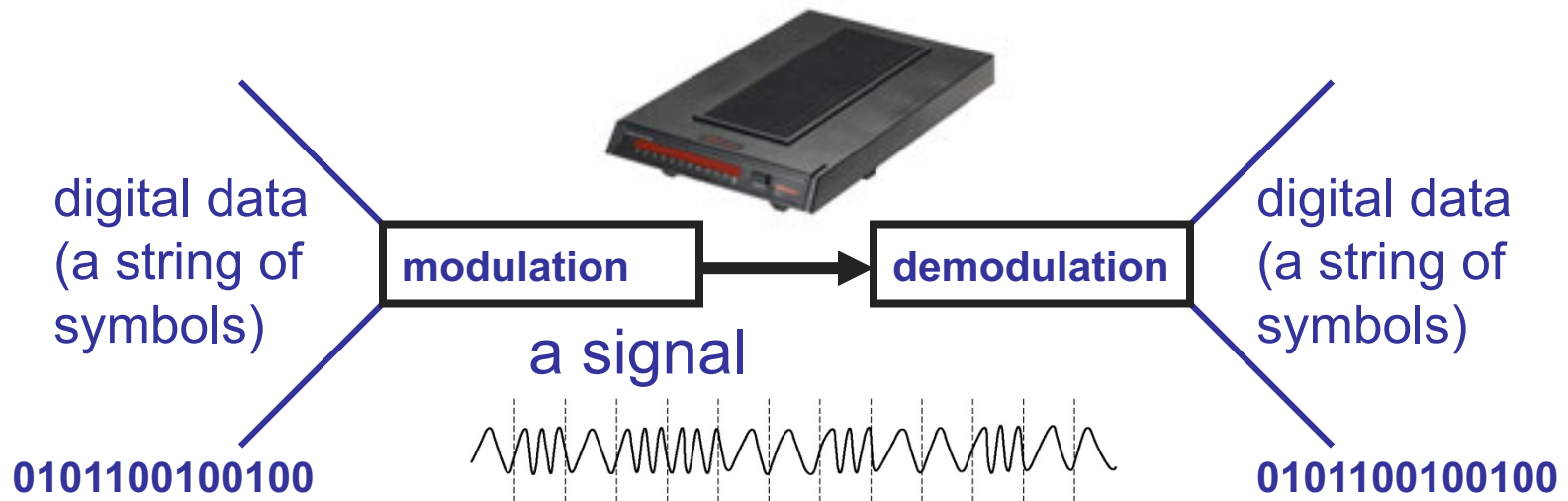
Lecture 2 Overview

- Signaling
 - ◆ Channel characteristics
 - ◆ Types of physical media
- Modulation
 - ◆ Narrowband vs. Broadband
 - ◆ Encoding schemes
- A lot of this material is **not in the book**
- **Caveat:** I am not an EE Professor

