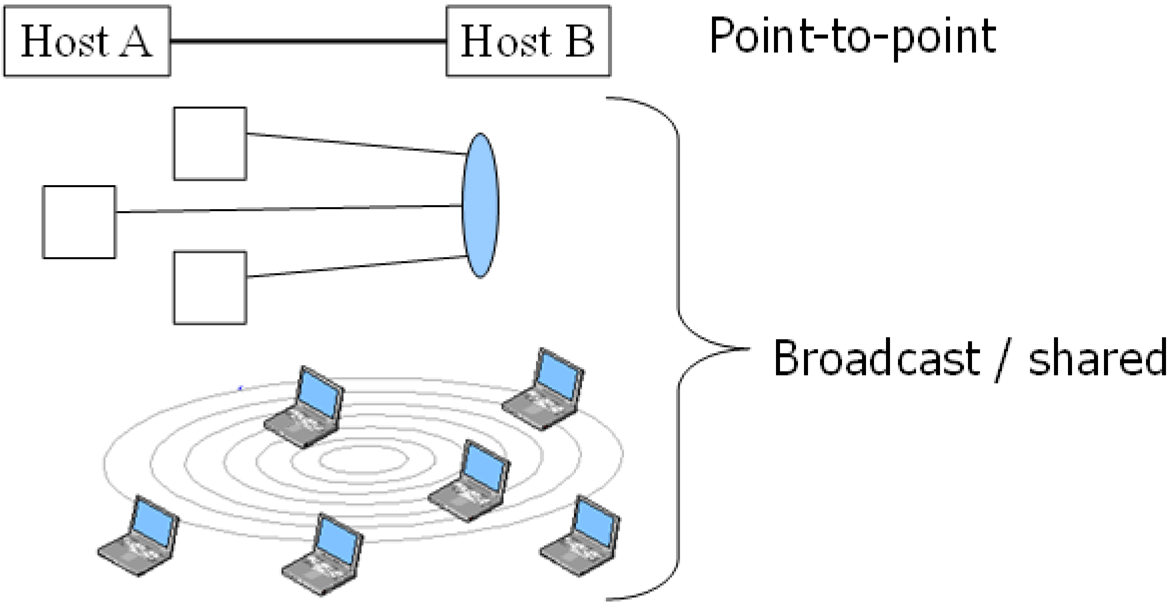
C:\cygwin\home\zahorjan\cse461\12au\02-directLinkA.cp3

