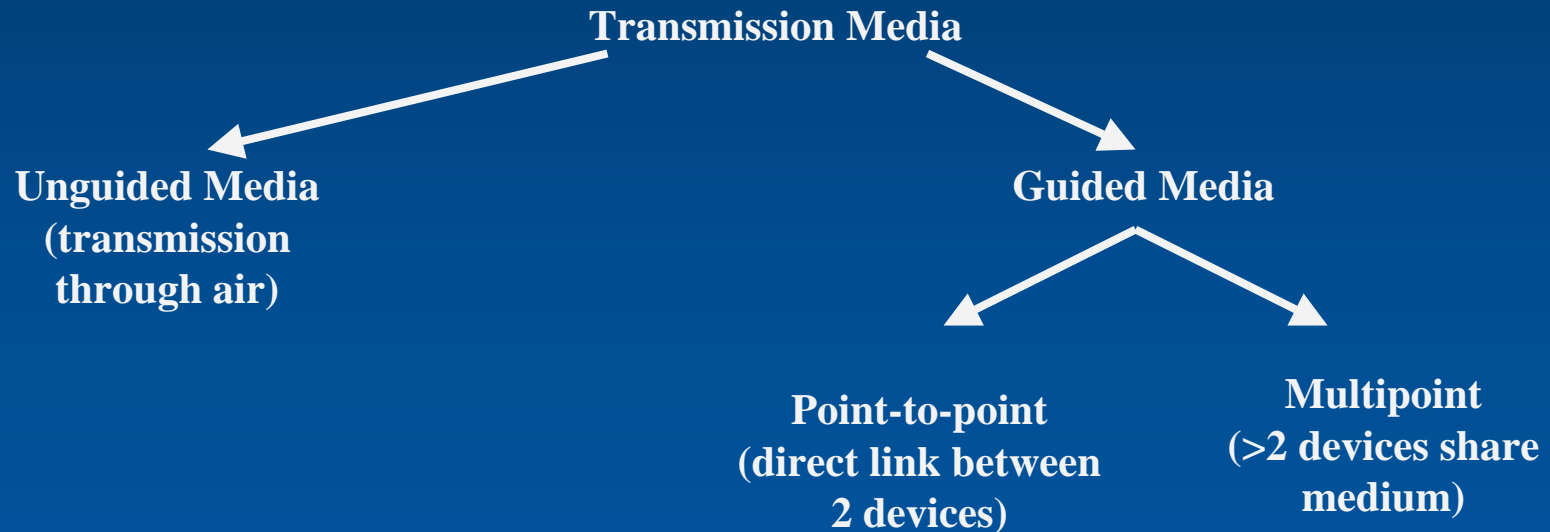


Physical Layer

Data Transmission

Transmission Media

- The transmission medium is the physical path between transmitter and receiver in a data transmission system.

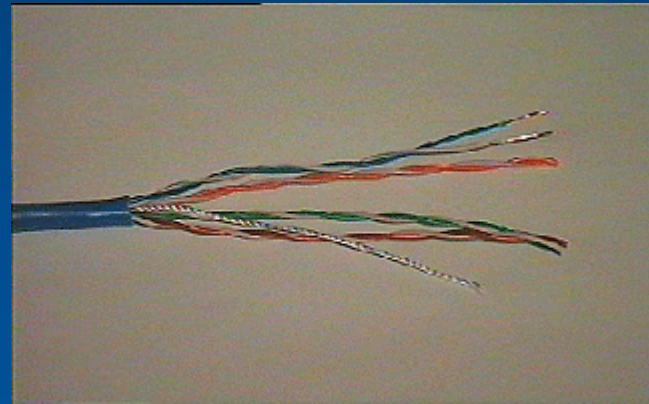


Transmission Media

- Transmission Medium can be:
 - **Simplex**
 - Transmission in one direction only.
 - **Half-duplex**
 - Transmission in both directions; but not at the same time.
 - **Full-duplex (duplex)**
 - Simultaneous transmission in both directions.

