William Stallings
Data and Computer Communications

Chapter 3
Data Transmission

Terminology (1)

- Transmitter
- Receiver
- Medium
  - Guided medium
    - e.g. twisted pair, optical fiber
  - Unguided medium
    - e.g. air, water, vacuum

Terminology (2)

- Direct link
  - No intermediate devices
- Point-to-point
  - Direct link
  - Only 2 devices share link
- Multi-point
  - More than two devices share the link

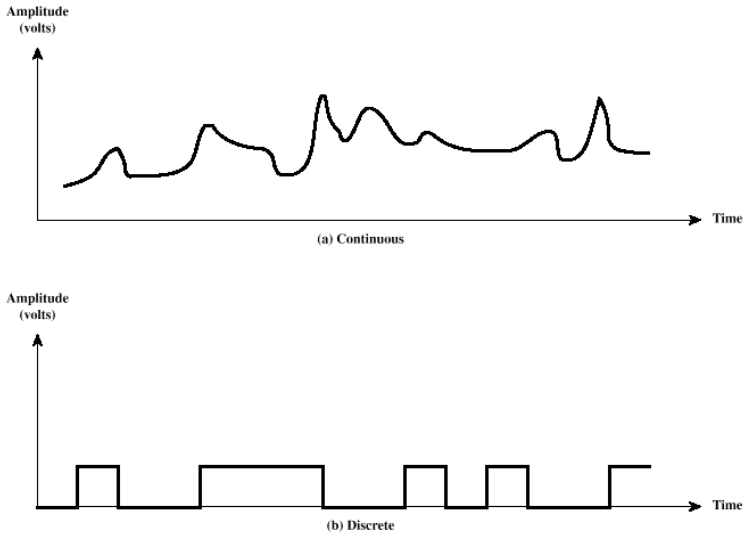
Terminology (3)

- Simplex
  - One direction
    - e.g. Television
- Half duplex
  - Either direction, but only one way at a time
    - e.g. police radio
- Full duplex
  - Both directions at the same time
    - e.g. telephone

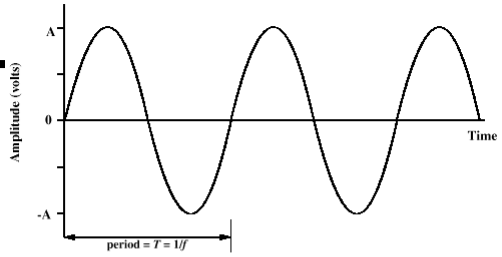
Frequency, Spectrum and Bandwidth

- Time domain concepts
  - Continuous signal
    - Various in a smooth way over time
  - Discrete signal
    - Maintains a constant level then changes to another constant level
  - Periodic signal
    - Pattern repeated over time
  - Aperiodic signal
    - Pattern not repeated over time

