CS5530
Mobile/Wireless Systems
Key Wireless Physical Layer Concepts

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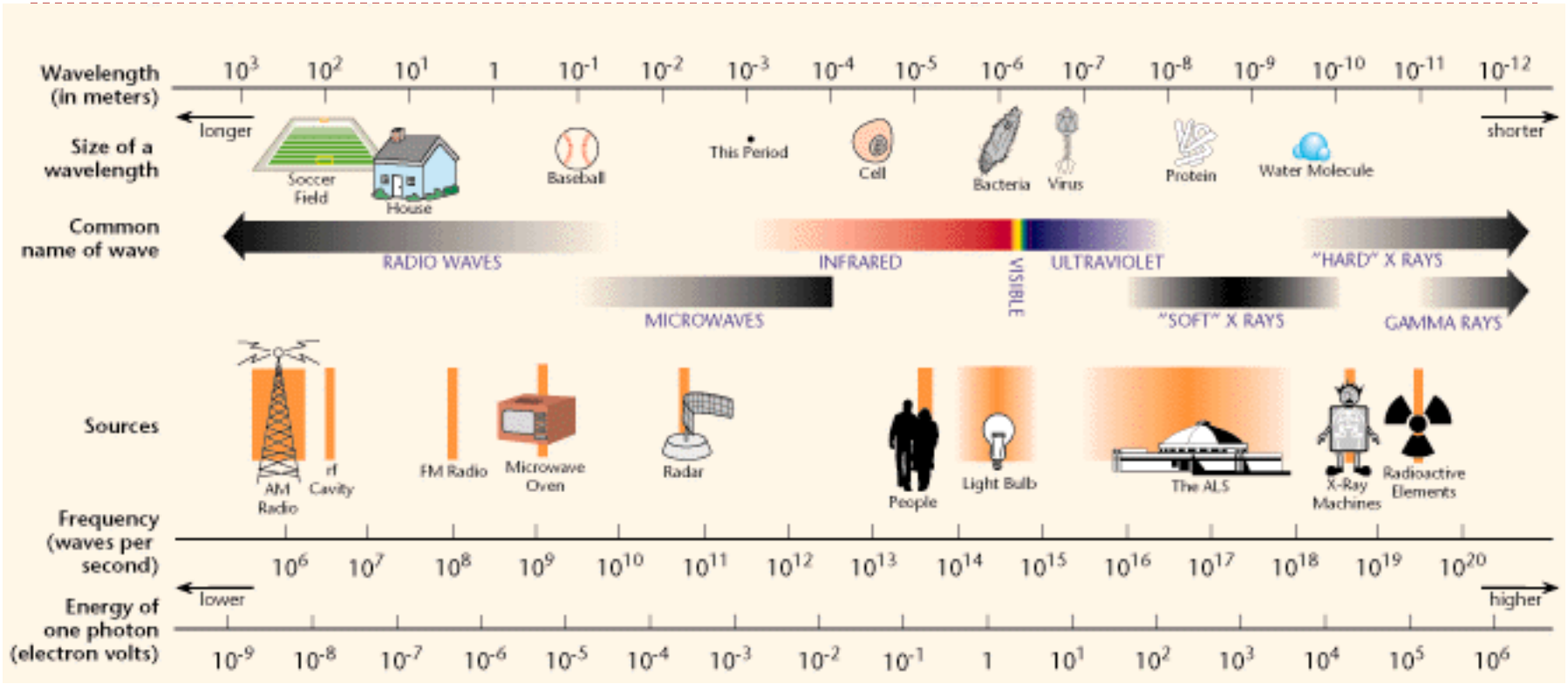
Outline

- Electromagnetic spectrum
- Reflection, diffraction and scattering of signals
- Multipath, Doppler shift
- Digital modulation and multiplexing
- Noise