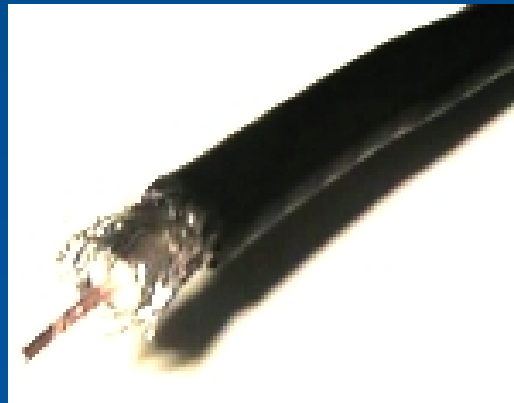
Twisted Pair

- Two insulated wires are twisted around each other, and combined with others into a cable
- Used to connect telephone subscribers to switching centers and for wiring local area networks
- Different qualities:
 - Two popular varieties:
 - Category 3: 10 Mbps
 - Category 5: 100 Mbps
- Most twisted pair cables are of type UTP (Unshielded twisted pair), that is, they do not have a ground shield.



Coaxial Cable

- Like twisted pair a coaxial cable (“coax”) has two conductors that are shielded
- Used for digital transmissions in local area networks (e.g., Ethernet in the 1980’s) and analog transmissions for cable television
- Coax used for Cable TV supports a spectrum of 50 - 750 Mhz



Optical Fiber

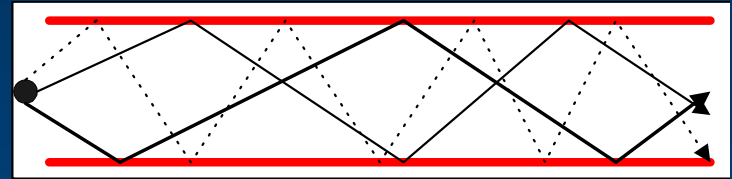
- Optical fiber is a thin (2-125 μm), flexible medium capable of conducting an optical ray.
- Fiber is built of various glasses or plastics.
- Very high bandwidth (currently up to 10 Gbps).
- Used for long-distance trunks, local area networks, high-speed transmissions.
- Inherently unidirectional.



Types of Optical Fiber

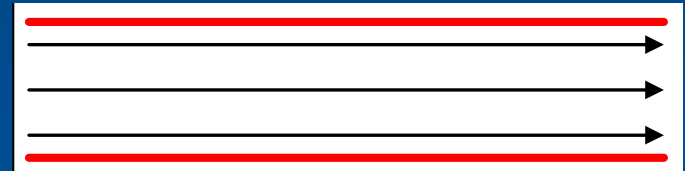
■ Multimode Fiber:

- Rays may take different paths



■ Single Mode Fiber:

- By reducing the radius of the fiber core to the order of the wavelength, only the axial ray can pass.



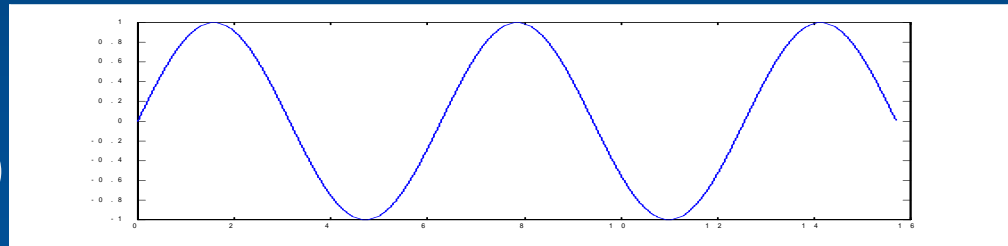
- Single Mode fiber has superior performance but needs a laser diode as a light source (instead of a LED for multimode fiber).

