

Data Transmission, Transmission Media and Data Encoding

Raj Jain

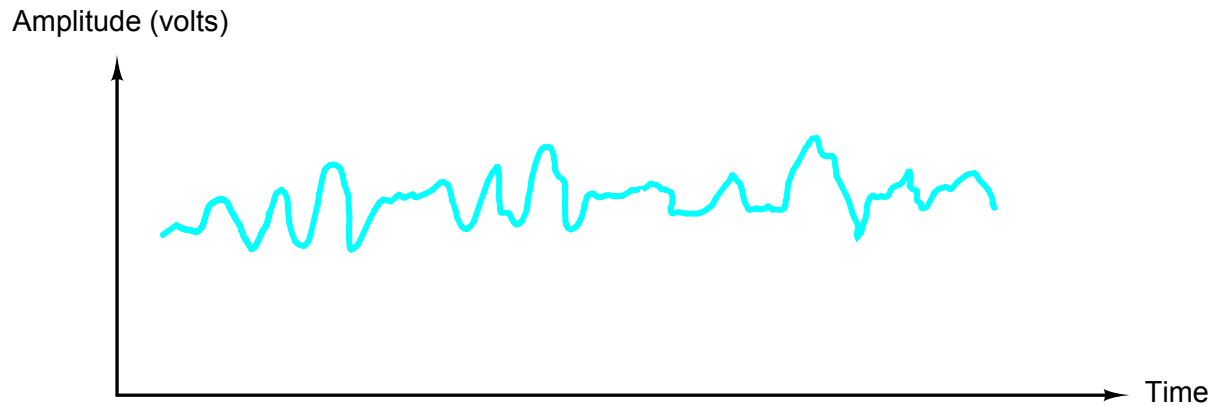
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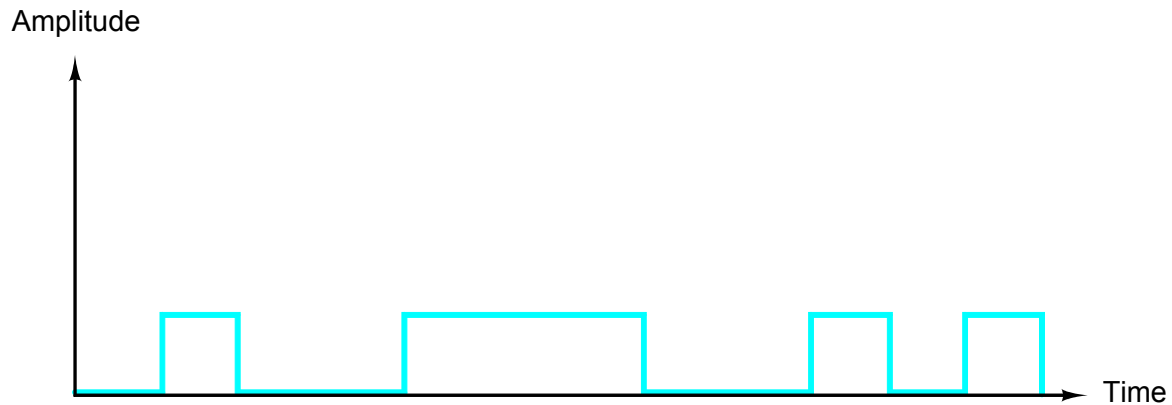


- ❑ Time Domain and Frequency Domain
- ❑ Decibels
- ❑ Data vs Signal
- ❑ Attenuation, Delay Distortion, Noise, Capacity
- ❑ Physical Media: Twisted pair, coaxial cable, optical fiber
- ❑ Bit, Hertz, and Baud
- ❑ Coding Design: Terminology + Considerations

