
Data Transmission, Transmission Media and Data Encoding

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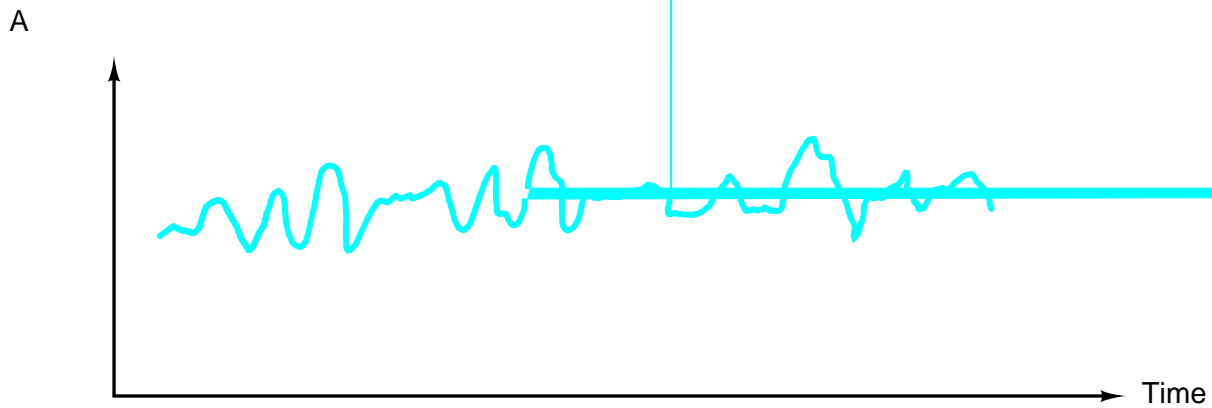
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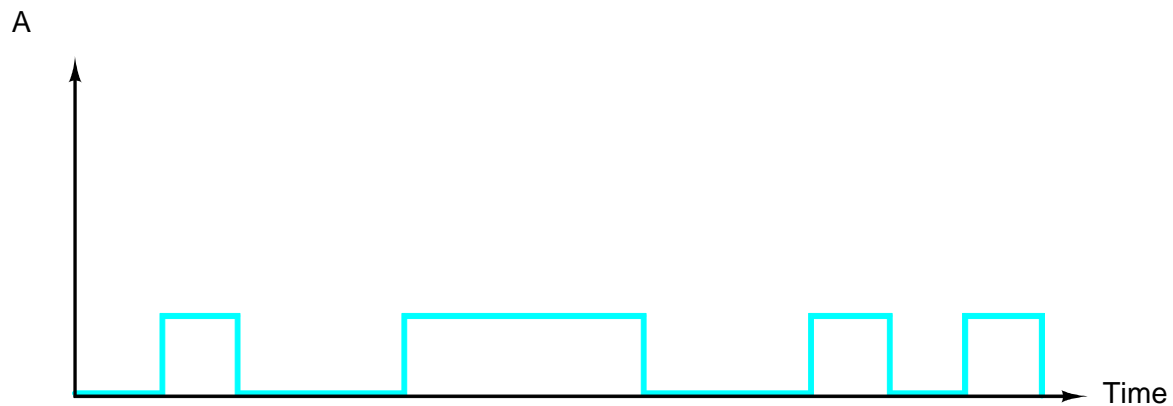


- q Time Domain and Frequency Domain
- q Decibels
- q Data vs Signal
- q Attenuation, Delay Distortion, Noise, Capacity
- q Physical Media: Twisted pair, coaxial cable, optical fiber
- q Bit, Hertz, and Baud
- q Coding Design: Terminology + Considerations