CSE 461: Introduction to Computer Communications Networks

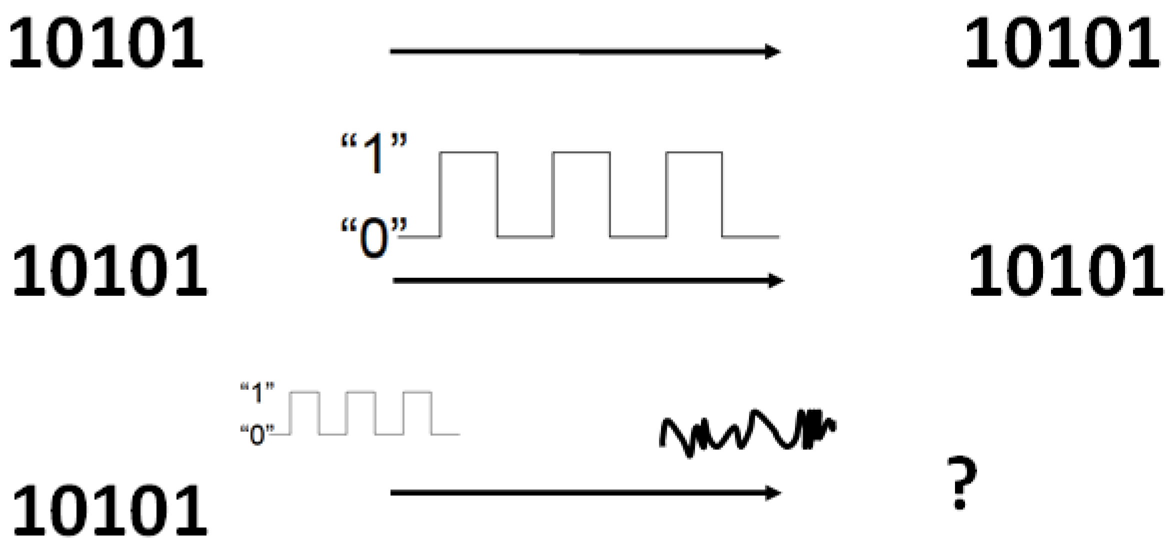
Physical and Data Link Layers

Direct Link Networks

"Direct link" ⇒ no switching/routing



First Problem: Sending Data



Received signal is <u>attenuated</u> and <u>distorted</u>

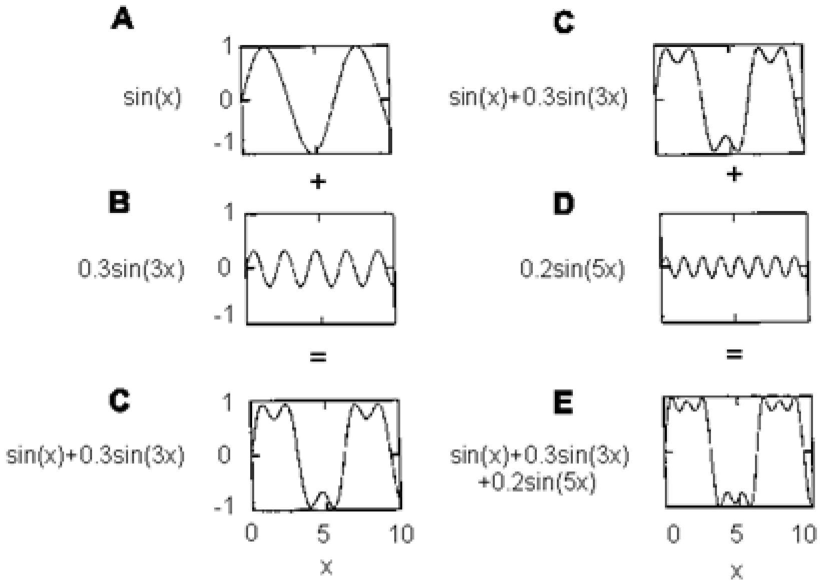
Where We're Headed

- It turns out that how fast communication can be depends on how much of the frequency spectrum we're allowed to use
  - 0-100Mz potentially offers transmission rates that are twice as high as 0-50MHz
- The rate actually achieved depends on lots of things
  - One is coding: what properties of the signal are used to represent bits

Terminology: "Bandwidth"

- The usual CS use of "bandwidth" is a measurement of bits/second
  - "I have only about 10 Mbps bandwidth into my house."
- The signal processing use of "bandwidth" is amount of frequency spectrum in MHz
  - "802.11n has a channel bandwidth of 40MHz"
- Why we care...
  - Bandwidth_{CS} is fundamentally limited by bandwidth_{EE}
  - The maximum possible bits/second is limited by the width of the available frequency spectrum

Aid to Intuition: Fourier Analysis (!)