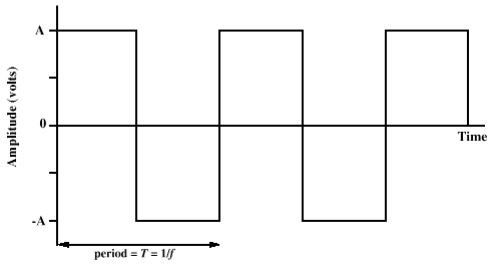
Continuous & Discrete Signals



Periodic Signals



(a) Sine wave

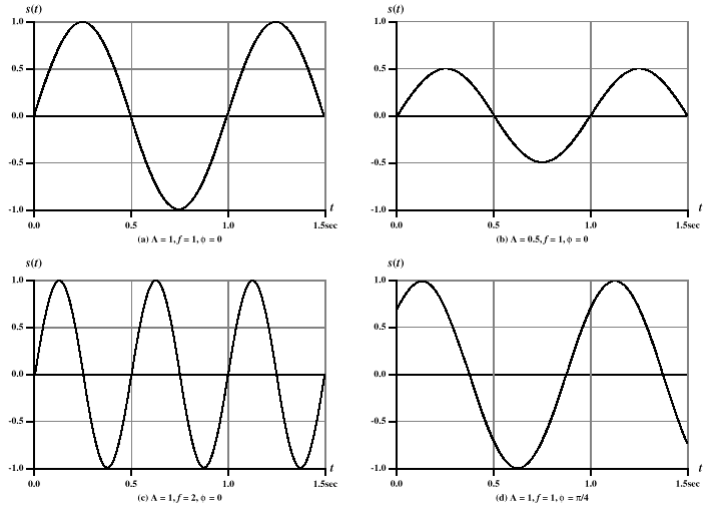


(b) Square wave

Sine Wave

- Peak Amplitude (A)
  - maximum strength of signal
  - volts
- Frequency (f)
  - Rate of change of signal
  - Hertz (Hz) or cycles per second
  - Period = time for one repetition (T)
  - T = 1/f
- Phase (ϕ)
  - Relative position in time

Varying Sine Waves



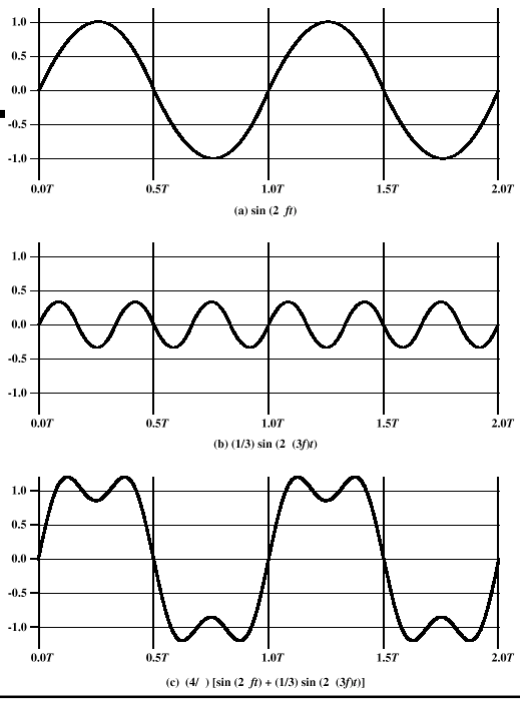
Wavelength

- 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 = $3*10^8$ ms^{-1} (speed of light in free space)

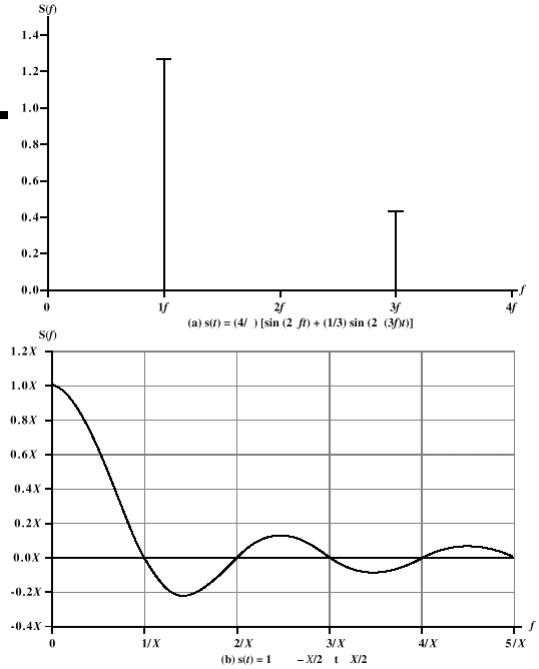
Frequency Domain Concepts

- Signal usually made up of many frequencies
- Components are sine waves
- Can be shown (Fourier analysis) that any signal is made up of component sine waves
- Can plot frequency domain functions

