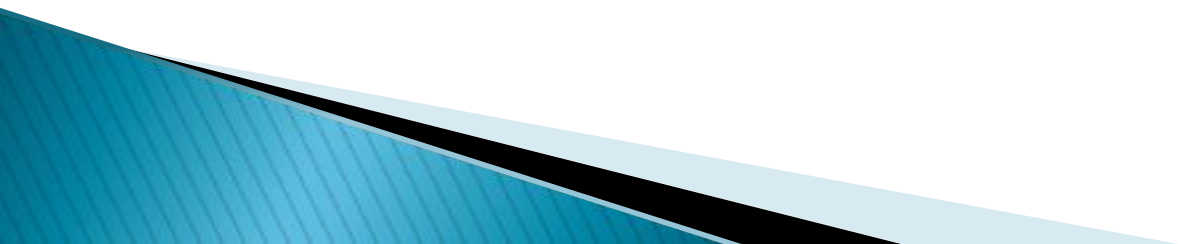
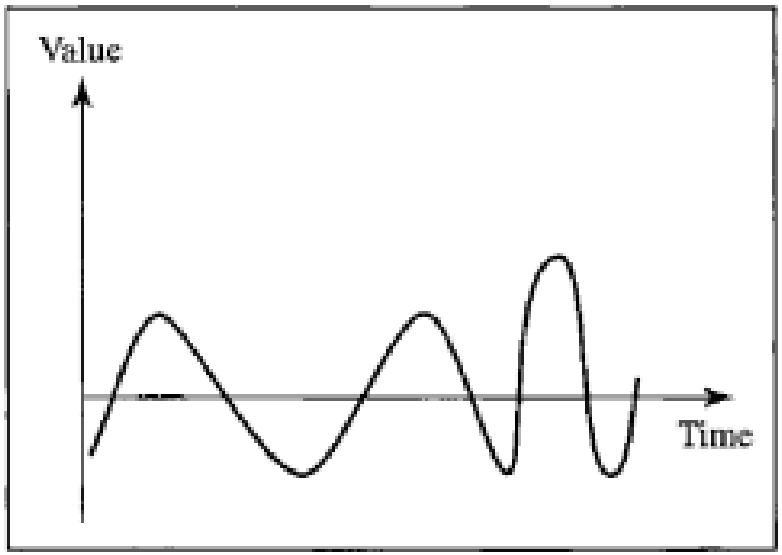
Analog and Digital data transmission



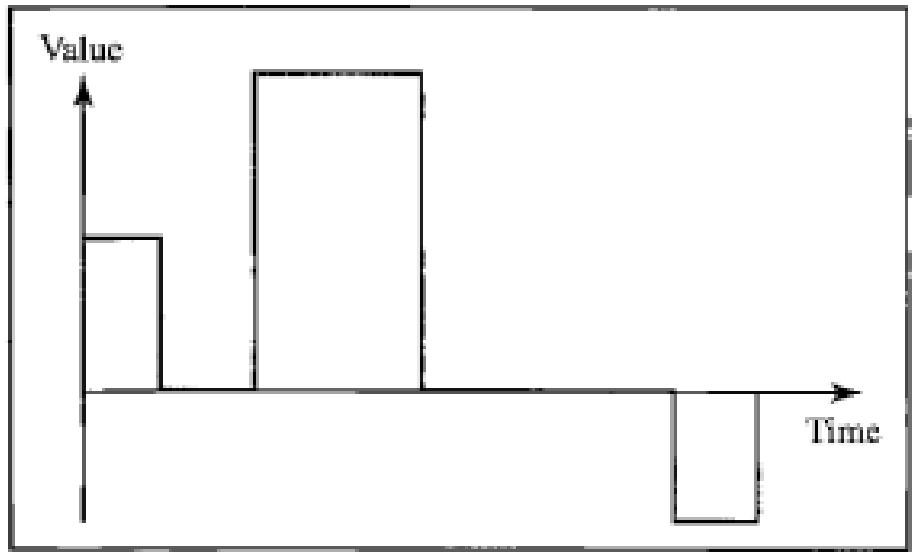
Analog and Digital ...

Data

- Entities that convey meaning or information
- Analog data take continuous values over time, e.g. voice, video, sensor data
- Digital data take discrete values, e.g. text, integers