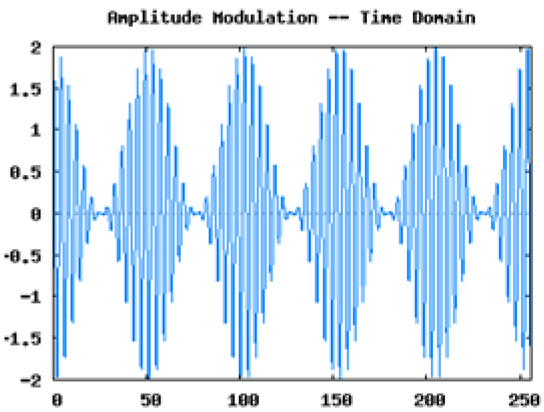


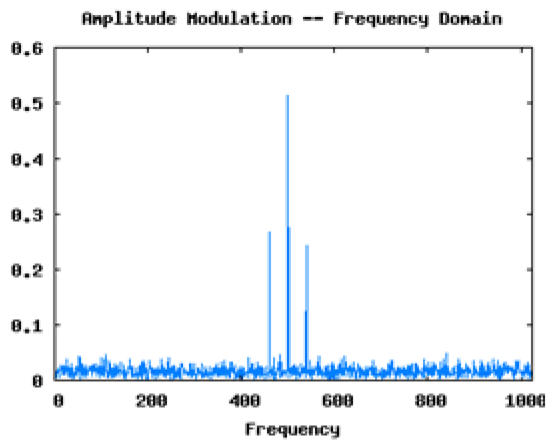
Explanation

http://www.yorku.ca/eye/squarwav.htm

Time Domain ⇔ Frequency Domain

Two different representations of one signal





http://arachnoid.com/maxima/fourier_analysis.html

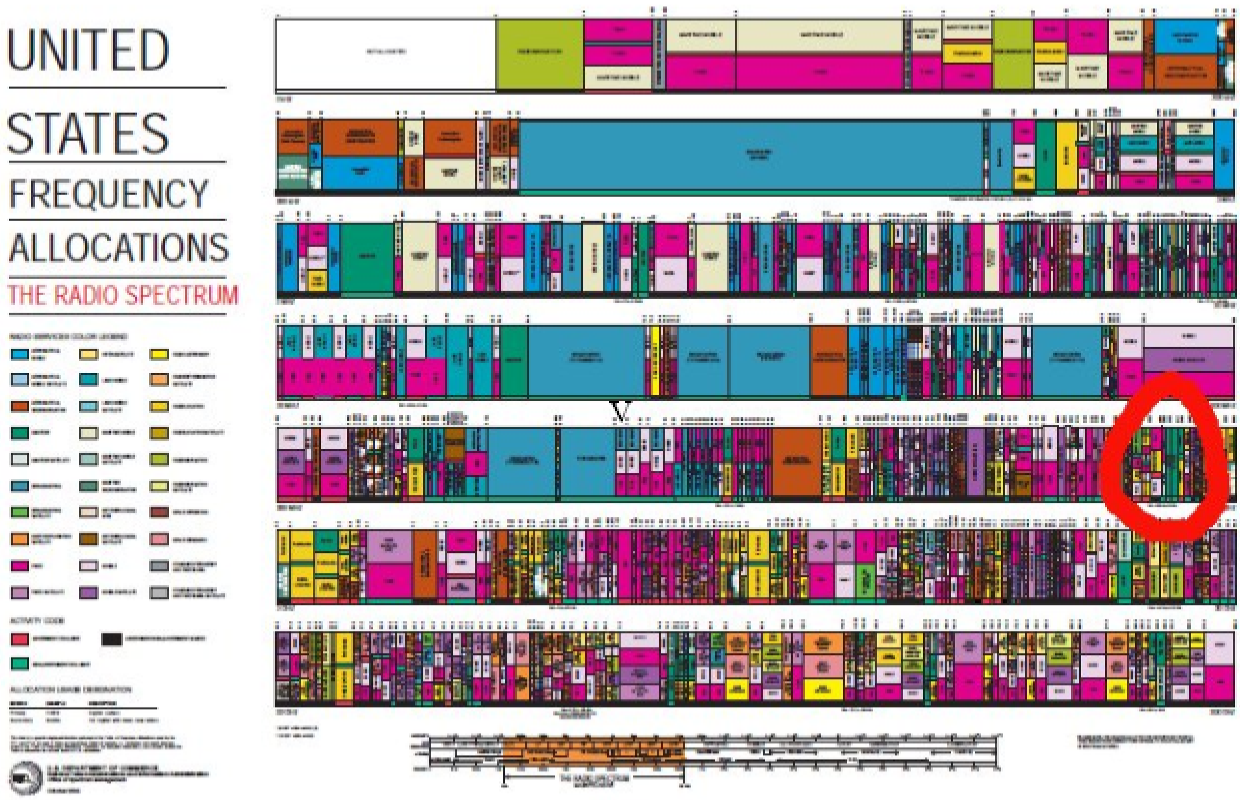
Properties of Media: Wires

Frequency (MHz)	Category 5e UTP Cable, solid Attenuation (dB)	Category 6 UTP Cable, solid Attenuation (dB)
0.772	1.8	1.8
1.0	2.0	2.0
4.0	4.1	3.8
8.0	5.8	5.3
10.0	6.5	6.0
16.0	8.2	7.6
20.0	9.3	8.5
25.0	10.4	9.5
31.25	11.7	10.7
62.5	17.0	15.4
100.0	22.0	19.8
200.0	—	29.0
250.0	—	32.8

