西北工業大學
NORTHWESTERN POLYTECHNICAL UNIVERSITY

Wireless Sensor Networks

Lecture 3: Basics of Physical-layer Communication (I)

Lecturer: Zhuo Sun

Office: 509 School of Computer Science

Email: zsun@nwpu.edu.cn

Course structure

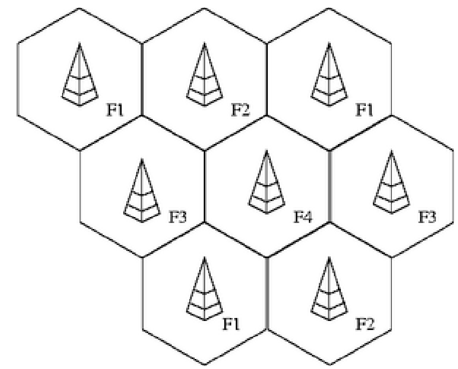
- WSN
  - WSN concepts
    - Concepts & applications of WSN
    - Node architecture & operating systems
  - Communcation protocols
    - Physical layer
    - MAC layer & link layer
    - Network layer
  - Node and network management
    - Time synchronization
    - Localization & positioning
    - Topology control
    - Security

Outline

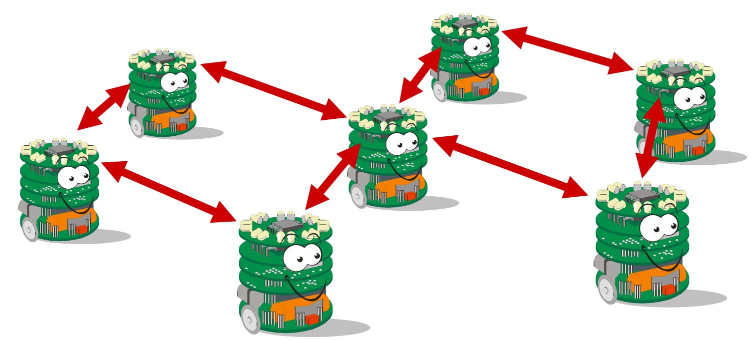
- Physical layer in OSI model
- Digital communication process
  - Source encoding
  - Modulation/Demodulation
- Wave propagation and noise (I)

Types of Radio Networks

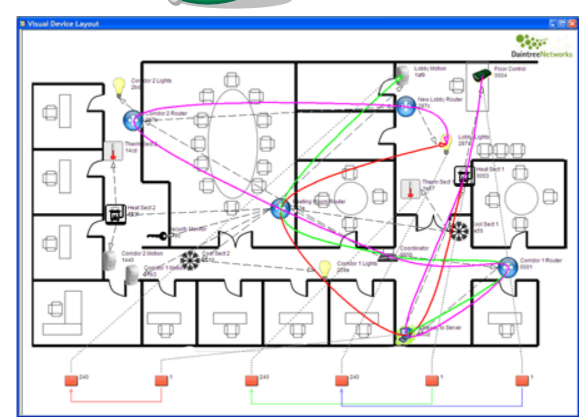
- Cellular Networks
  - base stations distributed over the field
  - each base station covers a cell
  - used for mobile phones
  - WLAN can be seen as a special case



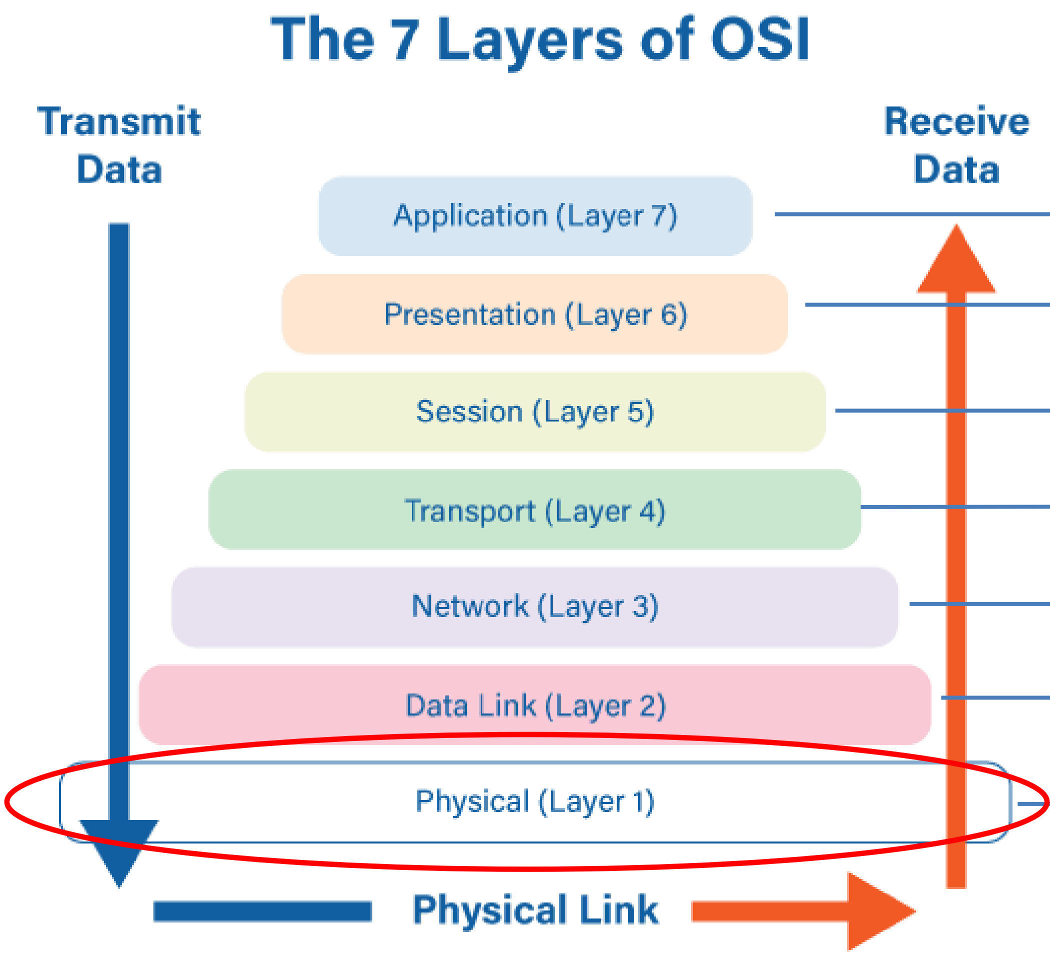
- Wireless Ad Hoc Networks
  - self-configuring network of mobile nodes
  - node serve as client and router
  - no infrastructure necessary



