

# Computer Networks

Signals (§2.2, 2.3)



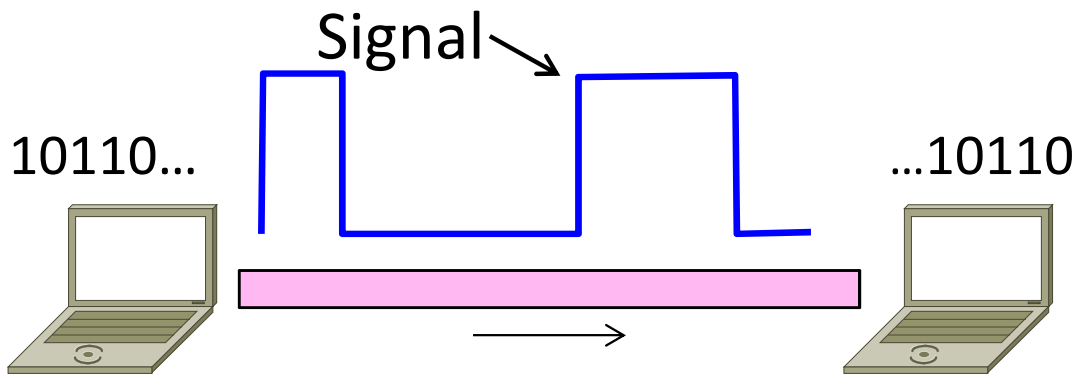
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# Topic

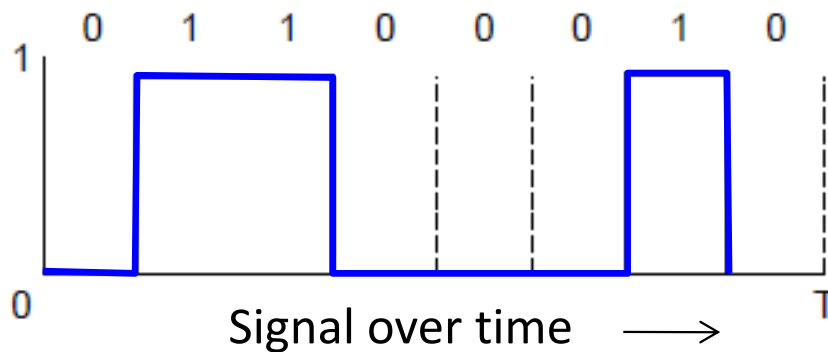
- Analog signals encode digital bits.  
We want to know what happens as signals propagate over media



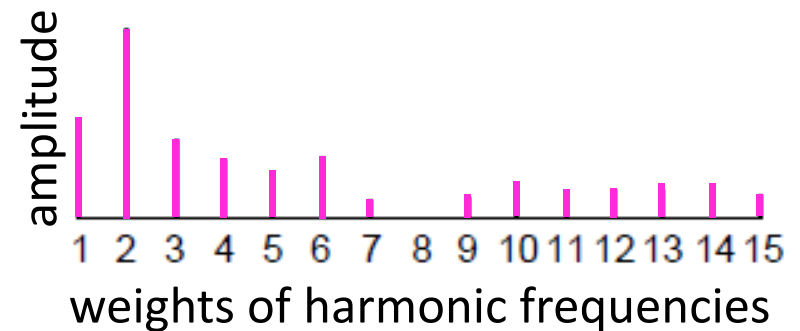
# Frequency Representation

- A signal over time can be represented by its frequency components (called Fourier analysis)

$$g(t) = \frac{1}{2}c + \sum_{n=1}^{\infty} a_n \sin(2\pi nft) + \sum_{n=1}^{\infty} b_n \cos(2\pi nft)$$