Analog vs Digital



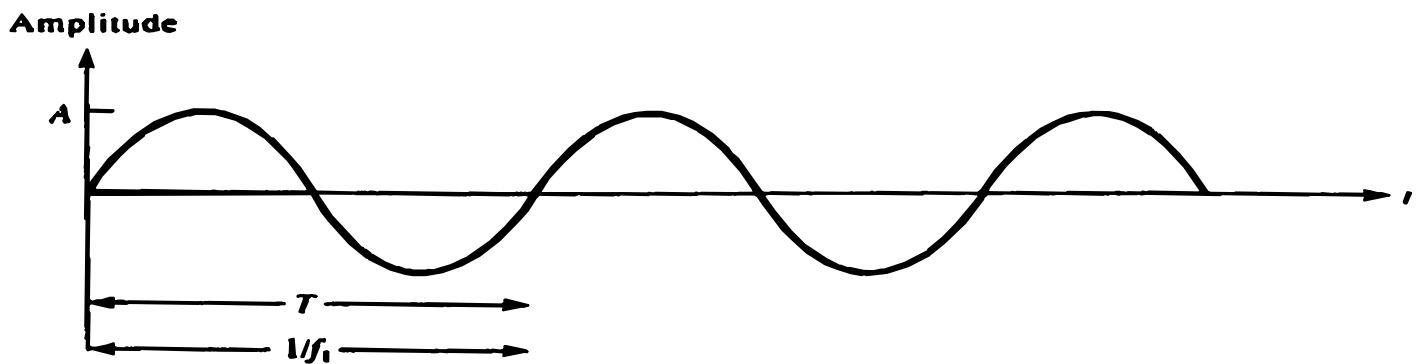
(a) Continuous



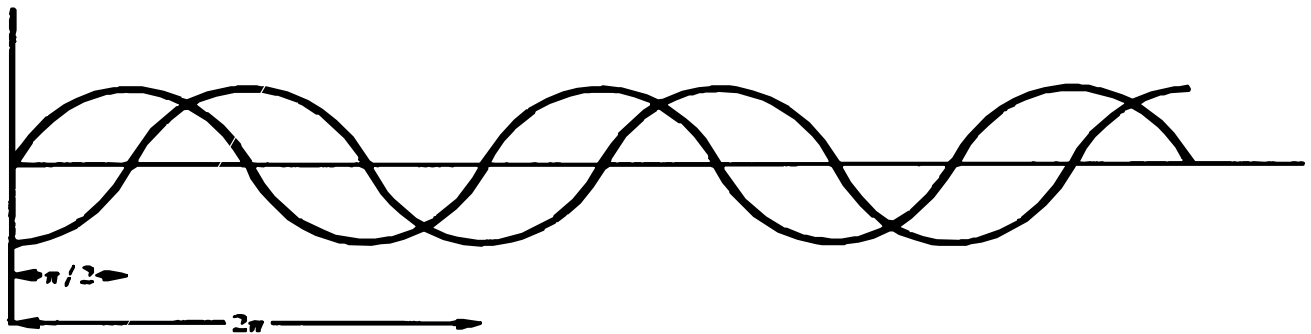
(b) Discrete

Frequency, Period, and Phase