Table T1: Attenuation of UTP cables, Categories 5e and 6, 100 m

http://www.siemon.com/uk/white_papers/04-01-15_cat6.asp

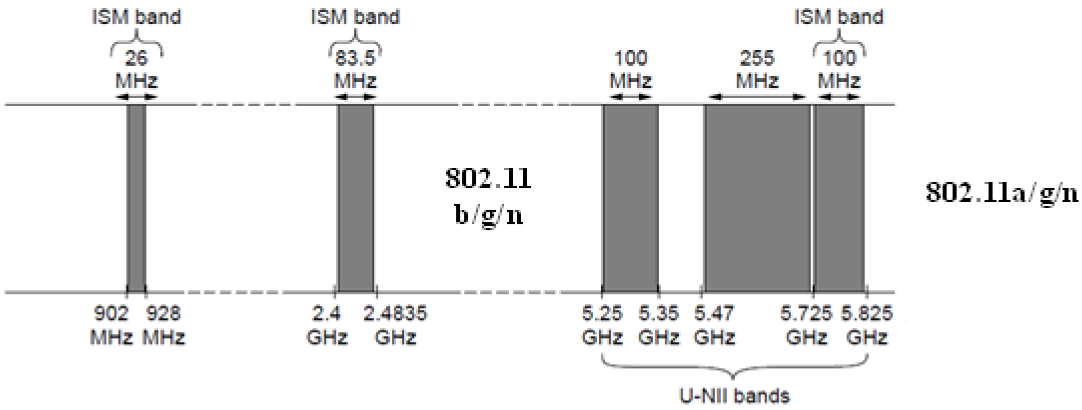
Radio Spectrum Allocation



http://www.ntia.doc.gov/files/ntia/publications/2003-allochrt.pdf

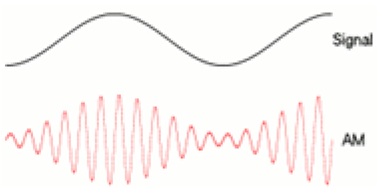
Unlicensed band

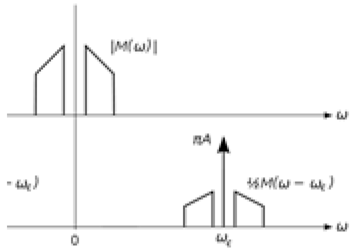
- ISM bands – Industrial, Scientific, and Medical
- Free for use at low power; devices manage interference
  - Widely used for networking (Bluetooth, Zigbee, Microwave)
  - Most importantly WiFi
- What percentage of the entire spectrum is used by 802.11?
  - 0.06%



Baseband / Passband

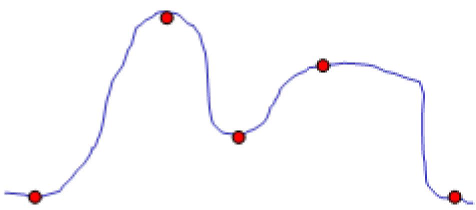
- We know that (more or less) any signal can be thought of as the sum of pure sines and cosines
- We know that transmission media have limited bandwidth
- Does it matter if the spectrum we have is 0-B MHz (baseband) or C to C+B MHz (passband)?
  - Nope





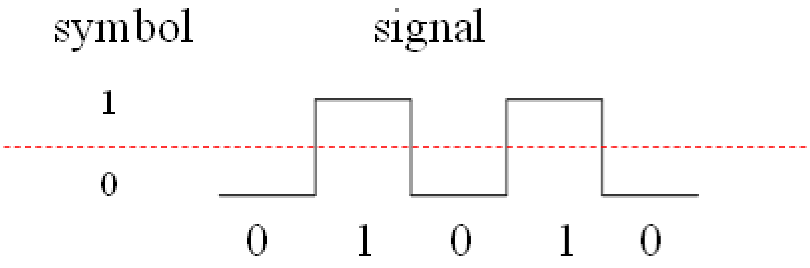
http://en.wikipedia.org/wiki/Amplitude_modulation

Sampling: Continuous Signal to Discrete Series

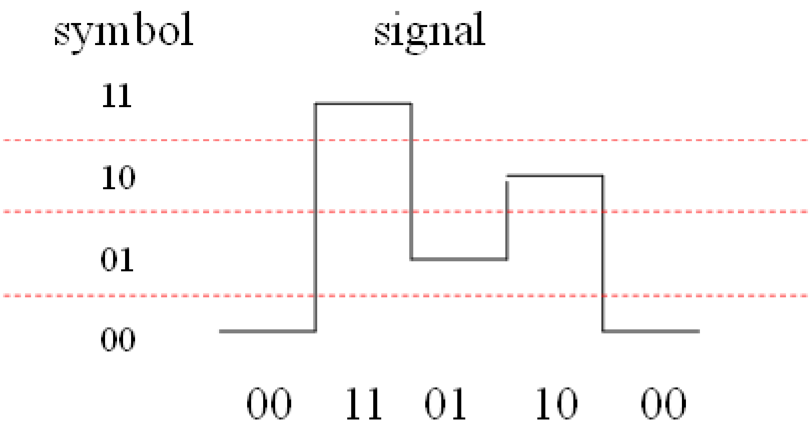


Every sample produces a symbol.