Signals

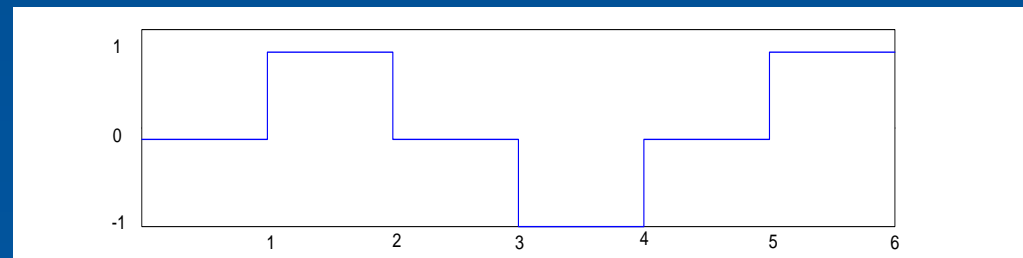
- Signals, electromagnetic or optical, are used to transmit data.
- A signal can be viewed as a function of time (time-domain) and as a function of its frequencies (frequency-domain)

- Signals:

- Continuous (analog)



- Discrete (digital)



Signals in the Time Domain

- A **continuous signal** has no discontinuities, that is, for all a :

$$\lim_{t \rightarrow a} s(t) = a$$

- **Periodic signals** are of the form:

$$s(t) = s(t + T) \quad \text{for all } t$$

- The most basic continuous periodic signal is a sine wave
- An aperiodic signal can be represented by (an infinite number of) sine waves

Sine Waves

- Generic sine wave is:

$$s(t) = A \sin(2\pi ft + \phi)$$

Amplitude A:

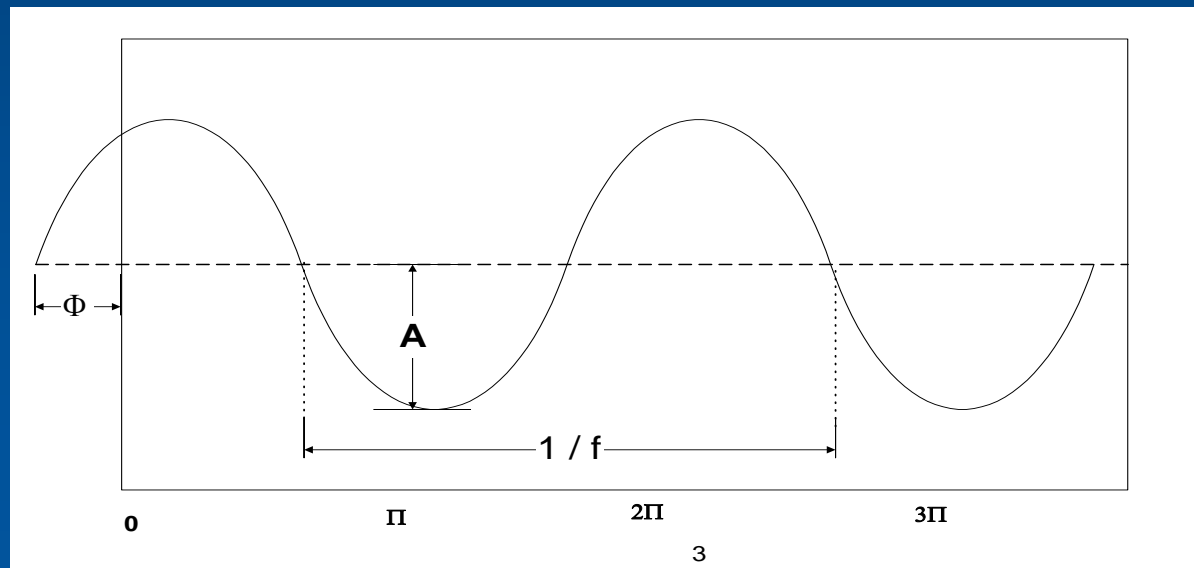
Peak value of a signal at any time

Frequency f:

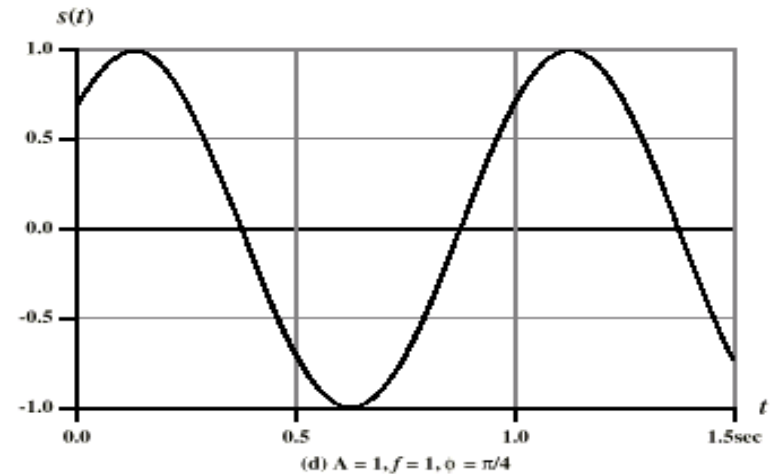
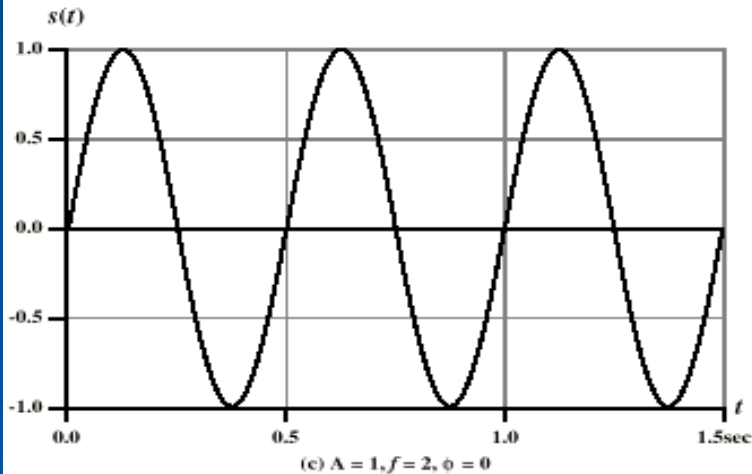
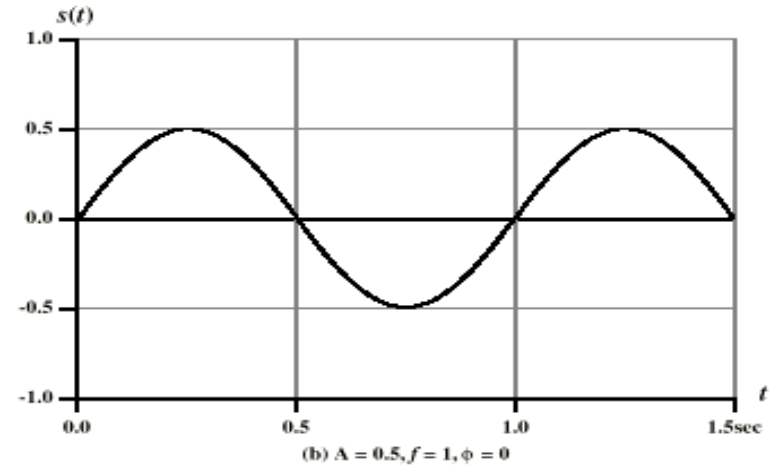
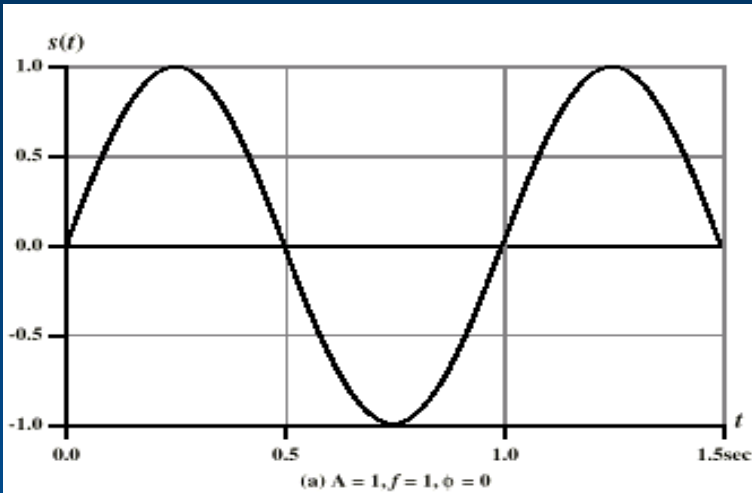
Inverse of the period