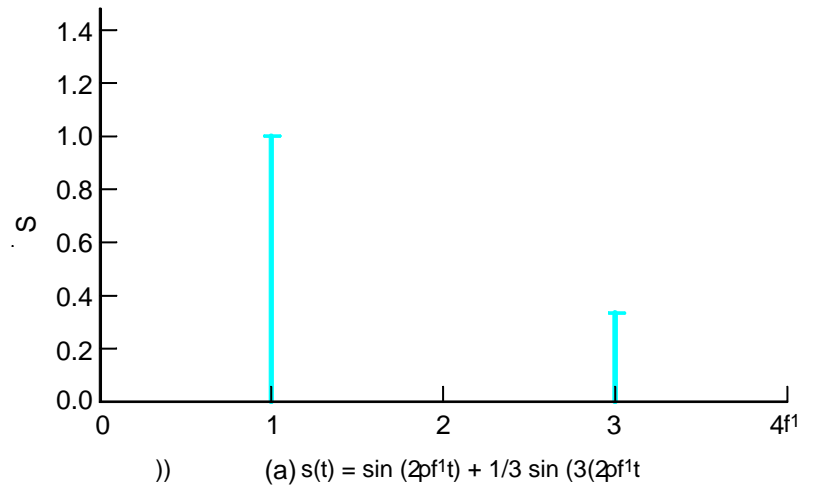
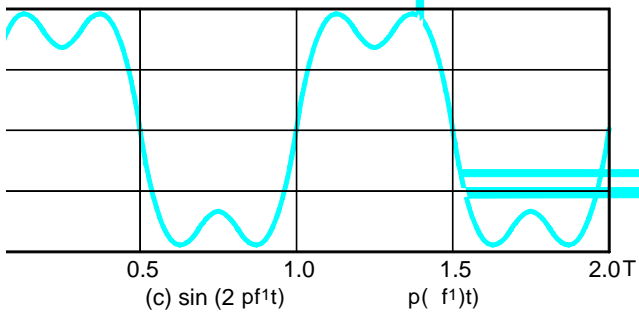
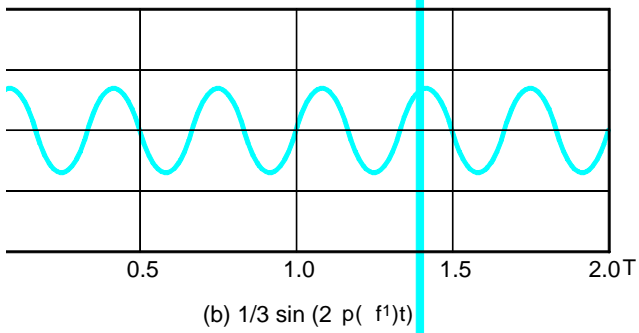
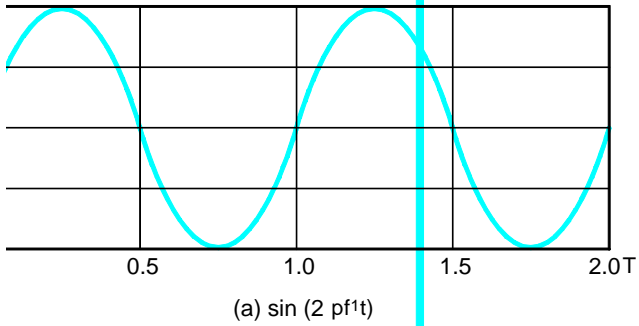
$$A \sin(2\pi ft + \theta)$$



