Signal Encoding Techniques

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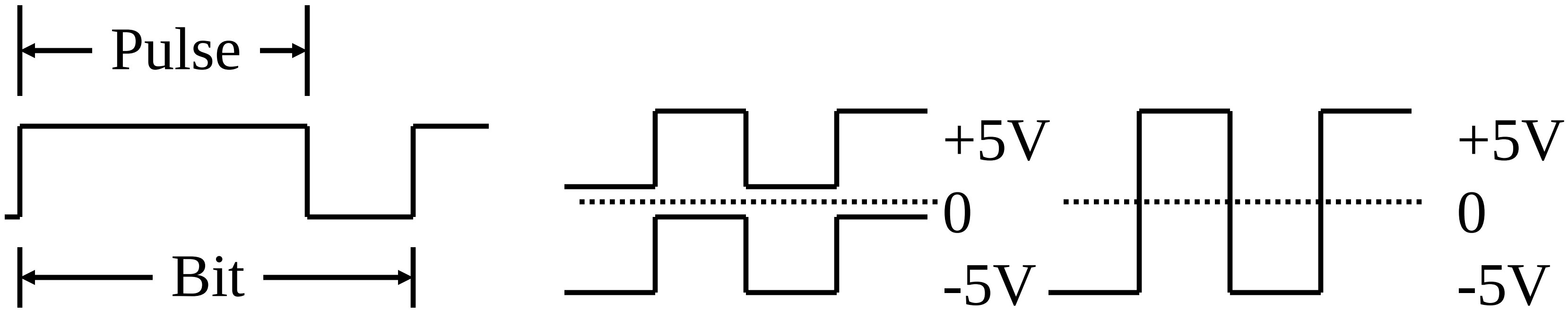
These slides are available on-line at:

http://www.cse.wustl.edu/~jain/cse473-05/

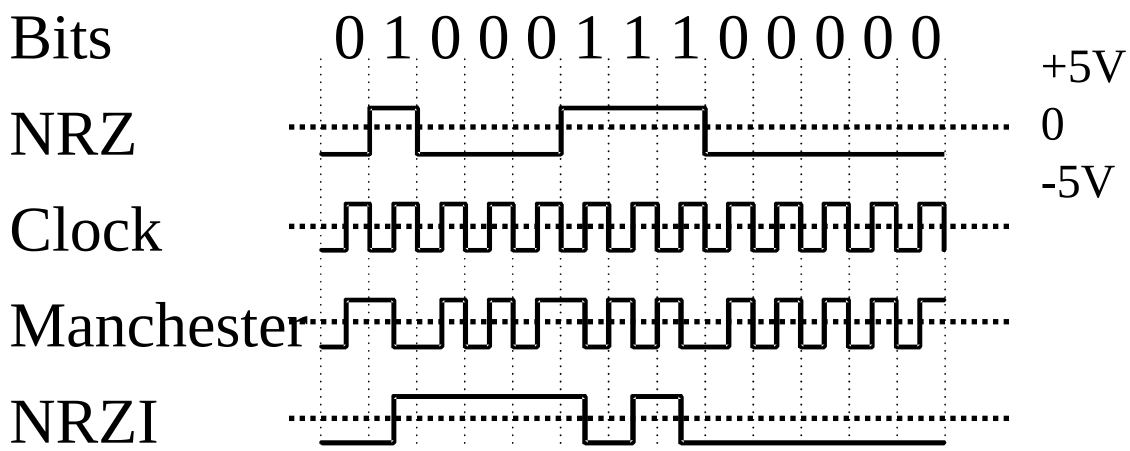
1. Coding Terminology and Design issues
2. Digital Data, Digital Signal: AMI, Manchester, etc.
3. Digital Data, Analog Signals: ASK, FSK, PSK, QAM
4. Analog Data, Digital Signals: PCM, Companding
5. Analog Data, Analog Signals: AM, FM

Coding Terminology



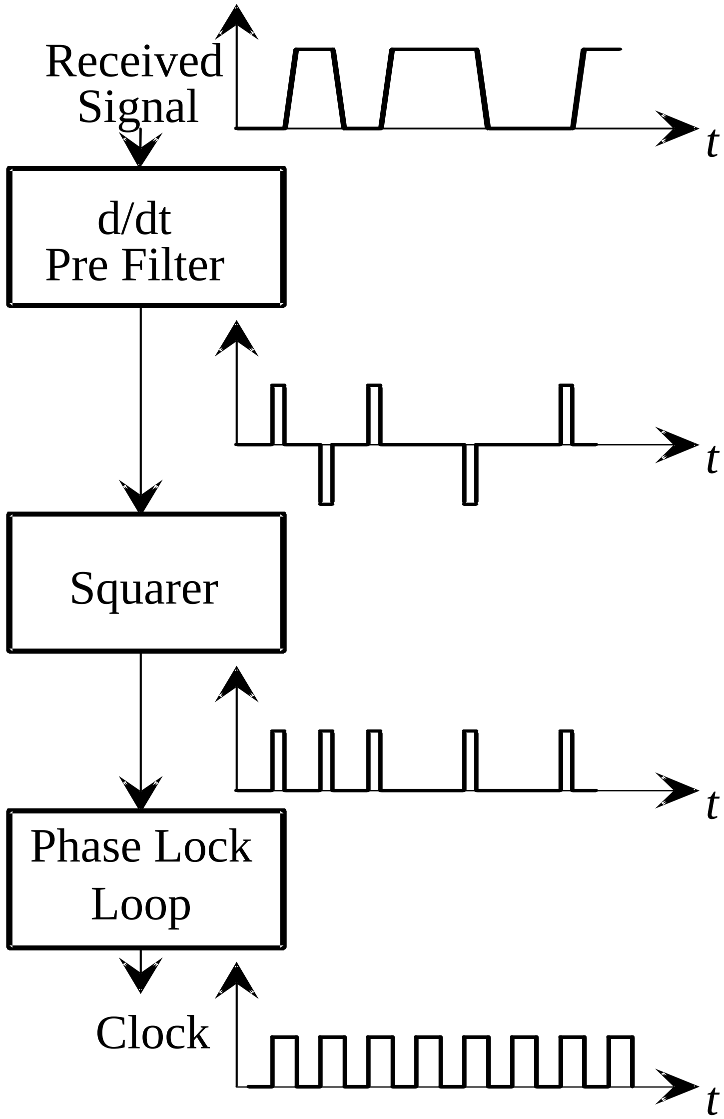
- **Signal element**: Pulse (of constant amplitude, frequency, phase)
- **Unipolar**: All positive or All negative voltage
- **Bipolar**: Positive and negative voltage
- **Mark/Space**: 1 or 0
- **Modulation Rate**: 1/Duration of the smallest element =Baud rate
- **Data Rate**: Bits per second
- Data Rate = Fn(Bandwidth, signal/noise ratio, encoding)