a. Analog signal



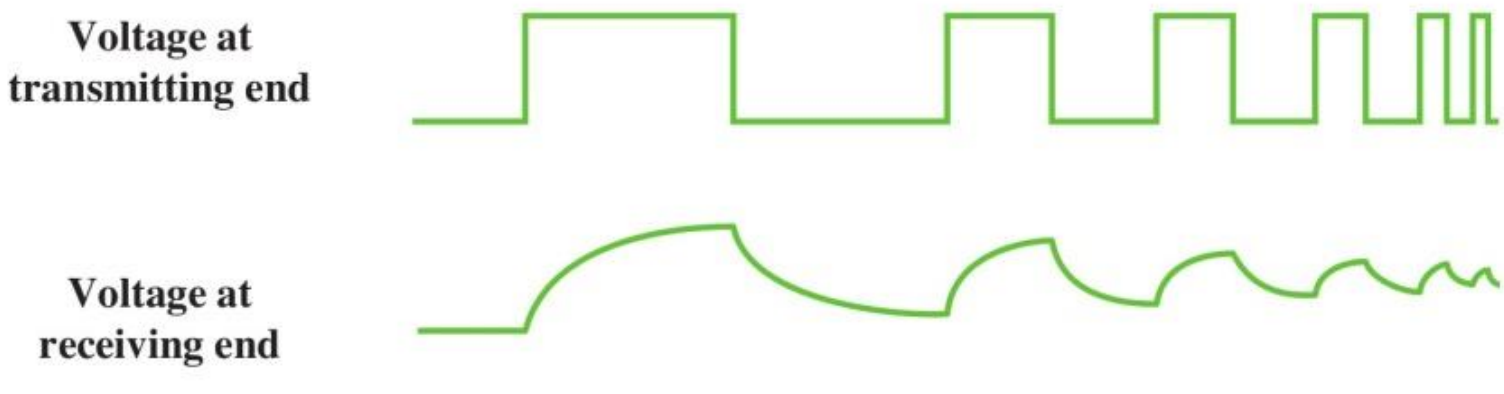
b. Digital signal

Analog and Digital …

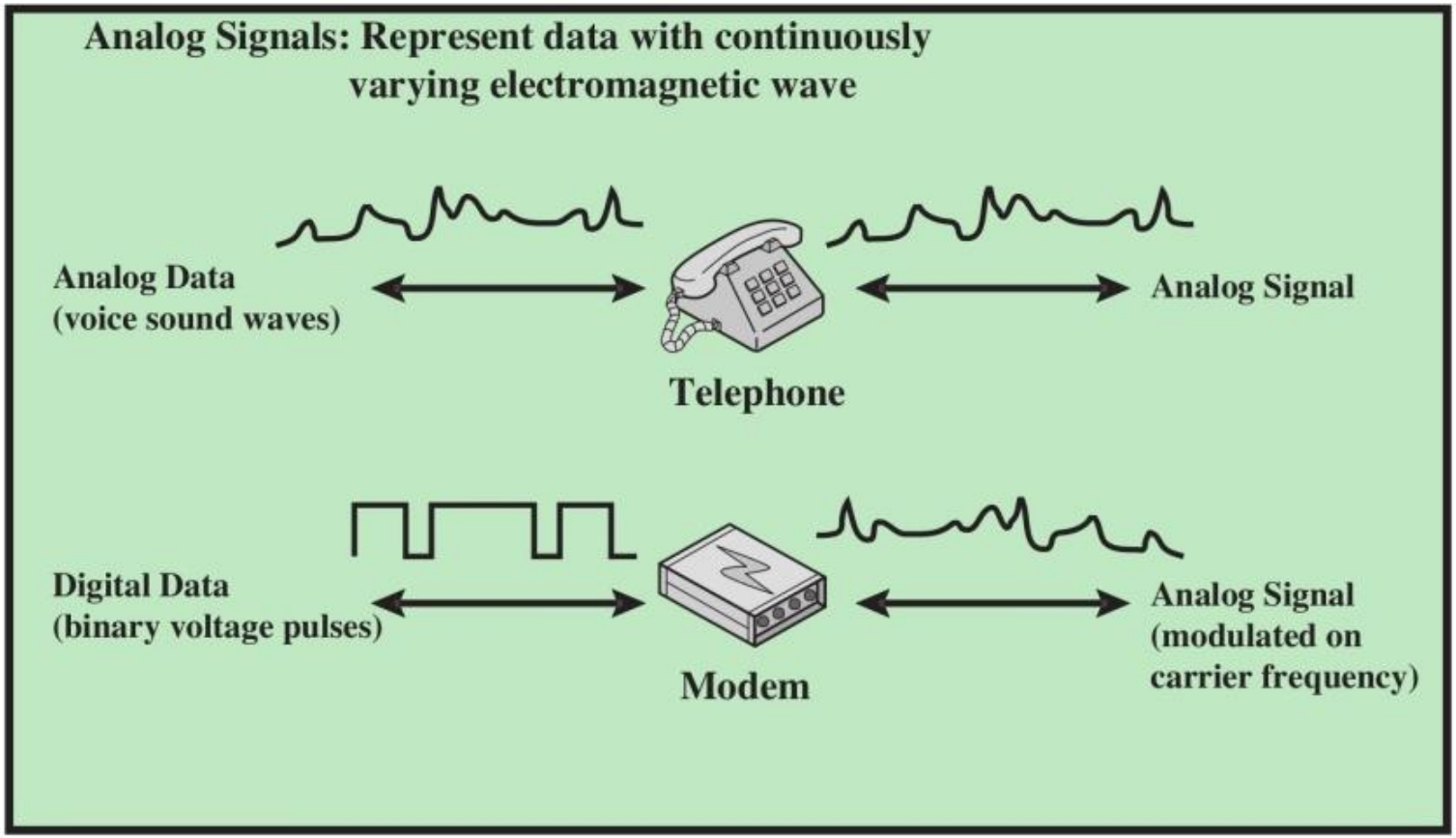
- Signals
- Electric or electromagnetic representations of data
- Transmission
  - Communication of data by propagating and processing signals

Analog vs Digital Signals

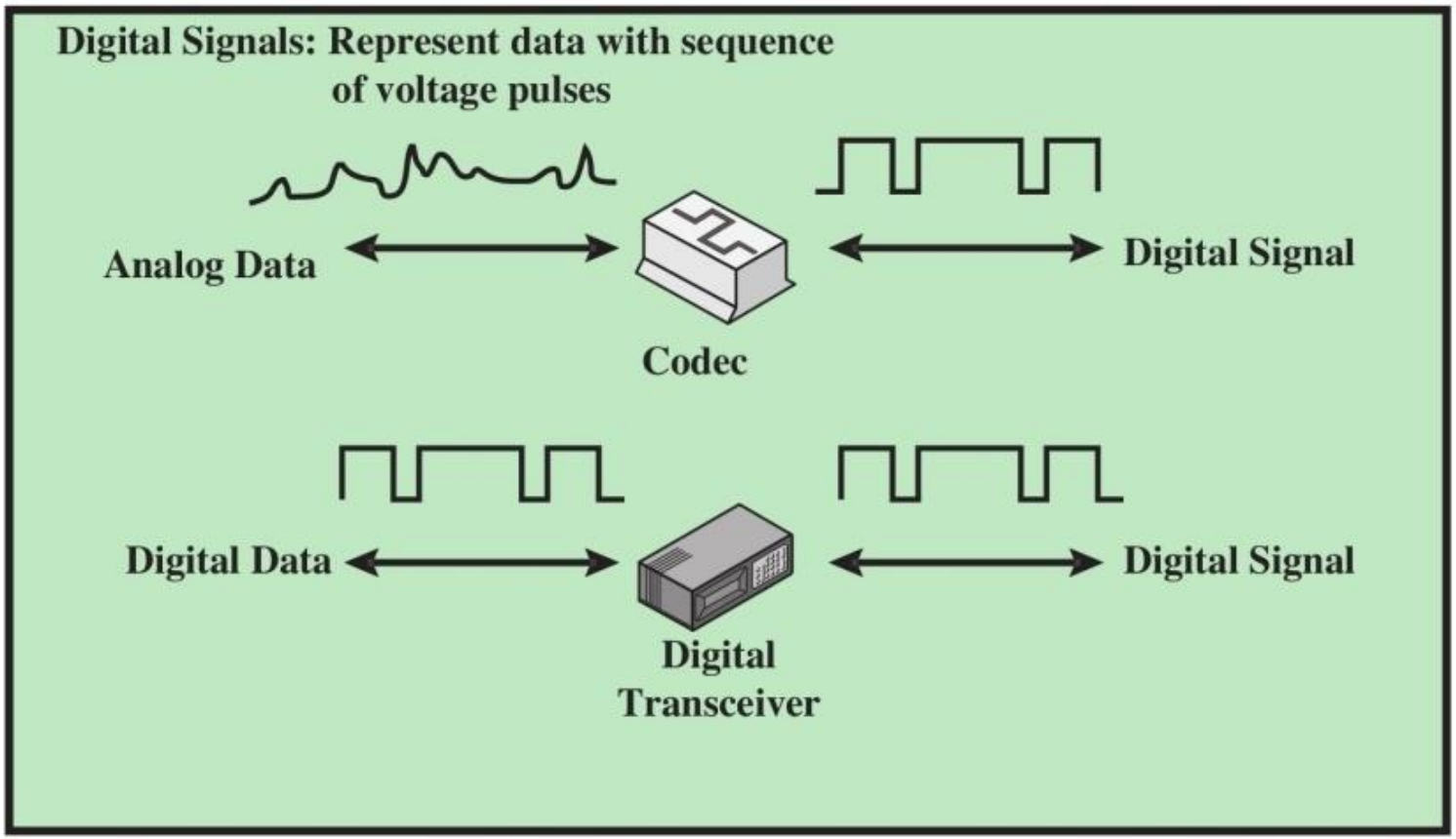
- Electric or electromagnetic representations of data
- Analog signal is continuously varying electromagnectic wave
- Digital signal is sequence of voltage pulses
- Digital signals generally cheaper and less susceptible to interference
- Digital signals suffer more from attenuation



Analog Signaling of Analog and Digital Data



Digital Signaling of Analog and Digital Data



Ananlog/Digital Signals and Data

	Analog Signal	Digital Signal
Analog Data	Two alternatives: (1) signal occupies the same spectrum as the analog data; (2) analog data are encoded to occupy a different portion of spectrum.	Analog data are encoded using a codec to produce a digital bit stream.
Digital Data	Digital data are encoded using a modem to produce analog signal.	Two alternatives: (1) signal consists of two voltage levels to represent the two binary values; (2) digital data are encoded to produce a digital signal with desired properties.