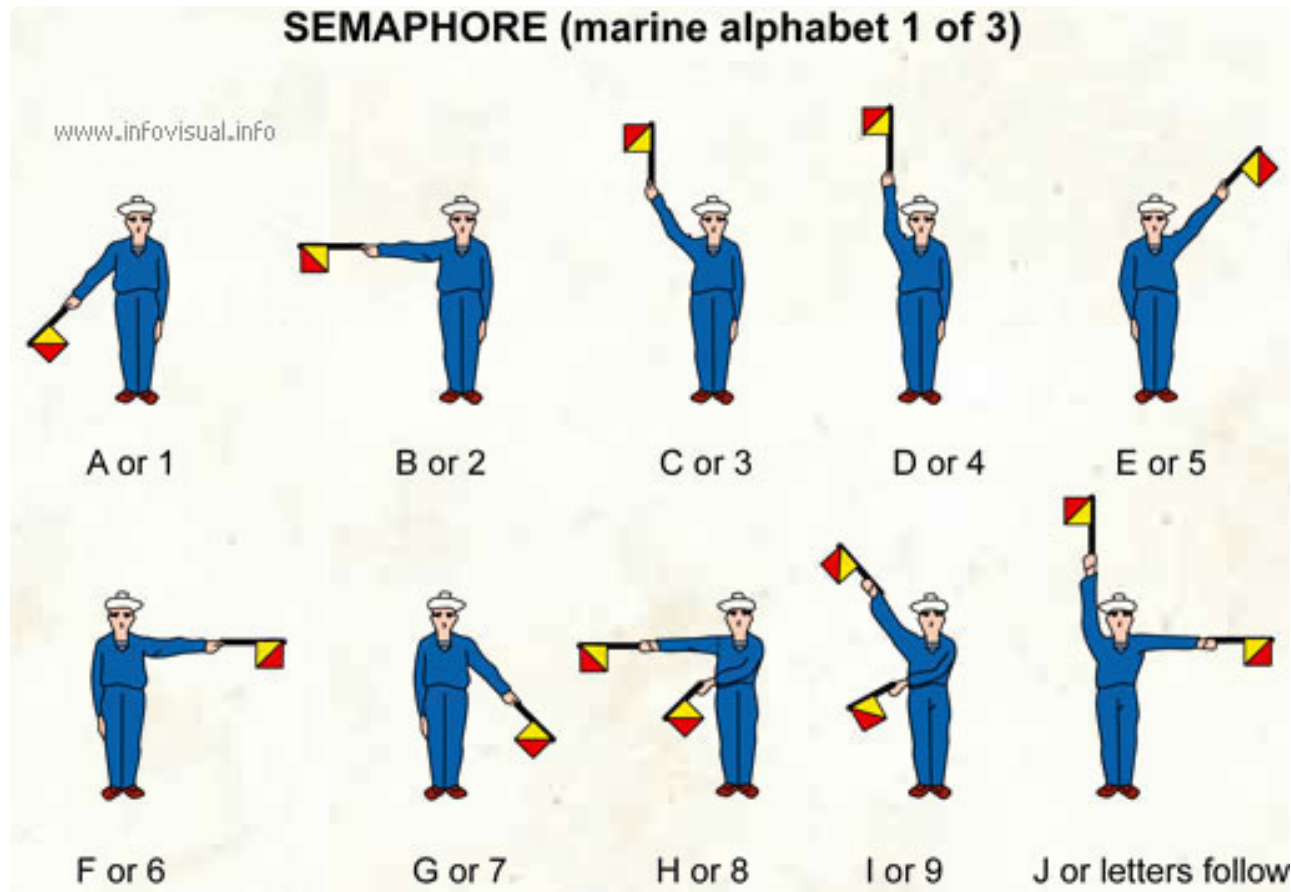


Today's Goal: Send bits

- A three-step process
 - ◆ Take an input stream of bits (digital data)
 - ◆ Modulate some physical media to send data (analog)
 - ◆ Demodulate the signal to retrieve bits (digital again)
 - ◆ Anybody heard of a **modem** (Modulator-demodulator)?