(a) Sine wave



Time Domain vs Frequency Domain



Data Rate vs Bandwidth

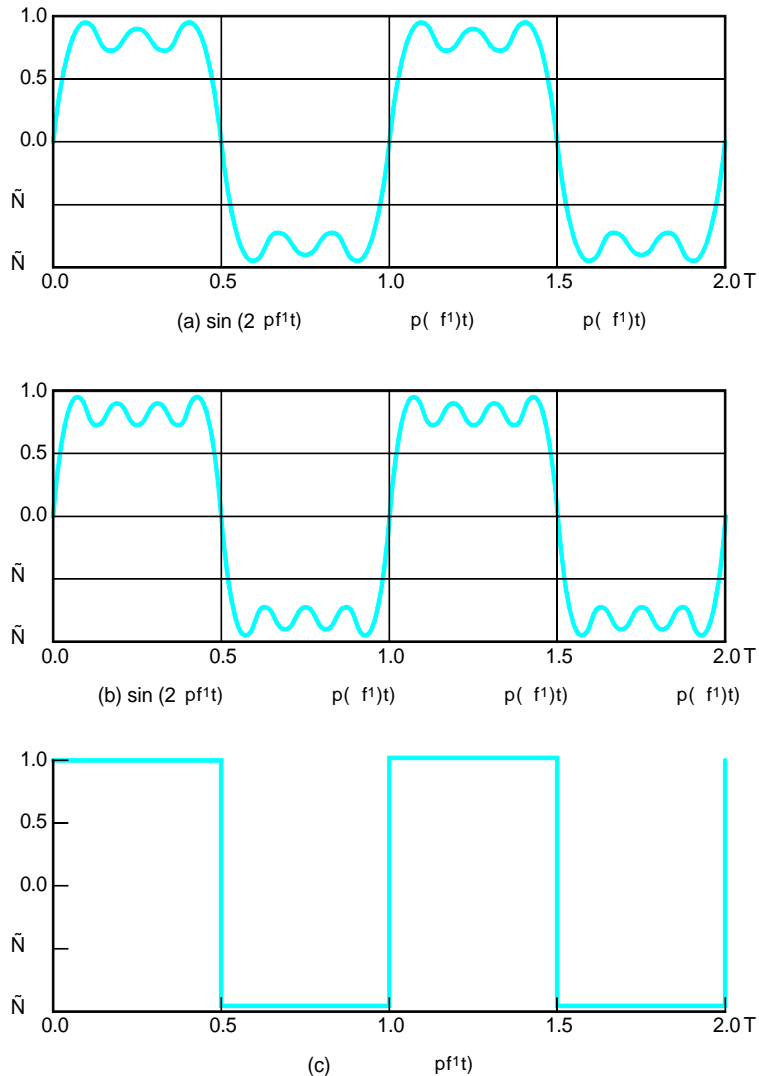