Electromagnetic Spectrum



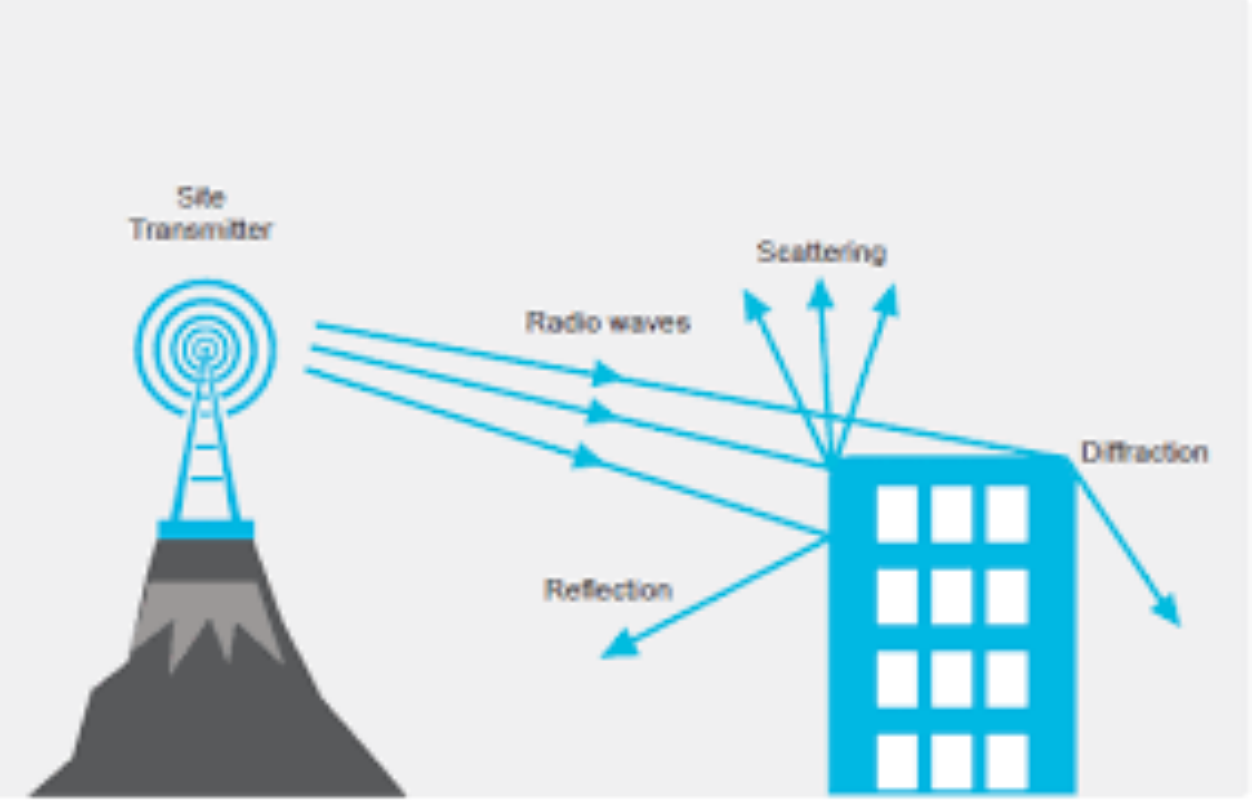
- Wireless communication
  - 100 kHz to 60 GHz
  - Higher frequency: only go in a straight line, can't go far

Image: http://www2.lbl.gov/MicroWorlds/ALSTool/EMSpec/EMSpec2.html

Antenna

- Transmitter converts electrical energy to electromagnetic waves
- Receiver converts electromagnetic waves to electrical energy
- Same antenna used for transmission and reception
  - Signal of same frequency cause interference
  - At receiver side

Reflection, diffraction and scattering



Reflection, diffraction and scattering

- Reflection
  - Surface large relative to the wavelength of signal
- Diffraction
  - Edge of impenetrable body is large relative to the wavelength of signal
- Scattering
  - Obstacle size in order of wavelength (lamp post)

- LOS
  - Diffracted and scattered signals are not significant
- Non-LOS
  - Diffraction and scattering are primary means of reception