Coding Design



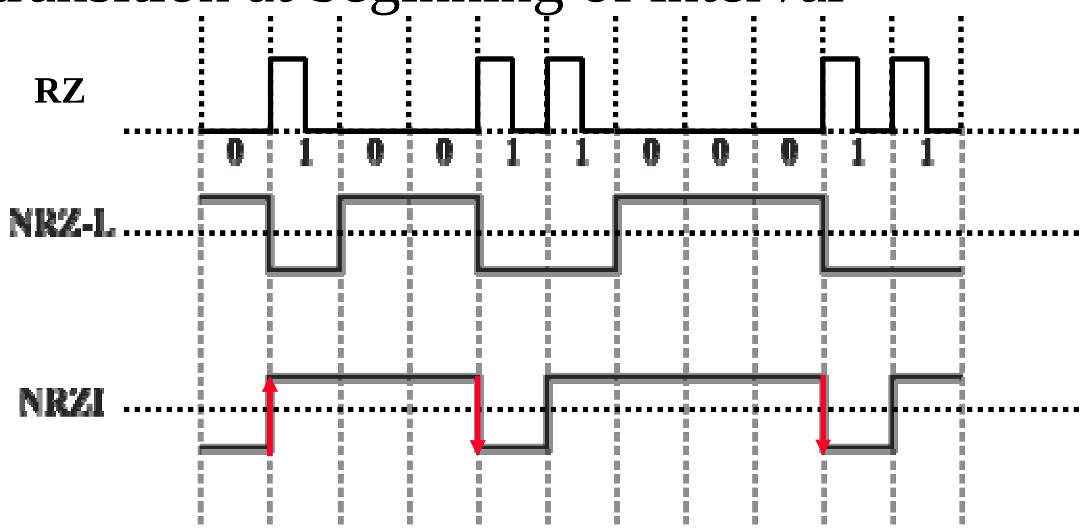
1. Pulse width indeterminate: Clocking
2. DC, Baseline wander
3. No line state information
4. No error detection/protection
5. No control signals
6. High bandwidth
7. Polarity mix-up ⇒ Differential (compare polarity)

Clock Recovery Circuit



Digital Signal Encoding Formats

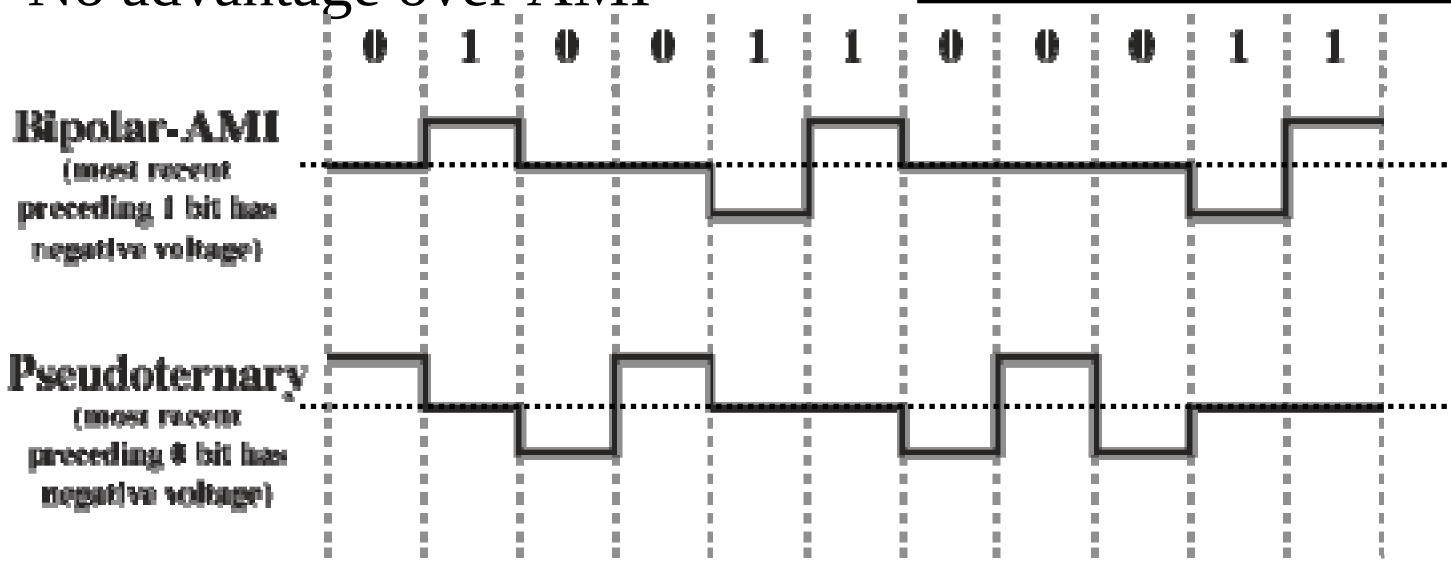
- **Return-to-Zero (RZ)**
  0 = Remain at zero, 1 = +ve for ½ bit duration
- **Nonreturn-to-Zero-Level (NRZ-L)**
  0 = high level, 1 = low level
- **Nonreturn to Zero Inverted (NRZI)**
  0 = no transition at beginning of interval (bit time)
  1 = transition at beginning of interval



Multi-level Binary Encoding

- **Bipolar-AMI:**
  - 0 = no line signal
  - 1= +ve or -ve for successive 1's
- **Pseudo-ternary:**
  - 0 = +ve or -ve for successive 0's
  - 1= no line signal
  - No advantage over AMI