- Wireless Sensor Networks
  - network of sensor devices with controller and radio transceivers
  - Self-management



7-layer OSI model



- use software to send/receive information
- prepare for the session layer
- creates communication sessions
- breaks into segments/ reassemble segments
- breaks into packets and routes packets
- establishes/terminates physical connection
- transmits/receives the raw data

Physical layer in the OSI model

- Functionality
  - Interface between a link layer device and the physical medium
  - Translate between logical communication requests and hardware-specific operation
  - Convert between link layer information and electromagnetic signals transmitted over the physical medium
  - Most closely associated with the devices' physical connection
  - Define data rate (bits/s or symbols/s)
  - Define transmission modes (simplex, half duplex, and full duplex)

Simplex　　　Half-duplex　　　Full-duplex

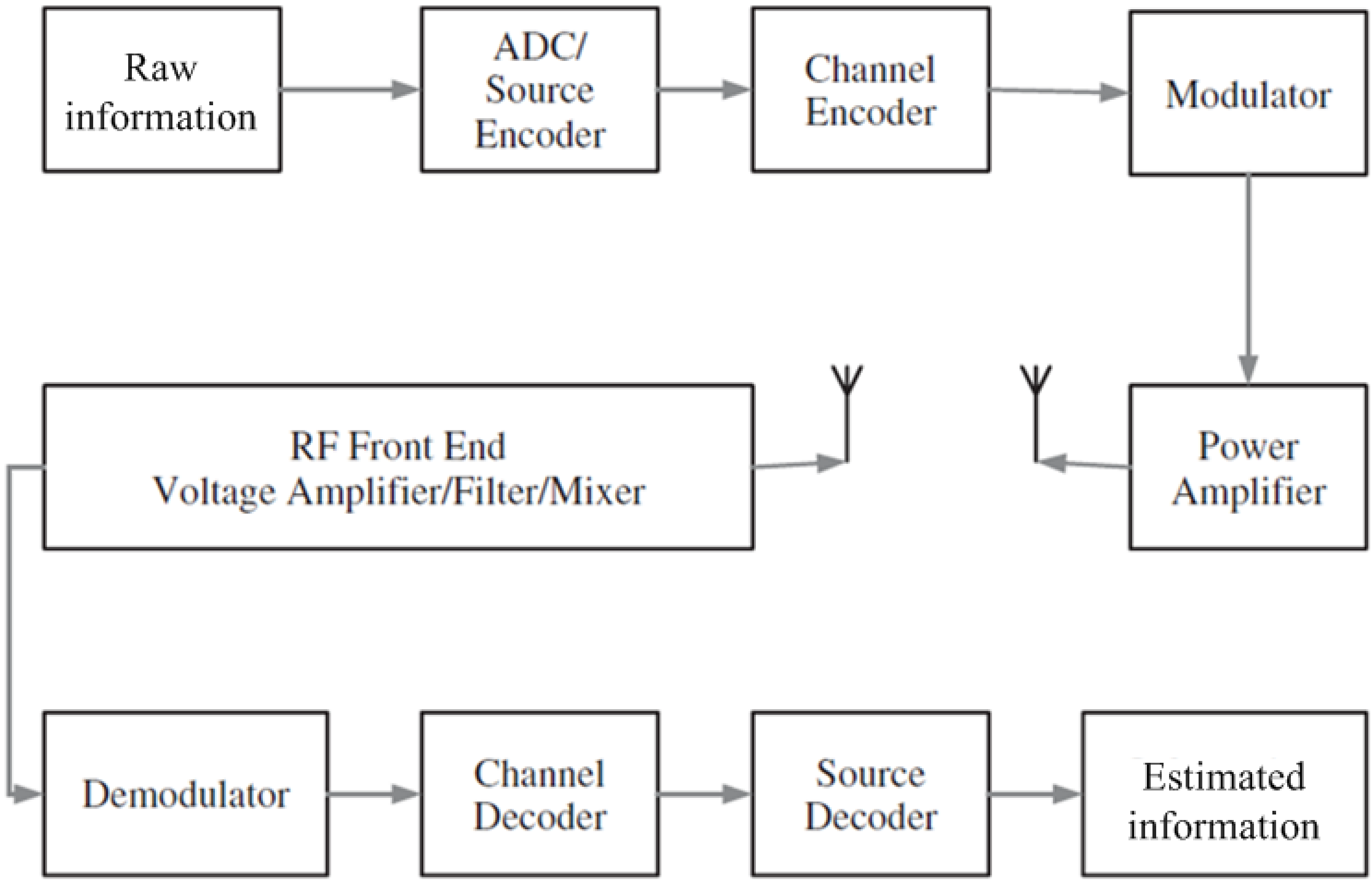
Question I

Question1: which layer is closest to the hardware in OSI model.

A. MAC layer
B. Network layer
C. Physical layer
D. Transport layer

Digital communication process