Multipath Propagation

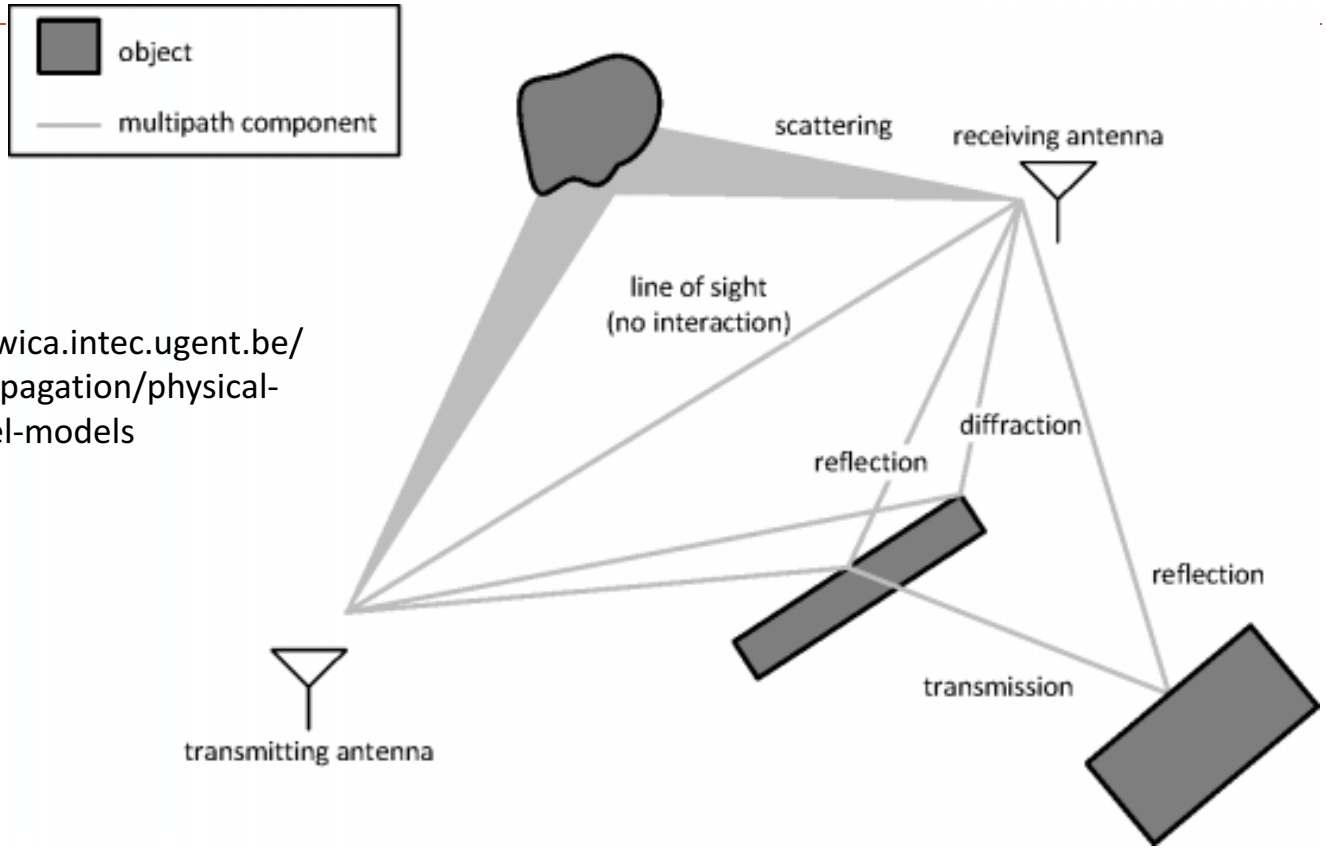
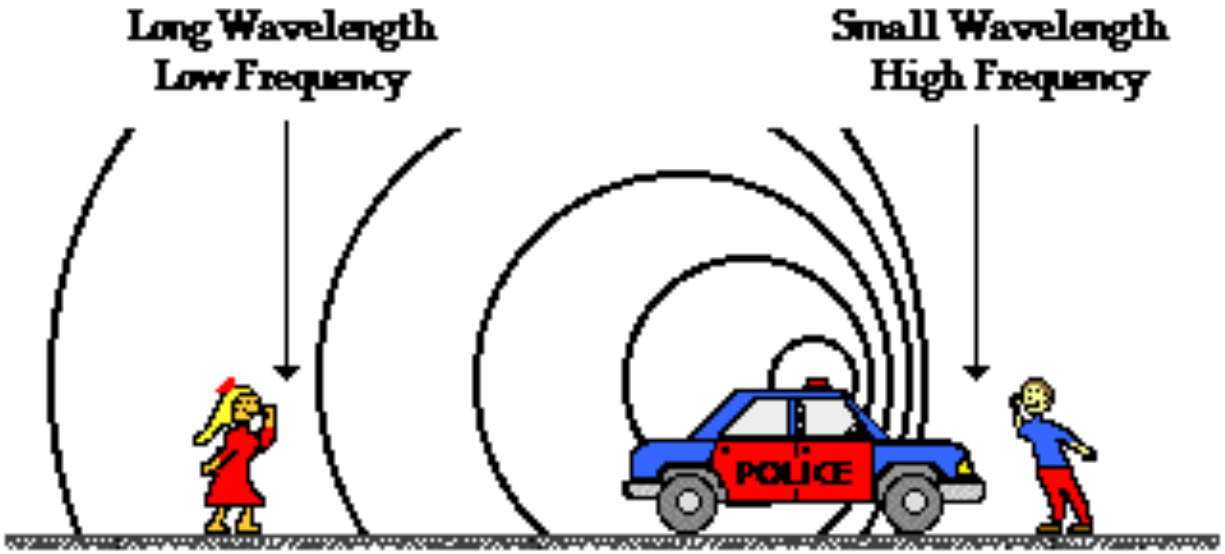