Phase Φ :

Relative position within a signal period



Varying Sine Waves -- $s(t) = A \sin(2\pi ft + \Phi)$

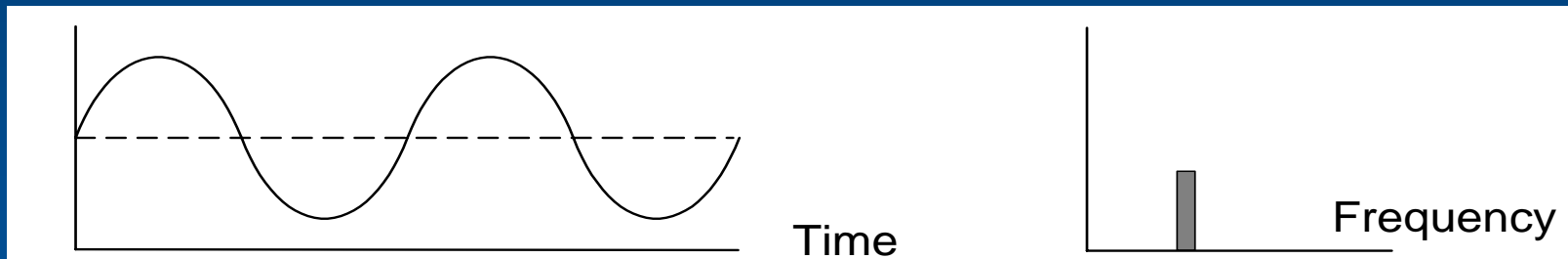


Wavelength

- Distance occupied by one cycle
- Distance between two points of corresponding phase in two consecutive cycles
- λ
- Assuming signal velocity v
 - $\lambda = vT$
 - $\lambda f = v$
 - $c = 3 \times 10^8 \text{ ms}^{-1}$ (speed of light in free space)

Signals in the Frequency Domain

- The time-domain view represents the amplitude of the signal as a function $s(t)$ of time
- In a similar way, one can represent a signal in terms of a frequency-domain function $S(f)$