A Simple Signaling System



Another Simple Signaling System



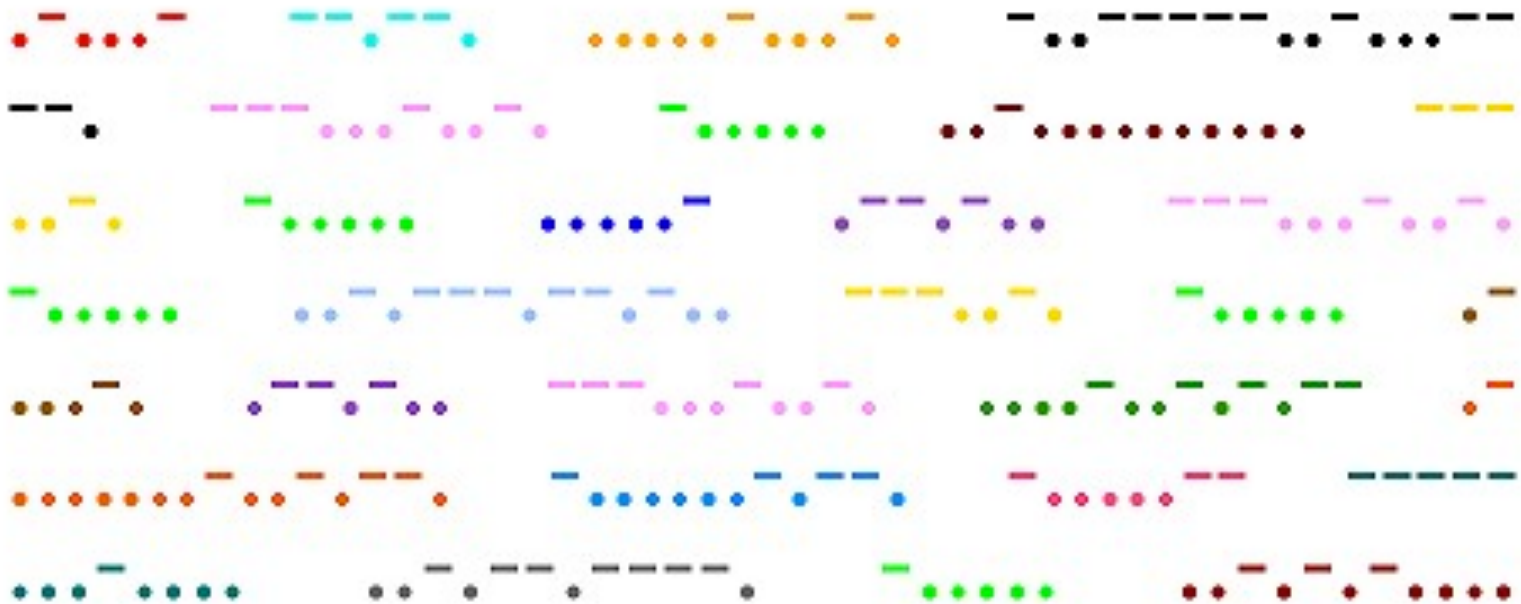
A ● ■■	V ● ● ● ■■
B ■■ ● ● ●	W ● ■■ ■■
C ■■ ● ■■ ●	X ■■ ● ● ■■
D ■■ ● ●	Y ■■ ● ■■ ■■
E ●	Z ■■ ■■ ● ●
F ● ● ■■ ●	. ● ■■ ● ■■ ● ■■
G ■■ ■■ ●	, ■■ ■■ ● ● ■■ ■■
H ● ● ● ●	? ● ● ■■ ■■ ● ●
I ● ●	/ ■■ ● ● ■■ ●
J ● ■■ ■■ ■■	@ ● ■■ ■■ ● ■■ ●
K ■■ ● ■■	1 ● ■■ ■■ ■■ ■■
L ● ■■ ● ●	2 ● ● ■■ ■■ ■■
M ■■ ■■	3 ● ● ● ■■ ■■
N ■■ ●	4 ● ● ● ● ■■
O ■■ ■■ ■■	5 ● ● ● ● ●
P ● ■■ ■■ ●	6 ■■ ● ● ● ●
Q ■■ ■■ ● ■■	7 ■■ ■■ ● ● ●
R ● ■■ ●	8 ■■ ■■ ■■ ● ●
S ● ● ●	9 ■■ ■■ ■■ ■■ ●
T ■■	0 ■■ ■■ ■■ ■■ ■■
U ● ● ■■	



Another Simple Signaling System



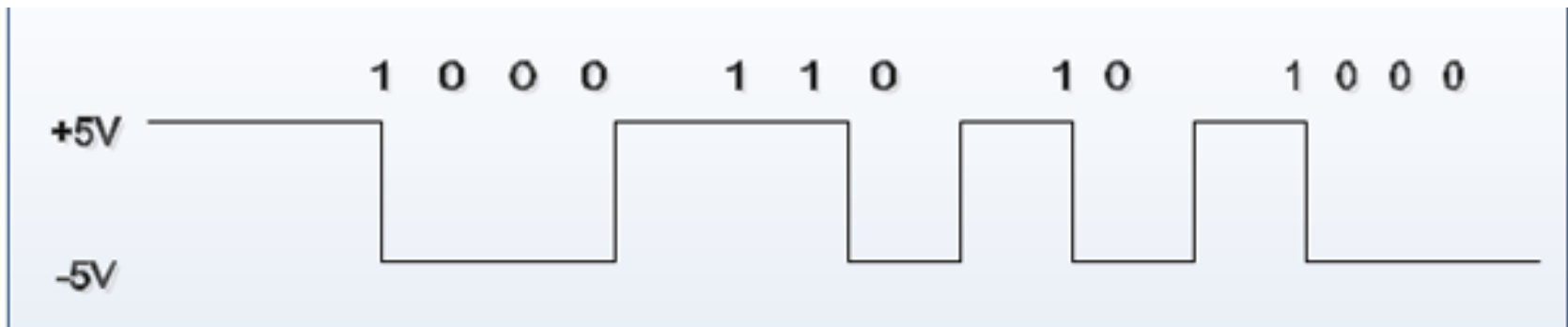
Let man have dominion over the fish of the sea and over the fowl of the air and over every living thing that moves upon the earth