Image:
http://www.wica.intec.ugent.be/research/propagation/physical-radio-channel-models

- Each propagation path travels from transmitting antenna to receiving antenna while interacting with physical objects in the environment
- Signals bounce off objects and take multiple paths

Doppler Shift



- If transmitter or receiver is mobile, the frequency of received signal changes
  - Moving towards each other: higher frequency
  - Moving away from each other: lower frequency

Doppler Shift (cont.)

- Frequency difference = speed (m/sec) / wavelength (m)
- Example:
  - 2.4 GHz: wavelength = speed of light / frequency = 3*10^8/2.4*10^9 = 0.125 m
  - 120 km/h (75 m/h) = 120*10^3/3600 = 33.3 m/s
  - Frequency difference = 33.3/0.125 = 267 Hz

Doppler Shift (cont.)

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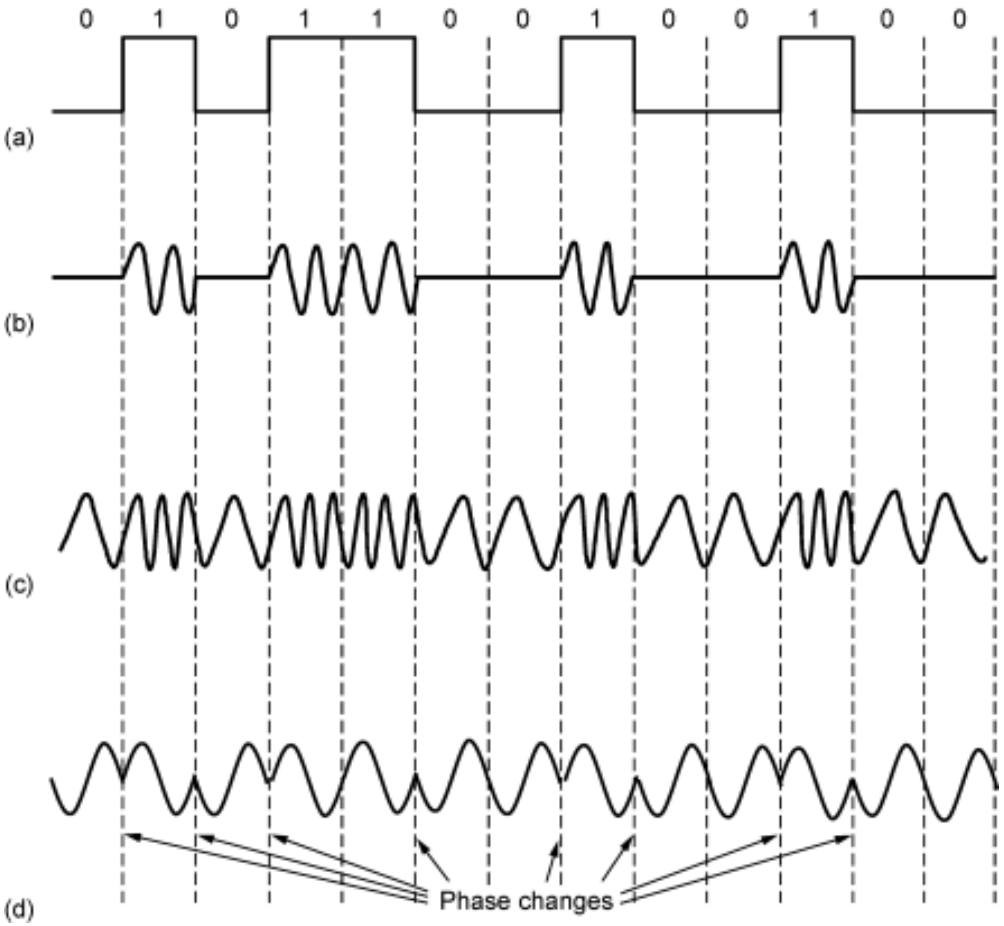
  - 120 km/h (75 m/h) = 120*10^3/3600 = 33.3 m/s
  - Frequency difference = 33.3/0.125 = 267 Hz
- Why important?
  - Mobile environment: walking, driving
  - Example: WiMax is only designed for speed lower than 60 km/h (37.5 m/h)