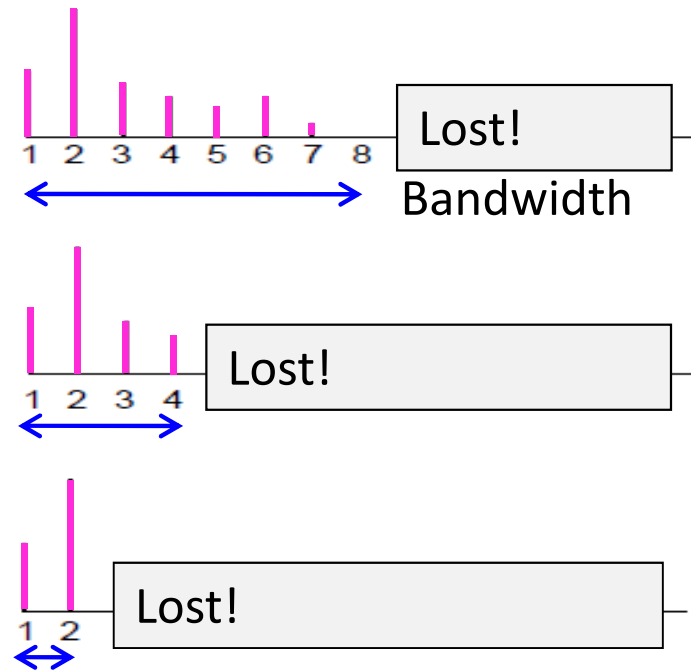
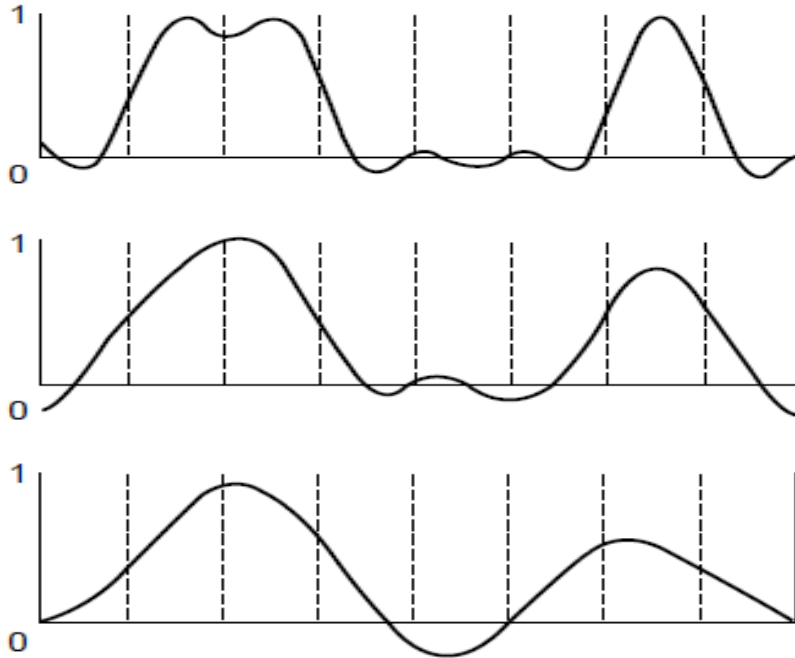


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# Effect of Less Bandwidth

- Fewer frequencies (=less bandwidth) degrades signal



# Signals over a Wire

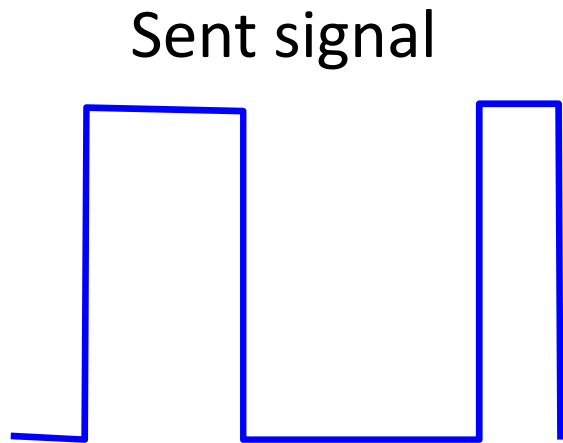
- What happens to a signal as it passes over a wire?
  1. The signal is delayed (propagates at  $\frac{2}{3}c$ )
  2. The signal is attenuated (goes for m to km)
  3. Frequencies above a cutoff are highly attenuated
  4. Noise is added to the signal (later, causes errors)

EE: Bandwidth = width of frequency band, measured in Hz

CS: Bandwidth = information carrying capacity, in bits/sec

# Signals over a Wire (2)

- Example:



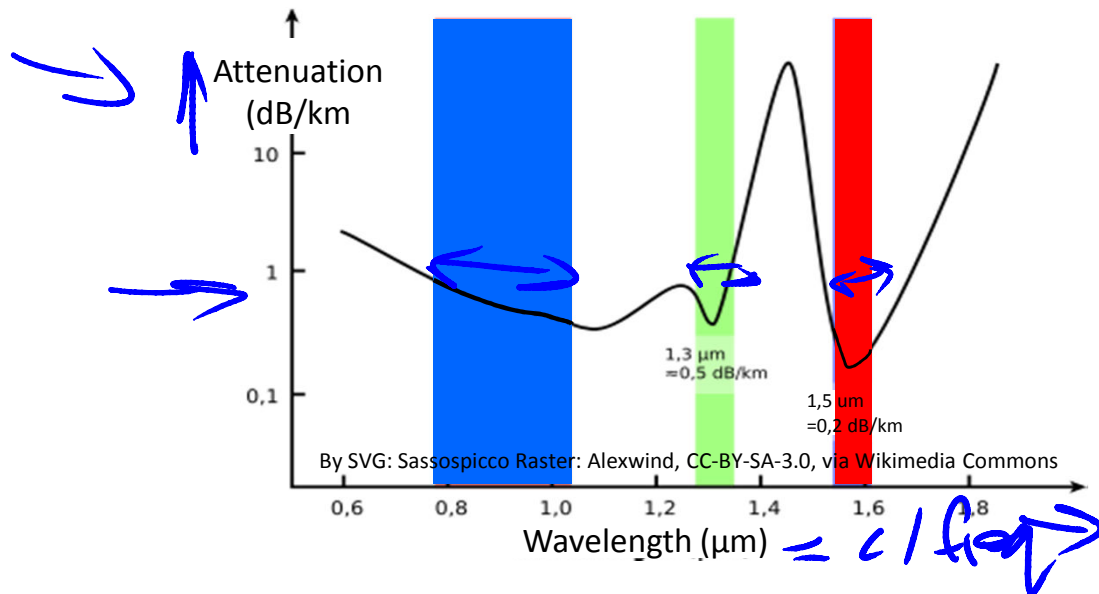
2: Attenuation:

→ 3: Bandwidth:

4: Noise:

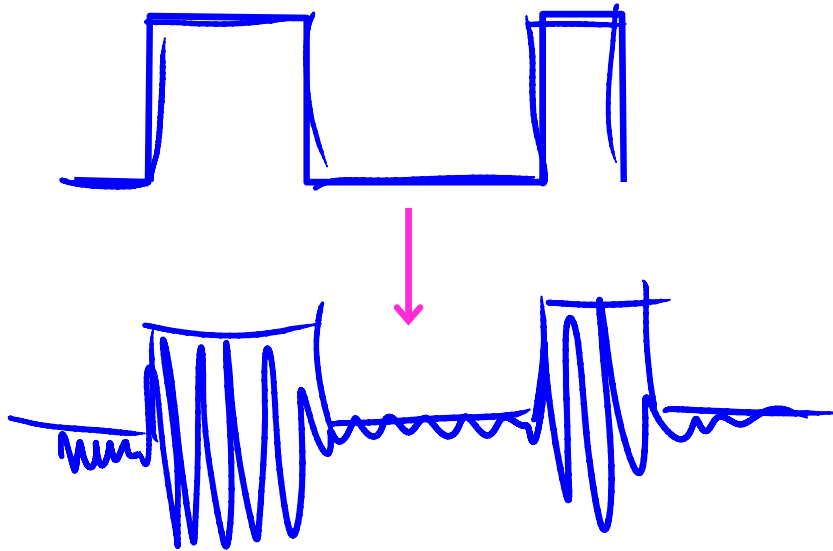
# Signals over Fiber

- Light propagates with very low loss in three very wide frequency bands
  - Use a carrier to send information