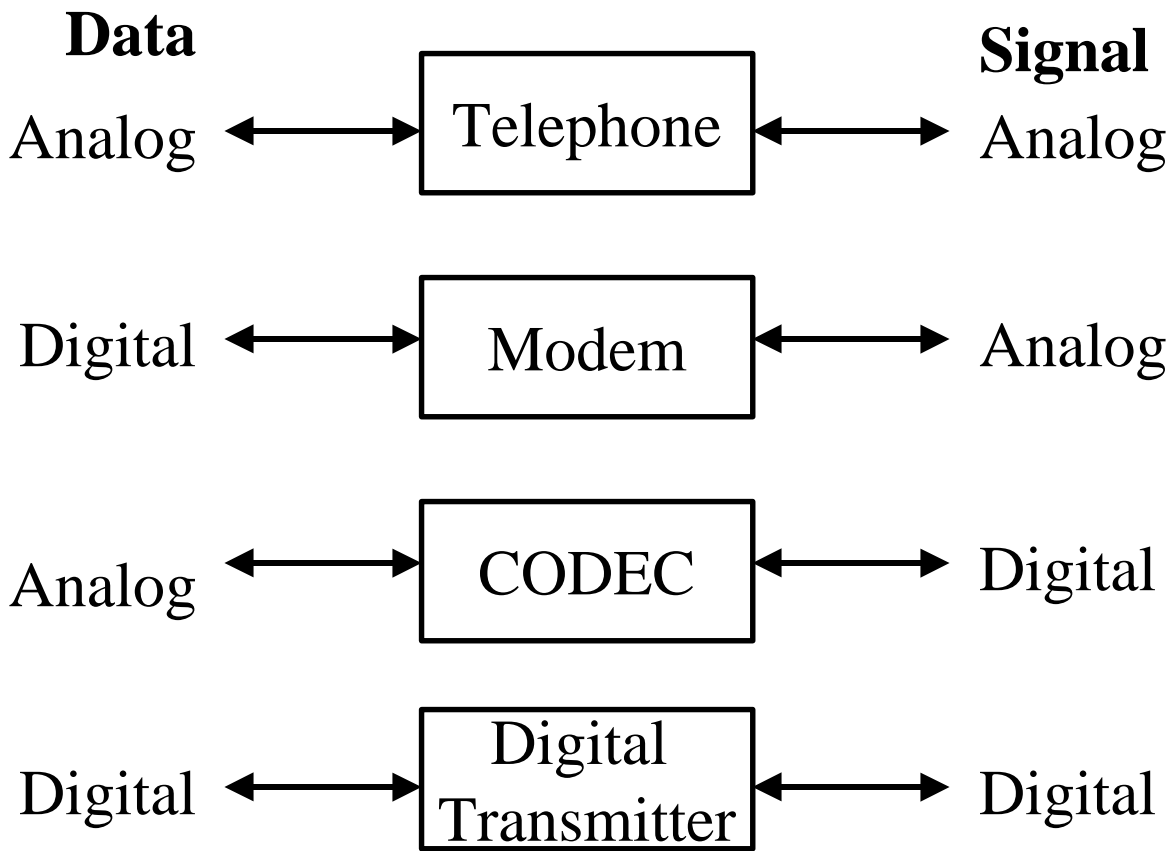
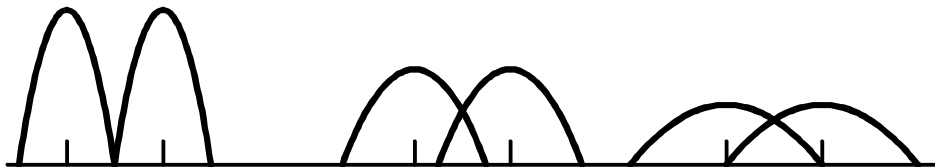
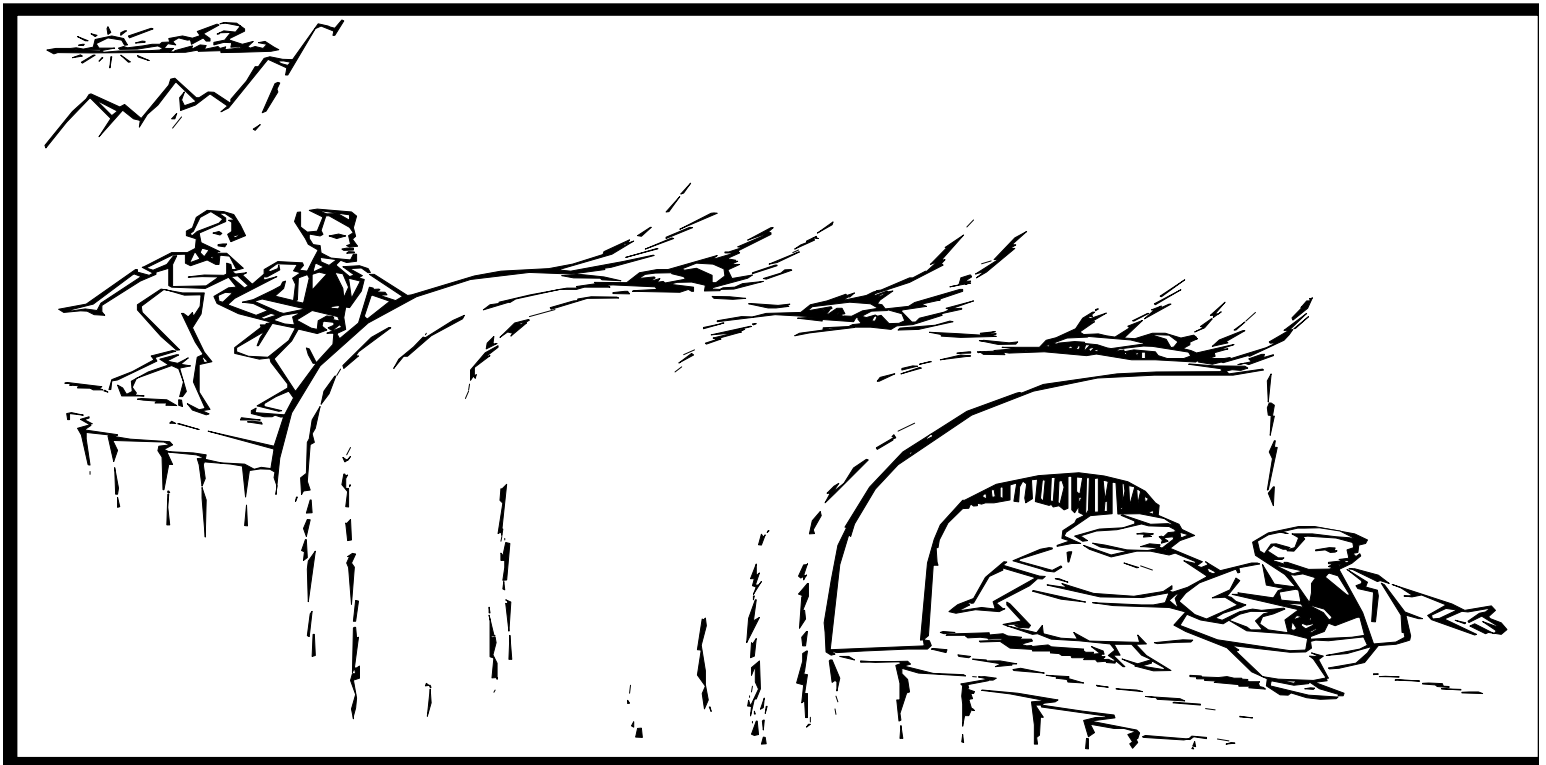