Binary signaling with Voltage



- Encode 1's and 0's on a wire
 - ◆ +5 volts = 1
 - ◆ -5 volts = 0





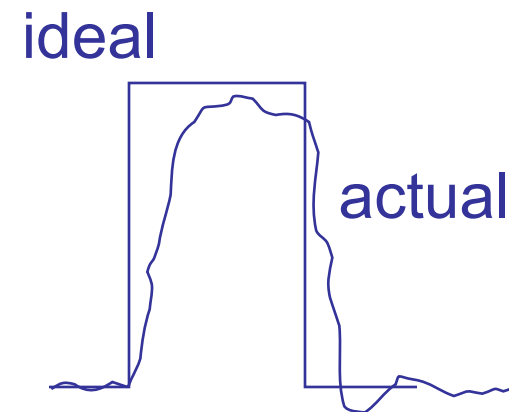
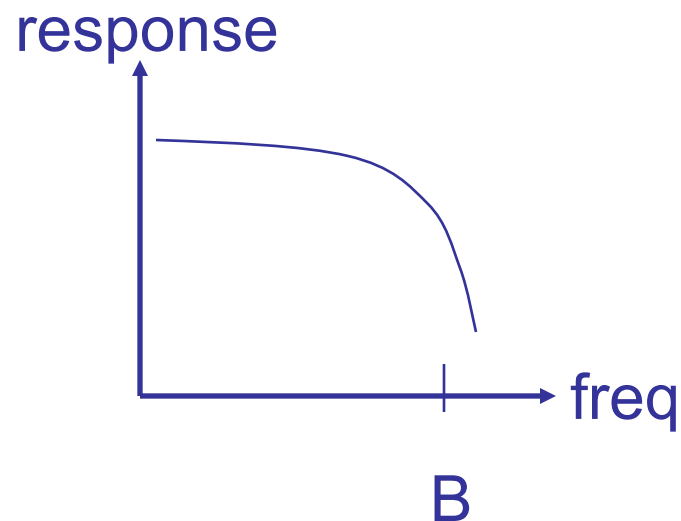
Signals and Channels

- A **signal** is some form of energy (light, voltage, etc)
 - ◆ Varies with time (on/off, high/low, etc.)
 - ◆ Can be continuous or discrete
- A **channel** is a physical medium that conveys energy
 - ◆ Any real channel will distort the input signal as it does so
 - ◆ How it distorts the signal depends on the signal



Channel Challenges

- Every channel degrades a signal
 - ◆ Distortion impacts how the receiver will interpret signal





Channel Properties

- **Bandwidth**-limited
 - ◆ Range of frequencies the channel will transmit
 - ◆ Means the channel is slow to react to change in signal
- Power **attenuates** over distance
 - ◆ Signal gets softer (harder to “hear”) the further it travels
 - ◆ Different frequencies have different response (**distortion**)
- Background **noise** or interference
 - ◆ May add or subtract from original signal
- Different physical characteristics
 - ◆ Point-to-point vs. shared media
 - ◆ Very different price points to deploy