Analog vs Digital



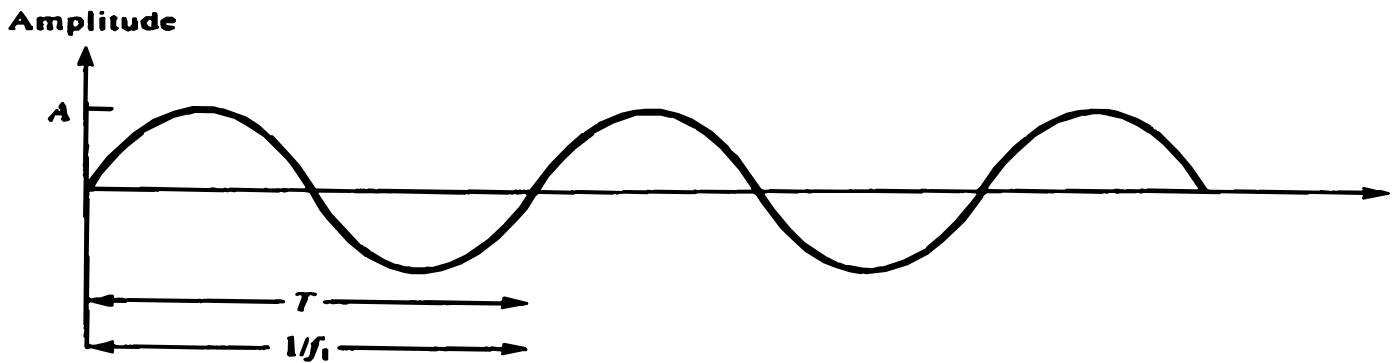
(a) Continuous



(b) Discrete

Frequency, Period, and Phase

□ $A \sin(2\pi ft + \theta)$



(a) Sine wave