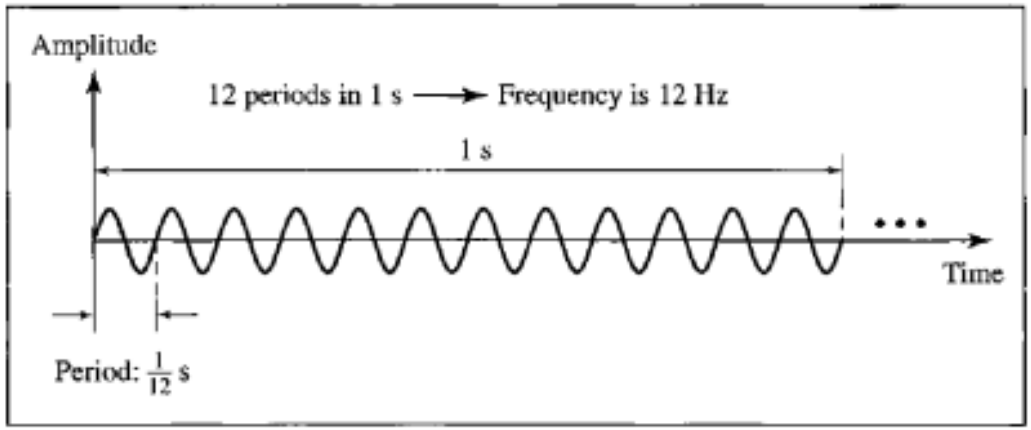
Analog vs Digital Transmission

- Analog transmission: analog signal is propagated through amplifiers
- Digital transmission: analog or digital signals are propagated through repeaters
- Digital transmission is preferred technology today: digital equipment, efficiently combine signals from different sources; security; repeaters can give more accurate data transmission