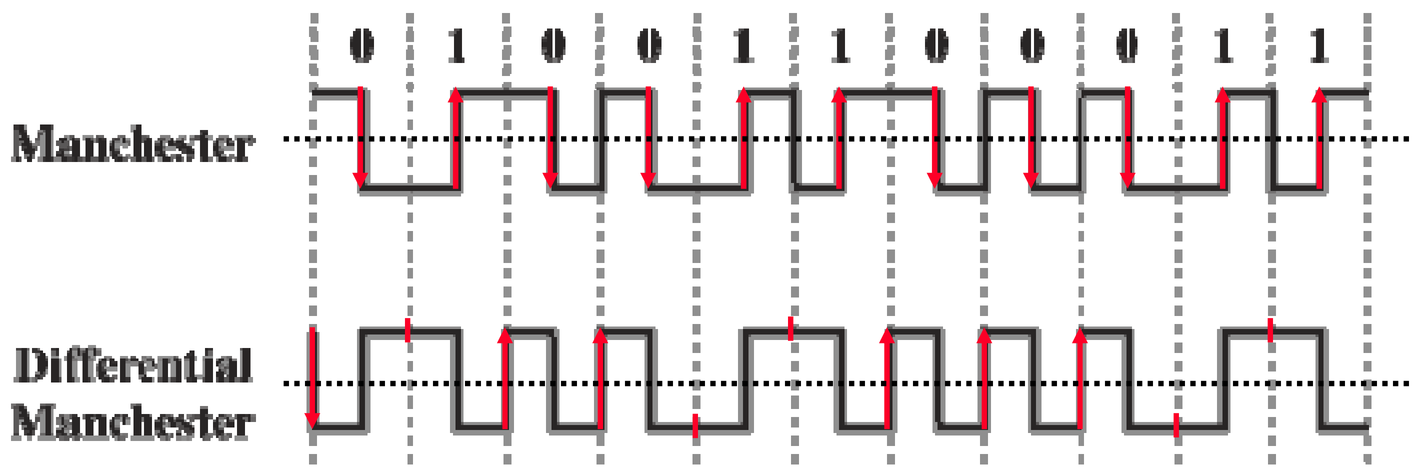
1. No loss of sync with 1's
2. zeros are a problem
3. No net dc component
4. Error detection
   Noise ⇒ violation
5. Two bits/Hz
6. 3 dB higher S/N
7. 2b/Hz. Not 3.16 b/Hz



Bi-phase

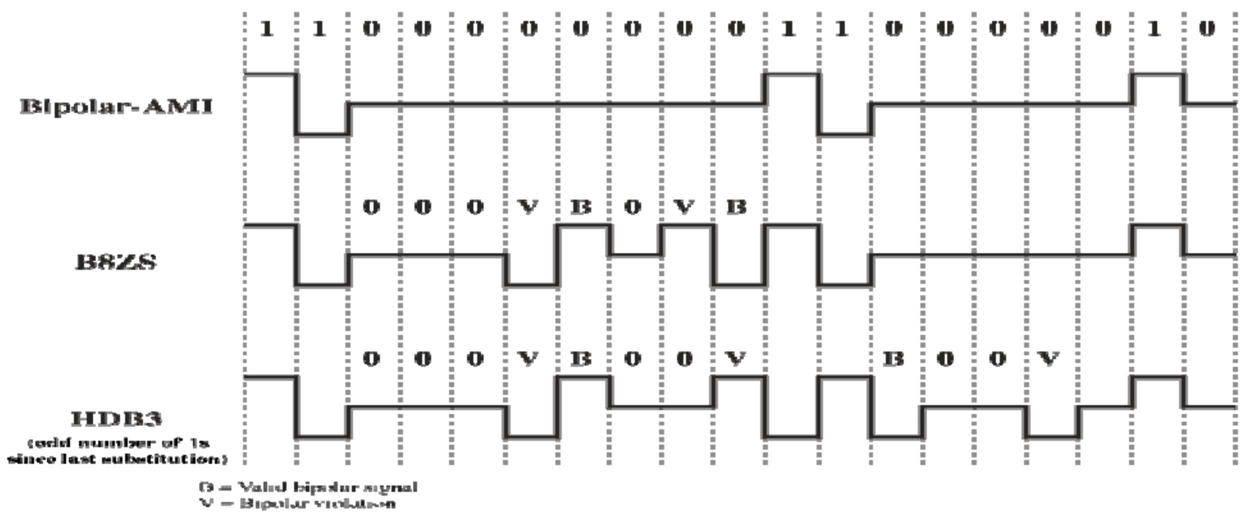
- **Manchester**: Used in Ethernet
  0 = High to low transition in middle
  1 = Low to high transition in middle
- **Differential Manchester**:
  Used in Token Ring
  Always a transition in middle
  0 = transition at beginning
  1= no transition at beginning