Digital Modulation and Multiplexing

- Digital Modulation
  - Process of converting between bits and signals that represent them
  - Regulate amplitude, phase, or frequency of a signal to convey bits
    - ASK, PSK, FSK
- Multiplexing
  - Use a single medium to carry several signals

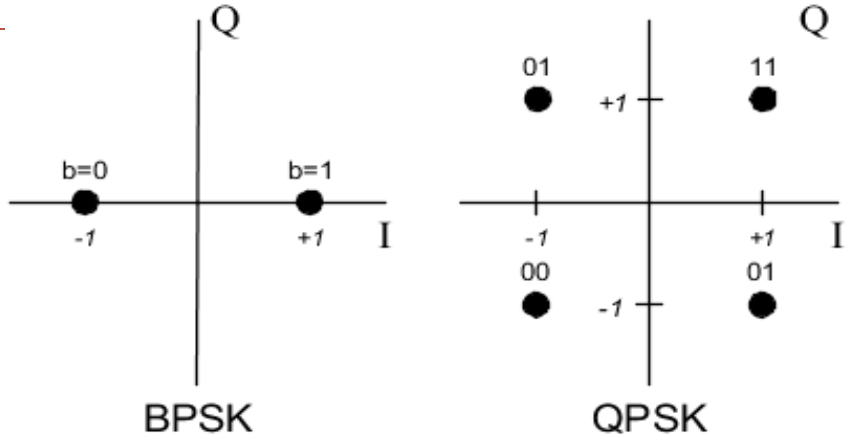
Digital Modulation and Multiplexing

- Digital Modulation
  - ASK (Amplitude Shift Keying)
    - Two different amplitudes: 0/1
  - FSK (Frequency Shift Keying)
    - Two different frequencies
  - PSK (Phase Shift Keying)
    - Wave is shifted 0 or 180 degrees
  - Only one of frequency / phase can be modulated at a time: they are related
  - Amplitude and phase can be modulated in combination