- Digital communication process(conversion between information and signal)



Digital communication process

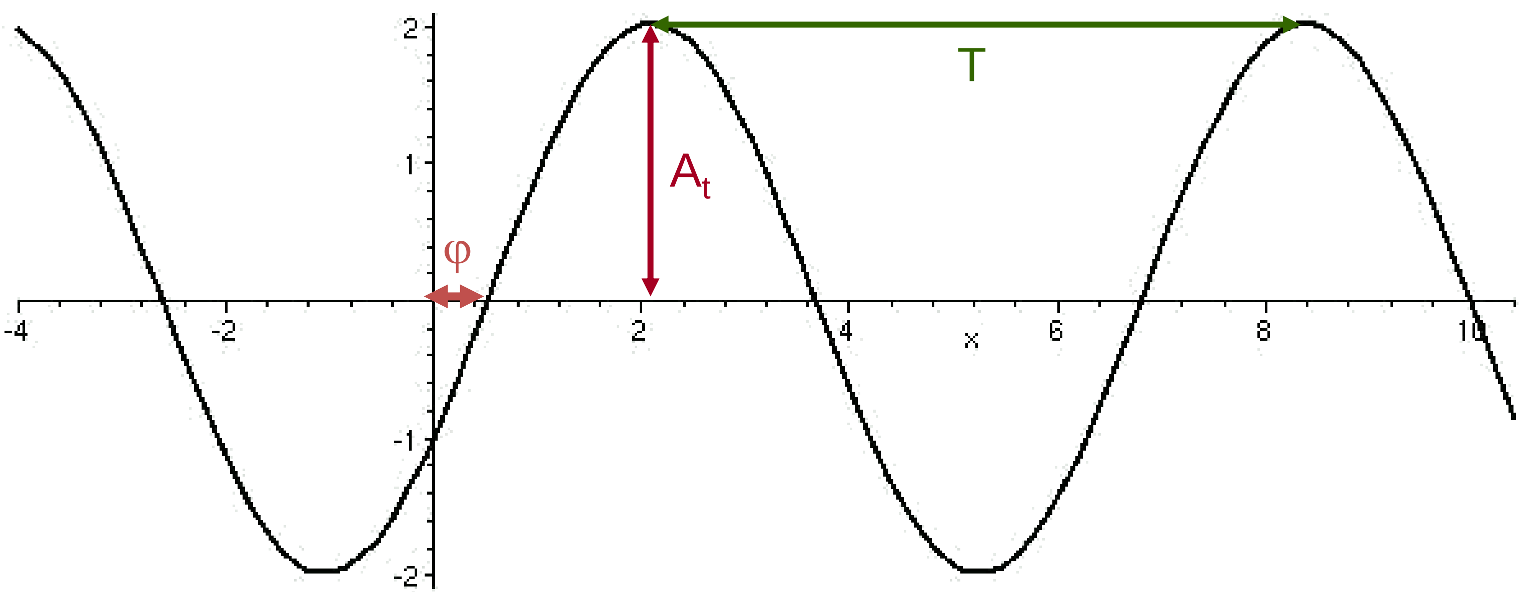
- Source encoding
  - Transform an analog signal into a digital sequence
  - Sampling: convert the continuous-time analog waveform to discrete-time sequence (but still continuous-valued).
  - Quantization : convert each continuous-valued symbol to discrete-valued representatives
  - Encoding: remove the redundancy in the data and generate roughly i.i.d. uniformly distributed bits
- Channel encoding
  - Add some redundancy to facilitate the detection and correctness of bit errors through a wireless channel

Digital communication process

- Modulation
  - Change one or more parameters of a periodic waveform according to the bit sequences (the wave carries the information of bit sequences, i.e., ***carrier signal***)
  - Changed parameter becomes a function of time
  - Sine/Cosine wave is used as the periodic waveform(carrier signal), a starting point for modulating the signal onto it
  - This periodic waveform has a ***center frequency*** f_c
  - The resulting signal requires a certain ***bandwidth*** to be transmitted (centered around center frequency)

