I. Communication Methods and Data Transmission

- transmitted signal moving across/through a medium is called **propagation**

Serial vs. Parallel Communication/Transmission

1. Serial
   - bits transmitted 1 at a time, in sequence, over a single channel
   - speed limited to the speed of the channel
   - works using existing media, but slowly

2. Parallel
   - simultaneous transmission of a group of bits on separate channels,
   - given the amount of time to transfer 1 bit serial, can transfer in parallel n bits over n channels
   - requires more complex physical media and transmits (typically) over relatively short distances

Asynchronous, Synchronous, & Isochronous

1. Asynchronous
   - encapsulating data within "start" and "stop" bits
   - data can be transmitted any time without the receiver having advance notification
   - receiver does not know (or need to) the length of the transmission
   - more cost effective than synchronous...most local links use this method, e.g. PC serial

2. Synchronous
   - communication between nodes is monitored by each node
   - nodes are in "sync" with each other
   - more costly, due to required timing/clocking mechanisms in hardware, but much lower data overhead than in async.

3. Isochronous
   - establishes a specific bandwidth and data rate requirements so data flow in continual and uninterrupted
   - critical for applications such as video (MPEG)

Directional Communication Techniques

1. Simplex
   - data may only flow in 1 direction
   - 1 node is sender, 1 node is receiver, e.g. Television

2. Half-Duplex
   - data may be sent in either direction, but only 1 way at a given time

3. Full-Duplex
   - sending and receiving occurs at the same time
   - two simplex lines, 1 going in each direction, working simultaneously

II. Analog and Digital Communication Techniques

Analog signals are smooth, continuous signals over (w.r.t.) time

Describing analog signals:

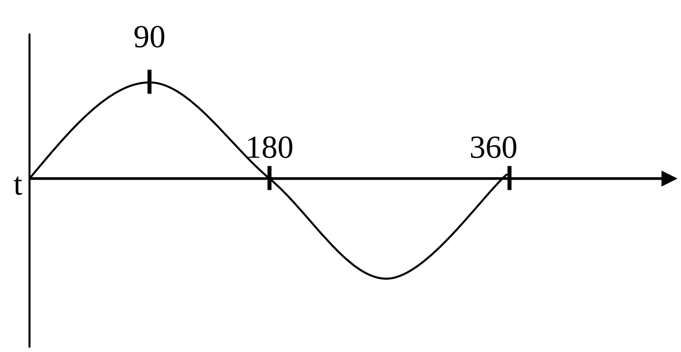
1. Amplitude (A) - peak value or strength

2. Frequency (f) - rate in which signal repeats, measured in cycles per second or Hertz (Hz)

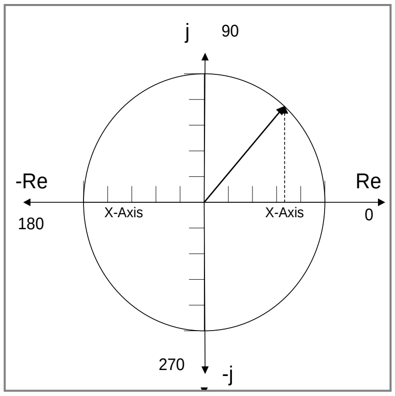
3. Phase (Φ - phi) - relative position in time within 1 cycle (period) of signal

4. Period (T) - time of 1 cycle, 1/f, in seconds/cycle

represented on a Cartesian graph:

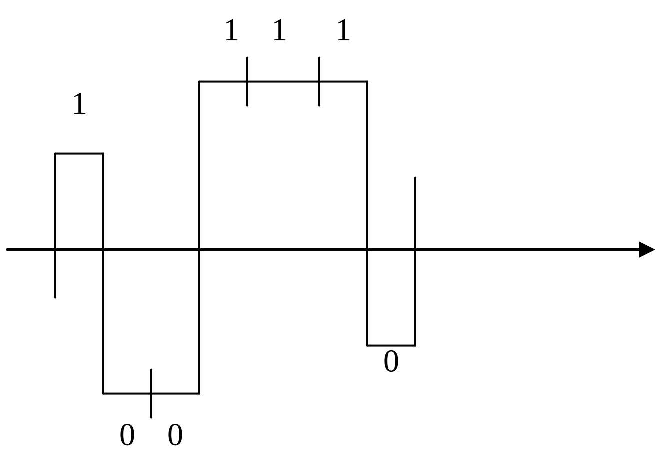


or represented in a polar coordinate system:



Digital Communications

- any method of communication based upon digital principles
- signals in digital communication are discrete (given any point in time, the signal has an exact value)
- exact values are either: on/off, 1/0, high/low, etc.