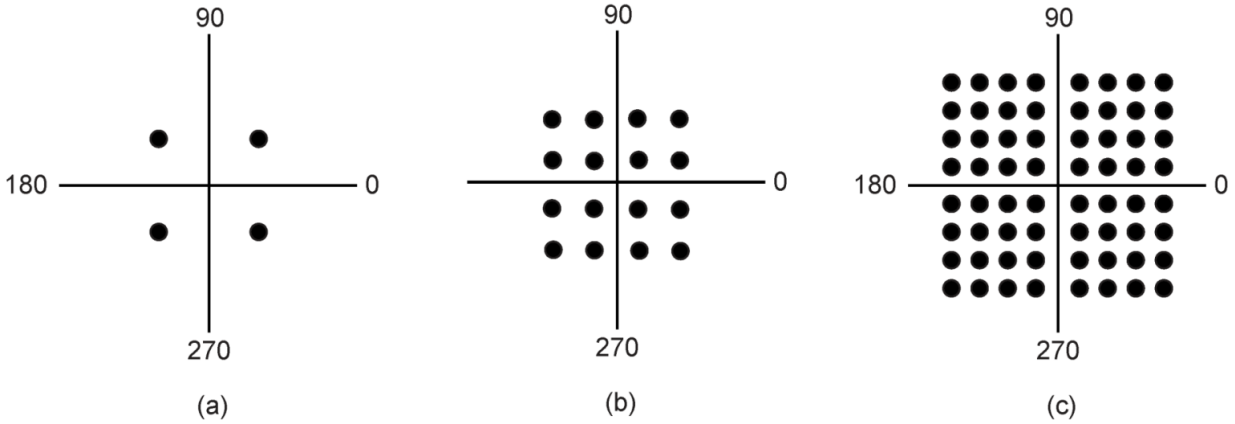


Digital Modulation and Multiplexing

- Digital Modulation
  - PSK (Phase Shift Keying)
    - Wave is shifted 0 or 180 degrees: BPSK
    - Wave is shifted 0/90/180/270 degrees: QPSK



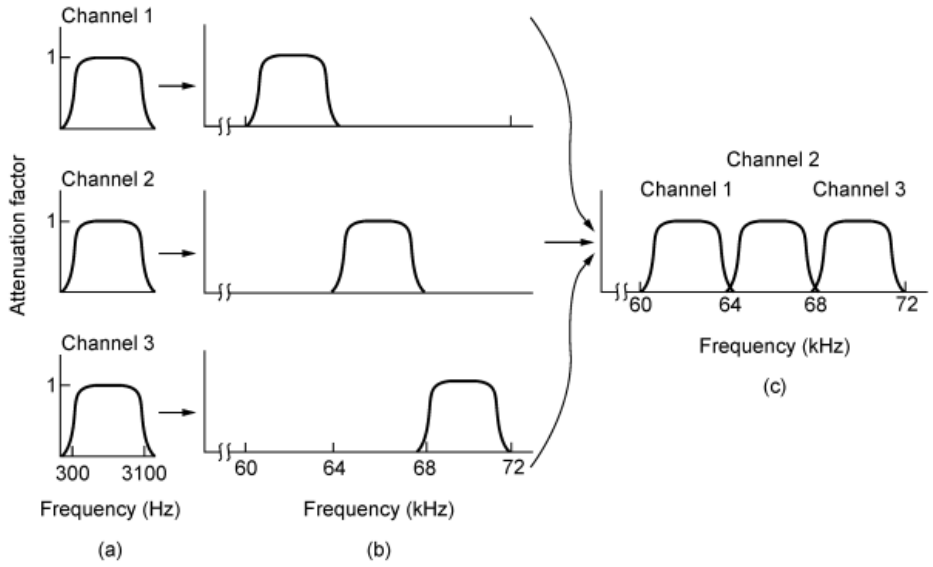
  - QAM (Quadrature Amplitude Modulation)
    - Amplitude and phase are modulated in combination



(a) QPSK. (b) 16 QAM. (c) 64 QAM.