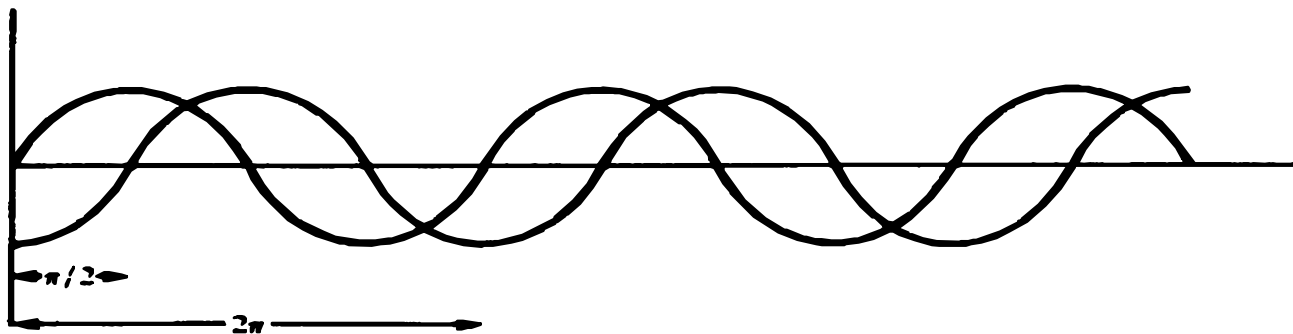
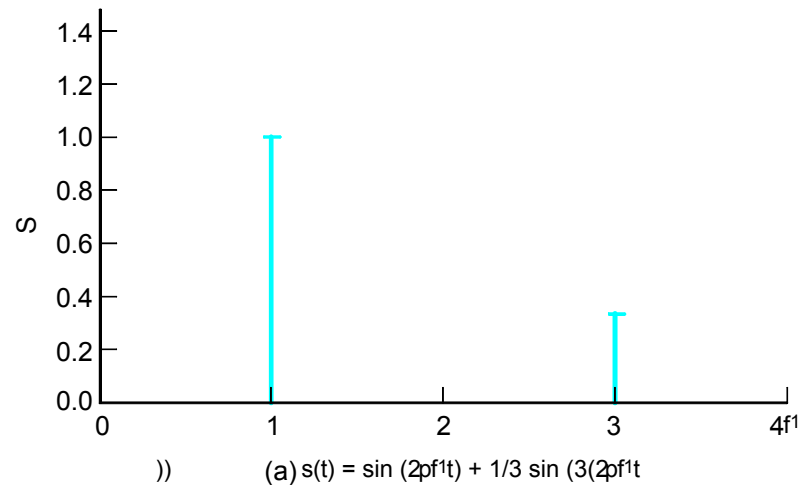
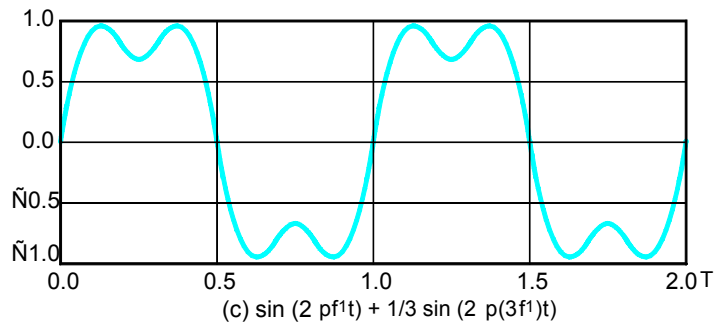
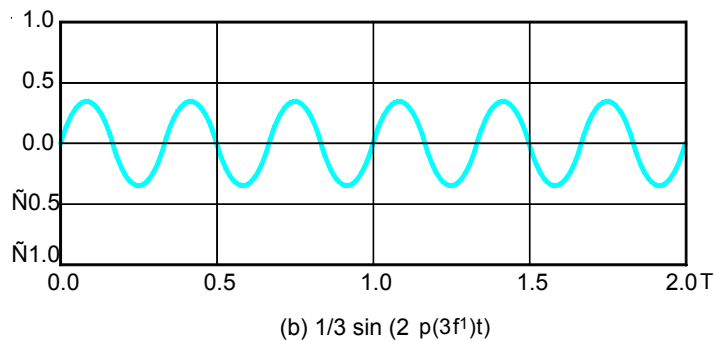
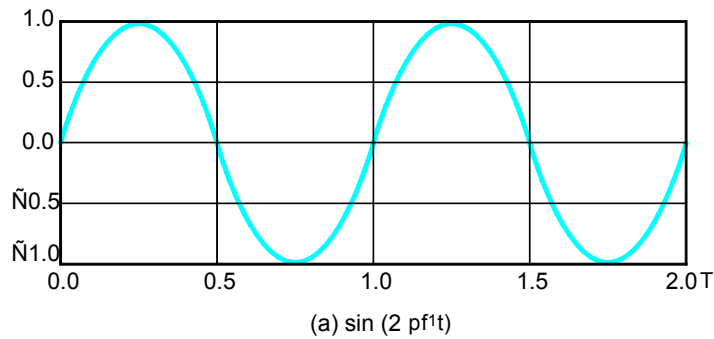