1. No DC
2. Clock sync
3. Error detection
4. 1 bit/Hz,
5. baud rate
   = 2 × bit rate

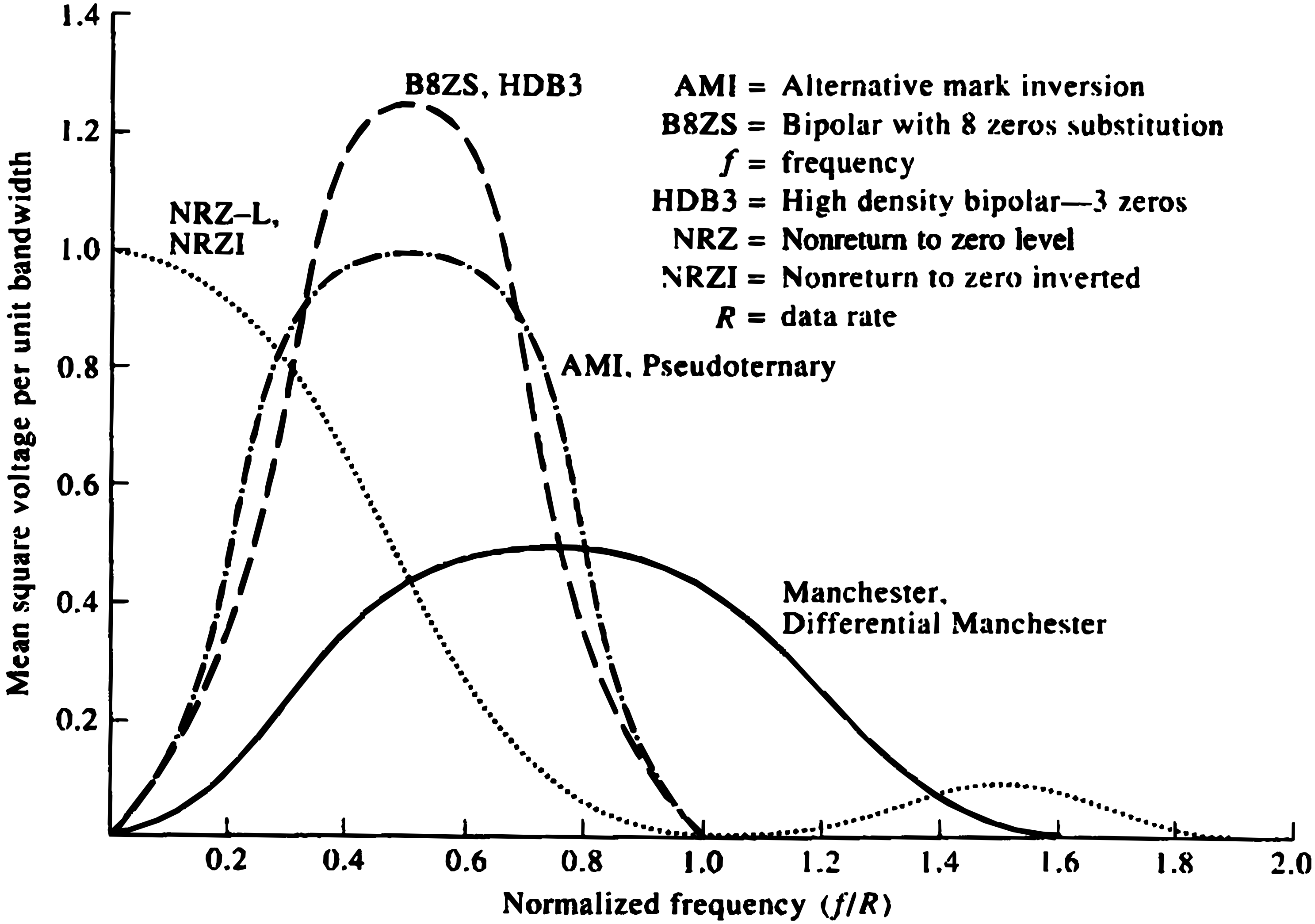


Scrambling

- **Bipolar with 8-Zero Substitution (B8ZS):**
  Same as AMI, except eight 0's replaced w two code violations
  0000 0000 = 000V 10V1
- **High Density Bi-polar w 3 Zeros (HDB3):** Same as AMI, except that four 0's replaced with one code violation
  0000 = 000V if odd number of ones since last substitution
  100V otherwise