Copper



- Typical examples

- ◆ Category 5/6 Twisted Pair
- ◆ Coaxial Cable

10M-10Gbps

50-100m

10-400Mbps

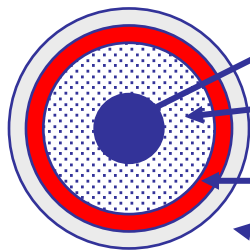
200m

twisted pair



Northwire, Inc. — DataCELL® GEV-1000™ Cable

coaxial
cable
(coax)

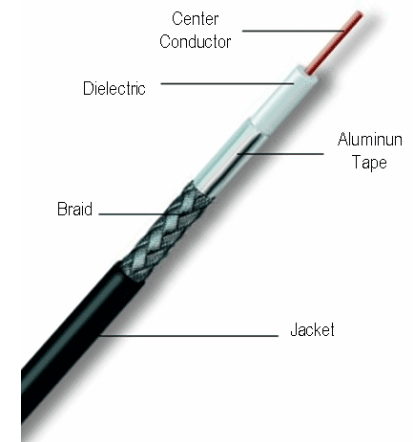


copper core

insulation

braided outer conductor

outer insulation

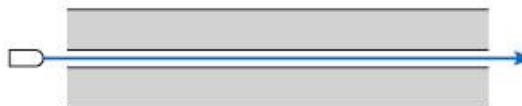
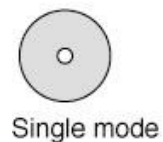
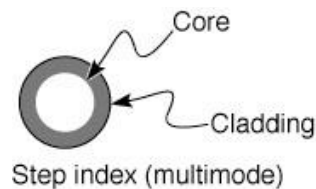


Fiber Optics



- Typical examples

- | | | |
|---------------------|--------------|-----------|
| ◆ Multimode Fiber | 100Mbps-10Gb | 500-2000m |
| ◆ Single Mode Fiber | 1-100Gbps | 100m-40km |



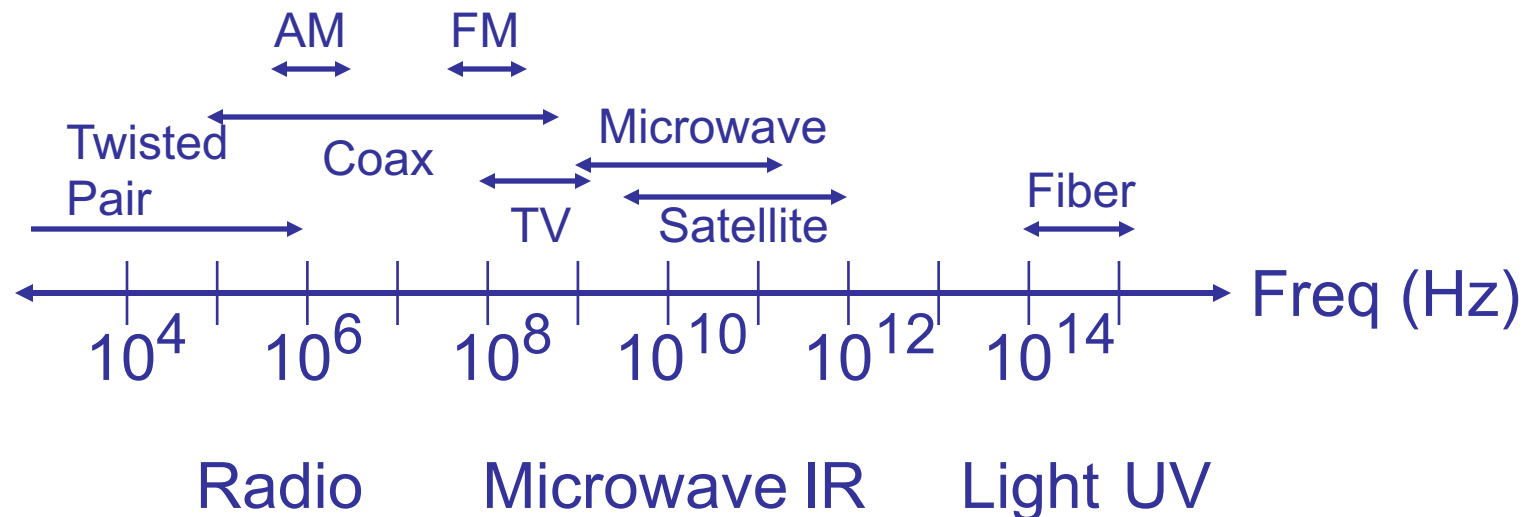
**Cheaper to drive
(LED vs laser) &
terminate**