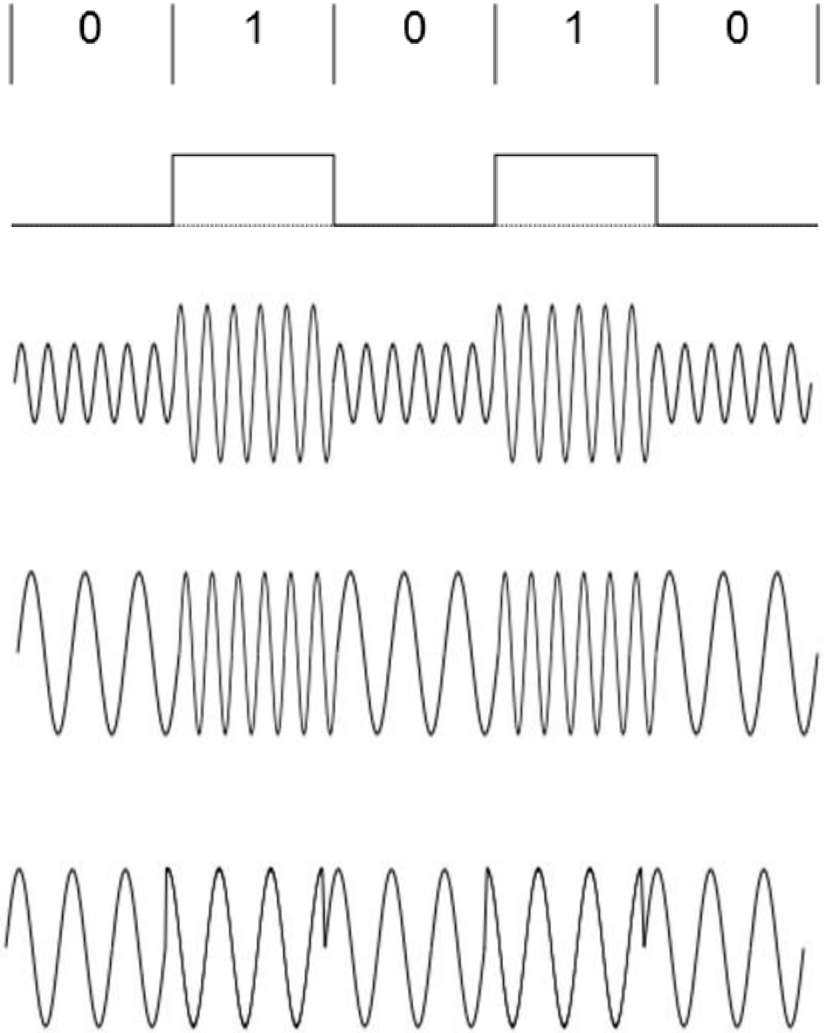
Digital communication process

- Parameters of a sine wave
  - $s(t) = A\sin(2\pi f t + \varphi)$
  - A: amplitude φ: phase shift
  - f: frequency = 1/T T: period



Digital communication process

- Typical modulation types
  - ***Amplitude Shift Keying***： Use data to modify the amplitude of a carrier signal
  - ***Frequency Shift Keying***： Use data to modify the frequency of a carrier signal
  - ***Phase Shift Keying***： Use data to modify the phase of a carrier signal



- Amplitude Shift Keying(ASK)
  - Let $E_i(t)$ be the symbol energy at time t, constant over [0, T]

$$s_i(t) = \sqrt{\frac{2E_i(t)}{T}} \cdot \sin(\omega_0 t + \phi)$$

  - Ei(t) is one of m different levels; Example: E0(t) = 1and E1(t)=2 represent logical zeros and ones, respectively. For data string 110100101, signal is modulated

