Transmission Fundamentals

W. Stallings, Chapter 2

Outline

- **Signal Concepts in time and frequency domain.**
- **Bandwidth and its relation with frequency components**
- **Bandwidth and its relationship between data rates in noise free channel (Nyquist bandwidth)**
- **Shannon Capacity Formula (error-free channel)**
- **Frequency range for general communication**
- **system (FM, AM, telephone, mobile, Satellite)**
- **Multiplexing schemes and application examples**
- **dB, dBW, dBm and SNR expression**

Signal Concepts

- Periodic signals:
  - A signal with an infinitely repeating intensity pattern, e.g sine wave

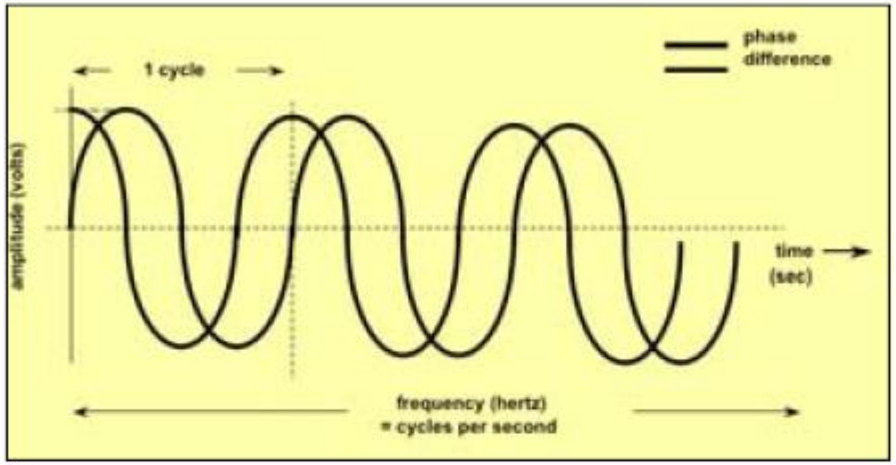


Figure is referred to Business Data Communications(5e), W. Stallings

Sin. Wave Parameters

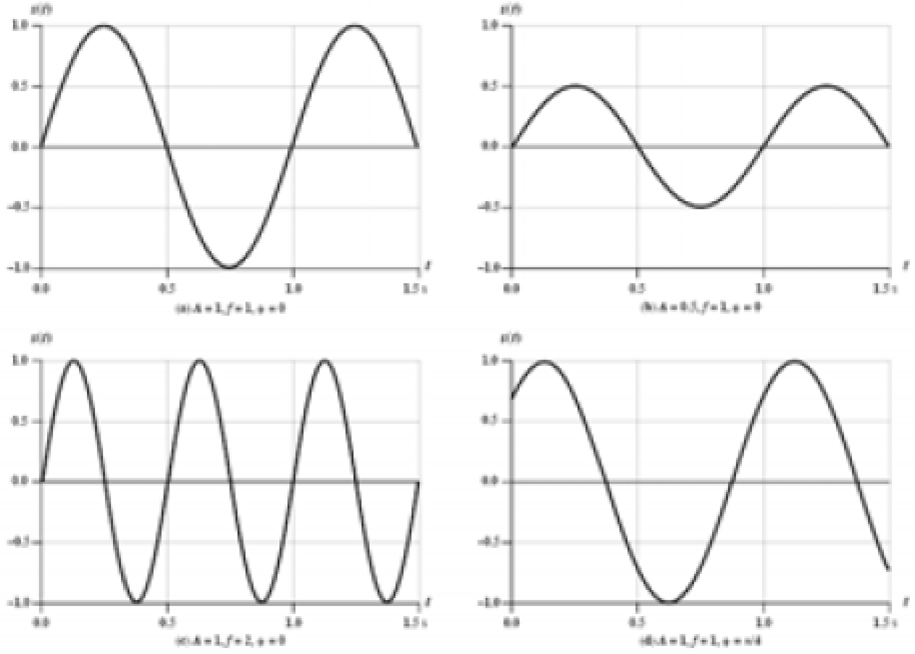
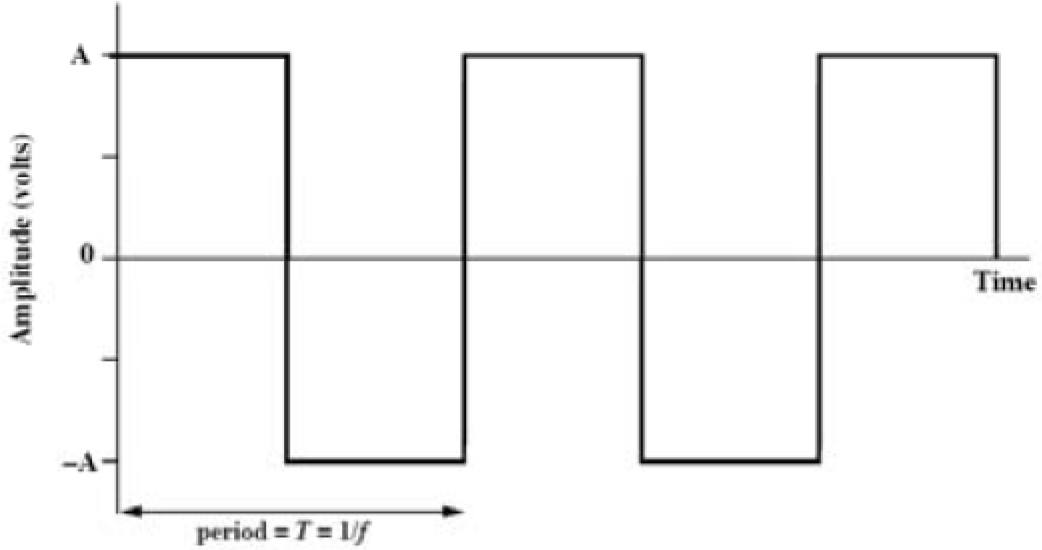