Fig 2.8

Data vs Signal



Attenuation and Dispersion (Delay Distortion)



Distance →

Decibels

$$\text{Attenuation} = \text{Log}_{10} \frac{\text{Pin}}{\text{Pout}} \text{ Bel}$$

$$\text{Attenuation} = 10 \text{ Log}_{10} \frac{\text{Pin}}{\text{Pout}} \text{ decibel}$$

$$\text{Attenuation} = 20 \text{ Log}_{10} \frac{\text{Vin}}{\text{Vout}} \text{ decibel}$$

Example 1: Pin = 10 mW, Pout=5 mW

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

Example 2: Pin = 100mW, Pout=1 mW

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

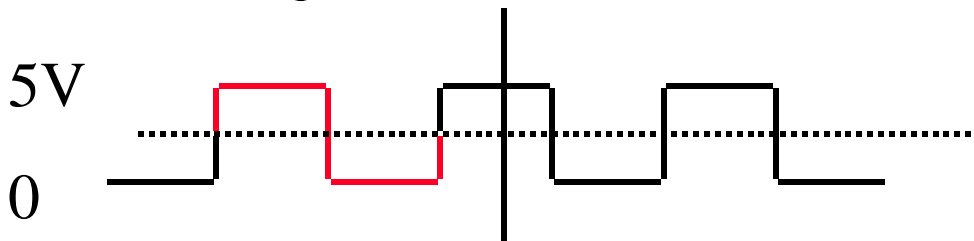
Channel Capacity

Capacity = Maximum data rate for a channel

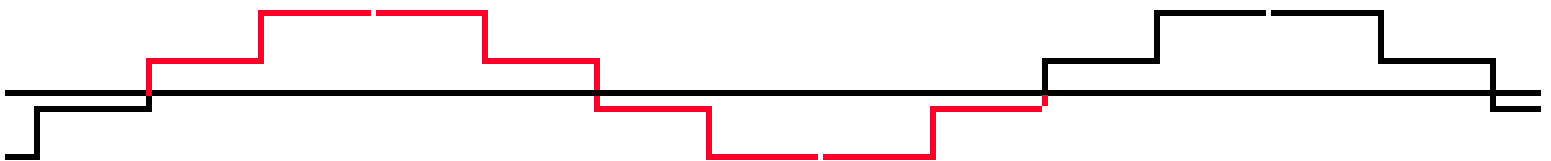
Nyquist Theorem: Bandwidth = W

$$\text{Data rate} \leq 2W$$

3level Encoding: Data rate = $2 \times \text{Bandwidth}$



Multilevel Encoding: Data rate = $2 \times \text{Bandwidth} \times \log_2 M$



example: $M=4$, Capacity = $4 \times \text{Bandwidth}$

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

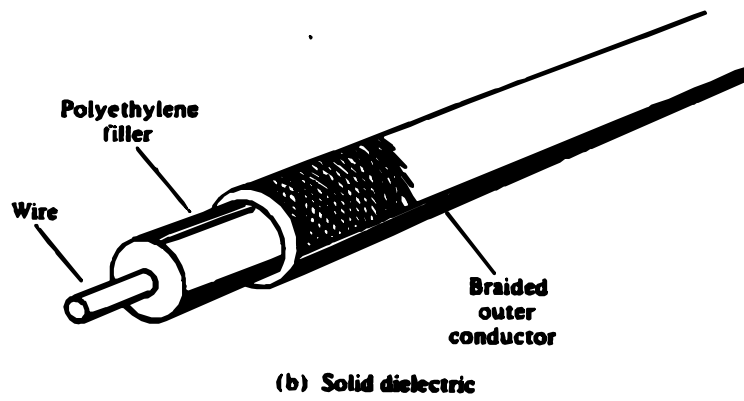
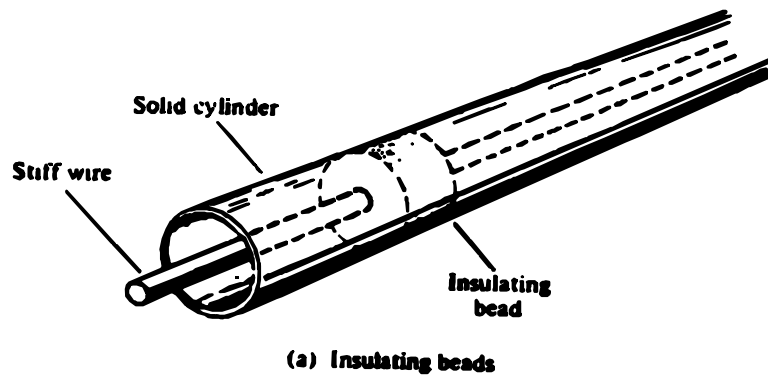
Twisted Pair