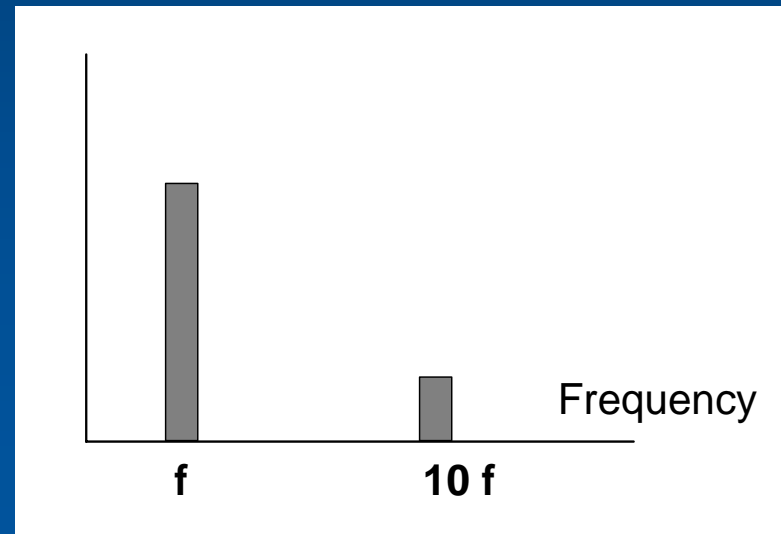
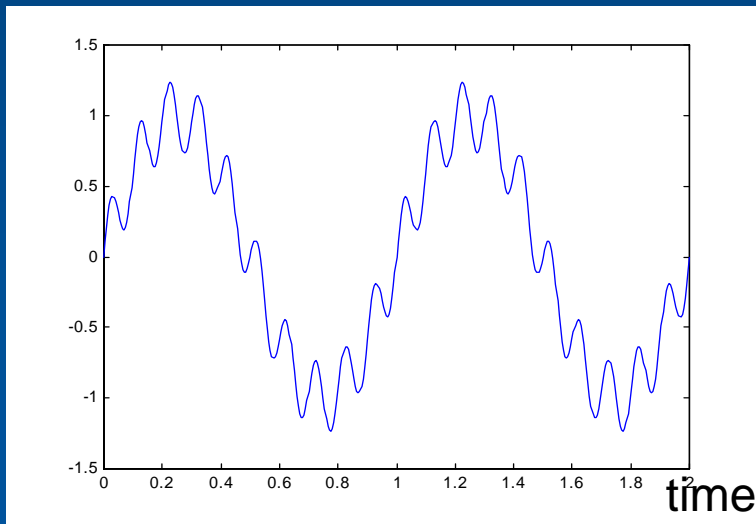
Electromagnetic Signals

- Electromagnetic signals are composed of multiple frequencies

- The plot for the signal in the time domain

$$s(t) = \sin(2 \pi f t) + 1/4 \sin(2 \pi (10f) t)$$

looks like this:

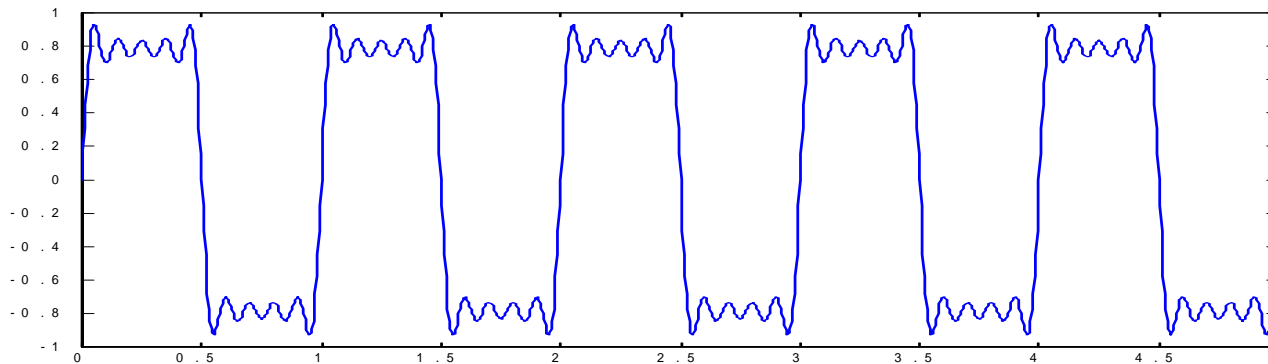


Fourier Analysis

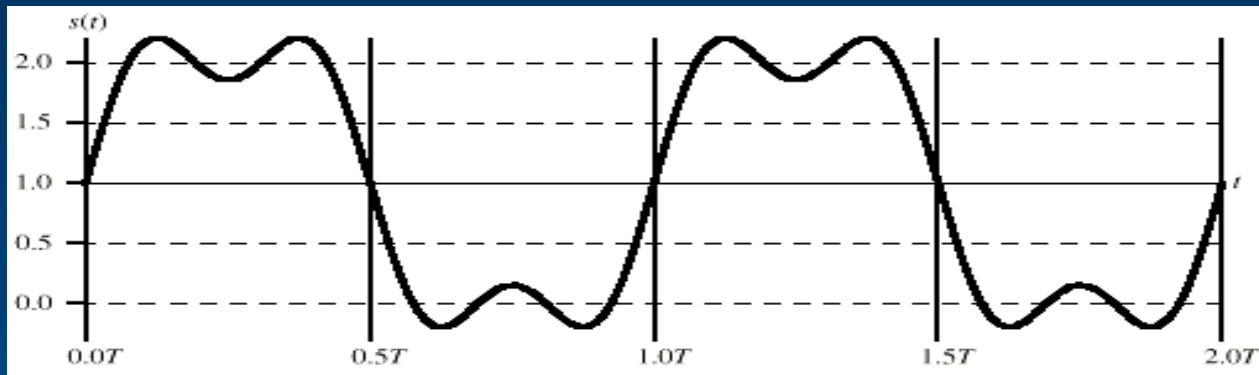
- Using Fourier Analysis any signal can be represented by a number of sine waves
- Any periodic signal can be expressed as sum of sine waves:

$$s(t) = \sum_j A_j \cos(2\pi f_j t)$$

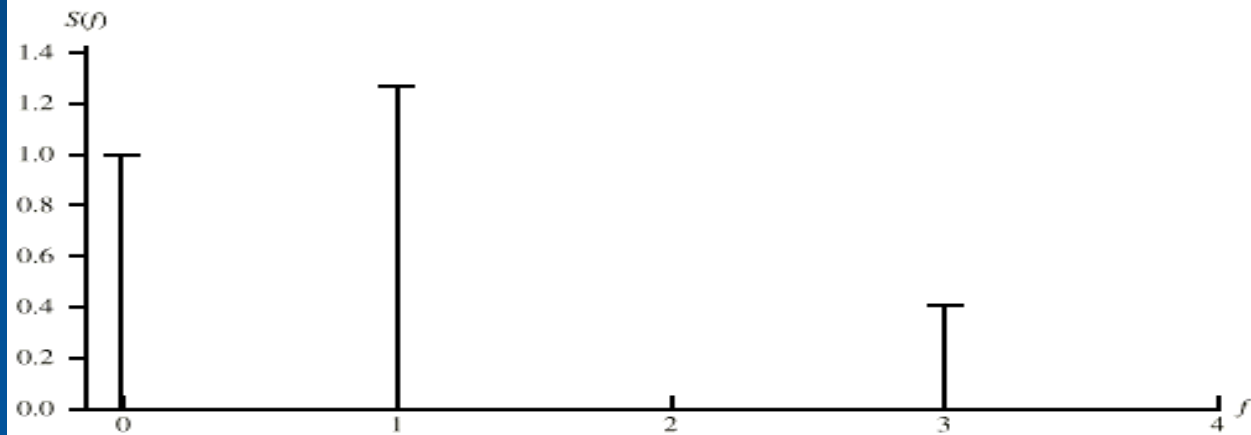
- Thus, a discrete signal can be represented:



Signal with DC Component



(a) $s(t) = 1 + (4/3) [\sin(2\pi ft) + (1/3) \sin(2\pi (3f)t)]$



(b) $S(f)$

Bandwidth and Capacity

- Spectrum** Range of frequencies of a signal
[f_{\min} , f_{\max}]
- Bandwidth** Width of the spectrum ($f_{\max} - f_{\min}$)
(measured in Hz)
- Capacity** Rate at which data can be transmitted (measured in bits per seconds, bps)
- Noise** Random noise which distorts a signal
(measured as ratio of signal power to noise power, units are decibels (dB))
- **Signal-to-Noise Ratio**
 - S: Signal Power. N: Noise Power
 - signal-to-noise ratio (db) = $10 \log_{10} S/N$