Figure 2.3 $s(t) = A \sin(2\pi ft + \phi)$

Digital Signal Concepts

- Square wave



Signal Concepts

- These parameters are valid for all type of waves (e.g. Audio, Seismic, cars moving in a queue ...)
- Electromagnetic waves in free space (~Air) have a velocity of c $\approx 3 \cdot 10^8$ m/s

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

Signal Concepts

- Frequency domain:
  - A mathematical tool using combinations of sine waves to approximate a complex waveform
  - Why sine waves ?
  - Because sine waves are easy to analyze and have a simple mathematical formulation.
  - Any electromagnetic signal can be shown to consist of a collection of periodic analog signals (sine waves) at different amplitudes, frequencies, and phases

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

Fourier Analysis

- Fourier analysis brings us to analysis signals in the property of frequency
  - Any periodic signal can be represented as a sum of sinusoids known as a Fourier series.

$$x(t) = \frac{A_0}{2} + \sum_{n=1}^{\infty}(A_n\cos(2\pi nf_0t) + B_n\sin(2\pi nf_0t))$$

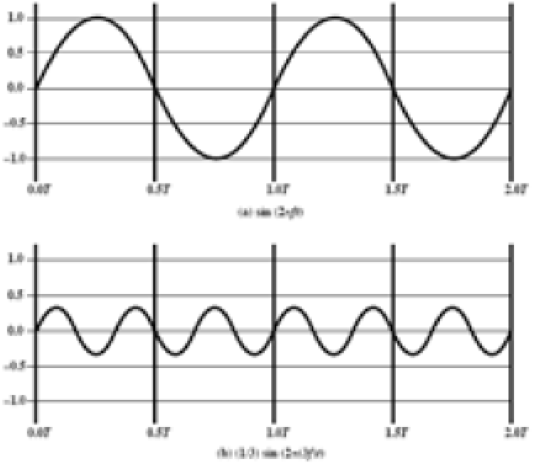
f_0: fundamental frequency (reciprocal of the period of the signal)

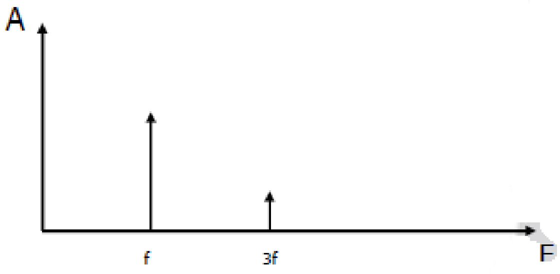
nf_0: integer multiples of fundamental frequency

  - Fourier transform can be used to the representation of aperiodic signals.

Signal Concepts

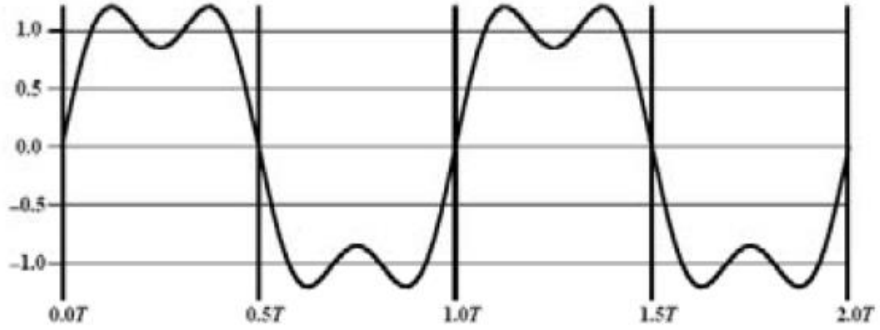
- Plotting Intensity of the wave against the frequency of the combined sine waves we are using to approximate the real signal.