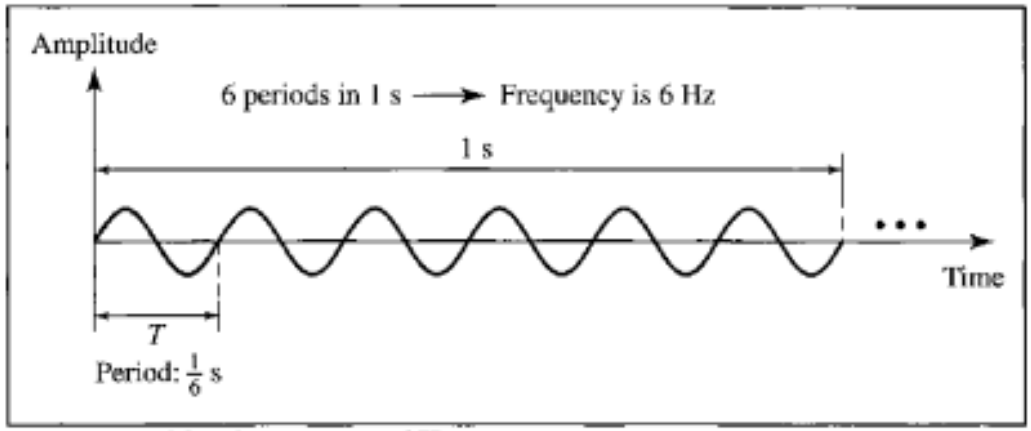
Concepts

- Amplitude
- Frequency
- Period
- Phase
- Wavelength

Amplitude and frequency

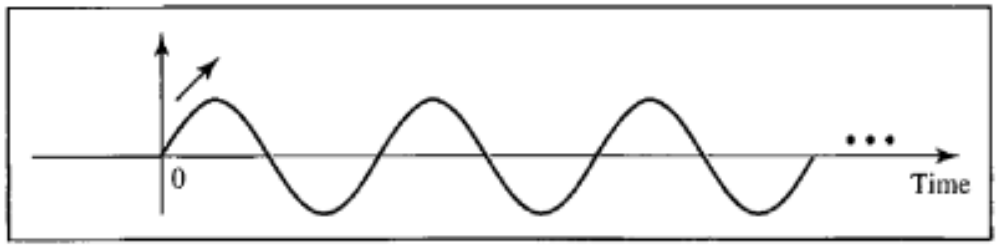


a. A signal with a frequency of 12 Hz

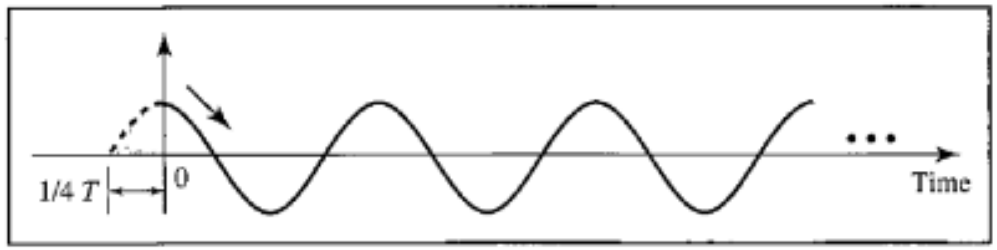


b. A signal with a frequency of 6 Hz

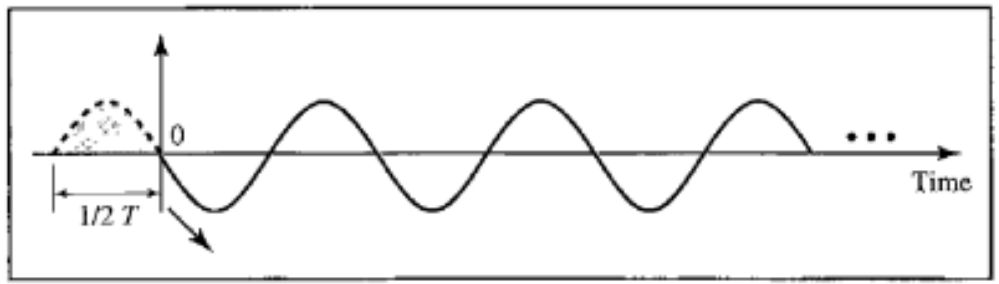
Phase and amplitude



a. 0 degrees

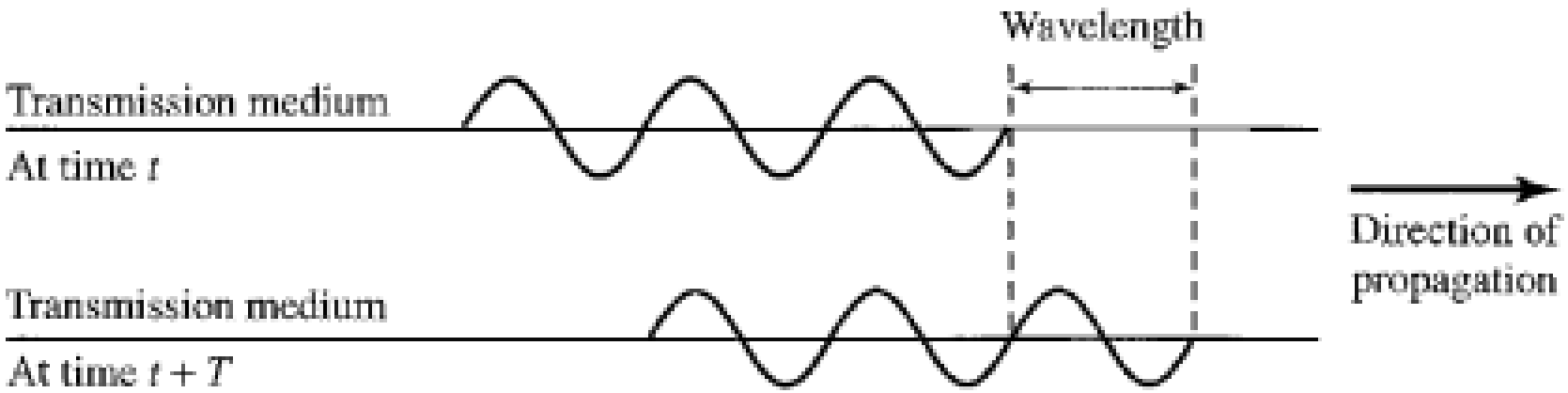


b. 90 degrees



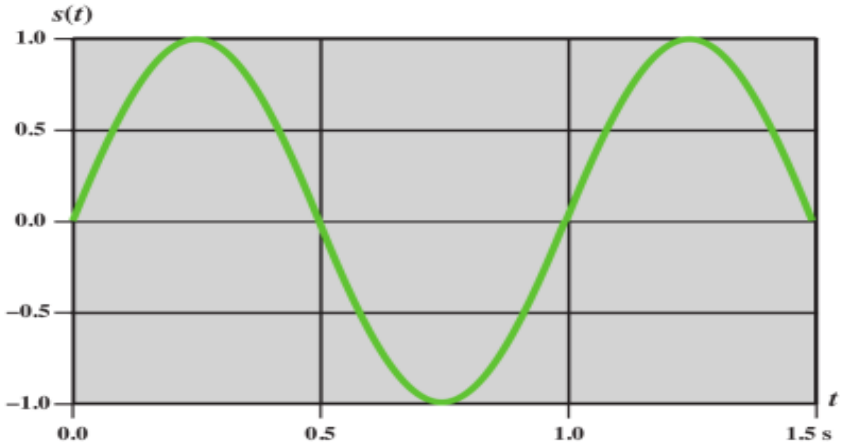
c. 180 degrees

Wavelength and period

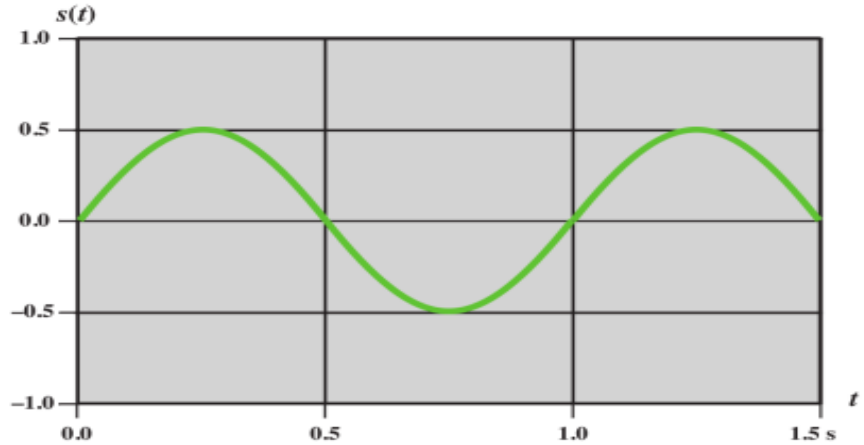


$$\textbf{Wavelength} = \textbf{propagation speed} \times \textbf{period} = \frac{\textbf{propagation speed}}{\textbf{frequency}}$$