**Longer distance
(low attenuation)
Higher data rates
(low dispersion)**

Wireless



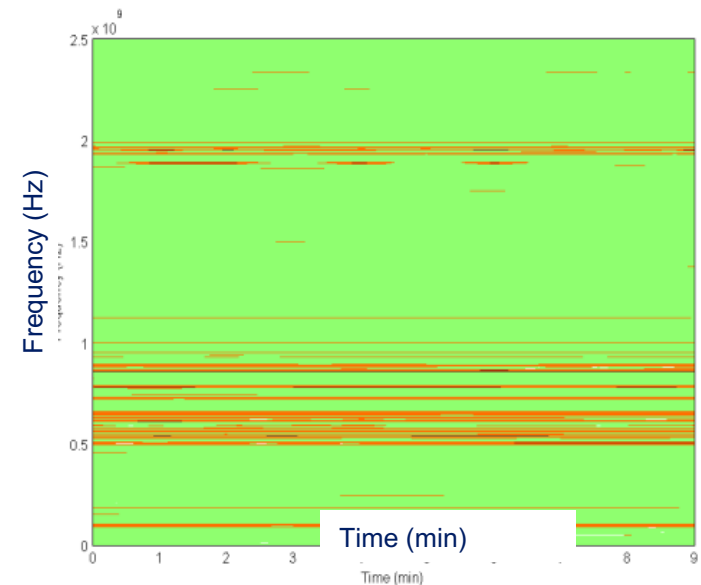
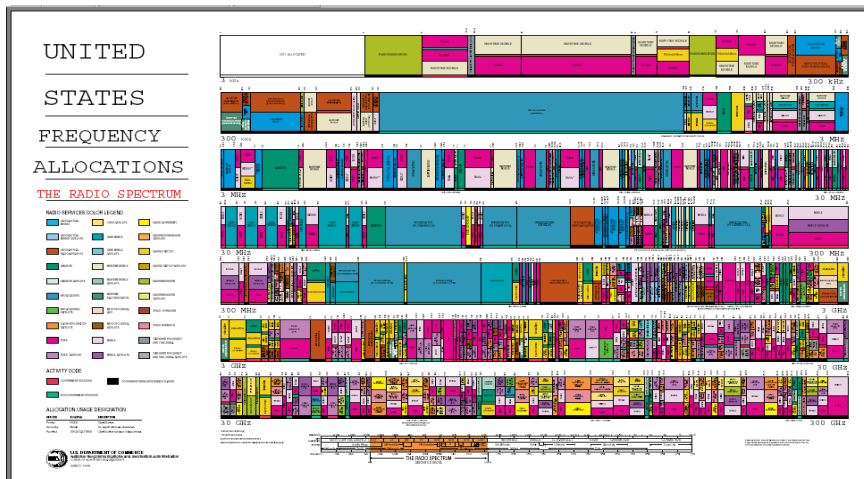
- Widely varying channel bandwidths/distances
- Extremely vulnerable to noise and interference



Spectrum Allocation



- Policy approach forces spectrum to be allocated like a fixed spatial resource (e.g. land, disk space, etc)
- Reality is that spectrum is time and power shared
- Measurements show that fixed allocations are poorly utilized



