

Signal Encoding Techniques

Raj Jain
Washington University
Saint Louis, MO 63131
Jain@cse.wustl.edu

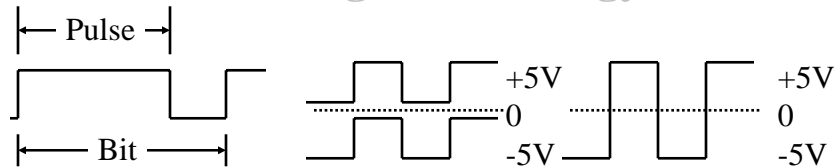
These slides are available on-line at:

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



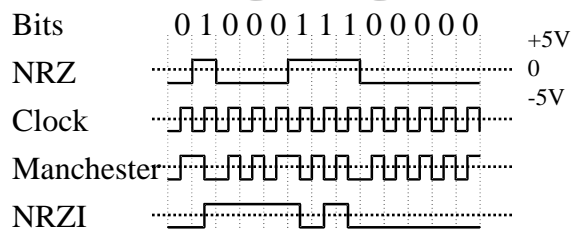
1. Coding Terminology and Design issues
2. Digital Data, Digital Signal: AMI, Manchester, etc.
3. Digital Data, Analog Signals: ASK, FSK, PSK, QAM
4. Analog Data, Digital Signals: PCM, Companding
5. Analog Data, Analog Signals: AM, FM

Coding Terminology



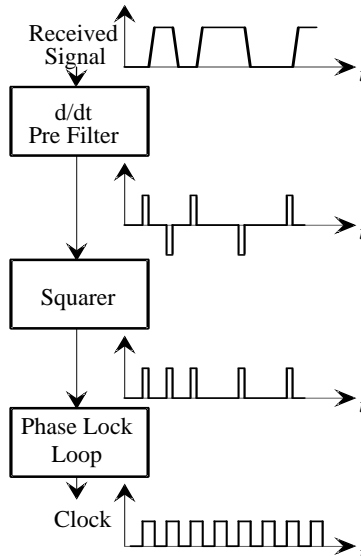
- ❑ **Signal element:** Pulse (of constant amplitude, frequency, phase)
- ❑ **Unipolar:** All positive or All negative voltage
- ❑ **Bipolar:** Positive and negative voltage
- ❑ **Mark/Space:** 1 or 0
- ❑ **Modulation Rate:** 1/Duration of the smallest element
=Baud rate
- ❑ **Data Rate:** Bits per second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

Coding Design



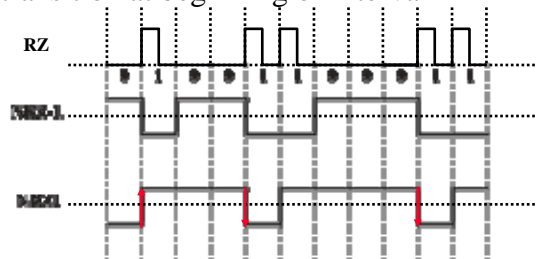
1. Pulse width indeterminate: Clocking
2. DC, Baseline wander
3. No line state information
4. No error detection/protection
5. No control signals
6. High bandwidth
7. Polarity mix-up \Rightarrow Differential (compare polarity)

Clock Recovery Circuit



Digital Signal Encoding Formats

- **Return-to-Zero (RZ)**
 0 = Remain at zero, 1 = +ve for $\frac{1}{2}$ 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

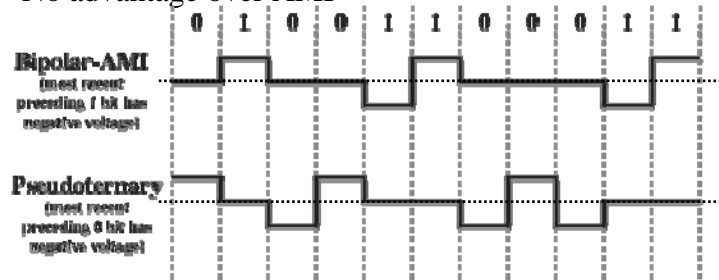
❑ **Bipolar-AMI:**

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 \Rightarrow violation |
| 5. Two bits/Hz |
| 6. 3 dB higher S/N |
| 7. 2b/Hz. Not 3.16 b/Hz |