Unshielded Twisted Pair (UTP)

- q Voice Grade: Telephone wire
 - q Data Grade: Better quality
- 100 Mbps over 50 m possible

Shielded Twisted Pair (STP)

Coaxial Cable



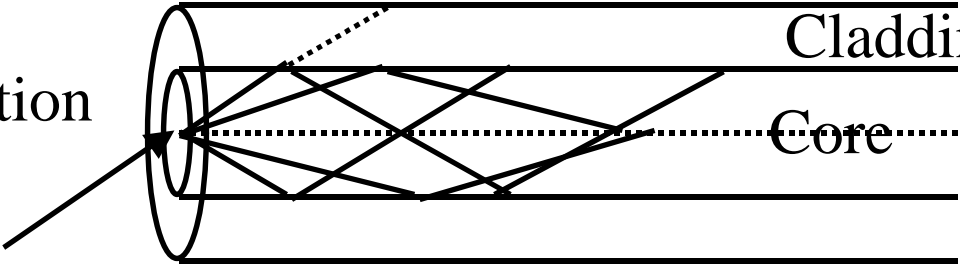
Optical Fiber

Modes

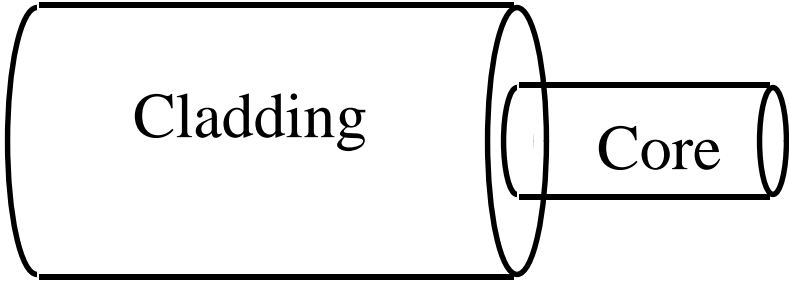
Index = Index of refraction

$n = \text{Speed in Vacuum} /$

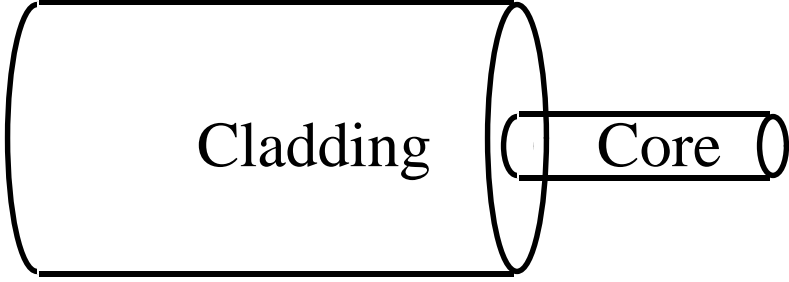
Speed in medium



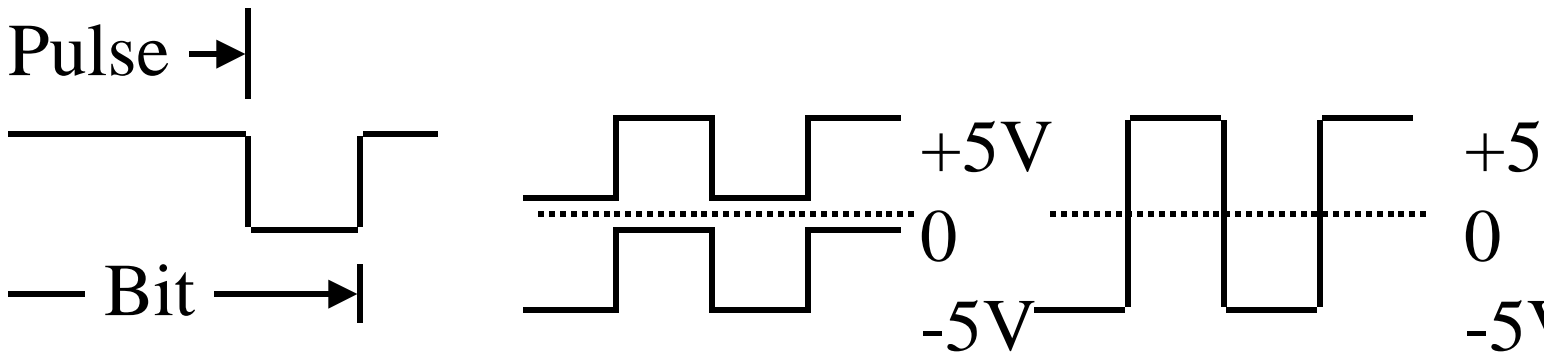
Multimode



Single Mode



Coding Terminology



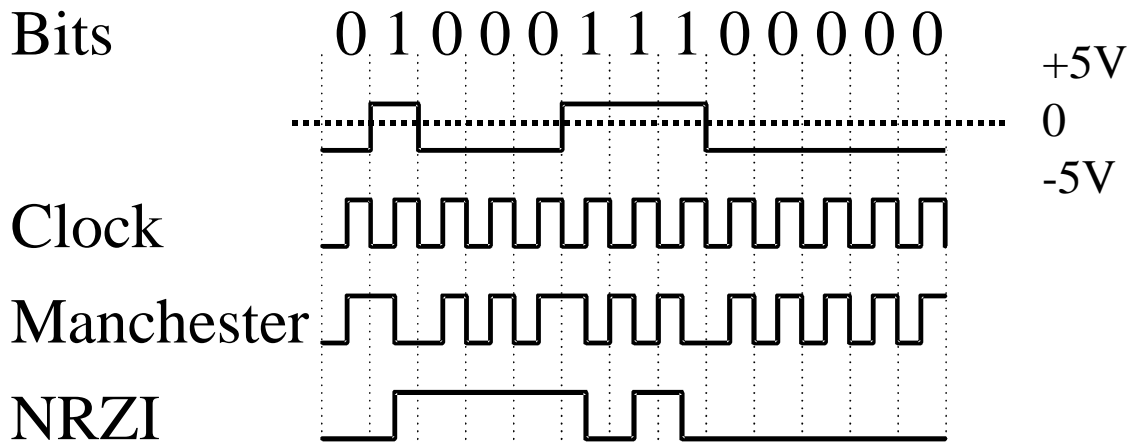