Information (bits) vs. Symbols



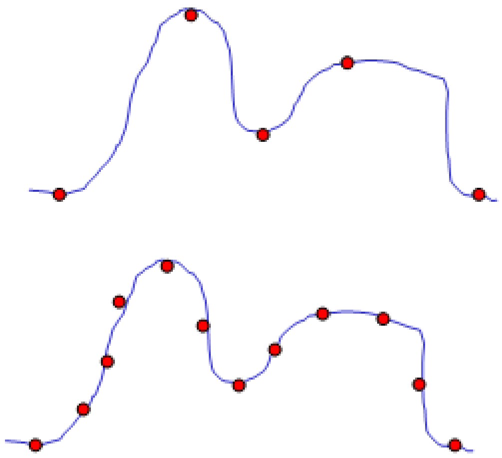
bits/second =
symbols/second * bits/symbol



Is there any limit to the potential bit rate?

Can I Increase Bit Rate By Sampling Faster?

bits/second = symbols/second * bits/symbol



Nyquist Formula: Limit on Symbol Rate

- If the signal is restricted to bandwidth_{EE} B, then…

  2B samples of the signal are sufficient to reconstruct the entire signal

- That is, once you've learned 2B "things," there's nothing more to learn from faster sampling of the input signal

- Thus, 2B is maximum possible (independent) symbol rate, even if there is no distortion at all in the received signal

How about more bits/symbol?

bits/second = symbols/second * bits/symbol

- Shannon's Theorem:

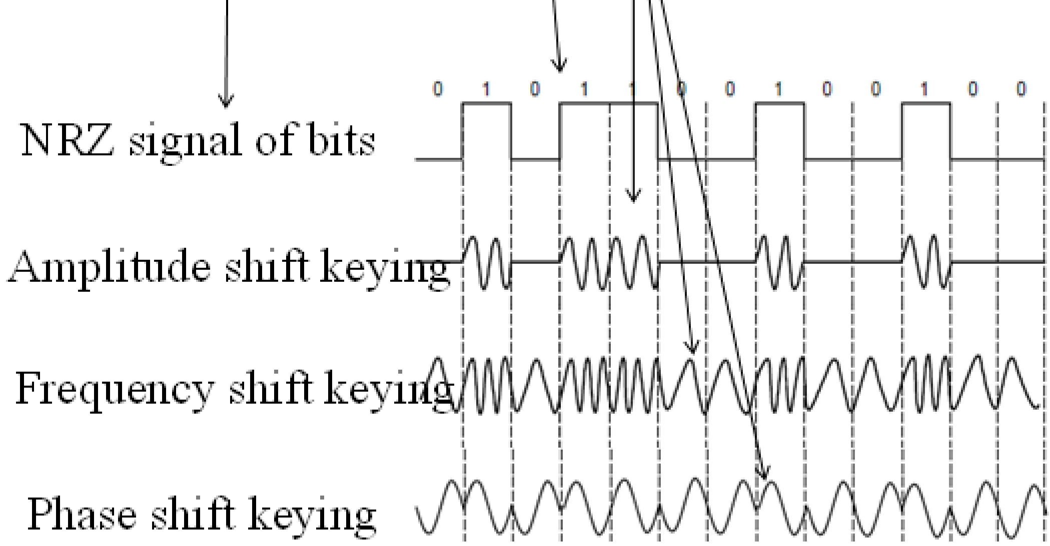
  $$\text{bit rate} \le B \log_2(1 + S/N)$$

  where S is the received signal power, N is the noise, and B is the available bandwidth$_{EE}$

- So, bit rate is:
  - Limited by noise (inaccuracy in sampling)
  - Limited by received power, with diminishing returns

