

Lecture 25:

Links and Signaling

CSE 123: Computer Networks

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Lecture 25 Overview

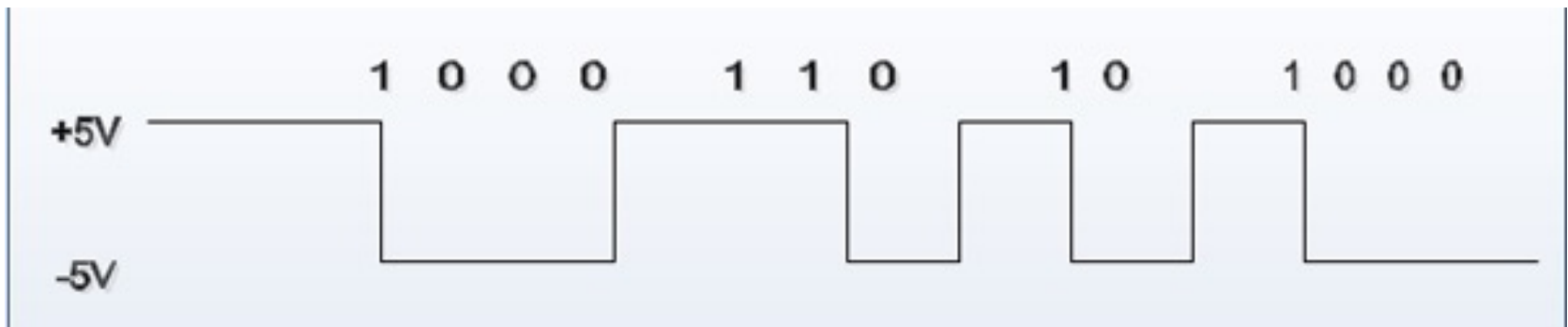
- Signaling
 - ◆ Channel characteristics
 - ◆ Types of physical media
- Modulation
 - ◆ Narrowband vs. Broadband
 - ◆ Encoding schemes
- A lot of this material is **not in the book**
 - ◆ **Caveat:** I am not an EE Professor