Bandwidth and Capacity

- Capacity of a noiseless channel (H. Nyquist, 1924)
 - B: bandwidth;
 - M: number of discrete levels of a signal;
 - C: Capacity

$$C = 2 B \log_2 M \quad \text{bps}$$

- Capacity of a noisy channel: (C. Shannon, 1948)
 - B: bandwidth
 - S/N: signal-to-noise ratio

$$C = B \log_2 (1 + S/N) \text{ bps}$$

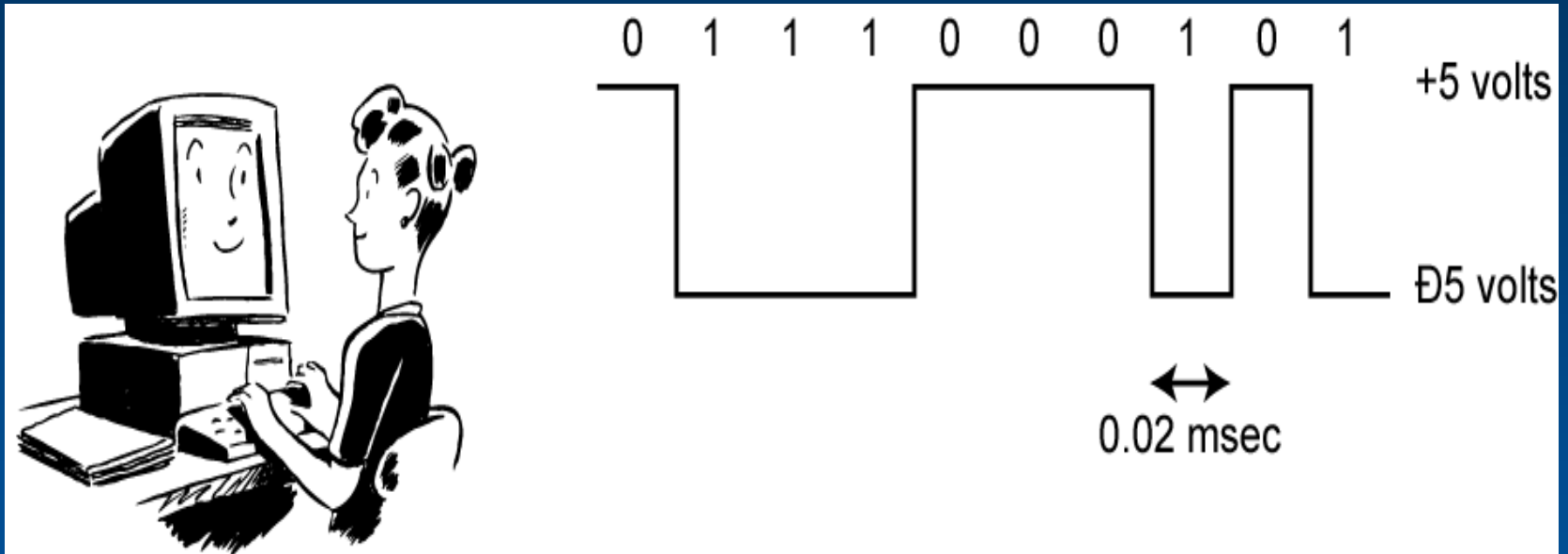
Components of Speech

- Frequency range (of hearing) 20Hz-20kHz
 - Speech 100Hz-7kHz
- Easily converted into electromagnetic signal for transmission
- Sound frequencies with varying volume converted into electromagnetic frequencies with varying voltage
- Limit frequency range for voice channel
 - 300-3400Hz

Video Components

- USA - 483 lines scanned per frame at 30 frames per second
 - 525 lines but 42 lost during vertical retrace
- So 525 lines x 30 scans = 15750 lines per second
 - 63.5 μ s per line
 - 11 μ s for retrace, so 52.5 μ s per video line
- Max frequency if line alternates black and white
- Horizontal resolution is about 450 lines giving 225 cycles of wave in 52.5 μ s
- Max frequency of 4.2MHz

Conversion of PC Input to Digital Signal



User input at a PC is converted into a stream of binary digits (1s and 0s). In this graph of a typical digital signal, binary one is represented by 0 volts and binary zero is represented by +5 volts. The signal for each bit has a duration of 0.02 msec, giving a data rate of 50,000 bits per second (50 kbps).