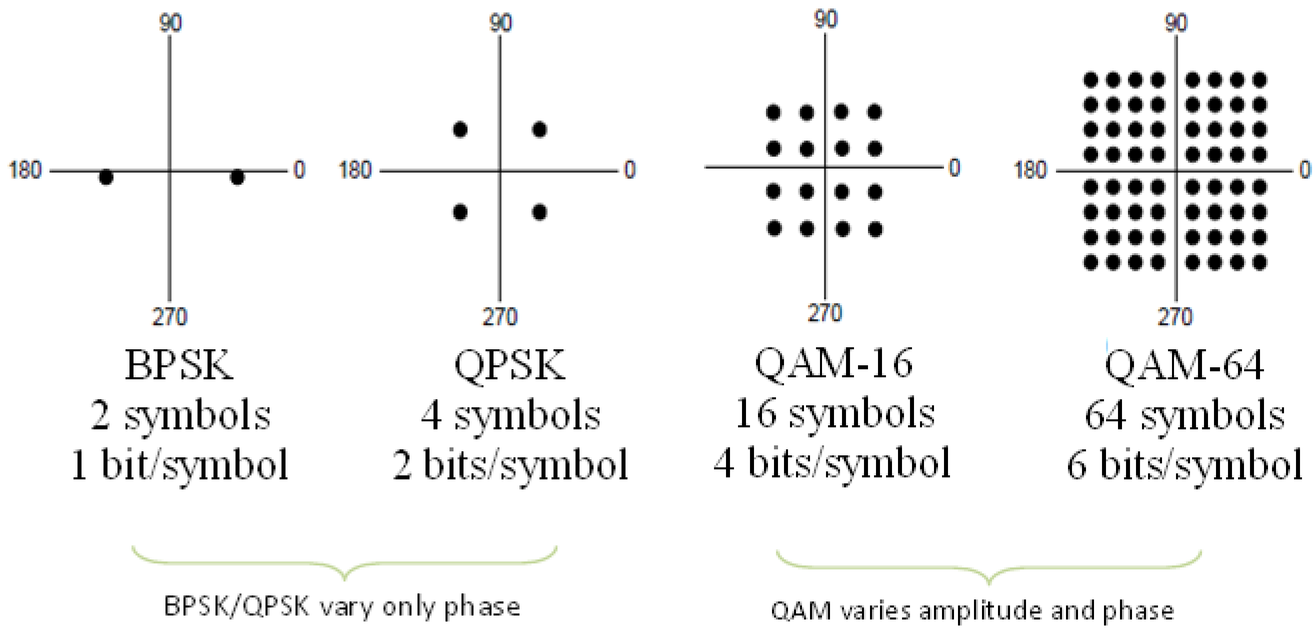
Engineering symbols: signal modulation

- The modulating signal has data; the carrier signal is the signal being moduled; the modulated signal is the radio wave
- To modulate, you can change the amplitude, the phase, or the frequency