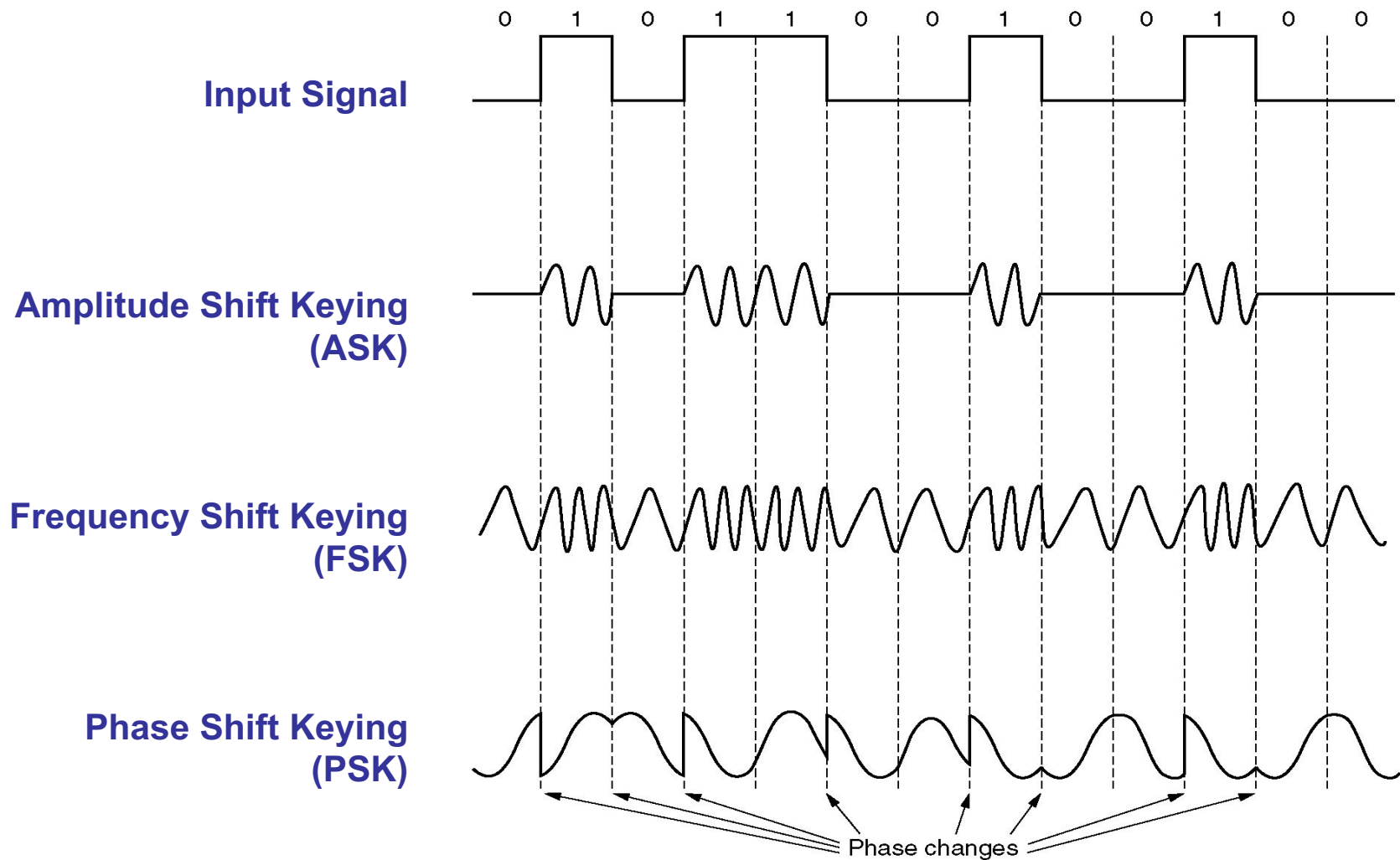
Wire signaling with Voltage



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



Wireless of Digital Modulation





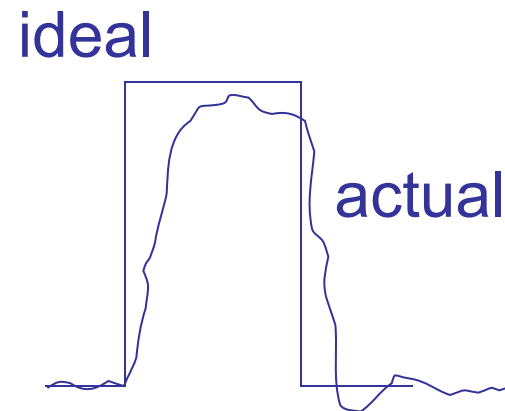
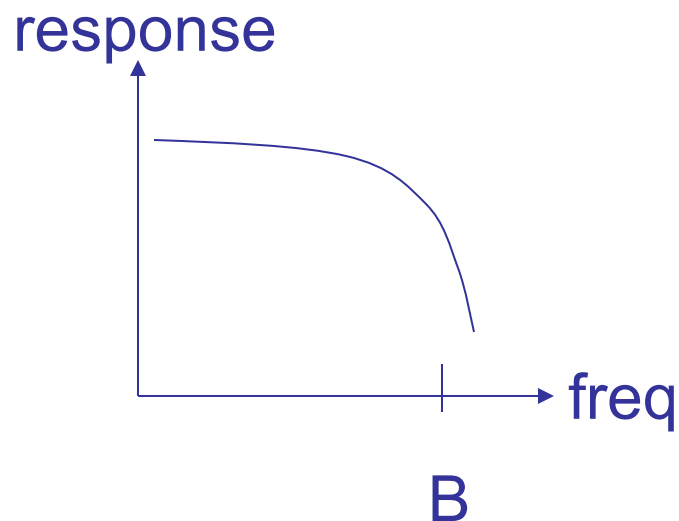
Signals and Channels