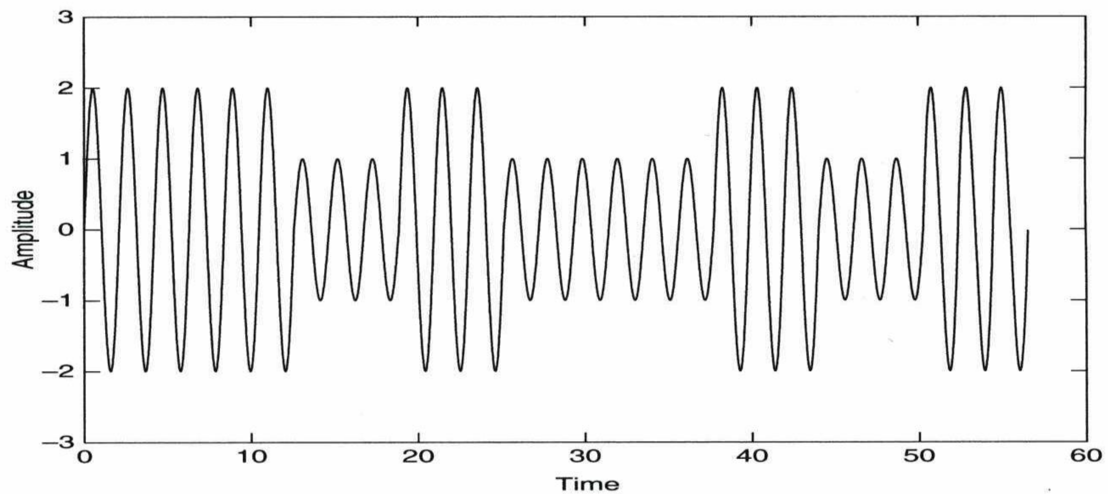


Figure 4.2 Amplitude shift keying (ASK) example

- Frequency Shift Keying(FSK)
  - For frequency signals $\omega_i(t)$

$$s_i(t) = \sqrt{\frac{2E}{T}} \cdot \sin(\omega_i(t) \cdot t + \phi)$$

  - For data string 110100101, signal is modulated

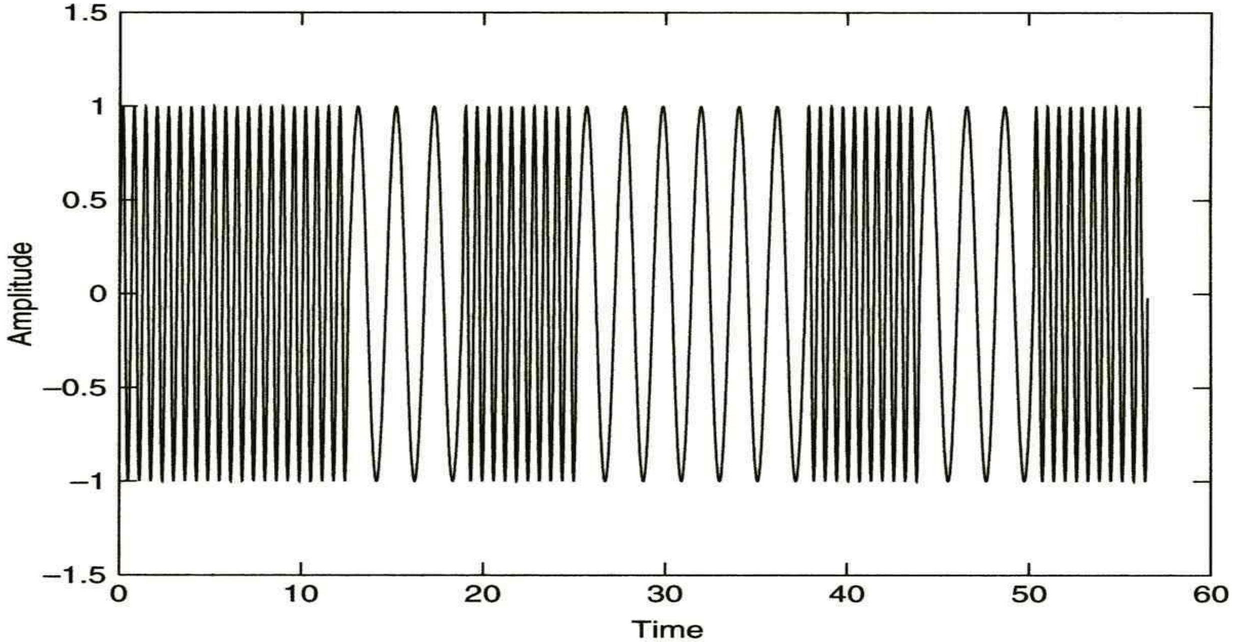


Figure 4.4 Frequency shift keying (FSK) example

- Phase Shift Keying(PSK)
  - For phase signals $\phi_i(t)$

$$s_i(t) = \sqrt{\frac{2E}{T}} \cdot \cos[\omega_0 t + \phi_i(t)]$$

  - For data string 110100101, signal is modulated

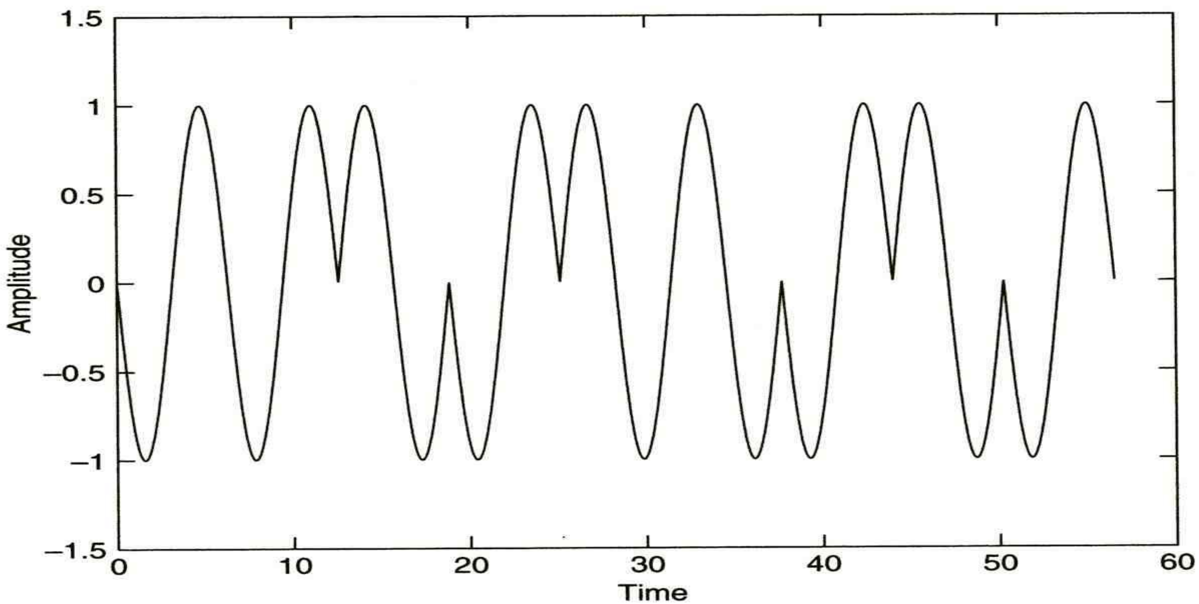


Figure 4.3 Phase shift keying (PSK) example

Receiver: Demodulation

- Map a received waveform to transmitted symbols
  - Necessary: one-to-one mapping between data and waveform
- However
  - Carrier synchronization: frequency can vary between sender and receiver (drift, temperature changes, aging, …)