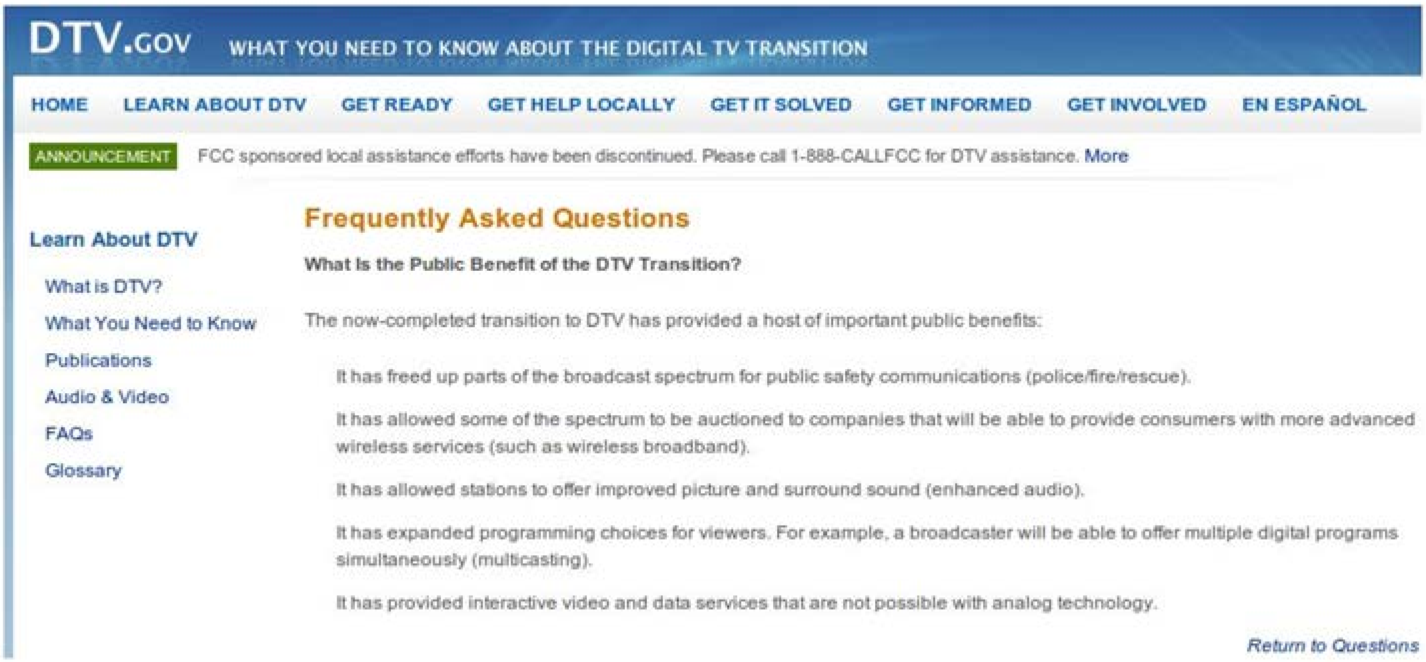


Multi-bit Symbols: Examples

- Represent amplitude (distance from origin) and phase (angle around origin) modulation in a *constellation diagram*



Links Are Valuable


DTV.GOV WHAT YOU NEED TO KNOW ABOUT THE DIGITAL TV TRANSITION

HOME LEARN ABOUT DTV GET READY GET HELP LOCALLY GET IT SOLVED GET INFORMED GET INVOLVED EN ESPAÑOL

ANNOUNCEMENT FCC sponsored local assistance efforts have been discontinued. Please call 1-888-CALLFCC for DTV assistance. More

Learn About DTV

- What is DTV?
- What You Need to Know
- Publications
- Audio & Video
- FAQs
- Glossary

Frequently Asked Questions

What Is the Public Benefit of the DTV Transition?

The now-completed transition to DTV has provided a host of important public benefits:

It has freed up parts of the broadcast spectrum for public safety communications (police/fire/rescue).

It has allowed some of the spectrum to be auctioned to companies that will be able to provide consumers with more advanced wireless services (such as wireless broadband).

It has allowed stations to offer improved picture and surround sound (enhanced audio).

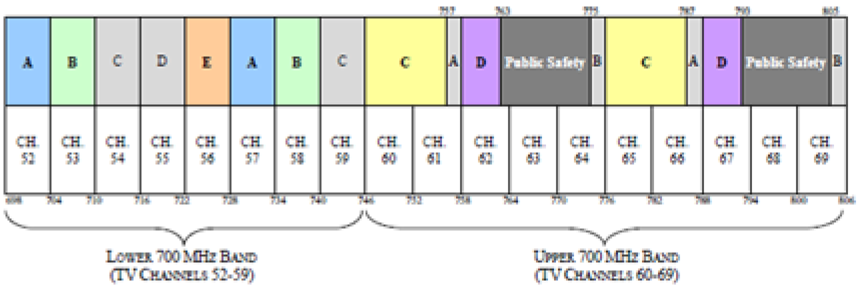
It has expanded programming choices for viewers. For example, a broadcaster will be able to offer multiple digital programs simultaneously (multicasting).

It has provided interactive video and data services that are not possible with analog technology.

Return to Questions

FCC Auction 73

Revised 700 MHz Band Plan for Commercial Services



Block	Frequencies (MHz)	Bandwidth	Pairing	Area Type	Licenses
A	698-704, 728-734	12 MHz	2 x 6 MHz	EA	176
B	704-710, 734-740	12 MHz	2 x 6 MHz	CMA	734
C	710-716, 740-746	12 MHz	2 x 6 MHz	CMA	734
D	716-722	6 MHz	unpaired	EAG	6
E	722-728	6 MHz	unpaired	EA	176
C	746-757, 776-787	22 MHz	2 x 11 MHz	REAG	12
A	757-758, 787-788	2 MHz	2 x 1 MHz	MEA	52
D	758-763, 788-793	10 MHz	2 x 5 MHz	Nationwide	1 *
B	775-776, 805-806	2 MHz	2 x 1 MHz	MEA	52

* Subject to conditions respecting a public/private partnership.