- 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

10-100Mbps

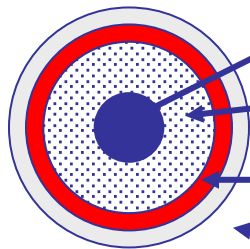
200m

twisted pair



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

coaxial
cable
(coax)

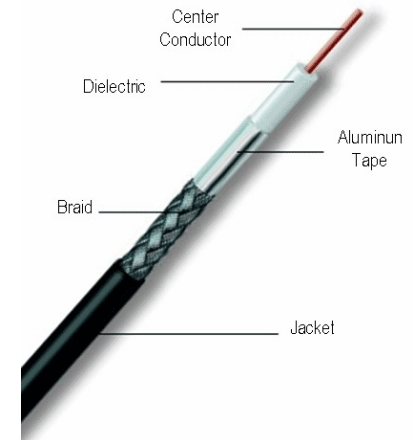


copper core

insulation

braided outer conductor

outer insulation

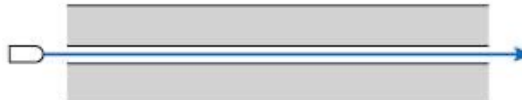
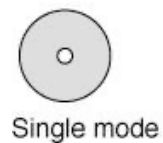
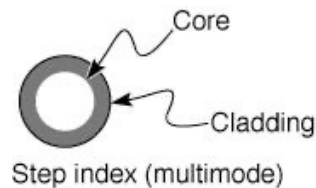


Fiber Optics



- Typical examples

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



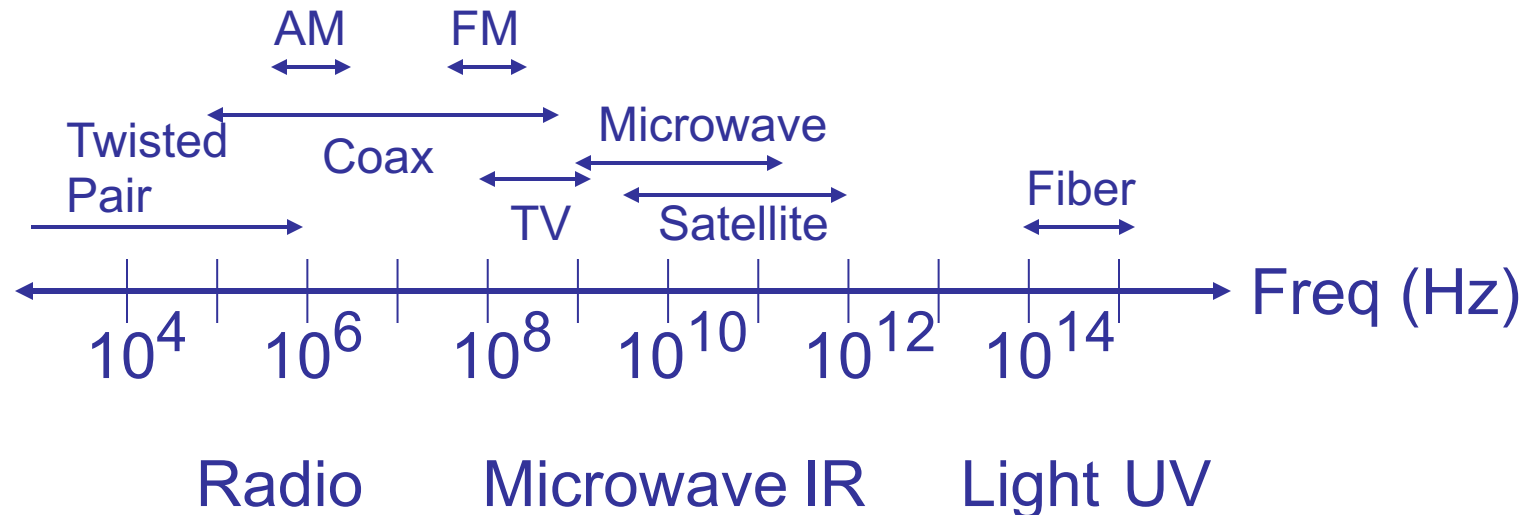
**Cheaper to drive
(LED vs laser) &
terminate**