Signal Spectrum

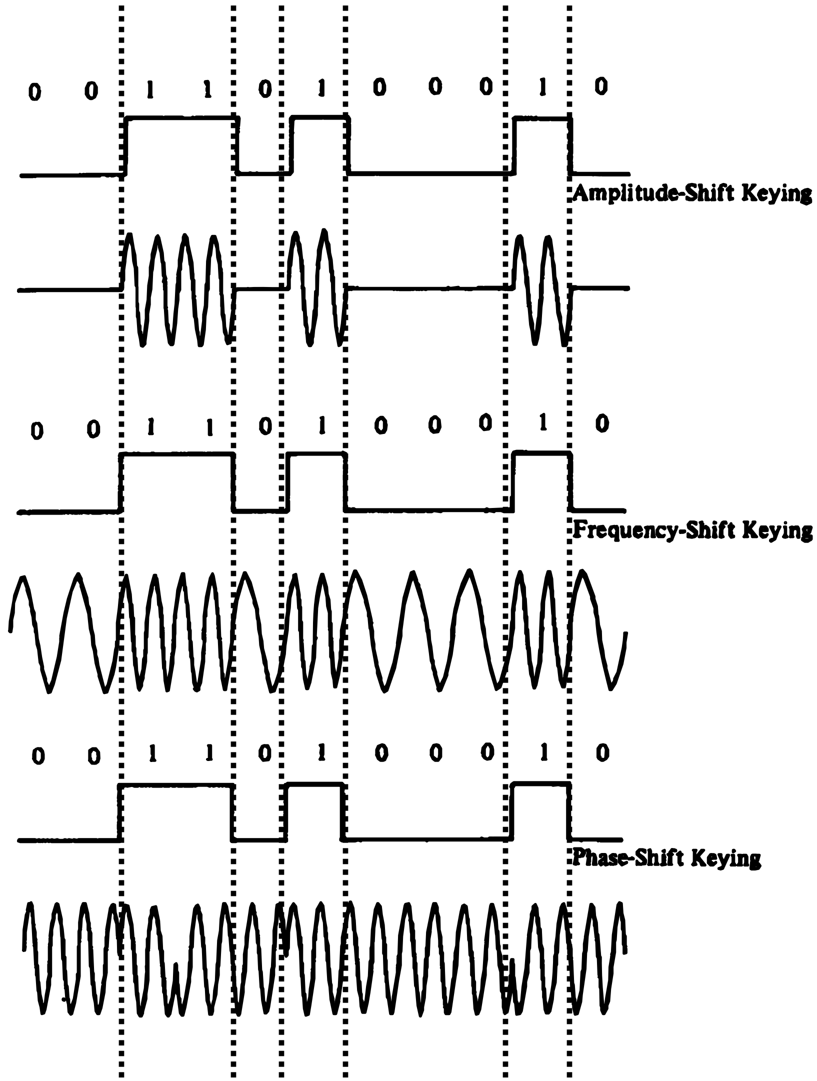


Digital Data Analog Signals

ASK

FSK

FSK



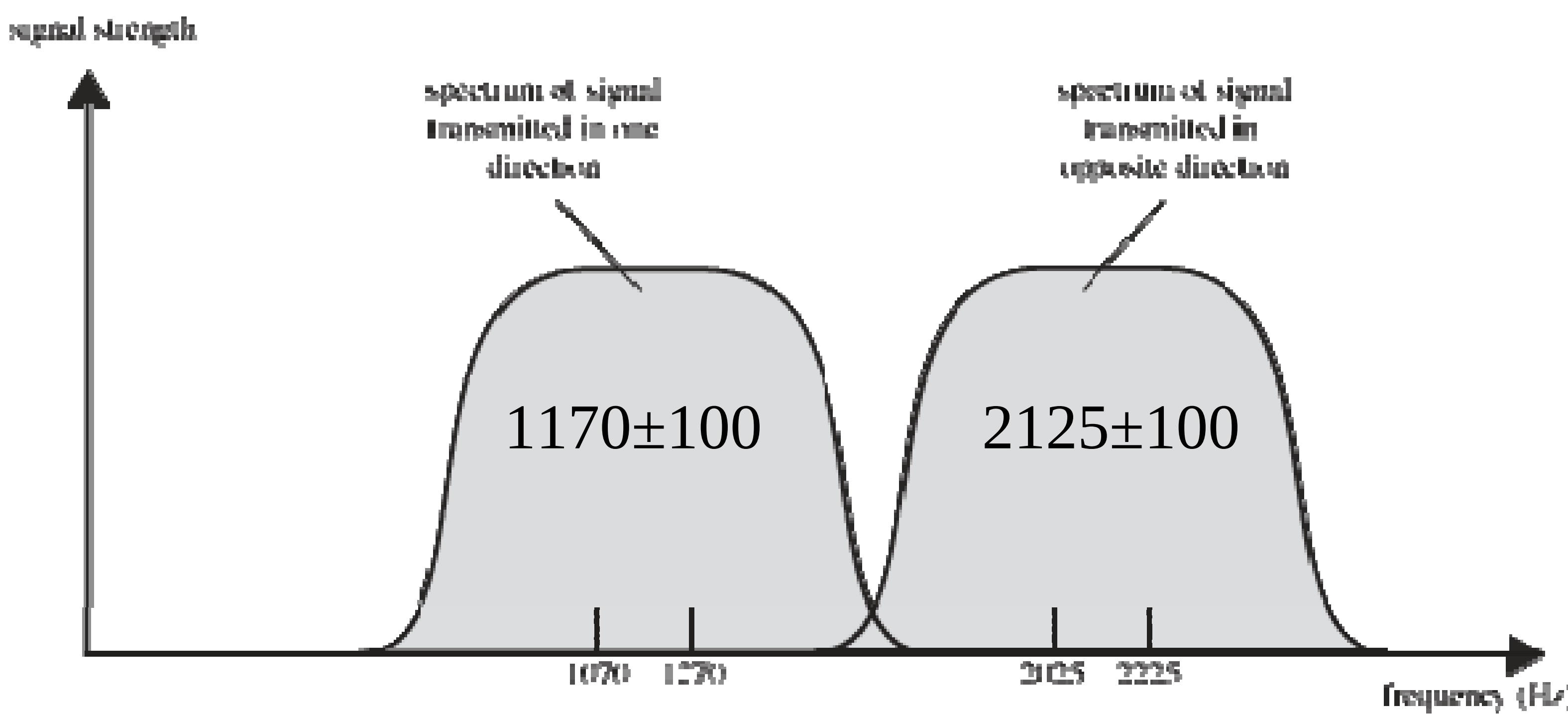
$A\ \mathrm{Sin}(2\pi ft+\theta)$

Used in Optical Nets

Used in 300-1200 bps modems

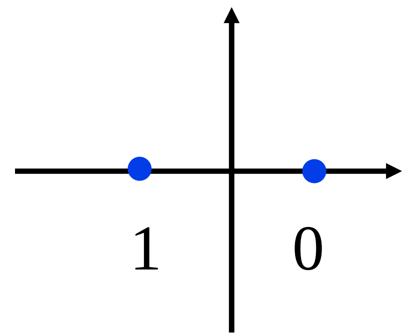
Frequency Shift Keying (FSK)

- Less susceptible to errors than ASK
- Used in 300-1200 bps on voice grade lines

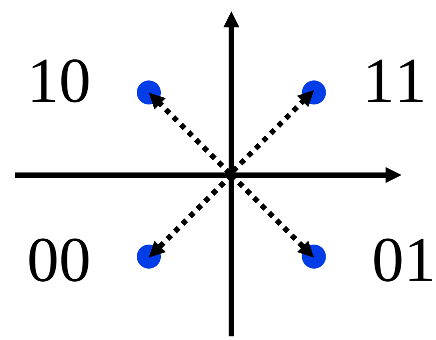


Phase-Shift Keying (PSK)

- **Differential PSK**:
  0 = Same phase, 1=Opposite phase
  $A\cos(2\pi ft)$, $A\cos(2\pi ft+\pi)$



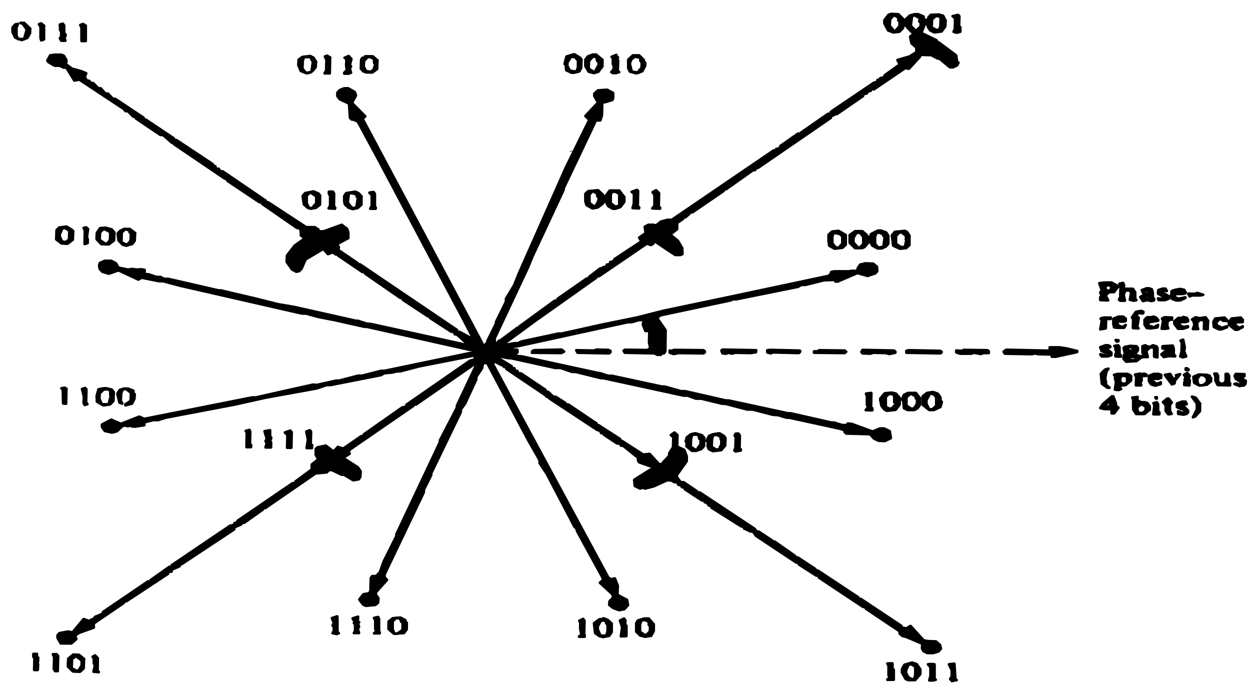
- **Quadrature PSK (QPSK):** Two bits
  $11=A\cos(2\pi ft+45°)$, $10=A\cos(2\pi ft+135°)$,
  $00=A\cos(2\pi ft+225°)$, $01=A\cos(2\pi ft+315°)$
  Sum of two signals 90° apart in phase
  (In-phase I , Quadrature Q),
  Up to 180° phase difference between successive intervals