Fig 2.3a+2.4

Time Domain vs Frequency Domain



Data Rate vs Bandwidth

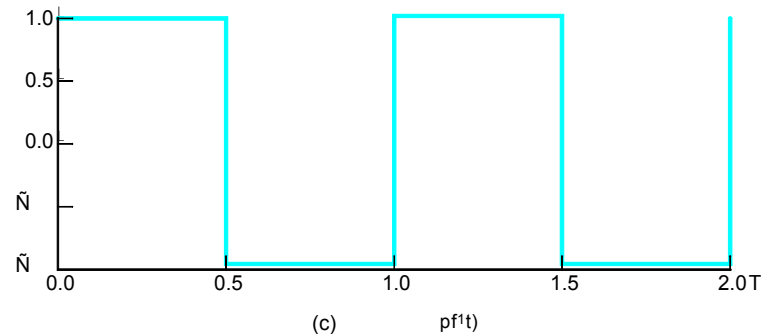
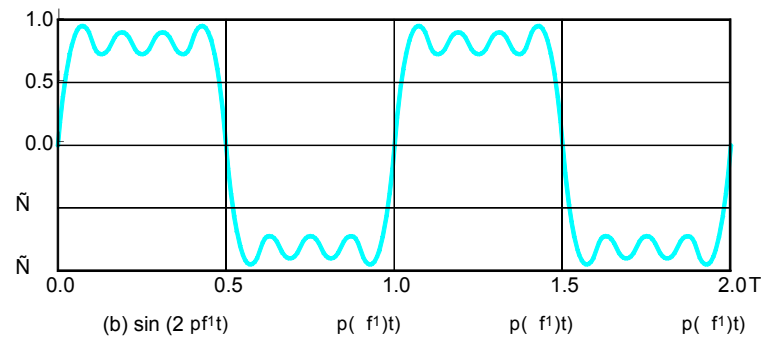