Bi-phase

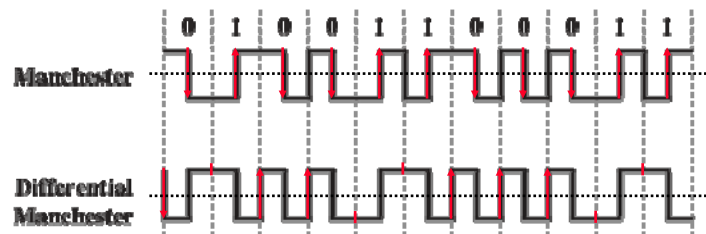
❑ **Manchester:** Used in Ethernet

0 = High to low transition in middle
 1 = Low to high transition in middle

❑ **Differential Manchester:**

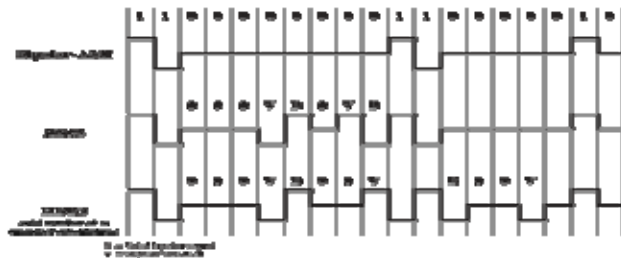
Used in Token Ring
 Always a transition in middle
 0 = transition at beginning
 1 = no transition at beginning

- | |
|-----------------------|
| 1. No DC |
| 2. Clock sync |
| 3. Error detection |
| 4. 1 bit/Hz, |
| 5. baud rate |
| = $2 \times$ bit rate |

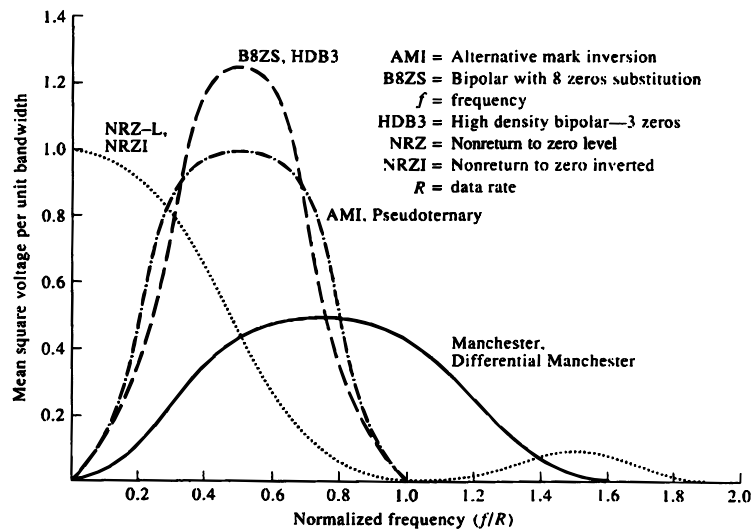


Scrambling

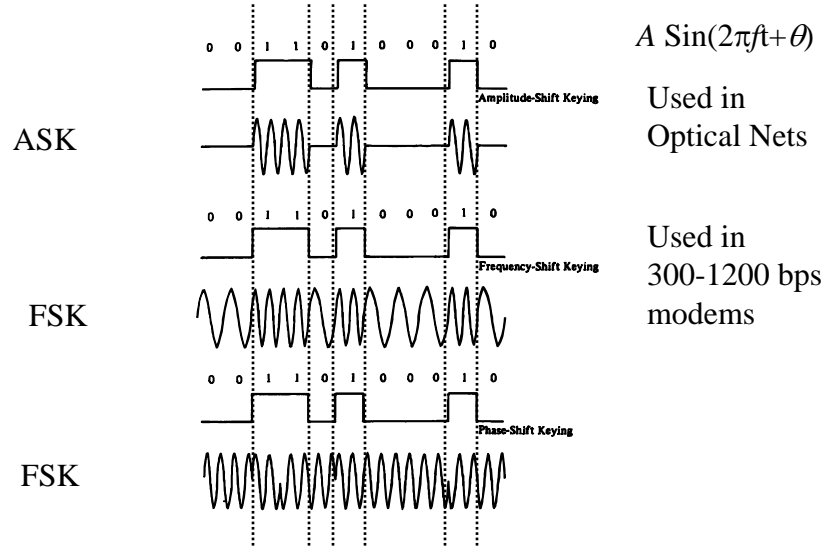
- ❑ **Bipolar with 8-Zero Substitution (B8ZS):**
 Same as AMI, except eight 0's replaced w two code violations
 $0000\ 0000 = 000V\ 10V1$
- ❑ **High Density Bi-polar w 3 Zeros (HDB3):** Same as AMI,
 except that four 0's replaced with one code violation
 $0000 = 000V$ if odd number of ones since last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