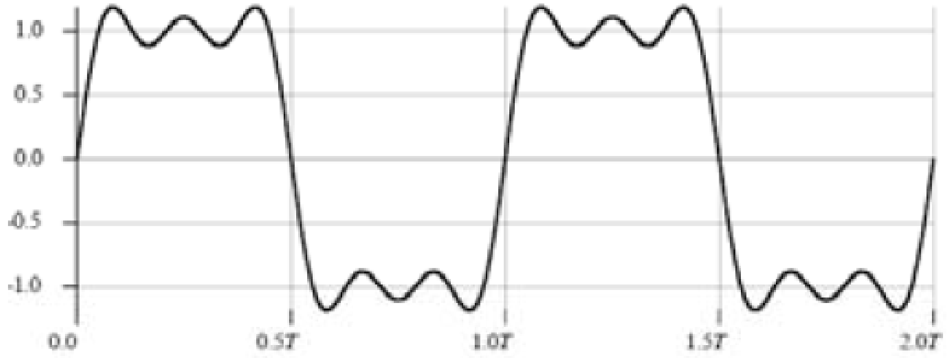
$$s(t) = A \times \frac{4}{\pi} \sum_{k\ \text{odd},\ k=1}^{\infty} \frac{\sin(2\pi k f t)}{k}$$

Signal Concepts

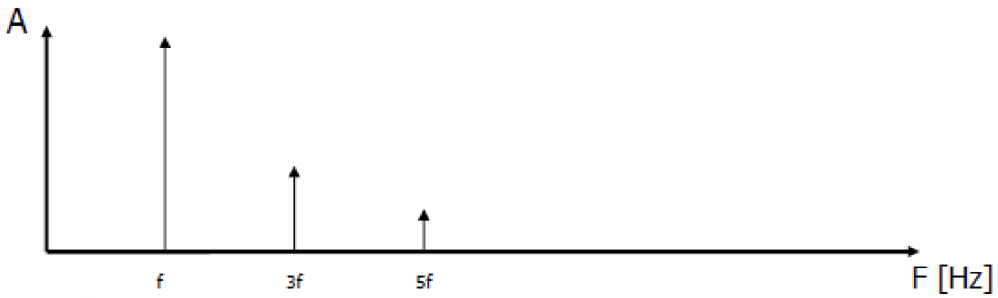


(c) (4/π) [sin (2πft) + (1/3) sin (2π(3f)t)]

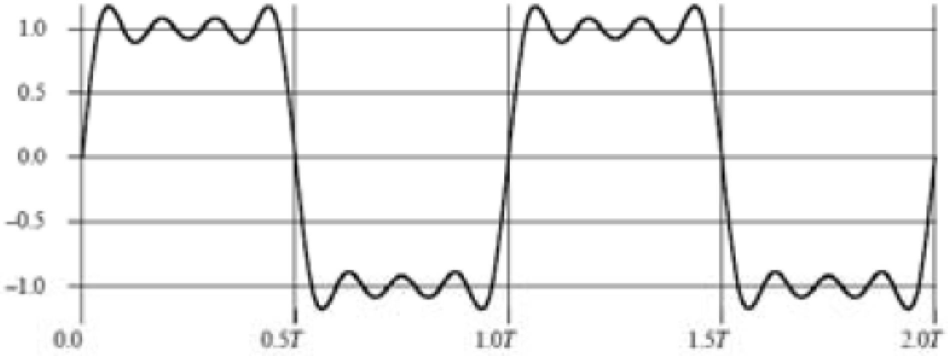
Signal Concepts



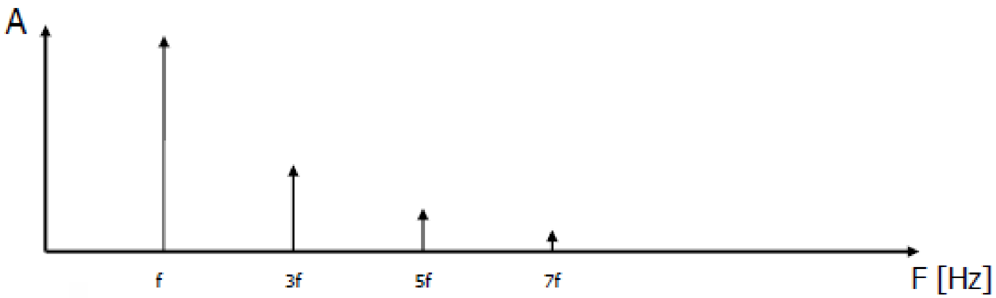
(a) $(4/\pi)\,[\sin(2\pi ft) + (1/3)\sin(2\pi(3f)t) + (1/5)\sin(2\pi(5f)t)]$