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

Wireless



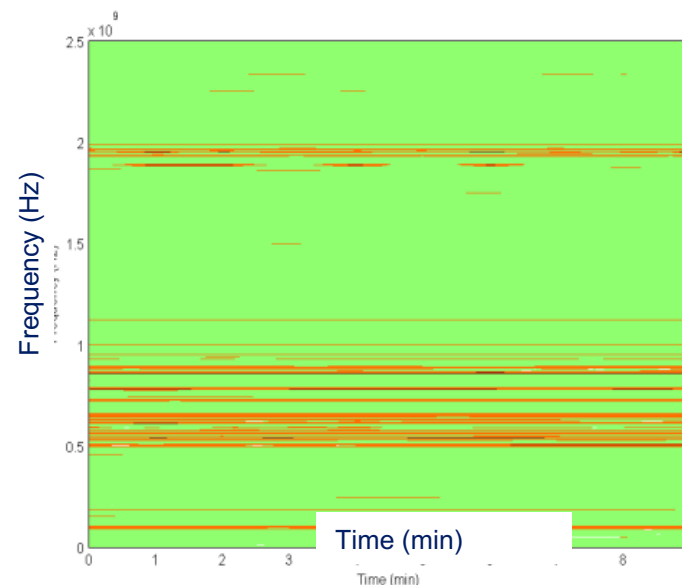
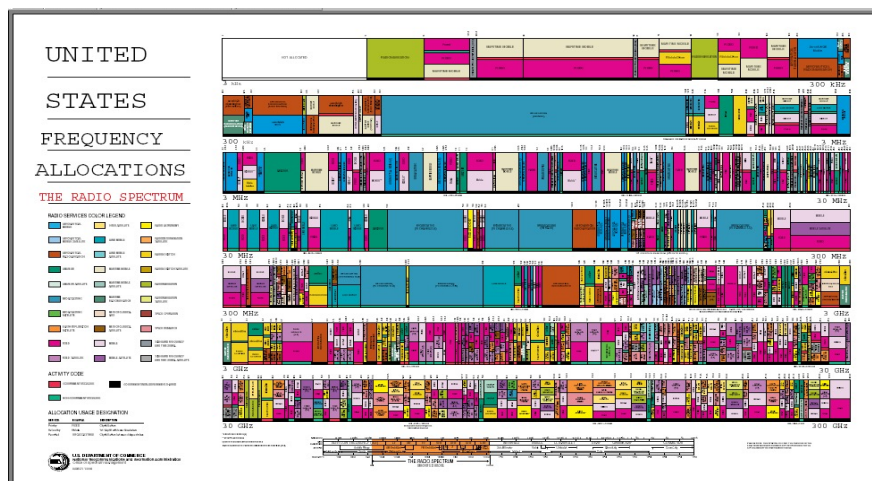
- Widely varying channel bandwidths/distances
- Extremely vulnerable to noise and interference