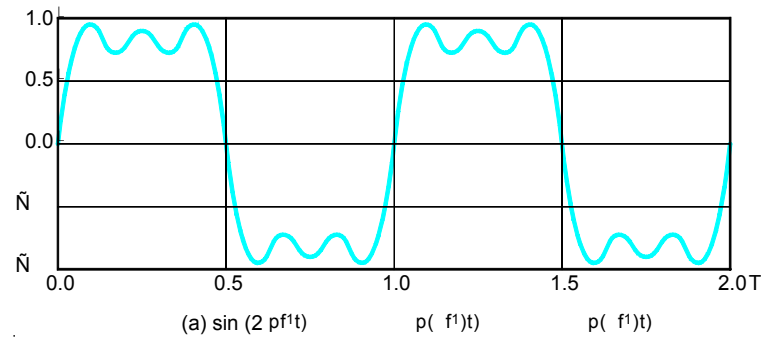
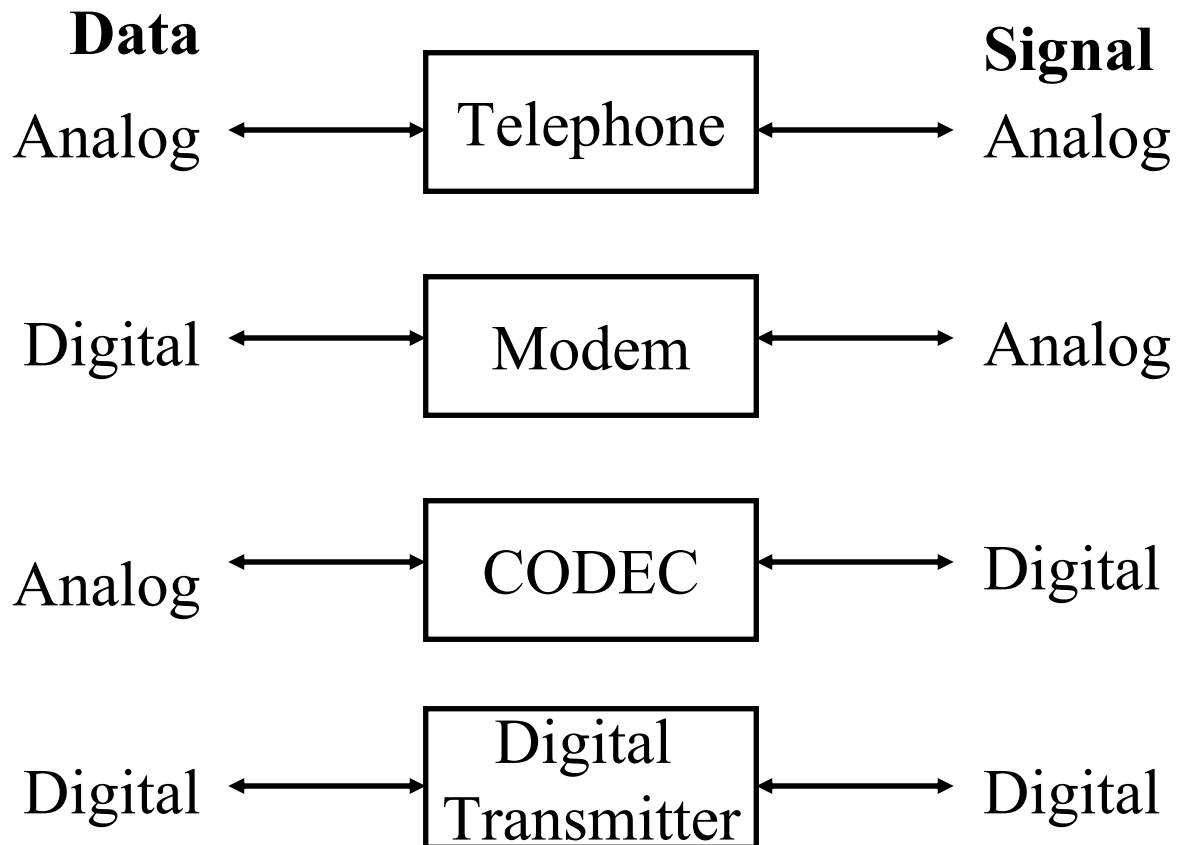
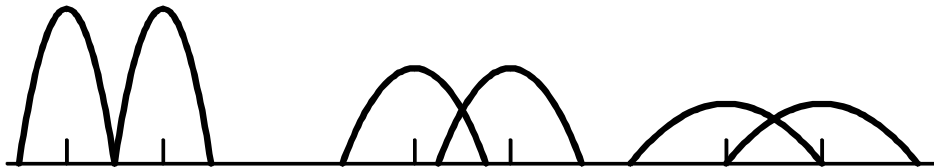
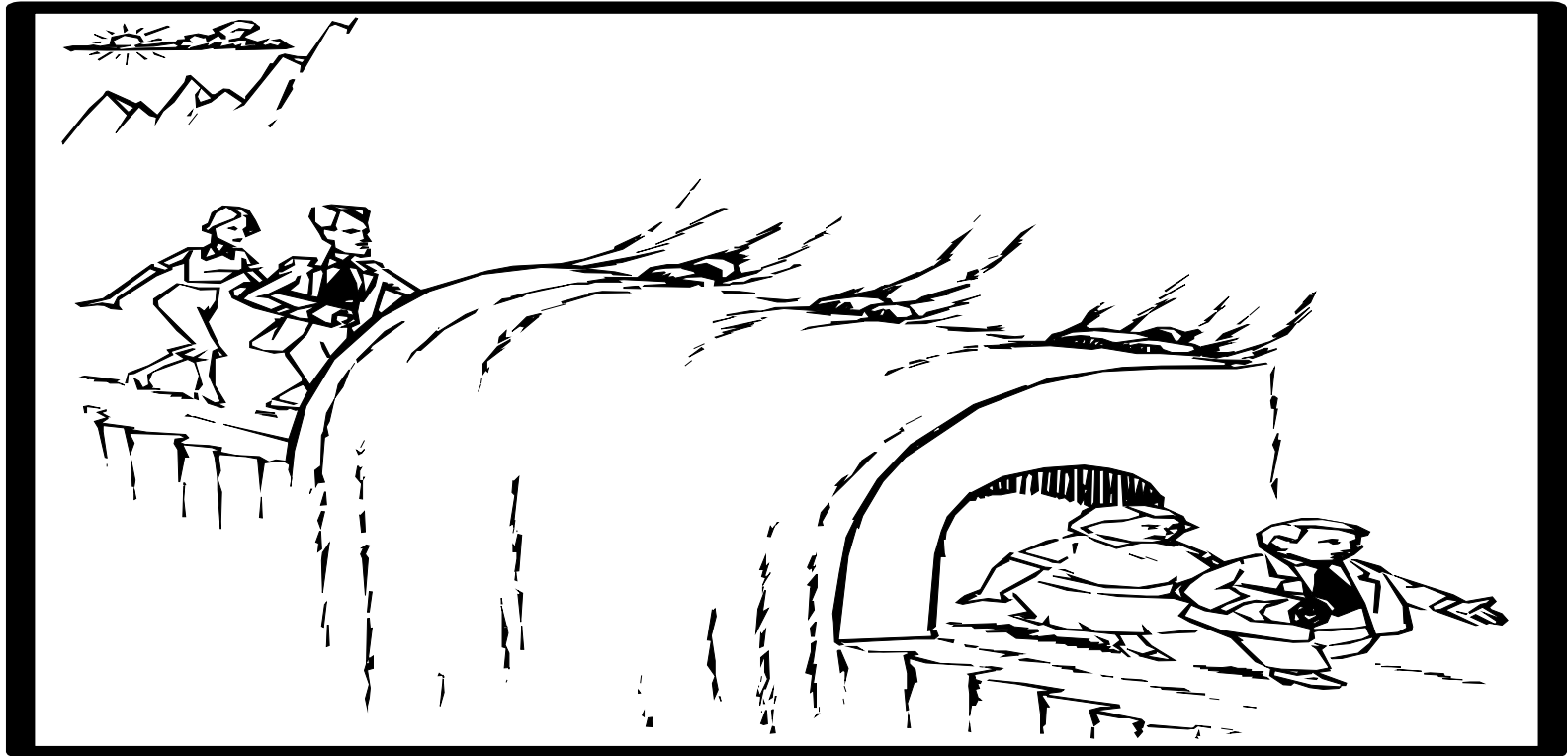