voltage (v): 5 >= v <= 15 reads as 1
-5 <= v >= -15 reads as 0
-5 > v < 5 ignored

wavelength (λ - lambda) - distance occupied by a single cycle

distance = rate * time

lambda = v * time
lambda = v * T
= v * 1/f
= v / f

lambda measured in meters
v is typically the speed of light, c represented as 3 * 10^8 meters/sec
f is measured in cycles/second

III. Speed and Capacity of a Communications Channel

speed: how fast from A to B
capacity: how much data was transferred

Bandwidth

- capacity of a communication channel
- difference of highest and lowest frequencies able to be carried across a channel

- voice phone line spectrum: 300-3300 Hz

- bandwidth: 3300 – 300 = 3000 Hz = 3 x 10^3 Hz = 3kHz

Data Rate

- amount of data transferred over a medium in a given period
- measured in bits per second (bps)

bps ≠ Baud

- bps: # of bits transmitted per second
- baud: # of signal changes per second

- bps = baud * # bits per baud

Throughput

- bandwidth represents the theoretical capacity of a medium, in bps
- throughput: the amount of data actually transmitted across a medium

- limitations to bandwidth include
  - noise
  - intermediate nodes processing capability
  - I/O speed
  - node overhead
  - network traffic

Noise

- any undesirable, extraneous signal on a transmission medium
  - intermodulation, e.g. EMI
  - ambient (thermal)
  - impulse
  - see Shannon's Limit (w.r.t. S/N ratio)

IV. Multiplexing

- data from multiple channels to share a common medium (see handout)

- data from several low speed channels combined at one end (mux), sent across a high speed circuit, then separated at the other end (demux)

Multiplexing Strategies

1. Frequency Division Multiplexing (FDM)

   - divide main frequency into sub-frequencies
   - each sub-frequency customized to the bandwidth of the data it must carry
   - TV, radio, analog telephones

2. Time Division Multiplexing (TDM)

   - more than one signal, but at different times
   - digital telephones

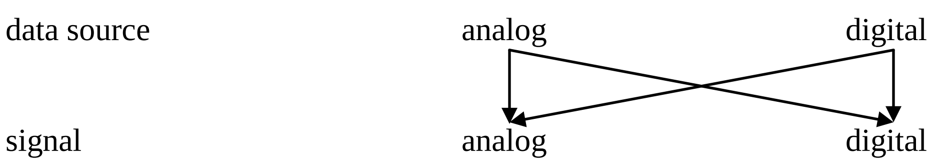
3. Wave Division Multiplexing (WDM)

- used with fiber optical media
- signal split into different optical wavelengths

Others

- statistical multiplexing
- demand access multiplexing (DAM)
- code division multiple access (CDMA)

V. Analog & Digital Transmission Concepts



Analog Data to Analog Signal

- baseband signal – uses original frequency (300 - 3300 for human voice)
- carrier signal – combine original signal with another (the carrier)
- changing carrier to represent data being carried called **modulation**
  - amplitude modulation (AM) – modulate signal strength
  - frequency modulation (FM)
  - phase modulation (PM)

- example is human voice over phone line

Analog Data to Digital Signal

- involves taking samples of the analog wave over time, using a technique called

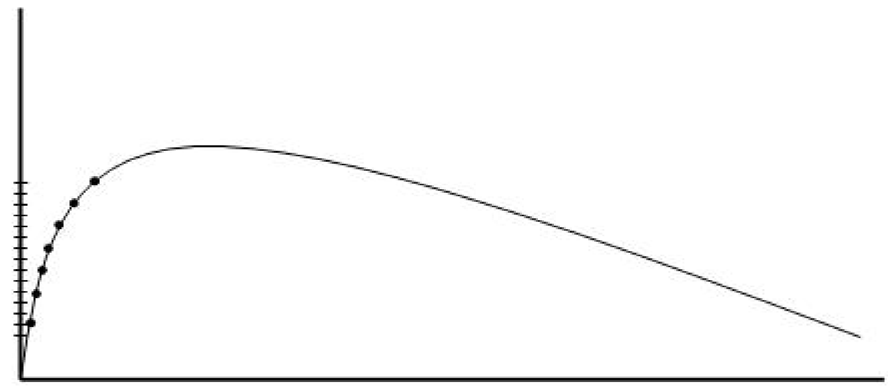
  Pulse Code Modulation (PCM)

  human voice: 300 – 3300 Hz
  phone company typically allocates 4000 Hz per channel (4 kHz)

  Nyquist's Theorem

  MDR = 2 x Hz x log2 N   (where N = # states)
  = 2 x 4000 x log2 2
  = 2 x 4000 x 1 = 8000

  PCM uses 8000 samples/second   (1/8000 x 10^6 = 125 microseconds/sample)
  - less samples, lose data
  - more samples, no better data