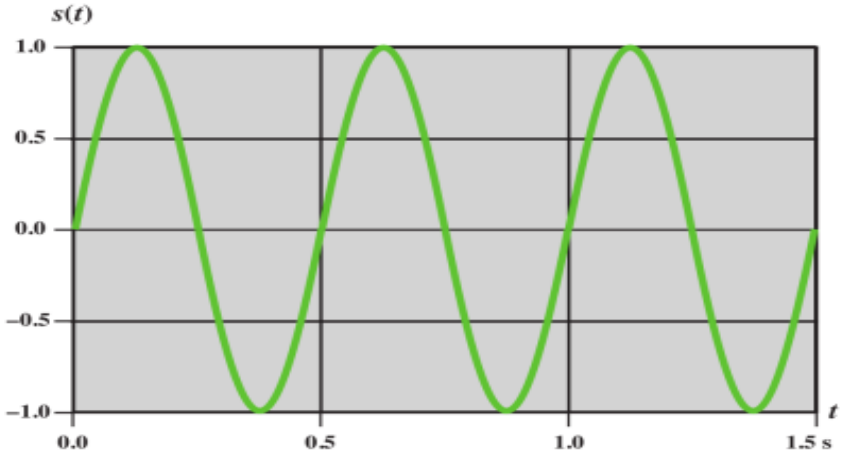
$$\lambda = \frac{c}{f}$$



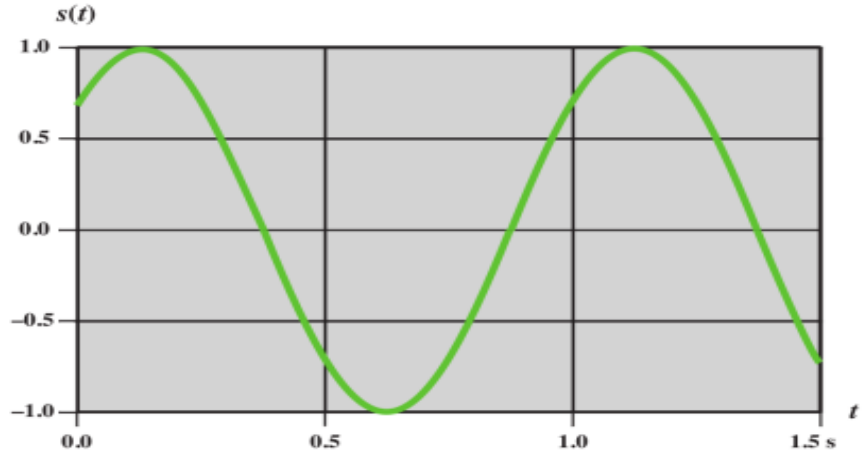
(a) $A = 1, f = 1, \phi = 0$



(b) $A = 0.5, f = 1, \phi = 0$



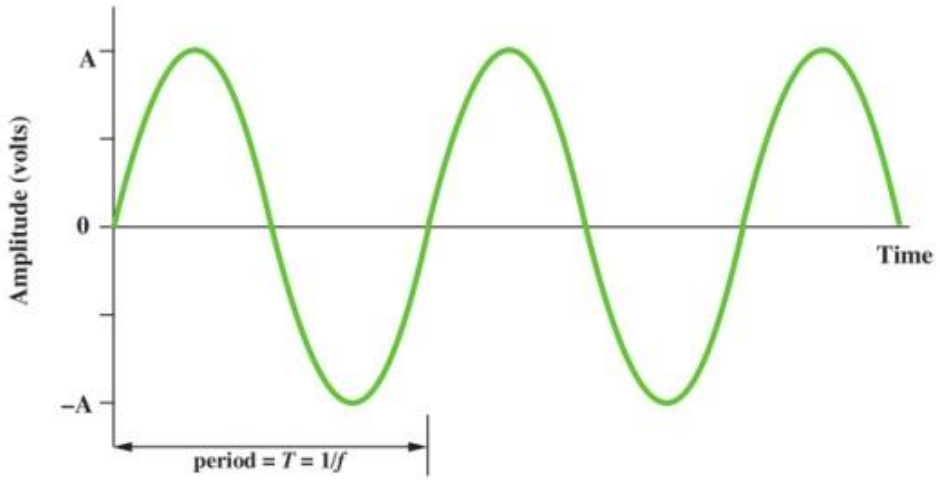
(c) $A = 1, f = 2, \phi = 0$



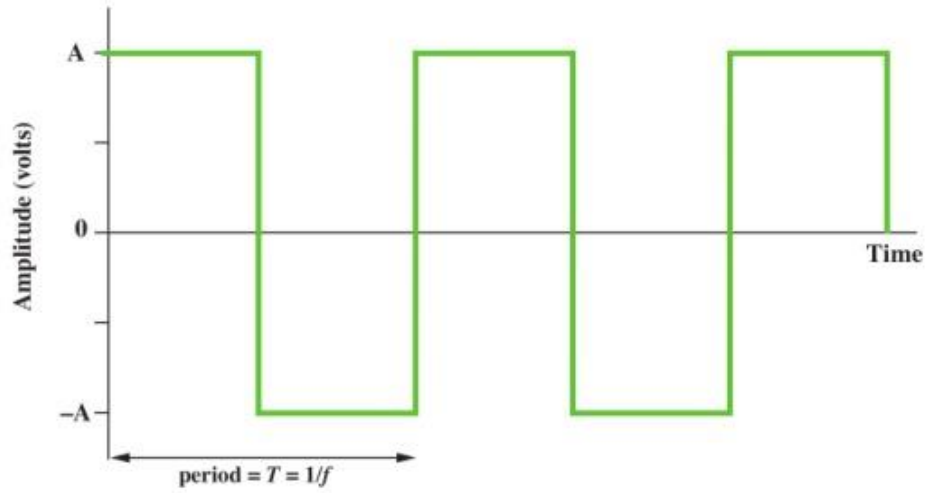
(d) $A = 1, f = 1, \phi = \pi/4$

Examples of Periodic Signals

Any signal is either periodic (the following two) or aperiodic

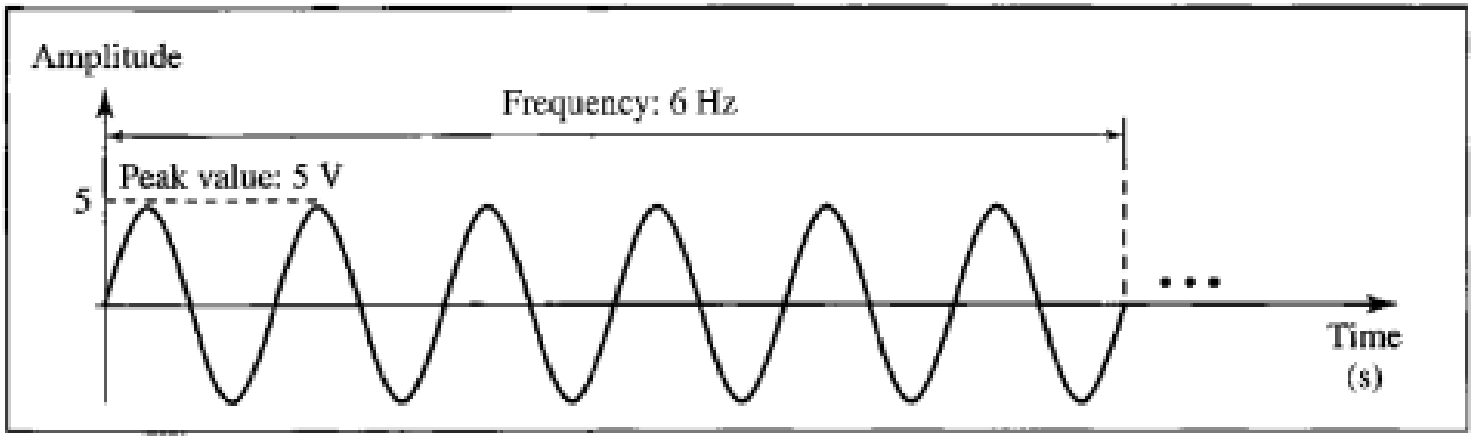


(a) Sine wave

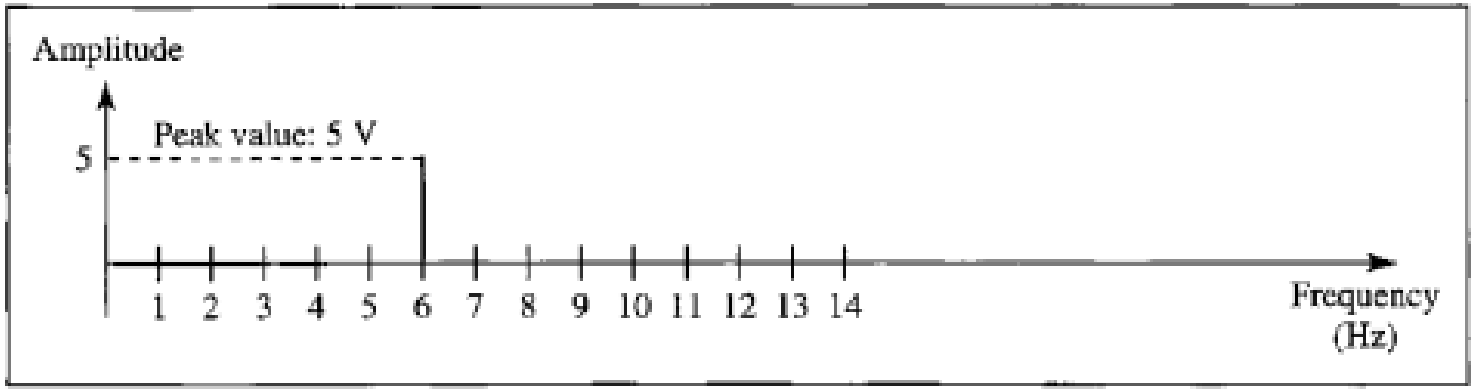


(b) Square wave

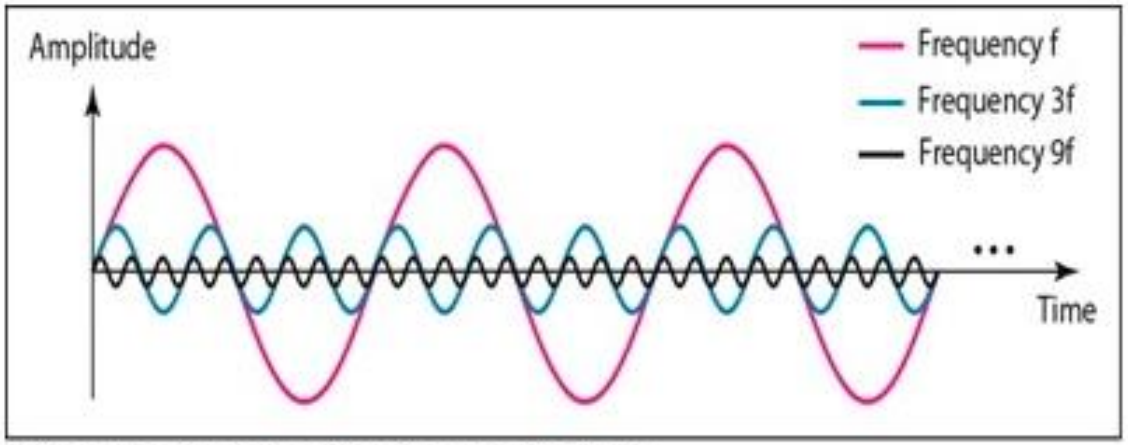
Time and frequency domain



a. A sine wave in the time domain (peak value: 5 V, frequency: 6 Hz)