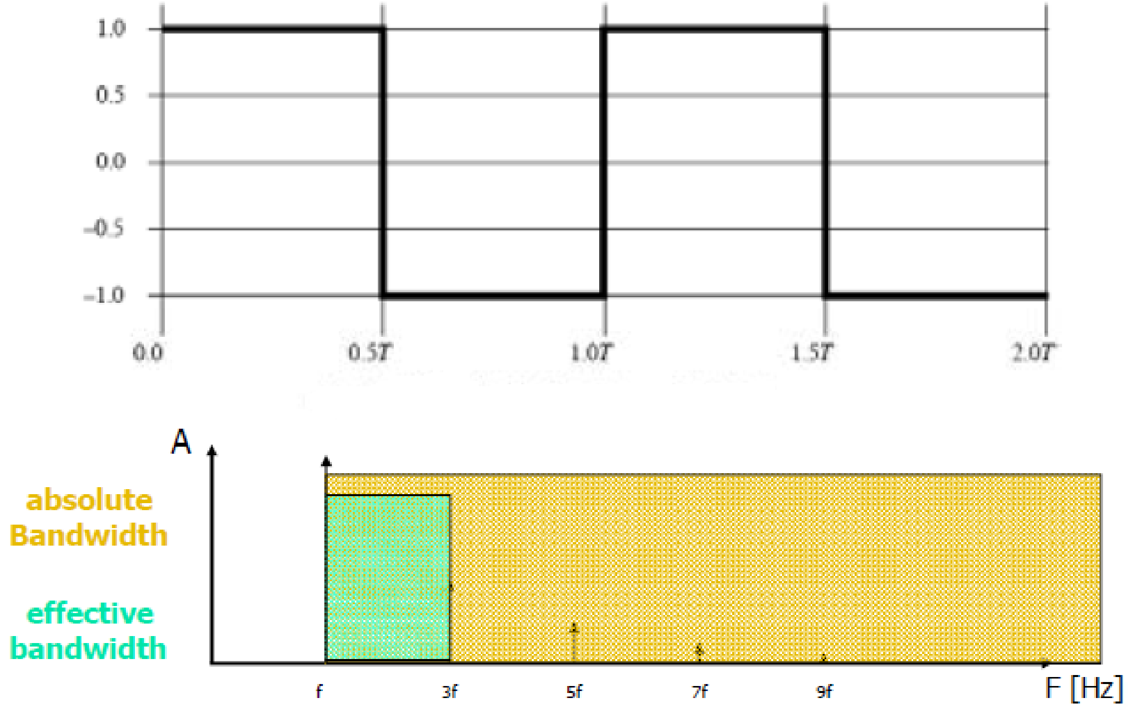
Signal Concepts



(b) $(4/\pi)\,[\sin(2\pi ft) + (1/3)\sin(2\pi(3f)t) + (1/5)\sin(2\pi(5f)t) + (1/7)\sin(2\pi(7f)t)]$



Signal Concepts



Bandwidth Concepts

- **Fundamental frequency** - when all frequency components of a signal are integer multiples of one frequency, it's referred to as the fundamental frequency
- **Spectrum** - range of frequencies that a signal contains
- **Absolute bandwidth** - width of the spectrum of a signal
- **Effective bandwidth** (or just bandwidth) - narrow band of frequencies that most of the signal's energy is contained in

Approximation of a Square Wave (Chapter 2, Page21)

- Case I

  3 of frequencies,f=1MHz
- Case II

  3 of frequencies, f=2MHz
- Case III

  2 of frequencies, f=4MHz

Calculate the bandwidth and data rate

Relationship between Data Rate and Bandwidth

- The greater the bandwidth, the higher the information-carrying capacity
- Observations
  - Any ‘digital’ waveform will have infinite bandwidth
  - The transmission system will limit the bandwidth that can be transmitted
  - For any given medium, the greater the bandwidth transmitted, the greater the cost
  - Limiting the bandwidth creates distortions

Thank You