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



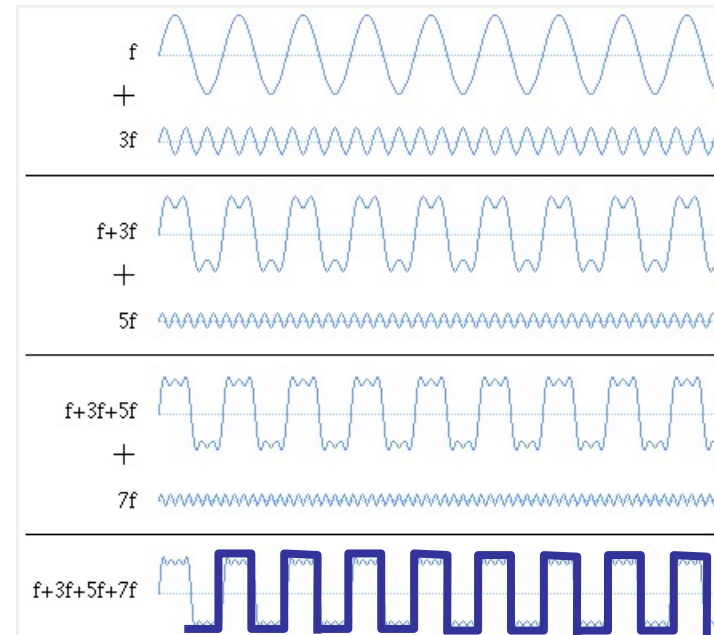
Two Main Tasks

- First we need to transmit a signal (modulation)
 - ◆ Determine how to send the data, and how quickly
- Then we need to receive a (degraded) signal (demod)
 - ◆ 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...





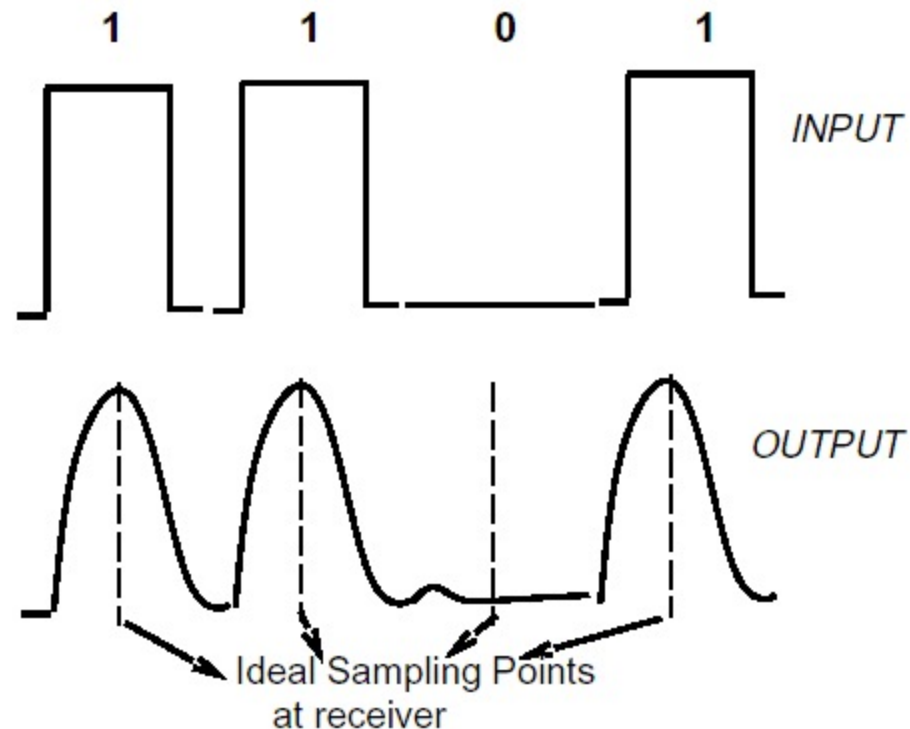
Why Different Schemes?