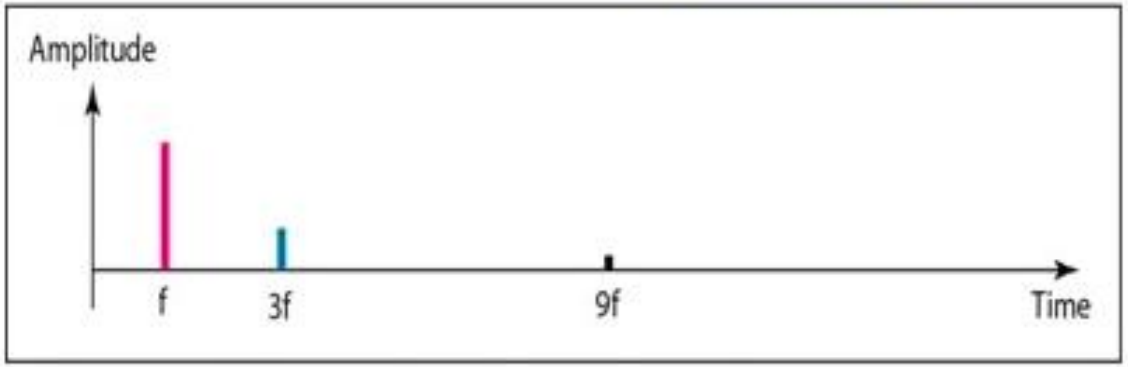


b. The same sine wave in the frequency domain (peak value: 5 V, frequency: 6 Hz)