  - Bit synchronization (actually: symbol synchronization): When does symbol representing a certain bit start/end?
  - Frame synchronization: When does a packet start/end?
  - Because of channel imperfections, this is done in a way in the best possible manner
  - Biggest problem: Received signal is ***not*** the transmitted signal!

Receiver: Demodulation

- When received waveform is distorted from transmitted one
  - Wrong demodulated symbols
  - Metric: symbol error rate (SER), bit error rate(BER)

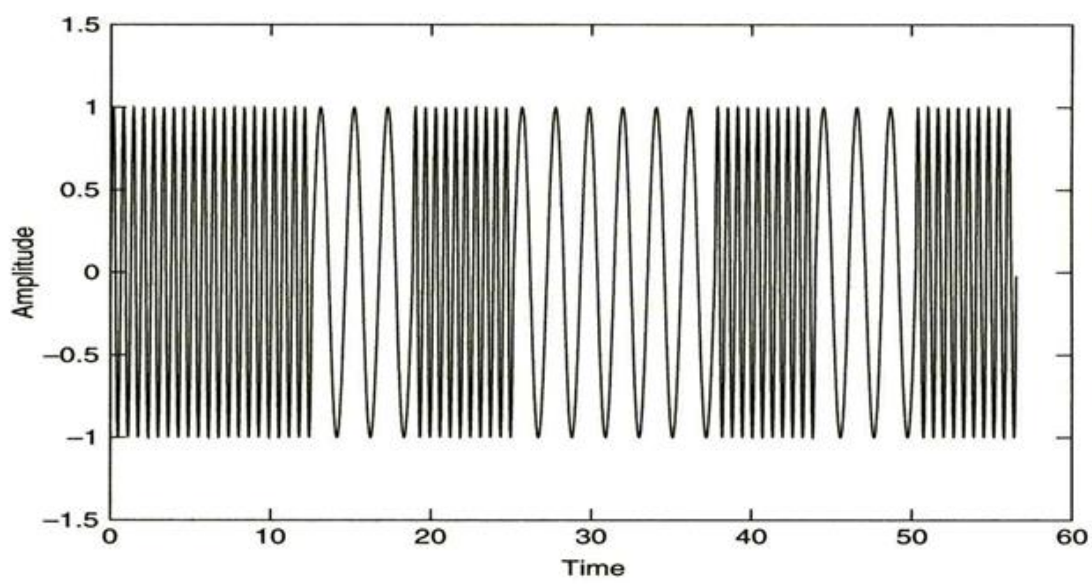
$$\mathrm{SER} = \frac{\text{Number of wrong symbols}}{\text{Total number of symbols}}$$

$$\mathrm{BER} = \frac{\text{Number of wrong bits}}{\text{Total number of bits}}$$

Question 2

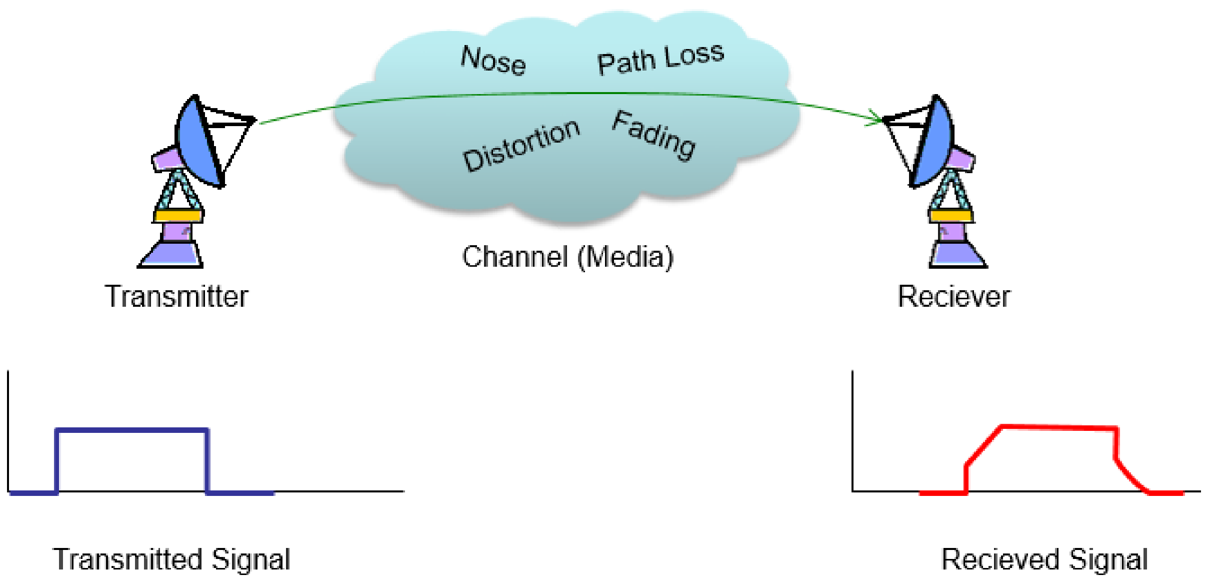
Question2: which modulation type the figure shows?