Fig 2.8

Data vs Signal



Attenuation and Dispersion (Delay Distortion)



Distance \longrightarrow

Decibels

□ Attenuation = $\text{Log}_{10} \frac{P_{in}}{P_{out}}$ Bel

□ Attenuation = $10 \text{ Log}_{10} \frac{P_{in}}{P_{out}}$ decibel

□ Attenuation = $20 \text{ Log}_{10} \frac{V_{in}}{V_{out}}$ decibel

□ **Example 1:** $P_{in} = 10 \text{ mW}$, $P_{out} = 5 \text{ mW}$

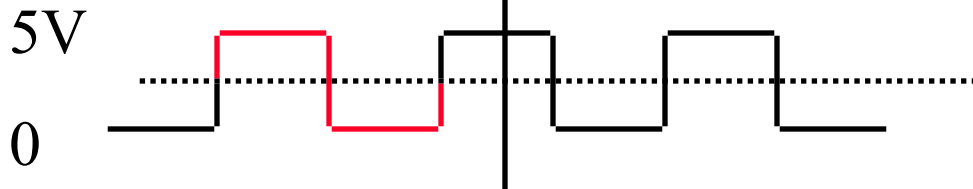
Attenuation = $10 \log_{10} (10/5) = 10 \log_{10} 2 = 3 \text{ dB}$

□ **Example 2:** $P_{in} = 100 \text{ mW}$, $P_{out} = 1 \text{ mW}$

Attenuation = $10 \log_{10} (100/1) = 10 \log_{10} 100 = 20 \text{ dB}$

Channel Capacity

- Capacity = Maximum data rate for a channel
- **Nyquist Theorem:** Bandwidth = W
Data rate $\leq 2 W$
- Bilevel Encoding: Data rate = $2 \times$ Bandwidth



- Multilevel: Data rate = $2 \times$ Bandwidth $\times \log_2 M$



Example: $M=4$, Capacity = $4 \times$ Bandwidth

Shannon's Theorem

- Bandwidth = H Hz
Signal-to-noise ratio = S/N
- Maximum number of bits/sec = $H \log_2 (1+S/N)$
- Example: Phone wire bandwidth = 3100 Hz

$$S/N = 30 \text{ dB}$$

$$10 \text{ Log}_{10} S/N = 30$$

$$\text{Log}_{10} S/N = 3$$

$$S/N = 10^3 = 1000$$

$$\begin{aligned} \text{Capacity} &= 3100 \log_2 (1+1000) \\ &= 30,894 \text{ bps} \end{aligned}$$

Transmission Media

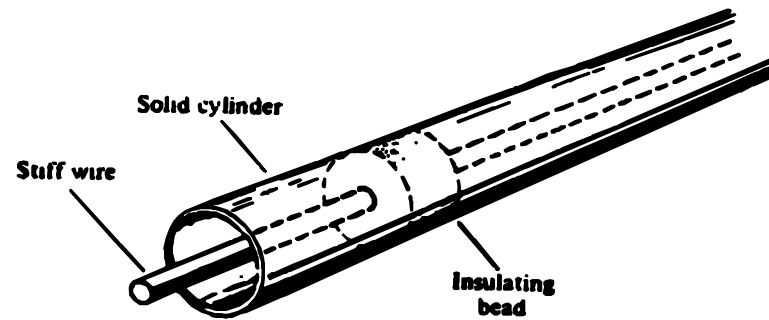
- ❑ Twisted pair
- ❑ coaxial cable
- ❑ Optical Fiber
- ❑ Terrestrial Microwave
- ❑ Satellite Microwave
- ❑ Radio

Twisted Pair

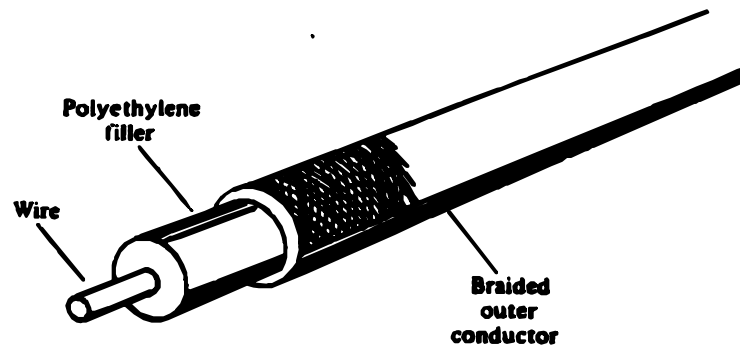
- Unshielded Twisted Pair (UTP)
 - Voice Grade: Telephone wire
 - Data Grade: Better quality
100 Mbps over 50 m possible