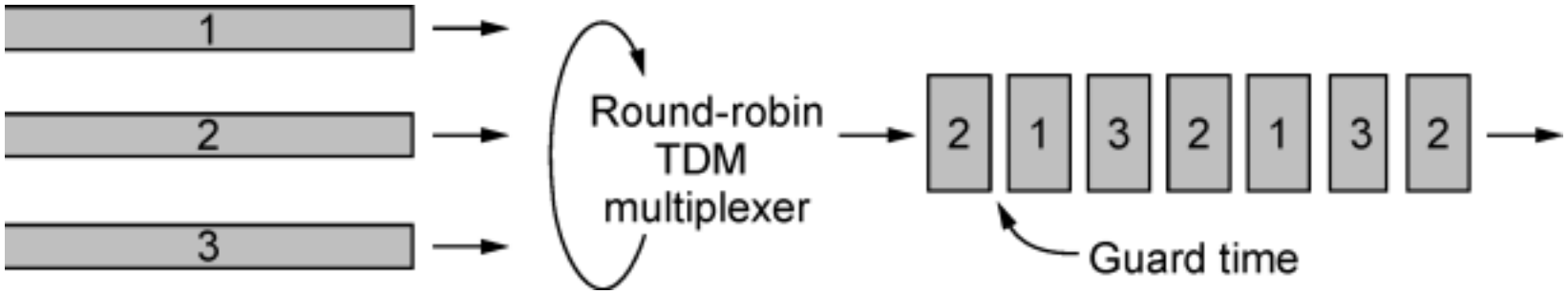
Digital Modulation and Multiplexing

- Multiplexing
  - FDM (Frequency Division Multiplexing)
    - Divides spectrum into frequency bands, with each user having exclusive possession of some band to send their signal



Digital Modulation and Multiplexing

- Multiplexing
  - FDM (Frequency Division Multiplexing)
  - TDM (Time Division Multiplexing)
    - Users take turns (round-robin), each one periodically getting entire bandwidth for a little burst of time

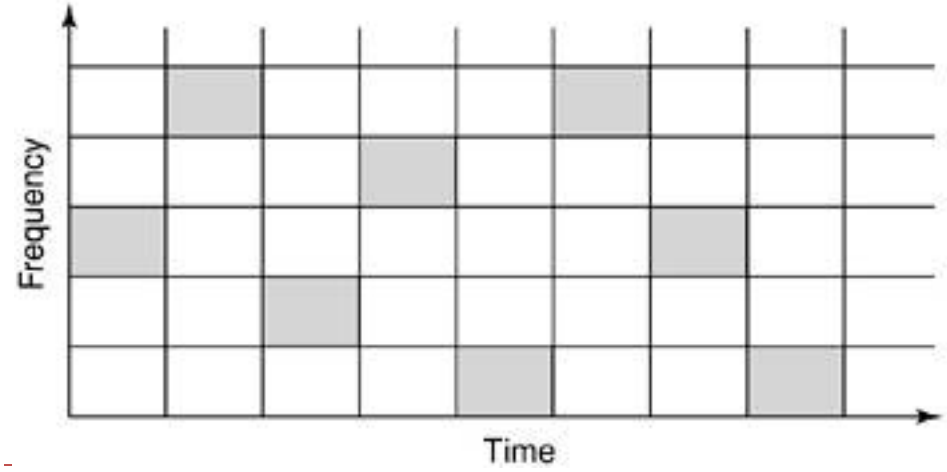


Digital Modulation and Multiplexing

- Multiplexing
  - FDM (Frequency Division Multiplexing)
  - TDM (Time Division Multiplexing)
  - CDM (Code Division Multiplexing)
    - A signal is spread out over a wider frequency band
    - More tolerant of interference
    - Allow multiple signals to share the same frequency band
      - CDMA (Code Division Multiple Access)

Frequency Hopping Spread Spectrum (FHSS)