The blocks shaded above in gray (Lower 700 MHz Band C and D Blocks and Upper 700 MHz Band A and B Blocks) were auctioned prior to Auction 73.

Links Are Valuable

The New York Times March 21, 2008

And the Winners Are . . .

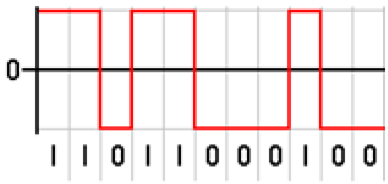
The government made $19.1 billion in its auction of wireless spectrum to 101 companies. The big spenders were established cellphone carriers, although a satellite TV company was a winner.

COMPANY	VALUE OF WINNING BIDS
Cellco Partnership (**Verizon Wireless**)	**$9,363,160,000**
AT&T Mobility Spectrum	**6,636,658,000**
Frontier Wireless (**Dish Network**)	**711,871,000**
Qualcomm	**558,142,000**
King Street Wireless (**US Cellular**)	**400,638,000**
MetroPCS 700 MHz	313,267,000
Cox Wireless	304,633,000
Cellular South Licenses	191,533,000
CenturyTel Broadband Wireless	148,964,000
Vulcan Spectrum (backed by Paul Allen)	112,793,000
Continuum 700	88,179,000
Cavalier Wireless	61,803,000
Puerto Rico Telephone Co.	31,402,000
Triad 700	22,694,000
McBride Spectrum Partners	8,490,000

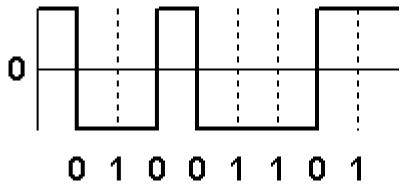
Sources: Federal Communications Commission; Goldman Sachs THE NEW YORK TIMES

Coding

- Modulate something – amplitude, frequency, phase
- A key issue is clocking
  - Higher transmission rates require better sync
- Some example encodings (thanks, *wikipedia*):



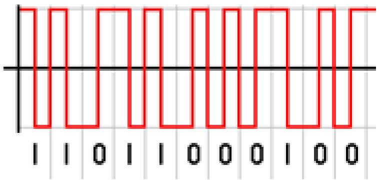
NRZ
(RS-232)



NRZI
(CDs, USB, Fast Ethernet)

Encoding: Self-Clocking

- Receiver can derive clock from the data signal
- Example 1:



Manchester
(10Mbps Ethernet)

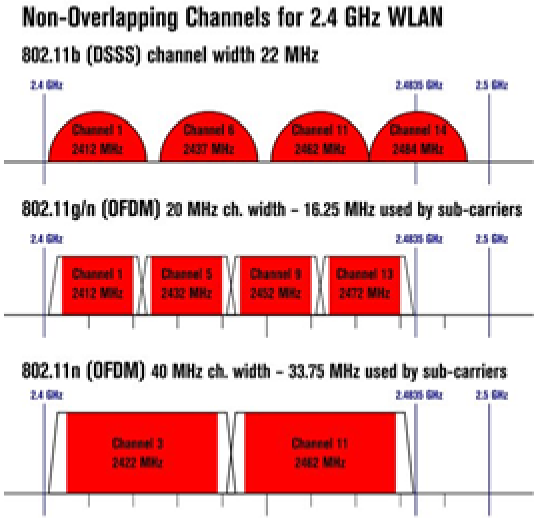
- Example 2: Use NRZI, but make sure there are transitions
  - 4B/5B multi-level transition (MLT)
    - 100Mbps Ethernet, with 3 levels of signal
  - 8B/10B MLT
    - 1000Mbps Ethernet, with 5 levels of signal
  - (MLT is used to limit the required signal bandwidth to what can be carried on cheap, CAT 5 cable (100MHz).)

Ethernet (802.3) History

	10 Mbps	100 Mbps	1000 Mbps
Medium	Cat 3 cable 16 Mhz	Cat 5 cable 100 MHz	Cat 5e cable 100 Mhz Cat 6 cable 250 MHz
Encoding	Manchester	NRZI 4b/5b MLT-3	PAM5 8b/10b

Wireless (802.11) History

- Each "release" (802.11b, 802.11g, etc.) provides a number of rates and uses a number of distinct codings and modulations



Encodings:
DPSK – 1 bit/symbol
QAM16 – 4 bits/symbol
QAM64 – 6 bits/symbol

Direct Link Networks: Framing and Errors