Hot topic: Whitespace communication



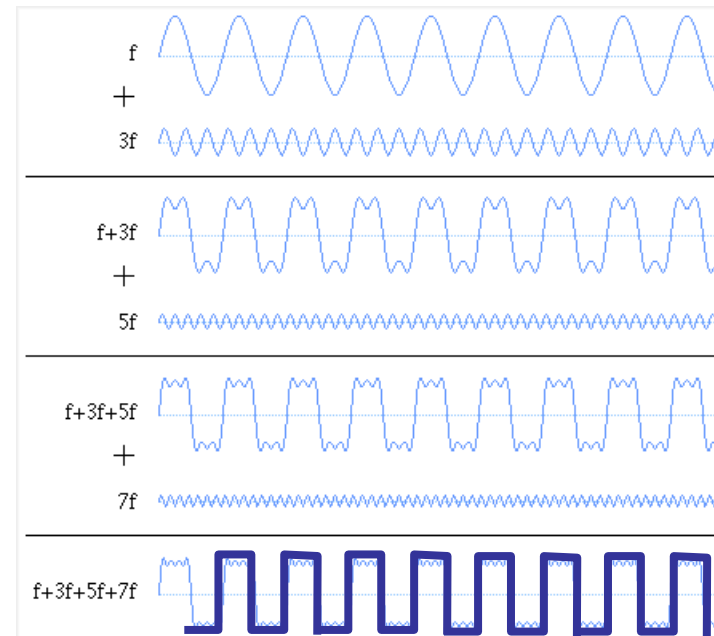
Two Main Tasks

- First we need to transmit a signal
 - ◆ Determine how to send the data, and how quickly
- Then we need to receive a (degraded) signal
 - ◆ Figure out when someone is sending us bits
 - ◆ Determine which bits they are sending
- A lot like a conversation
 - ◆ “WhatintheworldamIsaying” – needs punctuation and pacing
 - ◆ Helps to know what language I’m speaking



The Magic of Sine Waves

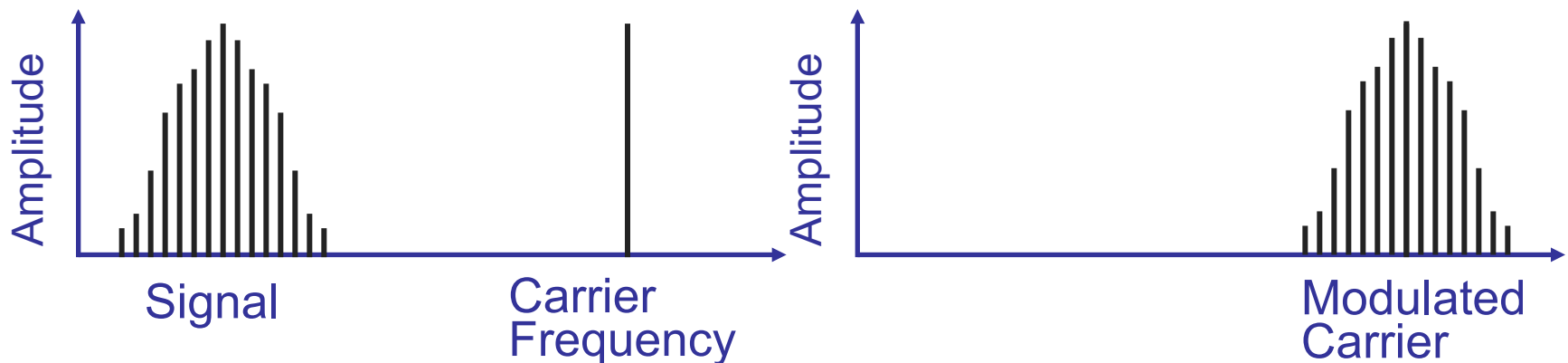
- All periodic signals can be expressed as sine waves
 - ◆ Component waves are of different frequencies
- Sine waves are “nice”
 - ◆ Phase shifted or scaled by most channels
- “Easy” to analyze
 - ◆ Fourier analysis can tell us how signal changes
 - ◆ But not in this class...