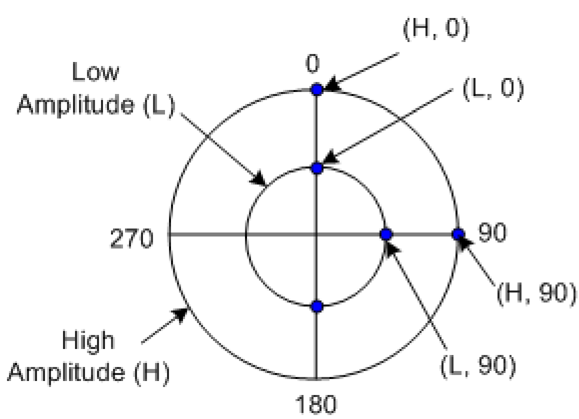
converting analog data to digital data uses a device called a **CODEC** (COder-DECoder)

Digital Data to Analog Signal

- modulate original signal to represent analog data
- uses a device called a **MODEM** (MOdulator-DEModulator) at each end
- each end must use same modulation technique

Modulation Techniques

- Amplitude Shift Keying (ASK)
  - varies signal strength while keeping frequency constant
  - unmodulated signal represents a 0, modulated signal represents a 1
- Frequency Shift Keying (FSK)
  - varies frequency while keeping amplitude constant
  - unmodulated signal represents a 0, modulated signal represents a 1
- Phase Shift Keying (PSK)
  - varies signal phase while keeping amplitude and frequency constant
  - unmodulated signal represents a 0, modulated signal represents a 1
- Quadrature Amplitude Modulation (QAM)
  - varies signal amplitude (2 values) and phase (4 values) while keeping frequency constant – represents 3 bit trios
  - unmodulated signal represents a 0, modulated signal represents a 1
  - how can we get 3 bits? how do we get 8 states?



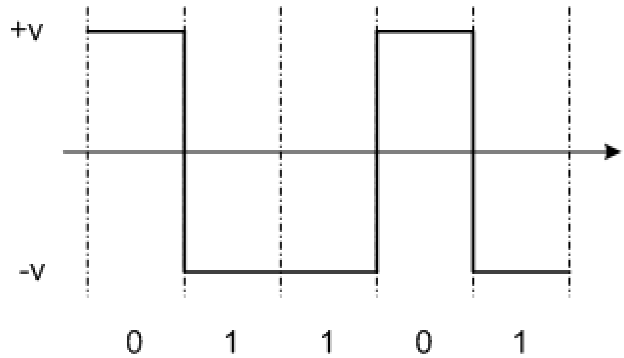
constellation diagram

Amp	Phase	bits
L	0	000
H	0	001
L	90	010
H	90	011
L	180	100
H	180	101
L	270	110
H	270	111

<u>Digital Data to Digital Signal</u> (Encoding Techniques)

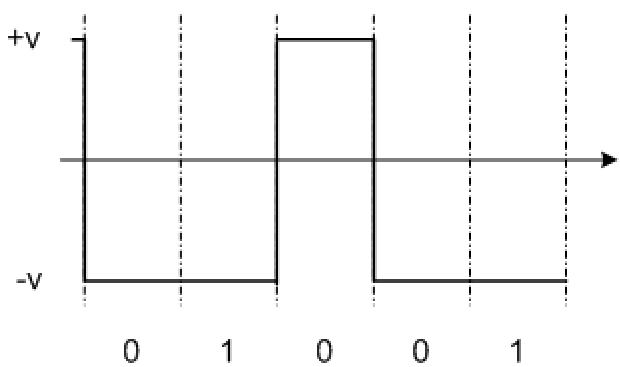
Non-Return to Zero Level (NRZ-L)

- zero encoded using +voltage, one encoded using –voltage
- never uses zero voltage
- can lead to problems with synchronization



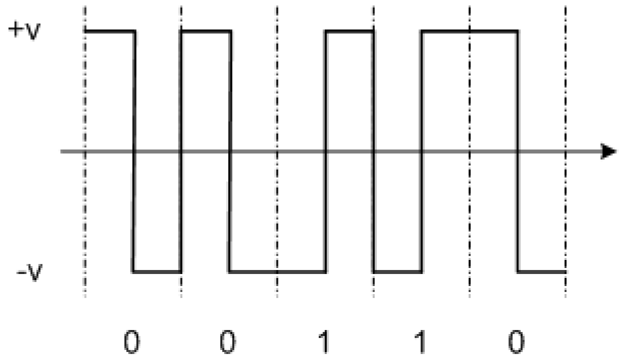
Non-Return to Zero Inverted (NRZ-I)

- invert signal when a zero is to be encoded
- no synchronization



Manchester (named for Manchester University in England)

- zero encoded using + - (downward) transition, one encoded using **–** + (upward) voltage
- provides synchronization
- provides error detection, since errors would have to invert both transitions to go undetected
- referred to as bi-phase
- method used by Ethernet



Differential Manchester

- bits are encoded based upon transitions from previous bit value
- transition from previous bit: 0, no transition: 1