- **Orthogonal QPSK (OQPSK):** Q stream delayed by 1 bit
  Phase difference between successive bits limited to 90°

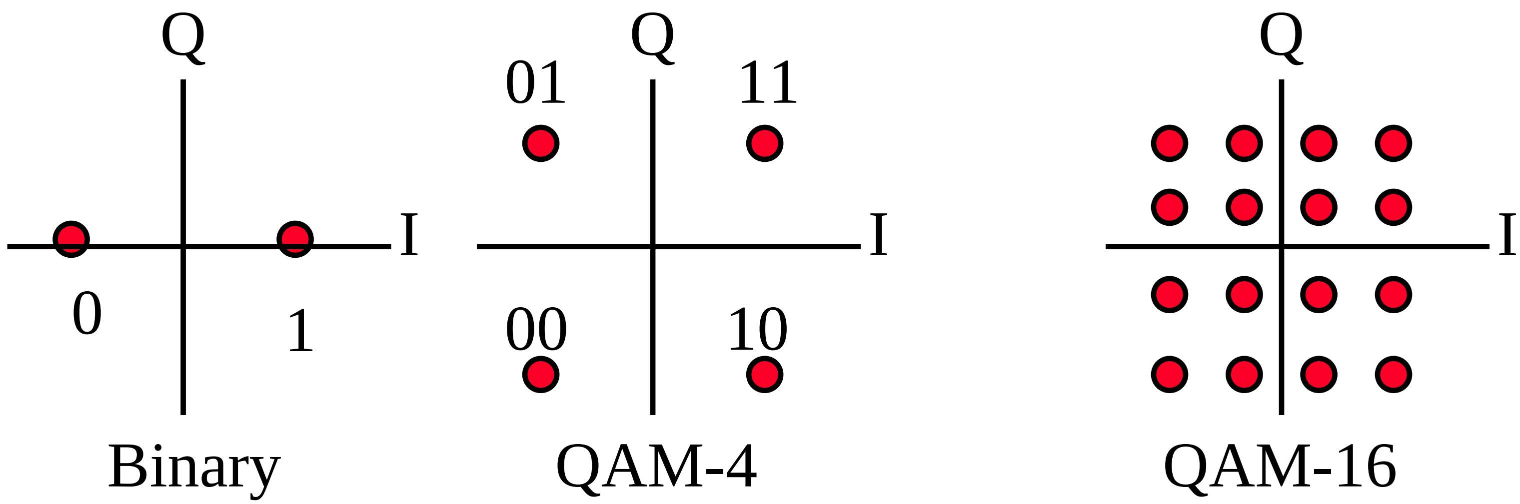
Multi-level PSK

- 9600 bps Modems use PSK with 4 bits
- 4 bits ⇒ 16 combinations
- 4 bits/element ⇒ 1200 baud
- 12 Phases, 4 with two amplitudes



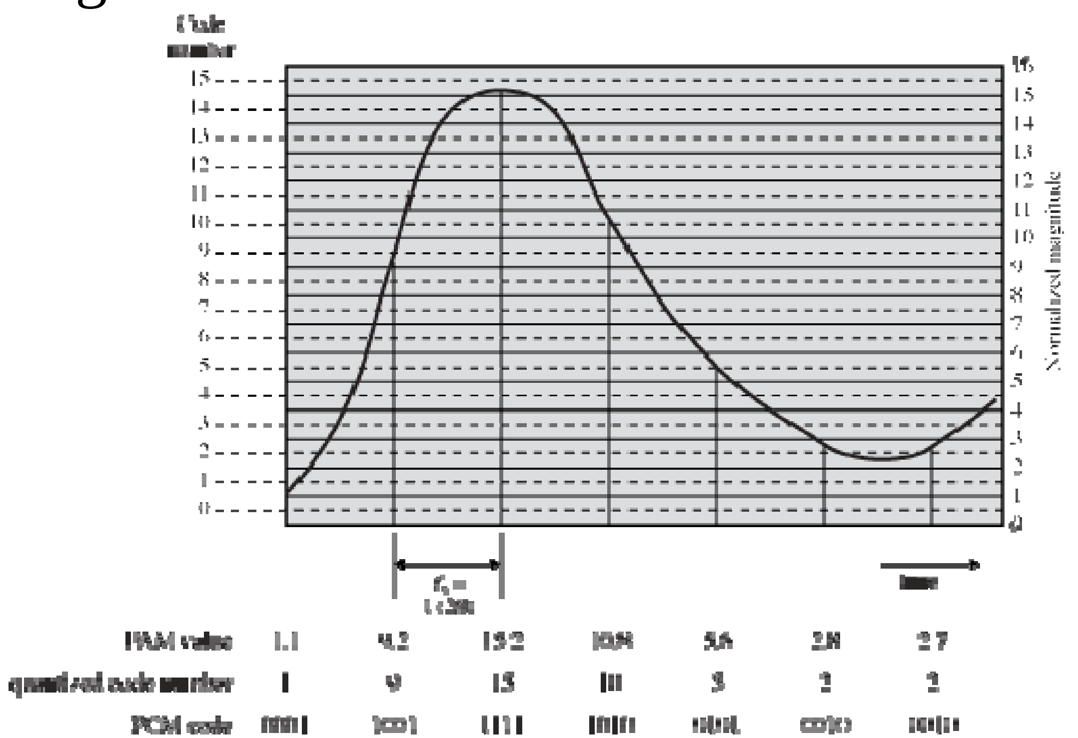
QAM

- Quadrature Amplitude and Phase Modulation
- QAM-4, QAM-16, QAM-64, QAM-256
- Used in DSL and wireless networks