Addition of Frequency Components



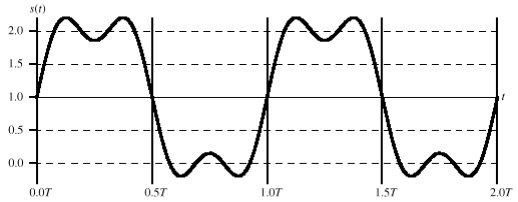
Frequency Domain



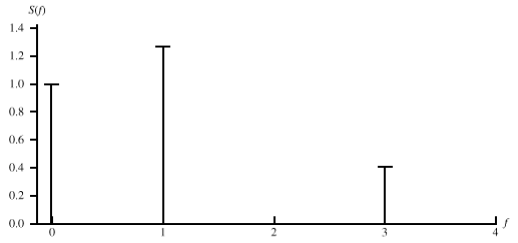
Spectrum & Bandwidth

- 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
- DC Component
  - Component of zero frequency

Signal with DC Component



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



(b) S(f)

Data Rate and Bandwidth

- Any transmission system has a limited band of frequencies
- This limits the data rate that can be carried

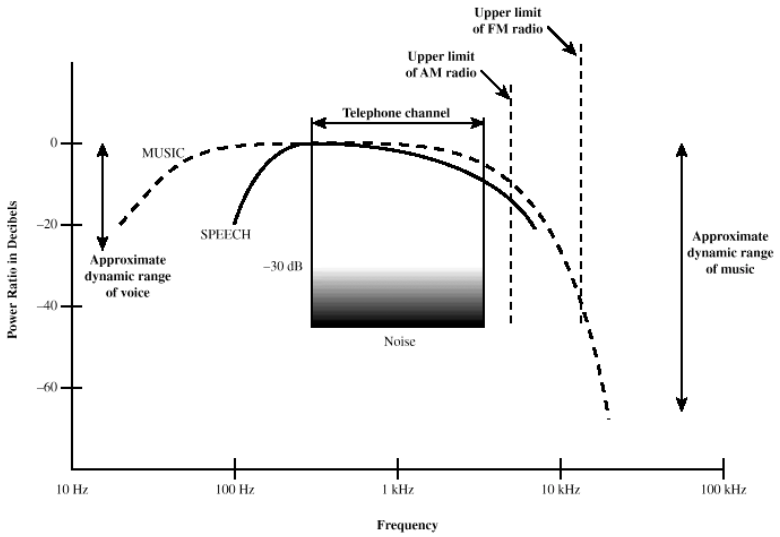
Analog and Digital Data Transmission

- Data
  - Entities that convey meaning
- Signals
  - Electric or electromagnetic representations of data
- Transmission
  - Communication of data by propagation and processing of signals

Data

- Analog
  - Continuous values within some interval
  - e.g. sound, video
- Digital
  - Discrete values
  - e.g. text, integers

Acoustic Spectrum (Analog)



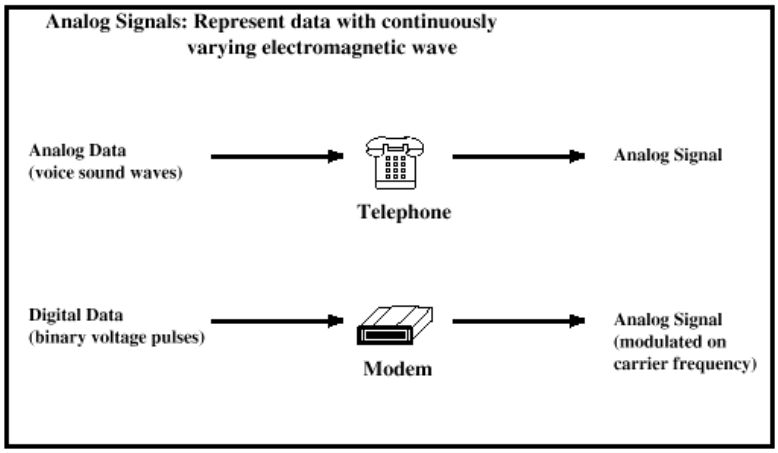
Signals

- Means by which data are propagated
- Analog
  - Continuously variable
  - Various media
    - wire, fiber optic, space
  - Speech bandwidth 100Hz to 7kHz
  - Telephone bandwidth 300Hz to 3400Hz
  - Video bandwidth 4MHz
- Digital
  - Use two DC components