A. Amplitude Shift Keying
B. Frequency Shift Keying
C. Phase Shift Keying



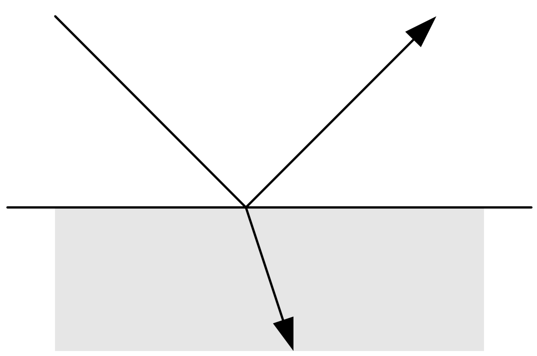
Wave propagation and noise

- Wireless transmission distorts any transmitted signal
  - Received ≠ transmitted signal
  - ***Uncertainty at receiver*** about the originally transmitted signal
  - Received ***bit errors***
  - ***Wireless channel:*** Abstract model describes these distortion effects

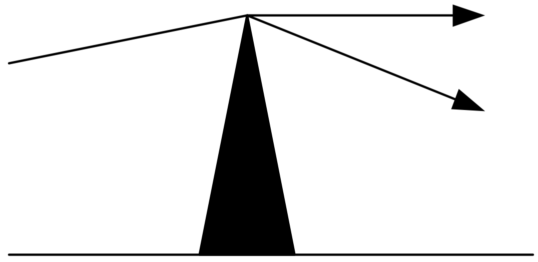


Wave propagation and noise

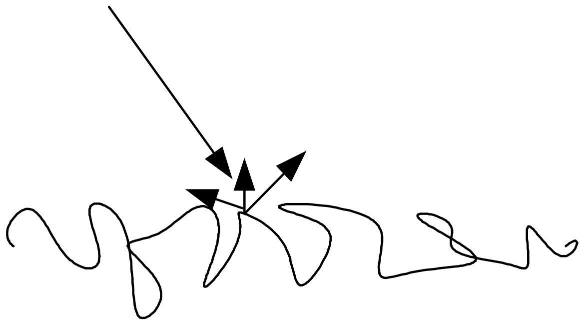
- Sources of distortion
  - Reflection/refraction – reflect from a surface/enter material
  - Diffraction – start "new wave" from a sharp edge
  - Scattering – multiple reflections at rough surfaces
  - Doppler fading – shift in frequencies (loss of center)