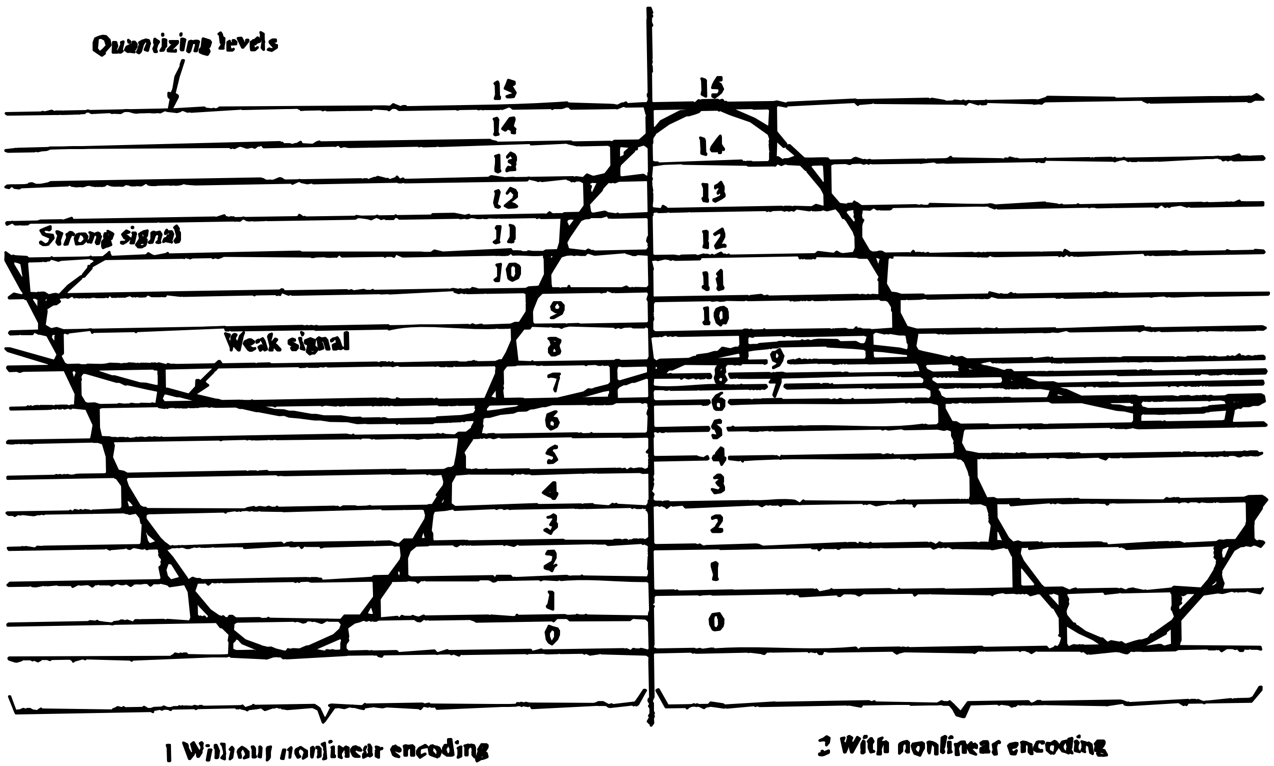
Analog Data, Digital Signals

- **Sampling Theorem**: 2 × Highest Signal Frequency
- 4 kHz voice = 8 kHz sampling rate
  8 k samples/sec × 8 bits/sample = 64 kbps
- Quantizing Error with *n* bits: S/N = 6.02*n* +1.76 dB



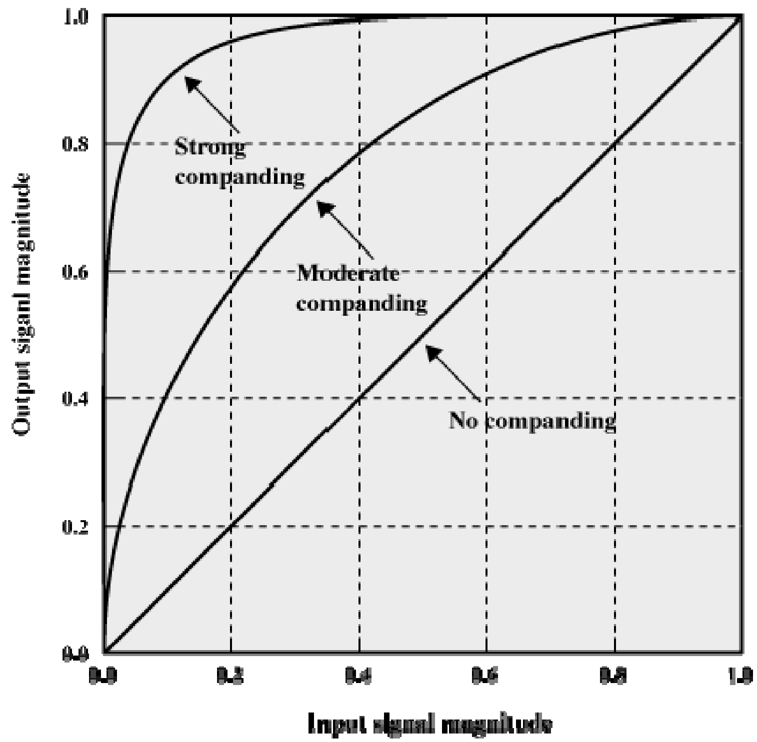
Nonlinear Encoding

- Linear: Same absolute error for all signal levels
- Non-linear: More steps for low signal levels