- 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

Sampling



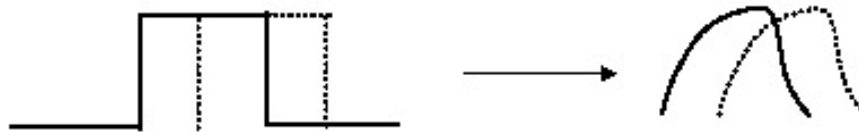
- To reconstruct signal we need to sample it





Intersymbol Interference

- Bandlimited channels cannot respond faster than some maximum frequency f
 - ◆ Channel takes some time to settle
- Attempting to signal too fast will mix symbols
 - ◆ Previous symbol still “settling in”
 - ◆ Mix (add/subtract) adjacent symbols
 - ◆ Leads to **intersymbol interference** (ISI)

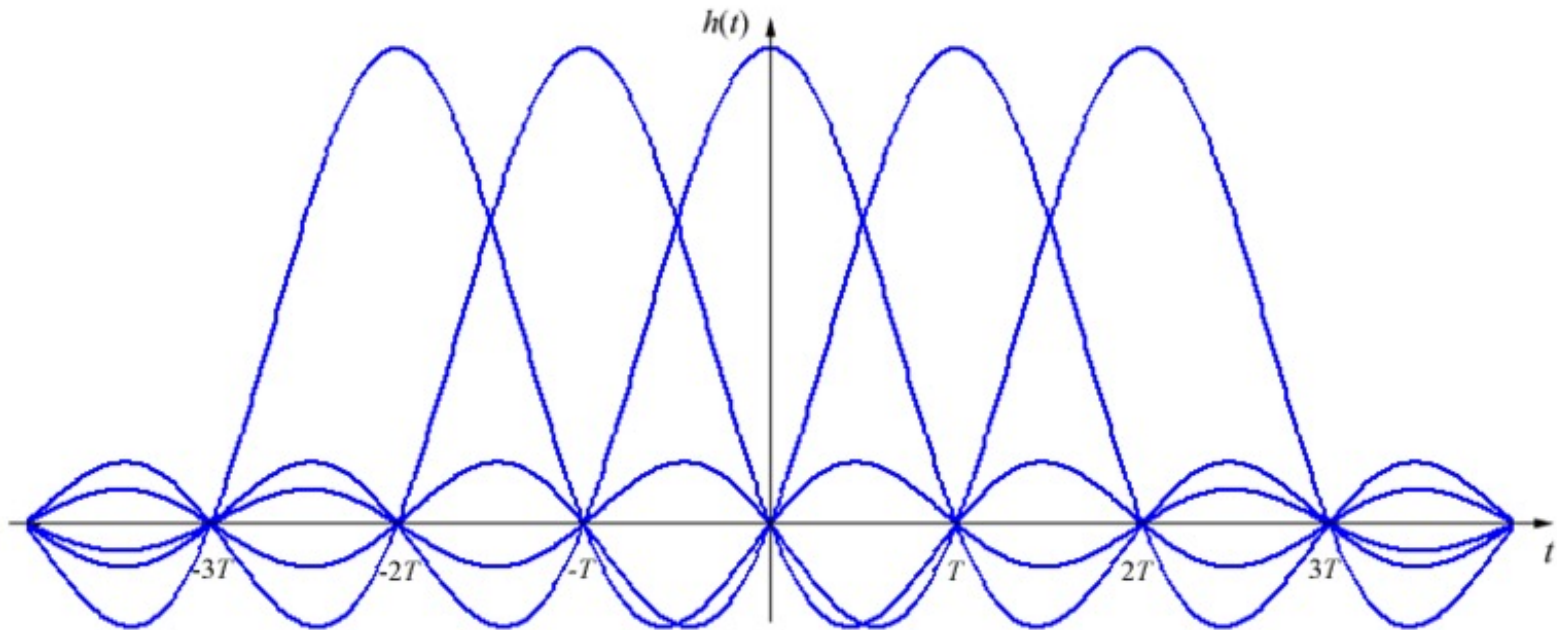


- OK, so just how fast can we send symbols?



Speed Limit: Nyquist

- In a channel bandlimited to f , we can send at maximum symbol (**baud**) rate of $2f$ without ISI





For Next Class

- Homework 4 released today (staggered from project)
- Read 2.2



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