Signal Spectrum



Digital Data Analog Signals



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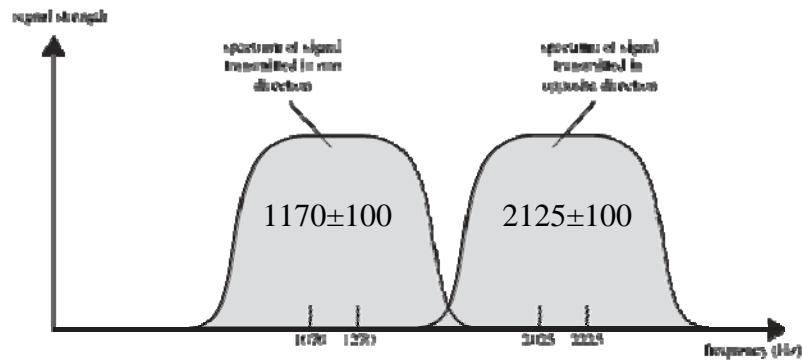
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Frequency Shift Keying (FSK)

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



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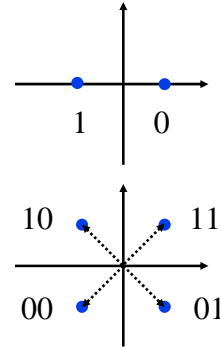
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Phase-Shift Keying (PSK)

❑ **Differential PSK:**

0 = Same phase, 1=Opposite phase
 $A \cos(2\pi ft)$, $A \cos(2\pi ft + \pi)$



❑ **Quadrature PSK (QPSK):** Two bits

$11 = A \cos(2\pi ft + 45^\circ)$, $10 = A \cos(2\pi ft + 135^\circ)$,
 $00 = A \cos(2\pi ft + 225^\circ)$, $01 = A \cos(2\pi ft + 315^\circ)$
 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°