- Shielded Twisted Pair (STP)

Coaxial Cable



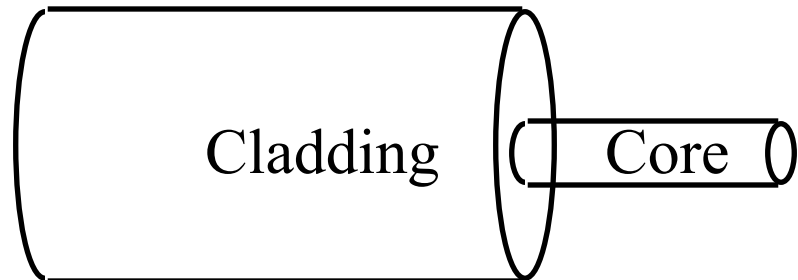
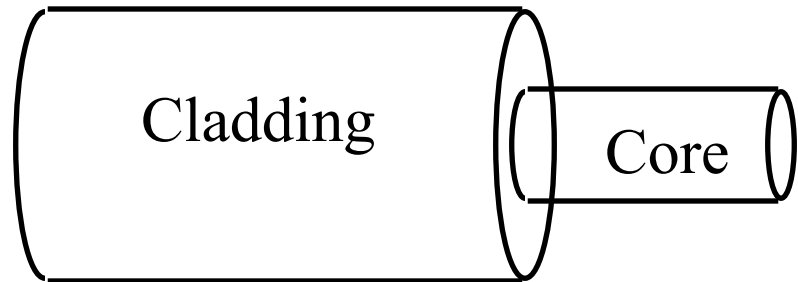
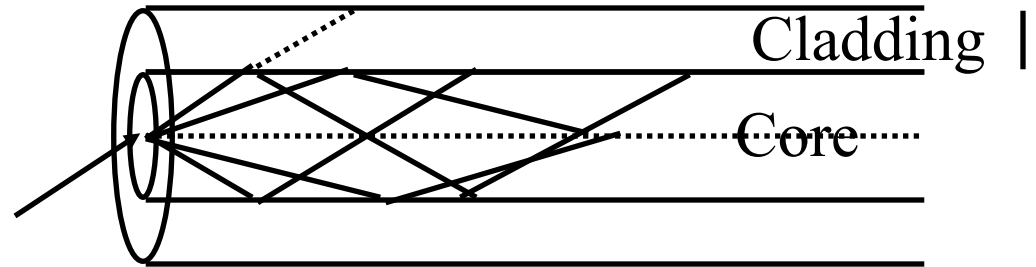
(a) Insulating beads



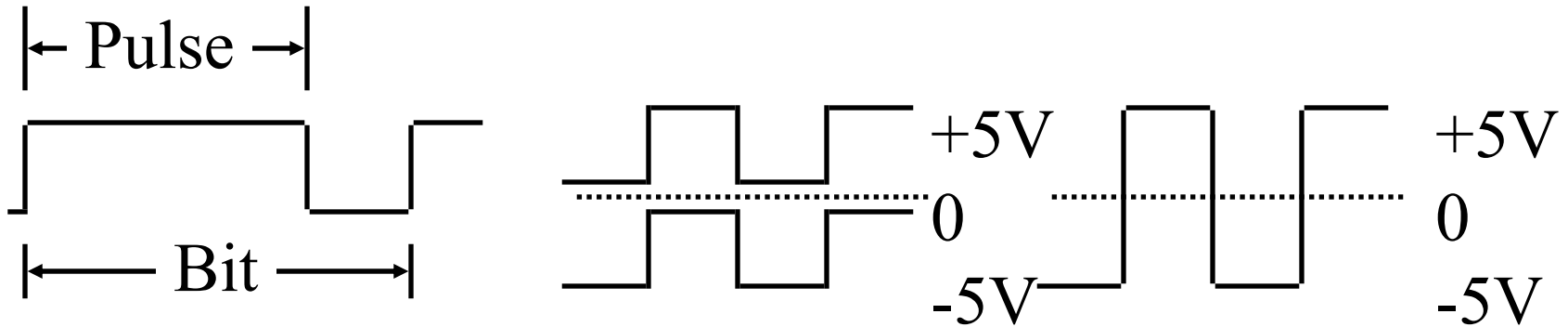
(b) Solid dielectric

Optical Fiber

- ❑ Modes
Index
= Index of refraction
= Speed in Vacuum /
Speed in medium
- ❑ Multimode
- ❑ Single Mode