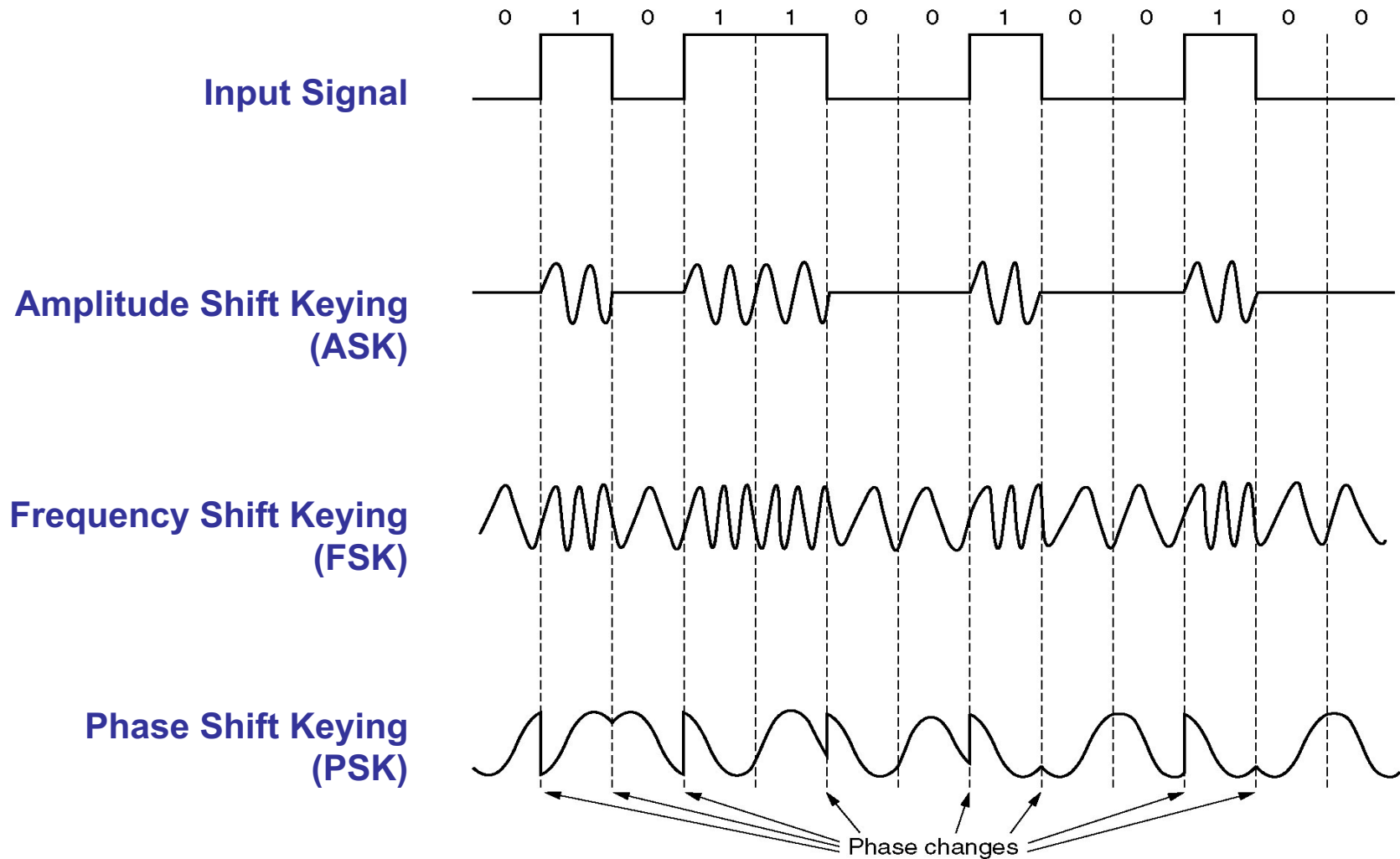


Carrier Signals

- **Baseband** modulation: send the “bare” signal
 - ◆ E.g. +5 Volts for 1, -5 Volts for 0
 - ◆ All signals fall in the same frequency range
- **Broadband** modulation
 - ◆ Use the signal to modulate a high frequency signal (**carrier**).
 - ◆ Can be viewed as the product of the two signals



Forms of Digital Modulation





Why Different Schemes?

- Properties of channel and desired application
 - ◆ AM vs FM for analog radio
- Efficiency
 - ◆ Some modulations can encode many bits for each symbol (subject to Shannon limit – more on this next class)
- Aiding with error detection
 - ◆ Dependency between symbols... can tell if a symbol wasn't decoded correctly
- Transmitter/receiver Complexity



For Next Class

- Read 2.3
- Log into Piazza; let us know if you have problems