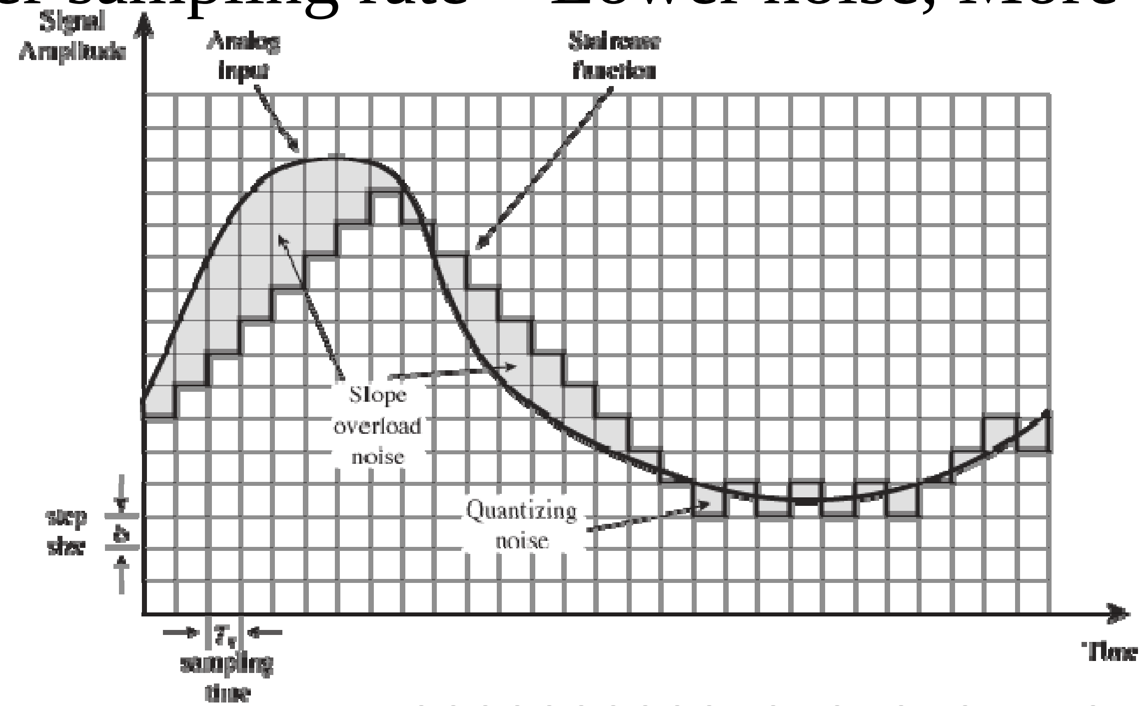
Companding

- Reduce the intensity range by amplifying weak signals more than the strong signals input
- Opposite is done at output



Delta Modulation

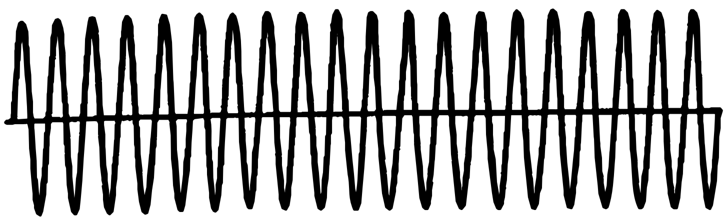
- 1 = Signal up one step, 0 = Signal down one step
- Larger steps ⇒ More quantizing noise,
  Less slope overhead noise
- Higher sampling rate = Lower noise, More bits



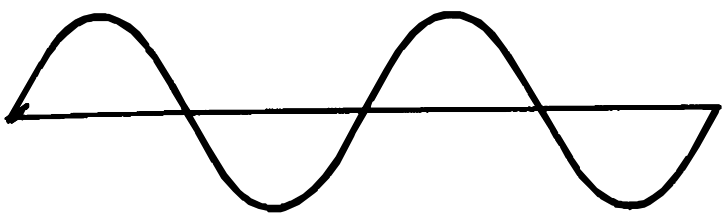
11111111000000000001010101011101

Analog Data, Analog Signals

Amplitude Modulation (AM)
Frequency Modulation (FM)
Phase Modulation (PM)

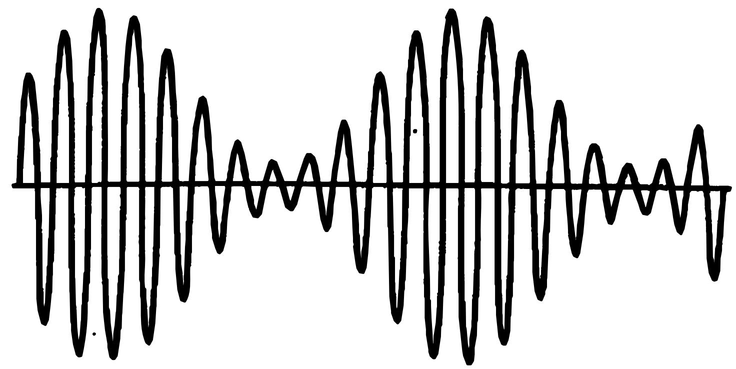


Carrier

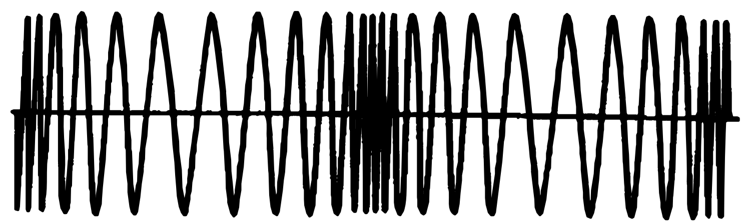


Modulating sine-wave signal

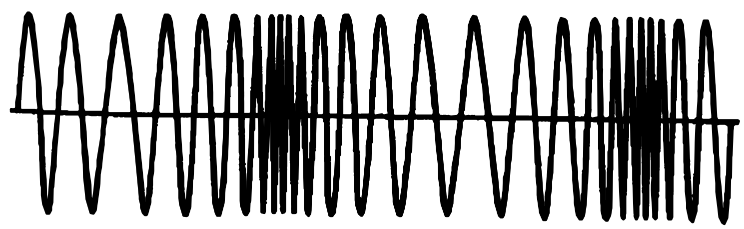
Both FM and PM are special cases of angle modulation



Amplitude-modulated (DSBTC) wave

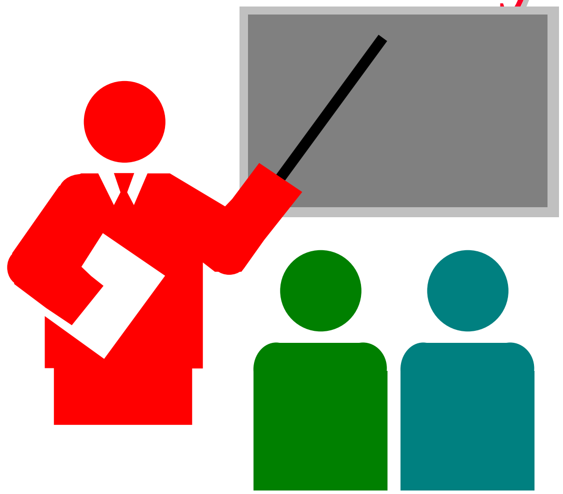


Phase-modulated wave



Frequency-modulated wave

Summary



- **Coding**: Higher data rate, error control, clock synchronization, line state indication, control signal
- **D-to-D**: RZ, NRZ-L, NRZI, Manchester, Bipolar, Biphase
- **D-to-A**: ASK, FSK, PSK, BPSK, QPSK, OQPSK, QAM
- **A-to-D**: PCM, Delta Modulation, Sampling theorem
- **A-to-A**: Amplitude, angle, frequency, phase modulation

Reading Assignment

- Read Chapter 5 of Stallings 7th edition.

Homework

- Submit answers to 5.10 (Bipolar violations) from Stallings 7th edition.