# Signals over Wireless

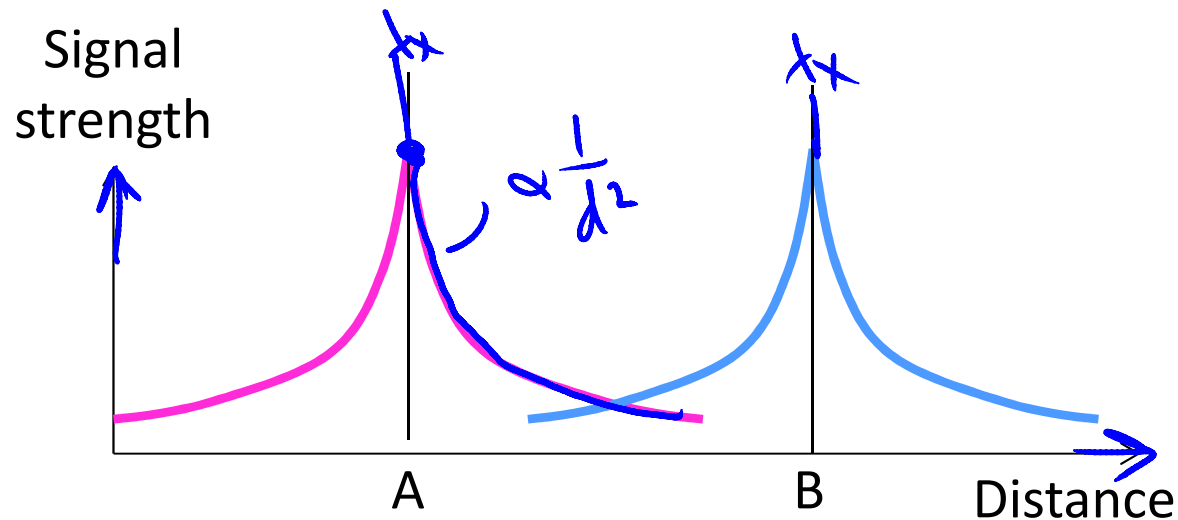
- Signals transmitted on a carrier frequency, like fiber (more later)





# Signals over Wireless (2)

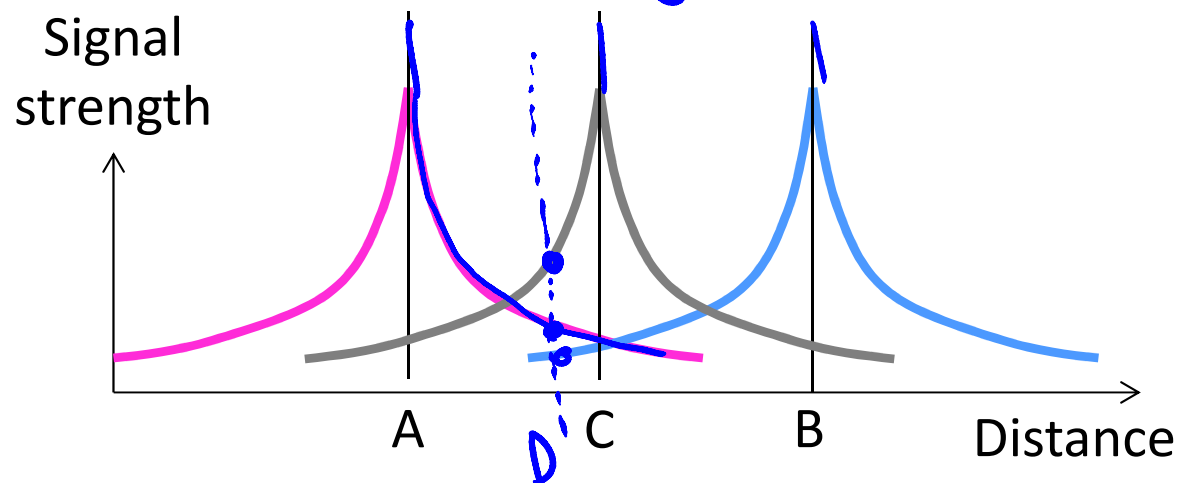
- Travel at speed of light, spread out and attenuate faster than  $1/\text{dist}^2$