Signal element: Pulse

Modulation Rate: $1/\text{Duration of the smallest element}$
=Baud rate

Data Rate: Bits per second

Data Rate = $F_n(\text{Bandwidth, signal/noise ratio, encoding})$

Coding Design



↳ pulse width indeterminate: Clocking

↳ DC, Baseline wander

↳ No line state information

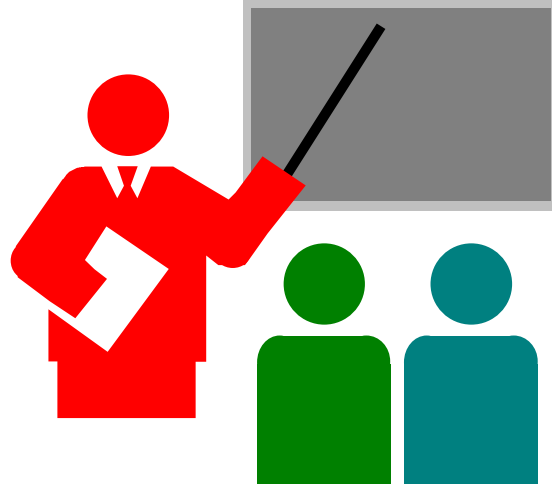
↳ No error detection/protection

↳ 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 synchronization,

NRZ, NRZI, Manchester, Multilevel

Homework

Read Sections 2.3, 2B (appendix), 3.1, 4.1 of Stallings.