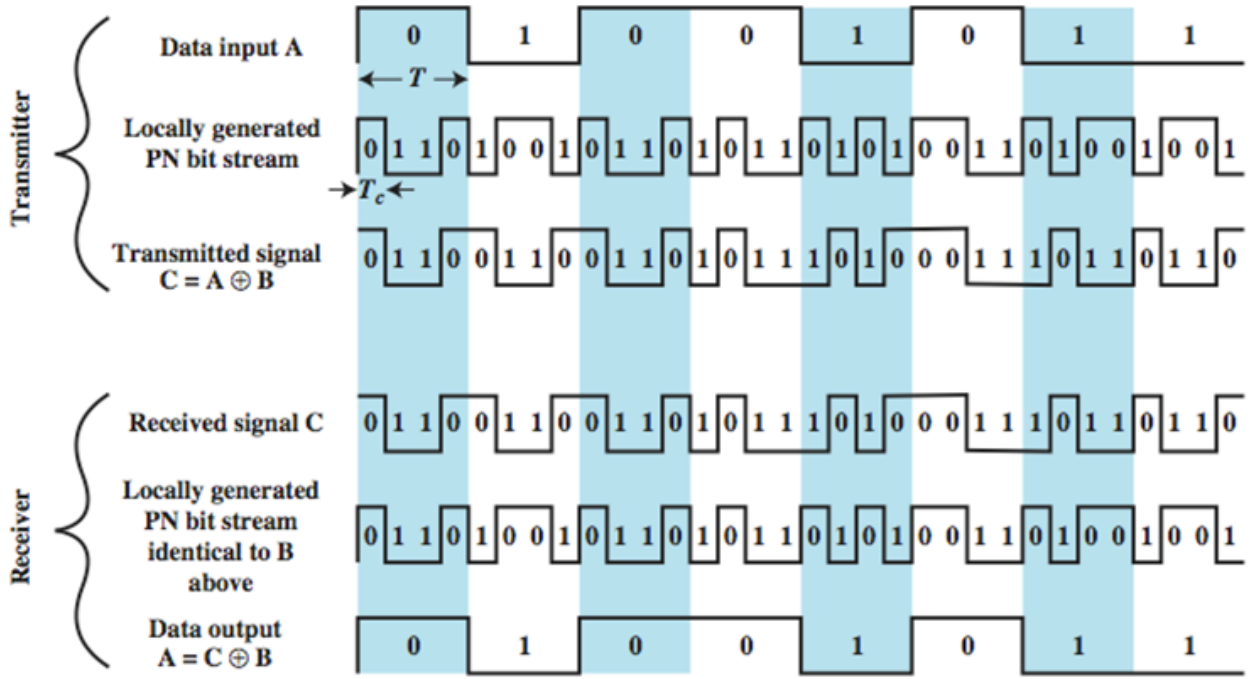
- Transmitting signals by rapidly switching among many frequency channels
  - Using a pseudorandom sequence known to only transmitter and receiver: training signal before transmission
  - Developed initially for military (prevent jamming and collision)
  - Spreads power over a wide spectrum (spread spectrum)



Hedy Lamarr

Direct Sequence Spread Spectrum (DSSS)

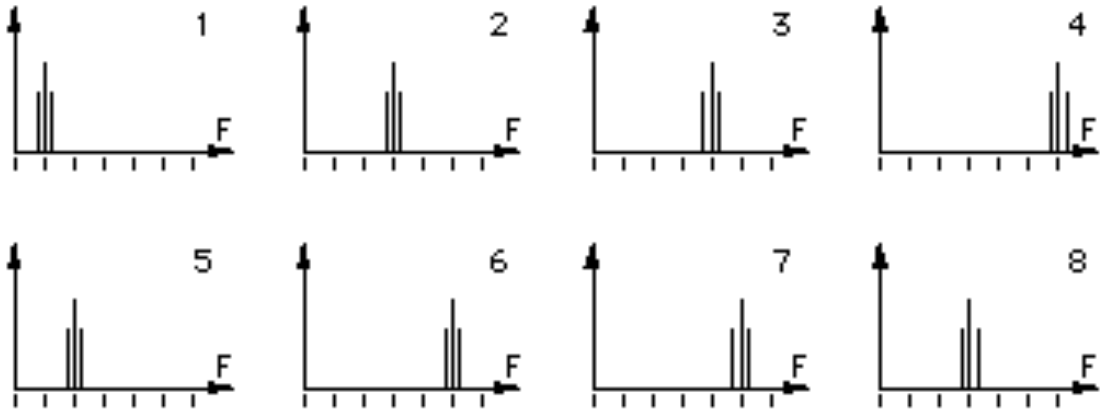
- Each bit is represented by multiple bits using a spreading code or chipping code
  - Transmitters XOR the chipping code with data to be transmitted
  - 10-100 bit chipping code: longer chipping code, more secure



FHSS and DSSS are two methods of CDMA

Applications

- FHSS in 802.11



  - A typical FHSS WLAN will subdivide the bandwidth into 79 non-overlapping channels, each 1MHz wide
  - 802.11 standard defines 78 different hopping patterns
  - The patterns allow for 26 networks to be co-located and still operate simultaneously

Noise and Different Sources

- Noise has 3 different sources
  - Thermal noise
    - Proportional to absolute temperature
    - Temperature measured from absolute zero in kelvins
  - Spurious emissions
    - Car ignition and electronic devices
    - More noise in urban areas
  - Receiver noise
    - Amplifier adds noise
    - Noise generated before the amplifier also gets amplified

Summary

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- Digital modulation and multiplexing
- Noise