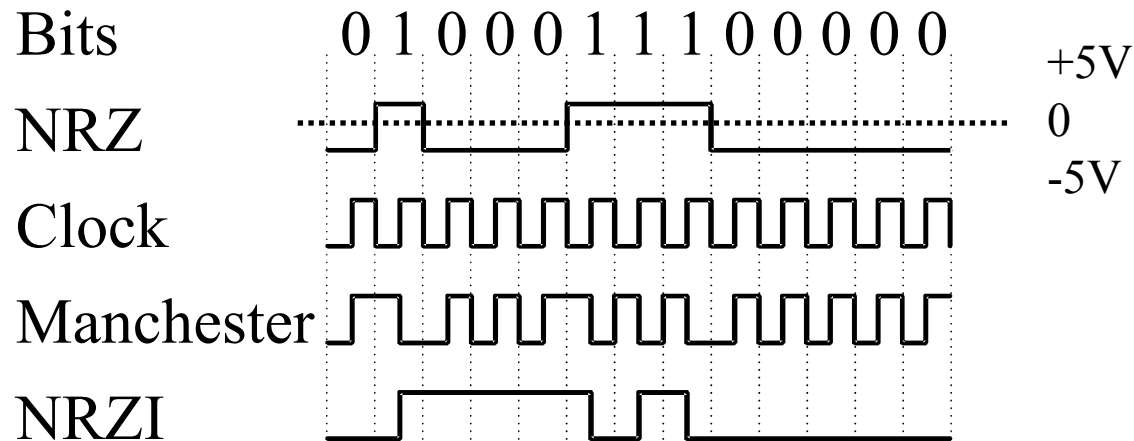


Coding Terminology



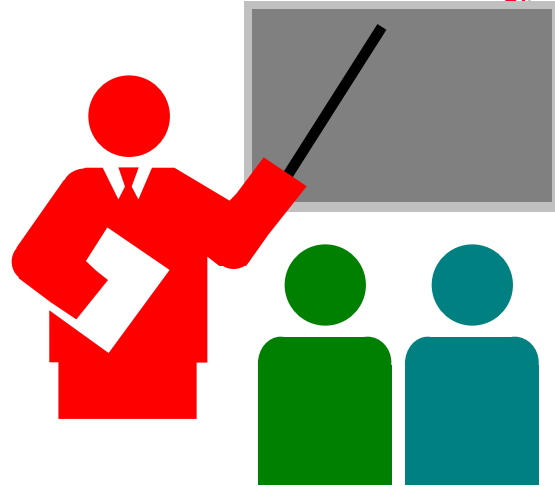
- ❑ Signal element: Pulse
- ❑ Modulation Rate:
1/Duration of the smallest element
=Baud rate
- ❑ Data Rate: Bits per second
- ❑ Data Rate = F_n (Bandwidth, signal/noise ratio, encoding)

Coding Design



- ❑ Pulse width indeterminate: Clocking
- ❑ DC, Baseline wander
- ❑ No line state information
- ❑ No error detection/protection
- ❑ No control signals
- ❑ High bandwidth
- ❑ Polarity mix-up \Rightarrow Differential (compare polarity)

Summary



- ❑ Time domain vs frequency domain
- ❑ Data rate vs Bandwidth
- ❑ Data vs Signal, Analog vs Digital
- ❑ Attenuation, Dispersion (delay distortion)
- ❑ Media: Twisted pair, coaxial, fiber
- ❑ Coding: Higher data rate, error control, clock sync
- ❑ NRZ, NRZI, Manchester, Multilevel

Homework

- Read Sections 3.3, 3B (appendix), 4.1, 5.1 of Stallings 6th edition.