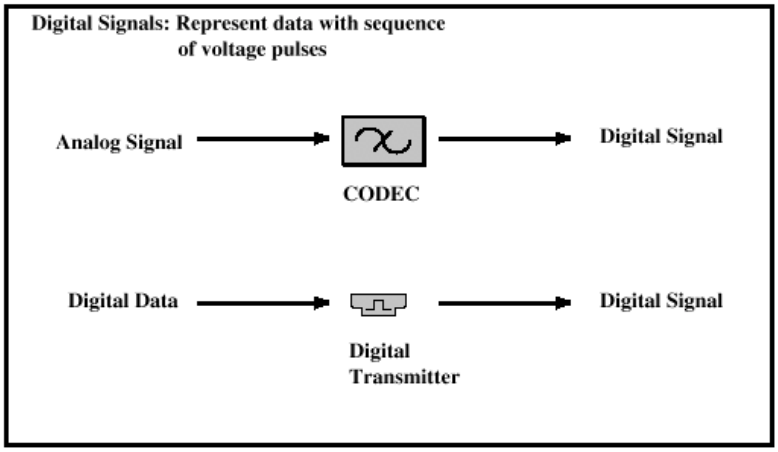
Data and Signals

- Usually use digital signals for digital data and analog signals for analog data
- Can use analog signal to carry digital data
  - Modem
- Can use digital signal to carry analog data
  - Compact Disc audio

Analog Signals Carrying Analog and Digital Data



Digital Signals Carrying Analog and Digital Data



Analog Transmission

- Analog signal transmitted without regard to content
- May be analog or digital data
- Attenuated over distance
- Use amplifiers to boost signal
- Also amplifies noise

Digital Transmission

- Concerned with content
- Integrity endangered by noise, attenuation etc.
- Repeaters used
- Repeater receives signal
- Extracts bit pattern
- Retransmits
- Attenuation is overcome
- Noise is not amplified

Advantages of Digital Transmission

- Digital technology
  - Low cost LSI/VLSI technology
- Data integrity
  - Longer distances over lower quality lines
- Capacity utilization
  - High bandwidth links economical
  - High degree of multiplexing easier with digital techniques
- Security & Privacy
  - Encryption
- Integration
  - Can treat analog and digital data similarly

Transmission Impairments

- Signal received may differ from signal transmitted
- Analog - degradation of signal quality
- Digital - bit errors
- Caused by
  - Attenuation and attenuation distortion
  - Delay distortion
  - Noise

Attenuation

- Signal strength falls off with distance
- Depends on medium
- Received signal strength:
  - must be enough to be detected
  - must be sufficiently higher than noise to be received without error
- Attenuation is an increasing function of frequency

Delay Distortion

- Only in guided media
- Propagation velocity varies with frequency

Noise (1)

- Additional signals inserted between transmitter and receiver
- Thermal
  - Due to thermal agitation of electrons
  - Uniformly distributed
  - White noise
- Intermodulation
  - Signals that are the sum and difference of original frequencies sharing a medium

Noise (2)

- Crosstalk
  - A signal from one line is picked up by another
- Impulse
  - Irregular pulses or spikes
  - e.g. External electromagnetic interference
  - Short duration
  - High amplitude

Channel Capacity

- Data rate
  - In bits per second
  - Rate at which data can be communicated
- Bandwidth
  - In cycles per second of Hertz
  - Constrained by transmitter and medium

Required Reading

- Stallings chapter 3