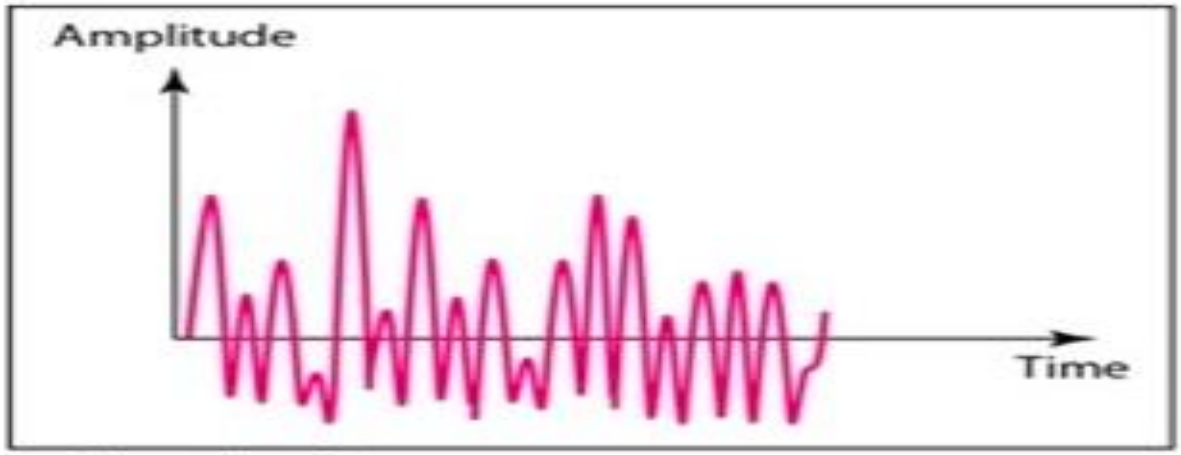


a. Time-domain decomposition of a composite signal

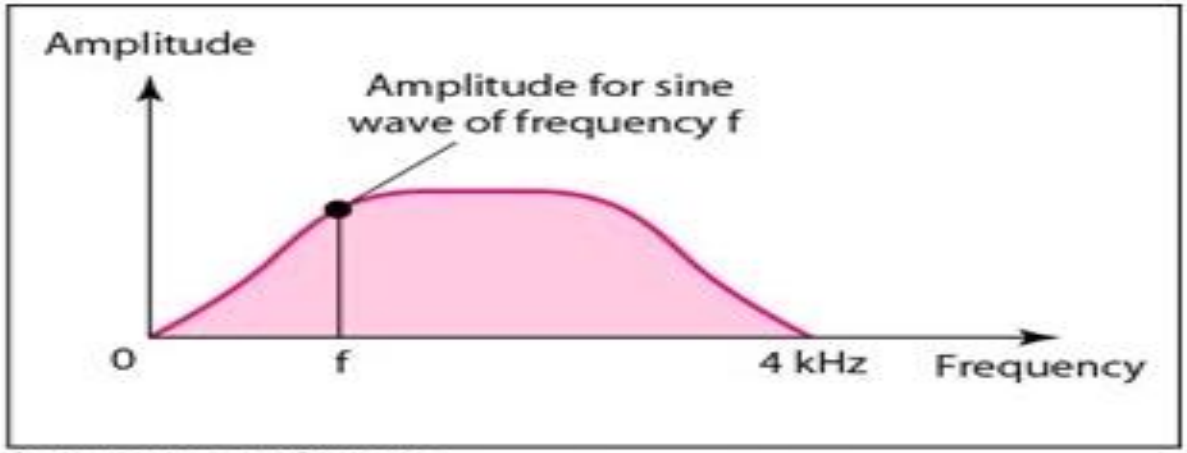
Periodic Signal



b. Frequency-domain decomposition of the composite signal



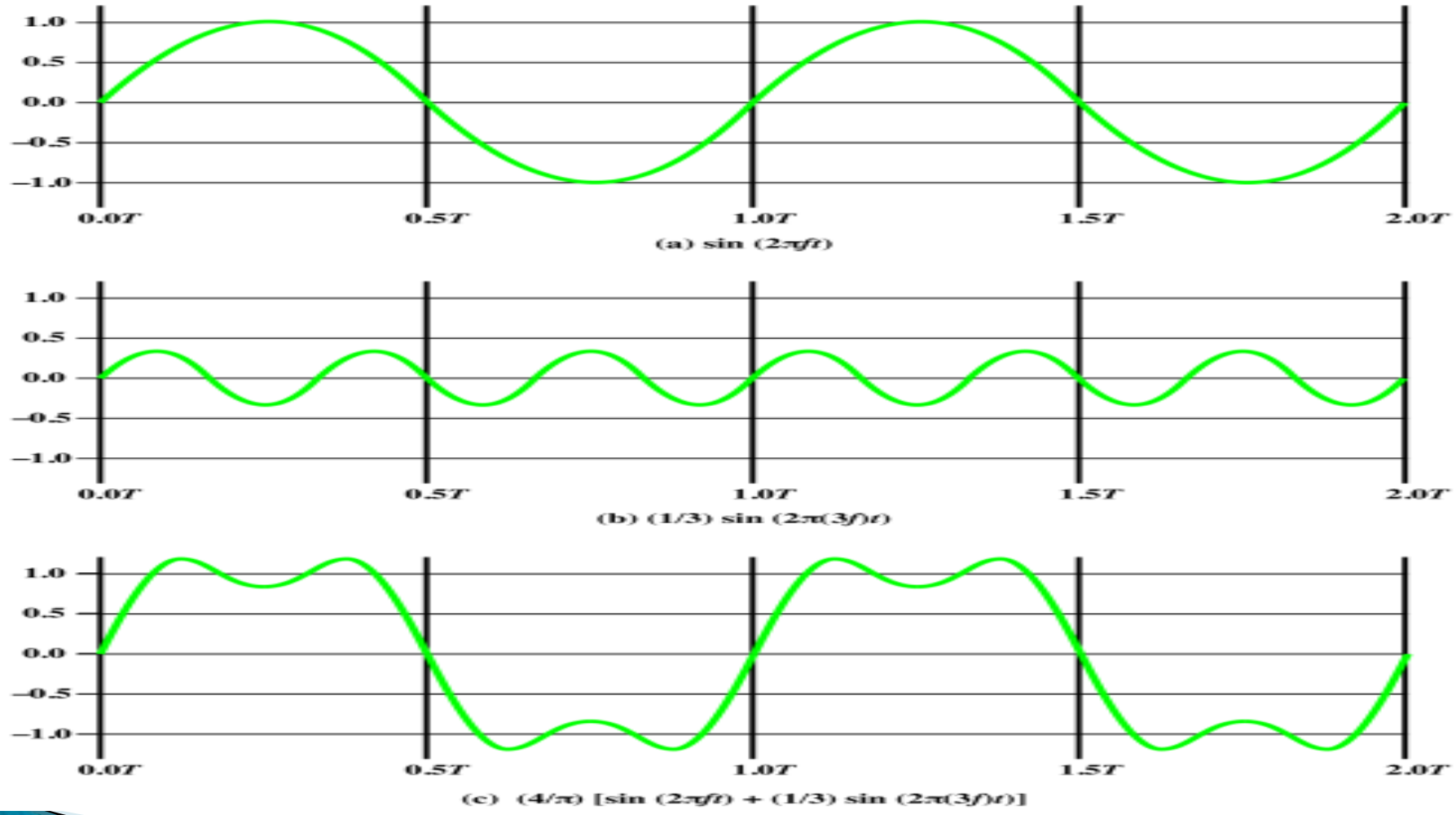
a. Time domain



b. Frequency domain

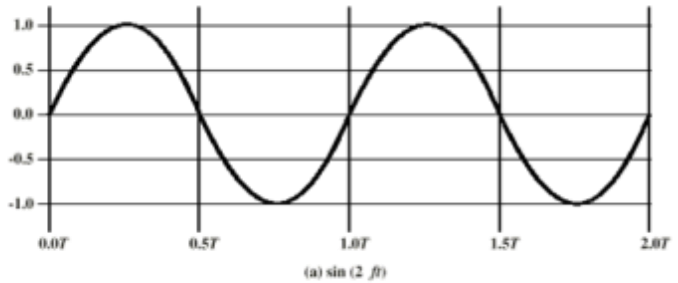
Aperiodic Signal

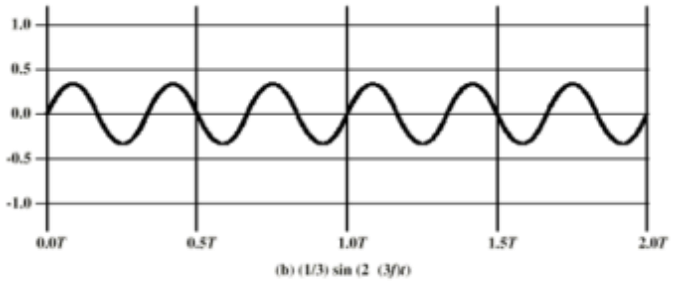
Composite signal

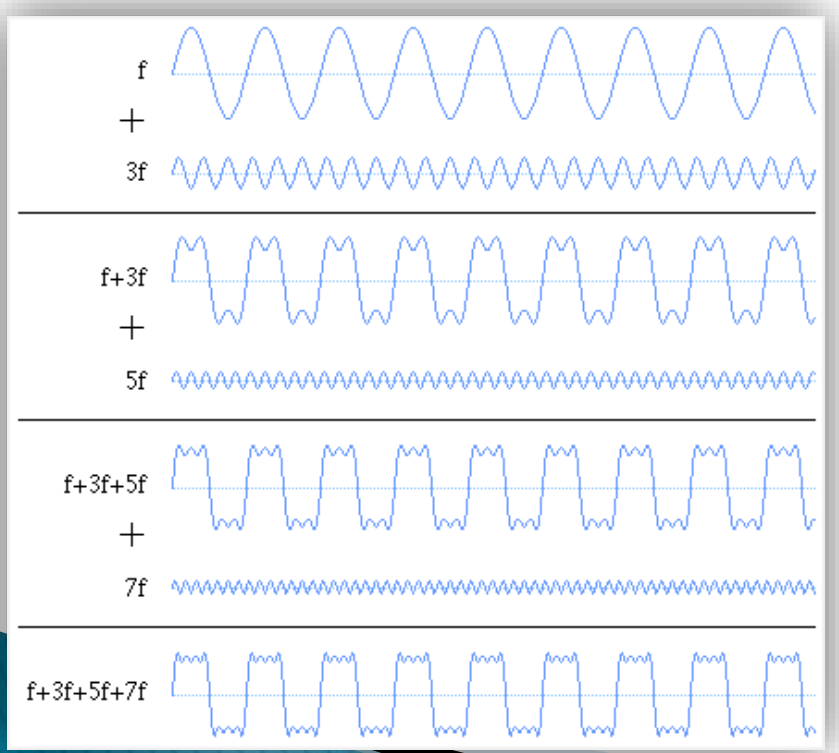


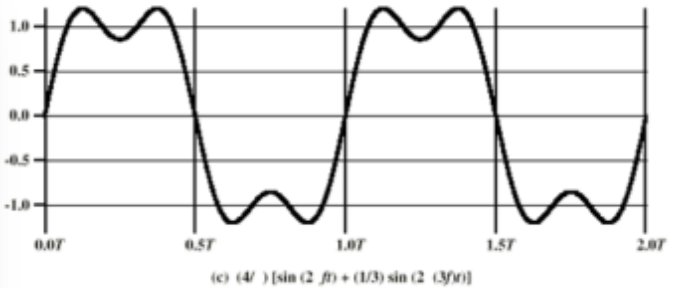
Addition of Frequency Components

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









- Digital signal has infinite bandwidth
- Adding odd harmonics converts analog to rectangular wave with effective bandwidth

Spectrum & Bandwidth

- Spectrum
  - range of frequencies contained in signal
- Absolute bandwidth
  - width of spectrum
- Effective bandwidth
  - Often just bandwidth
  - Narrow band of frequencies containing most of the energy

Bandwidth limit of system determines data rate

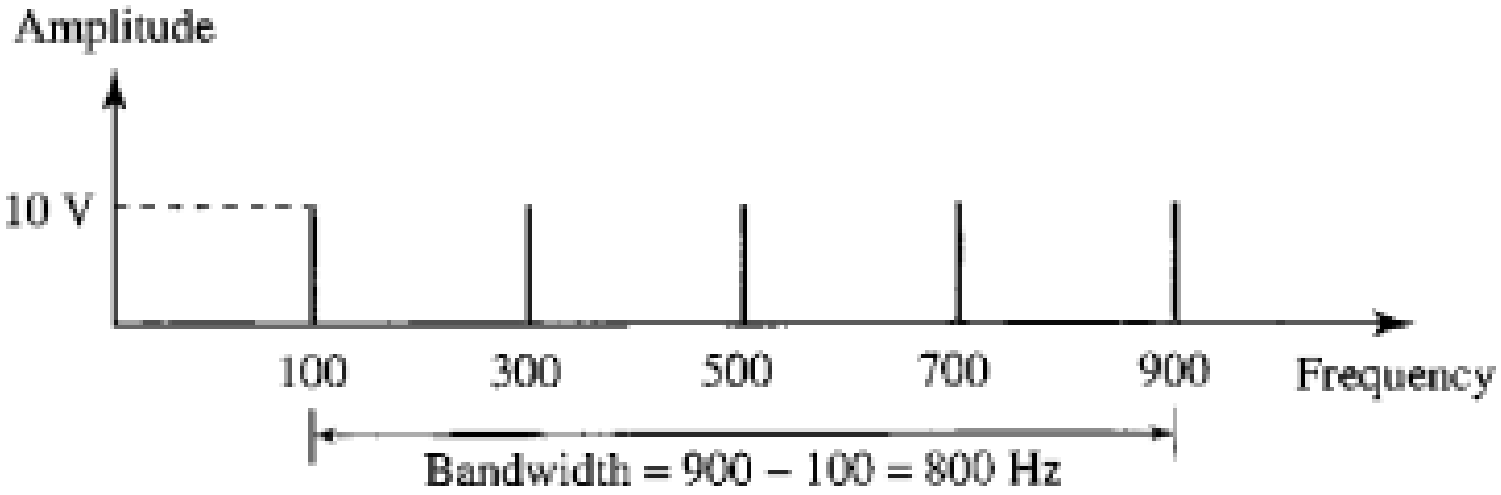
- Bit interval(T): It is the time required to send a single bit.
- Bit rate: It is number of bit intervals per second.(1/T)
- Propagation time: It is the time required for signal to travel from one point of transmission medium to another.
- Propagation time=Distance/ Propagation speed

Problem

- If a periodic signal is decomposed into five sine waves with frequencies of 100, 300, 500, 700 and 900, what is its bandwidth? Draw the spectrum, assuming all components have a maximum amplitude of 10 V.