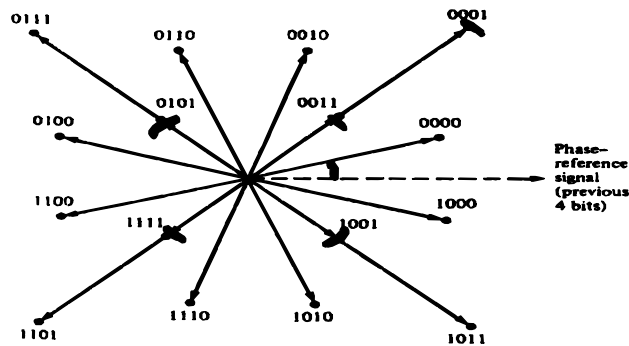
Multi-level PSK

❑ 9600 bps Modems use PSK with 4 bits

❑ 4 bits \Rightarrow 16 combinations

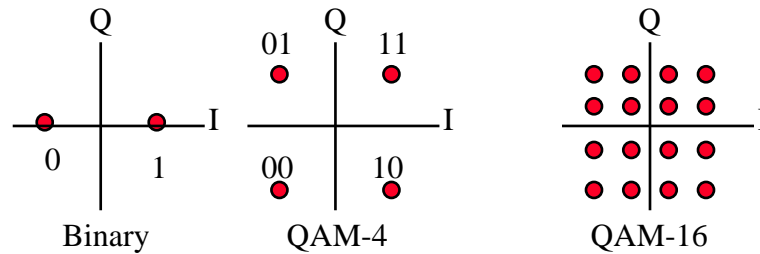
❑ 4 bits/element \Rightarrow 1200 baud

❑ 12 Phases, 4 with two amplitudes



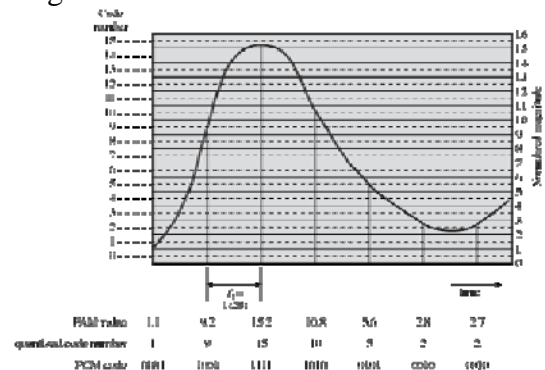
QAM

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



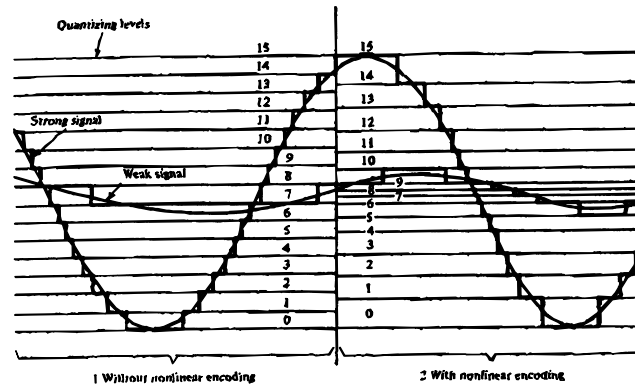
Analog Data, Digital Signals

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



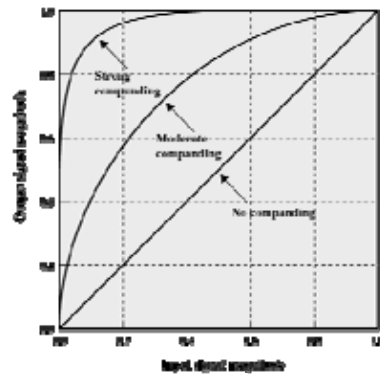
Nonlinear Encoding

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



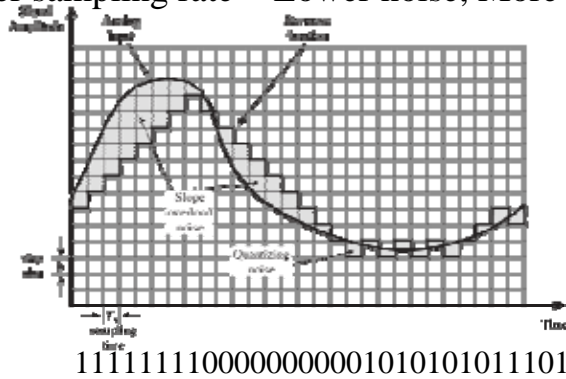
Comping

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



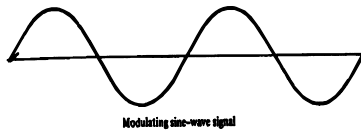
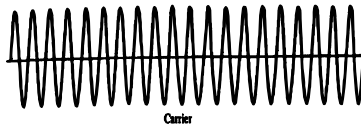
Delta Modulation

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

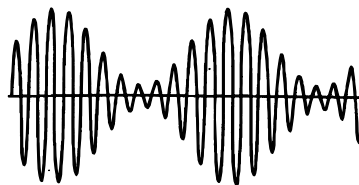


Analog Data, Analog Signals

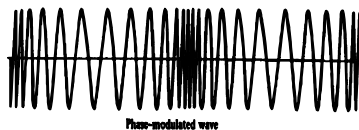
Amplitude Modulation (AM)
Frequency Modulation (FM)
Phase Modulation (PM)



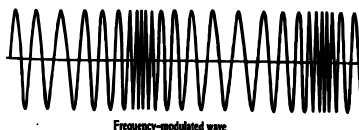
Both FM and PM are special cases of angle modulation



Amplitude-modulated (DSB-TC) wave

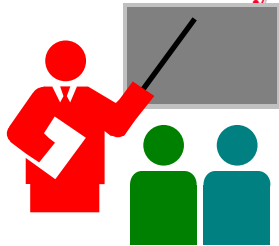


Phase-modulated wave



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.