# Signals over Wireless (3)

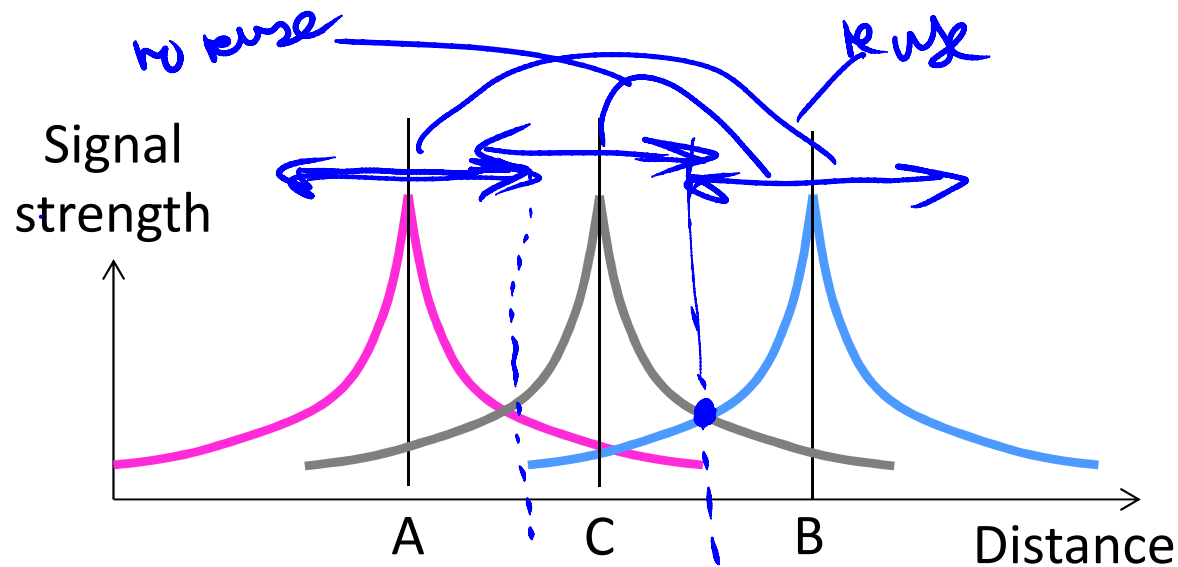
- Multiple signals on the same frequency interfere at a receiver

*D sees = strong C + weak A, B*



# Signals over Wireless (4)

- Interference leads to notion of spatial reuse (of same freq.)



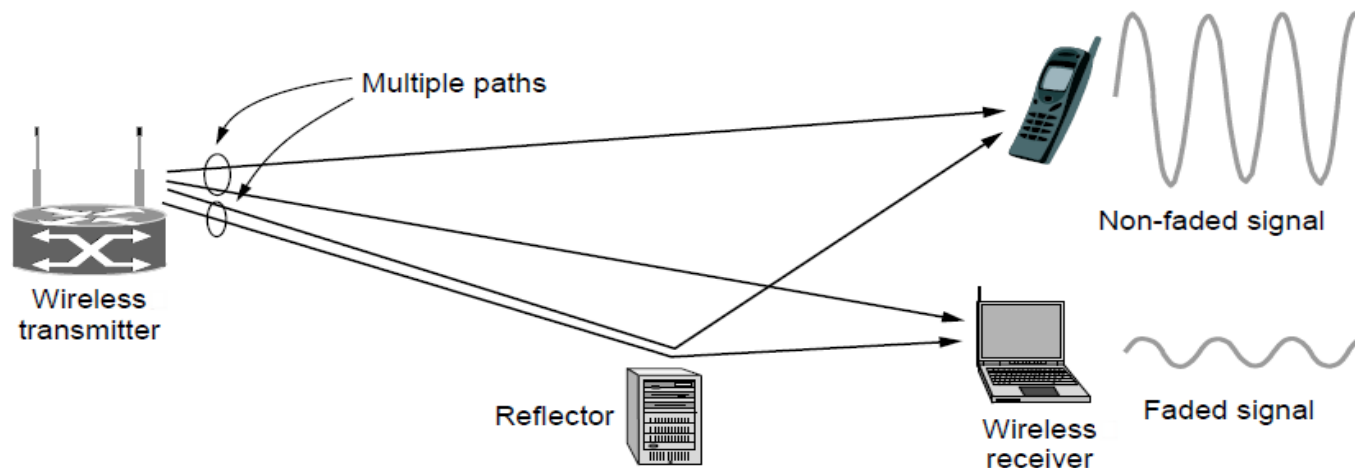
# Signals over Wireless (5)

- Various other effects too!
  - Wireless propagation is complex, depends on environment
- Some key effects are highly frequency dependent,
  - E.g., multipath at microwave frequencies

802.11  
3h

# Wireless Multipath

- Signals bounce off objects and take multiple paths
  - Some frequencies attenuated at receiver, varies with location
  - Messes up signal; handled with sophisticated methods (§2.5.3)



# END

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