Reflection/refraction



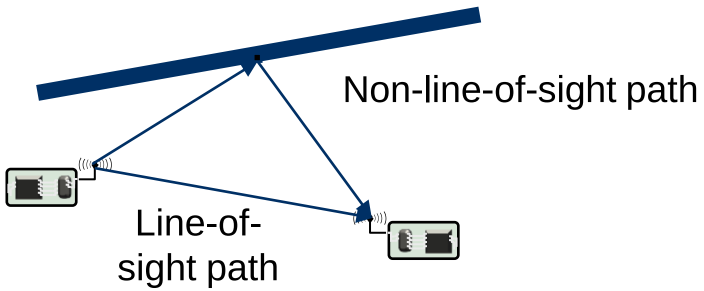
Diffraction

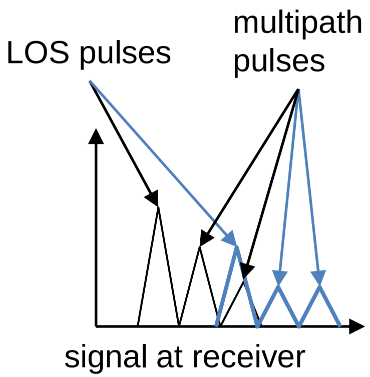


Scattering

Wave propagation and noise

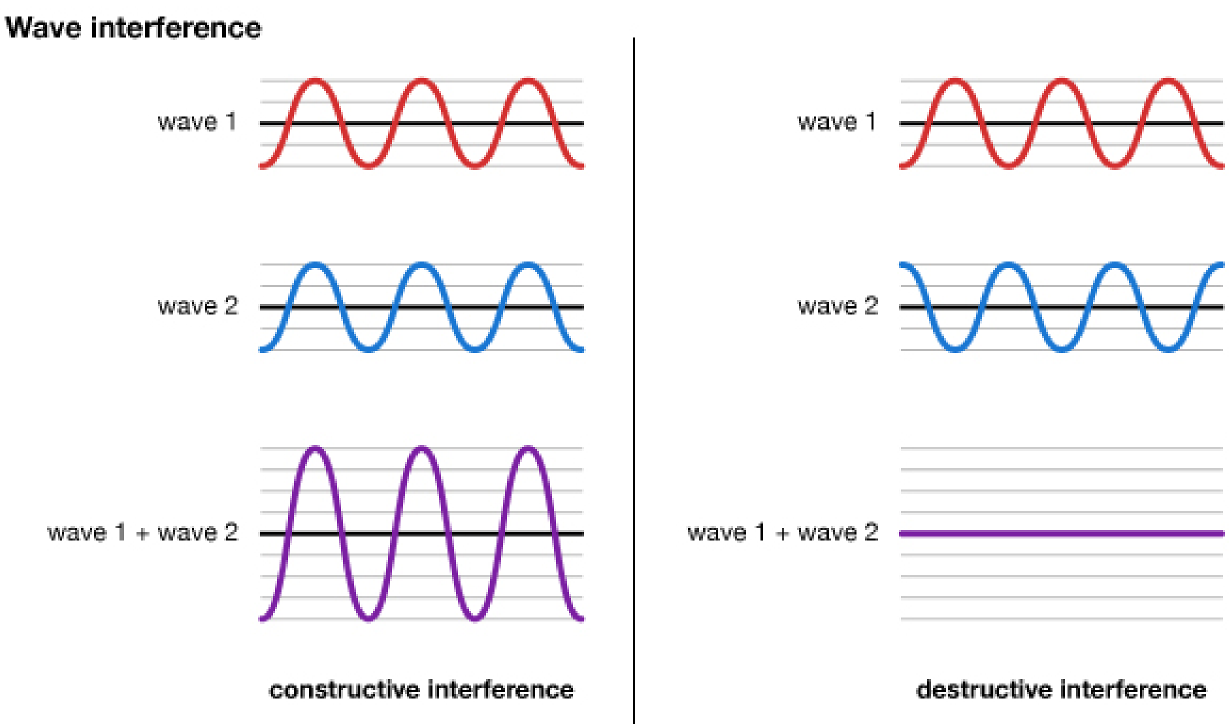
- Due to reflection, scattering, …,
  - ***Multiple copies*** of the same signal at the receiver
  - ***Multipath***: Line of Sight (LoS) path & Non line Of Sight (NLOS) path
  - ***Delay spread***: arrival time dispersion range
  - ***Superposition*** of multiple delayed copies of the same signal





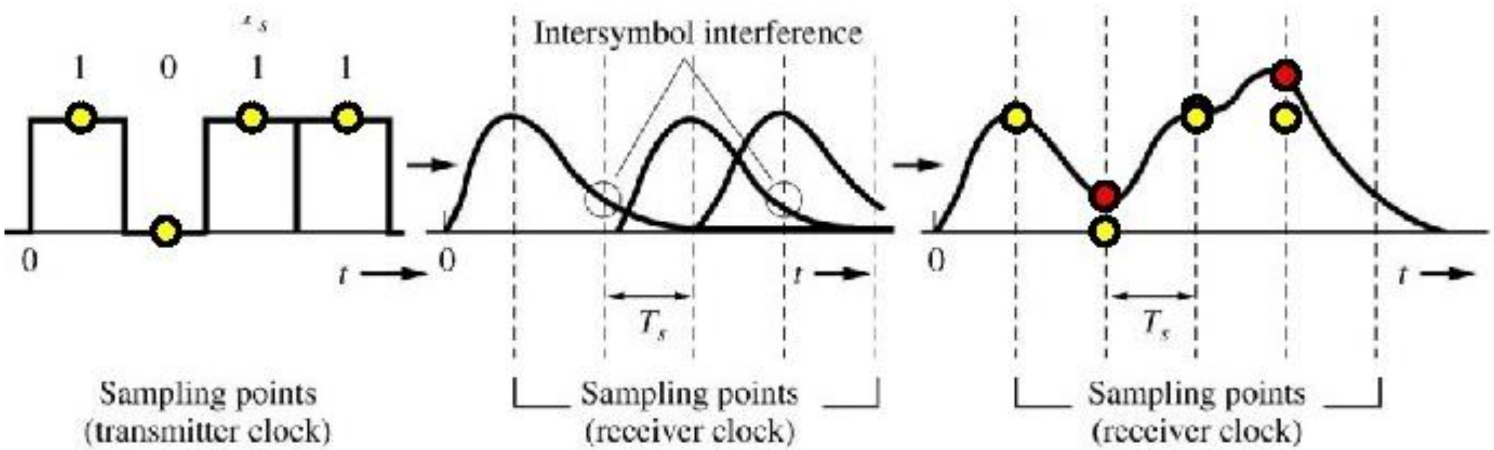
Wave propagation and noise

- Due to reflection, scattering, …,
  - Superposition of multiple copies with ***different phase shifts***
  - ***Destructive*** or ***constructive*** interference



Wave propagation and noise

- Due to reflection, scattering, …,
  - Superposition of multiple signals with ***different delays***
  - ***InterSymbol Interference (ISI)***: one symbol overlaps with delayed copies of previously sent symbols



Assignment

Assignment: Briefly describe what the results are caused from multi-path propagation?