Solution

- Bandwidth= $f_h - f_l$ = 900-100=800Hz

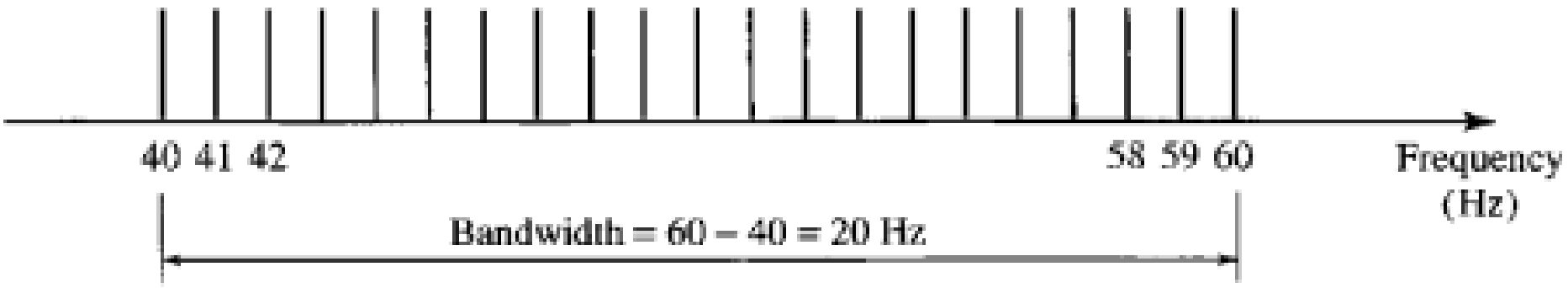


Problem

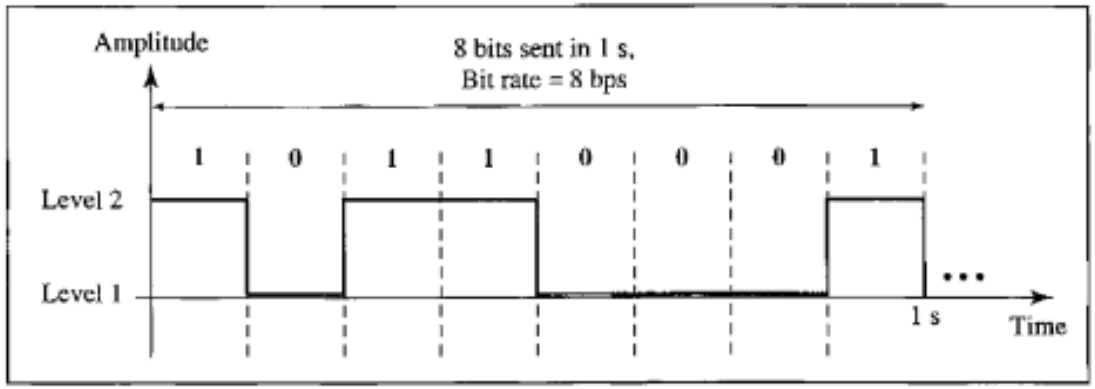
- A periodic signal has a bandwidth of 20Hz. The highest frequency is 60Hz. What is the lowest frequency? Dra the spectrum if the signal contain all frequencies of same amplitude.

Solution

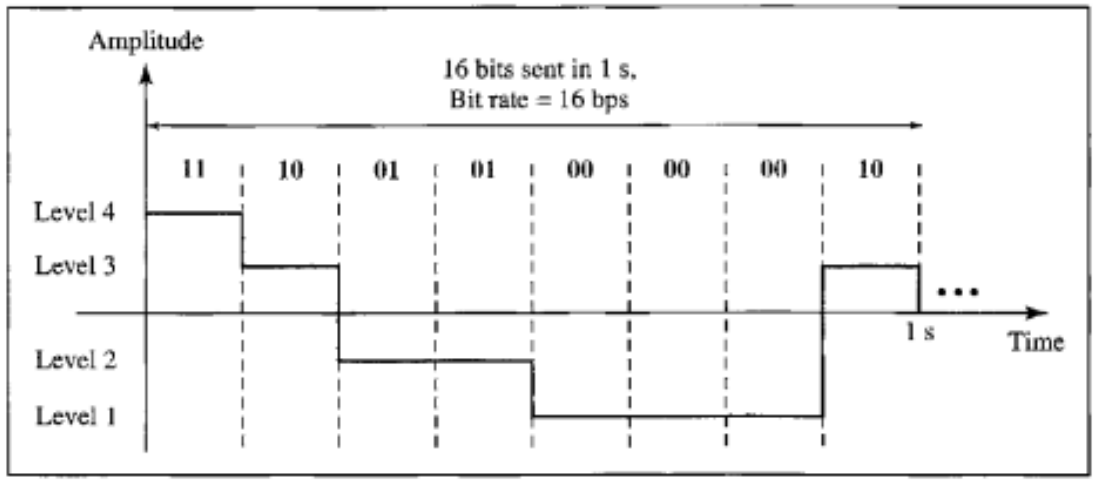
- Bandwidth= $f_h - f_l$
- 20=60-fl
- f_l =60-20=40 Hz



Digital signal



a. A digital signal with two levels



b. A digital signal with four levels

- A digital signal has 8 level, how many bits are needed per level?

Tradeoffs

Bandwidth

- Bandwidth is a limited resource
- Greater the bandwidth, greater the cost

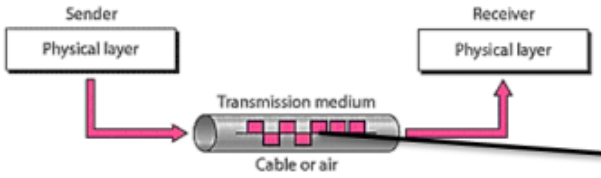
Data Rate

Digital data is approximated by signal of limited bandwidth

Greater the bandwidth, greater the data rate

Accuracy

Receiver must be able to interpret received signal, even with transmission impairments



SIGNALS

TIME DOMAIN

FREQUENCY DOMAIN

ANALOG SIGNAL

DIGITAL SIGNAL

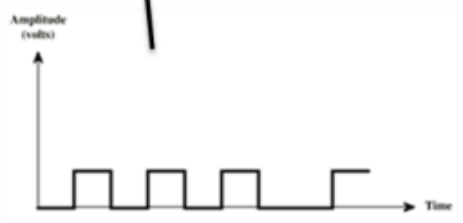
PERIODIC

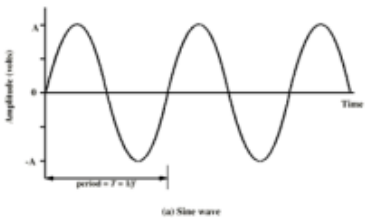
APERIODIC

Multiple frequency components of Sine wave

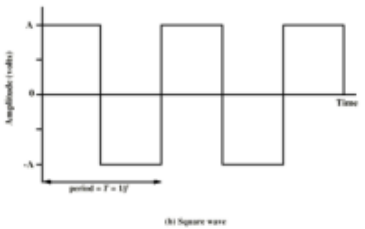
Continuous

Discrete





(a) Sine wave



(b) Square wave