School of Business
Eastern Illinois University

Fundamentals of Data & Signals (Part II)

(September 28, 2016)

© Abdou Illia, Fall 2016

Learning Objectives

- Identify the basic characteristics of a signal
- Understand signal *strength* and *attenuation*
- Understand Principles of transmitting data using signals

Analog versus Digital

- Analog and Digital signals
  - Could be affected by Interference
  - Could be affected by Noise
- Interference = External signals
- Noise = Random electrical energy generated in the line when the signal is propagating (traveling)
  - Occurs unless the line is at absolute zero temperature

Noise and Signals

4

- Noise appears as an analog waveform

Figure 2-1 in textbook

Figure 2-3 in textbook

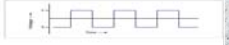


Figure 2-5 in textbook

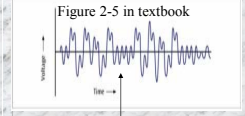
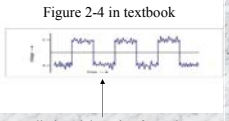


Figure 2-4 in textbook



Difficult to distinguish Noise from the original waveform

Easy to distinguish Noise from the original waveform

- Can use filtering devices (filters) to remove/reduce Noise

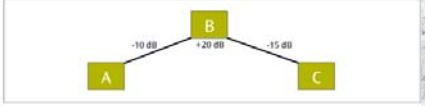
Attenuation

5

- Attenuation = Loss of Signal Strength
- Function of Distance and Friction within the Medium
- If high signals get too weak, the receiver will not be able to detected it.
- Decibel (dB) is a relative measure of signal loss or gain of strength.
- $dB = 10 \log_{10} (P2 / P1)$, Where P2 & P1 are ending and beginning power levels (in watt)

Figure 2-10
Example demonstrating decibel loss and gain

(Figure 2-10 in textbook)



Overall gain or loss = -10 dB + 20dB - 15dB = -5dB

Attenuation

6

- A signal starts at a transmitter with 10 watts of power and arrived at a receiver with 5 watts of power. Calculate the loss of power in dB.

1. $dB = 10 \log_{10} (P2 / P1)$
2. $dB = 10 \log_{10} (5/10)$
3. $dB = 10 \log_{10} (0.5)$
4. $dB = 10 (-0.3)$
5. $dB = -3$

Q: What is the decibel loss of a signal that starts at 50 watts and experiences a 10-watt loss over a given section of cable ?

Q: What is the decibel loss of a signal that loses half its power during the course of transmission ?

Q: Do Week 6 Exercise available in the Notes section of the course website.

Three Main Characteristics of Signals

7

- Amplitude
- Frequency
- Phase

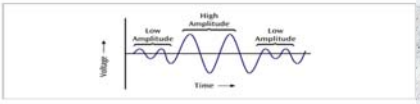
Amplitude

8

- The amplitude of a signal is the height of the wave above or below a given reference point.
- Height can denote
  - Voltage level (measured in volts)
  - Power level of the signal (in watts)
  - Current level of signal (in amps)

Figure 2-6
A signal with two different amplitudes

(Figure 2-6 in textbook)



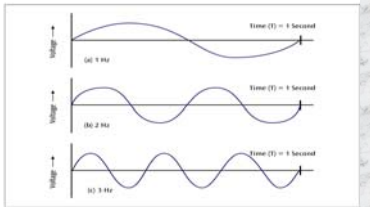
Frequency

9

- Frequency is the number of times a signal makes a complete cycle within a given time frame
- Frequency, or Cycles per second, measured in Hertz (Hz)

Figure 2-7
Three signals of 1 Hz, 2 Hz, and 3 Hz

(Figure 2-7 in textbook)



Q: What is the frequency (in Hz) of a signal that repeats 80000 times within one minute ?

Frequency and related concepts

10

- Human voice, as well as all signals, composed of multiple frequencies
- Multiple frequencies allow to distinguish one person's voice from another
- Average human voice frequency: From 300 Hz to 3100Hz
- Telephone system transmits signals in the range of 300 Hz to 3100 Hz
- Spectrum = The range of frequencies that a signal spans from minimum to maximum
- Bandwidth = The absolute value of the difference between the lowest and highest frequencies of a signal
- Example: $|3100\ \text{Hz} - 300\ \text{Hz}| = 2800\ \text{Hz}$
- Effective Bandwidth versus Theoretical Bandwidth (Noise, interference)

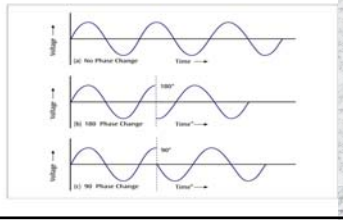
Q: What is the bandwidth of a signal composed of frequencies from -50 Hz to 500 Hz ?
Note: *Negative* frequency used here to help understand the meaning of Absolute value

Phase

11

- The phase of a signal is the position of the waveform relative to a given moment of time or relative to time zero.
- Phase changes often occur on common angles, such as 45, 90, 180, etc

(Figure 2-8 in textbook)



Converting Digital Data into Digital Signals

12

- There are numerous techniques (Encoding schemes) for converting digital data into digital signals
- Those techniques are implemented in Hardware and Software
- Most common techniques:
  - Non-Return to Zero Level (NRZ-L)
  - Differential Manchester

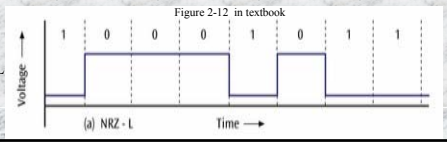
NRZ-L Encoding Scheme

13

- Transmits 1s as low level voltage and 0s as high level voltage
- Problem associated to NRZ-L: Long sequences of 0s in data produce signal that never changes.
- The receiver can have problem to know when one bit ends and the next bit begins (since Receiver and Sender use different clock systems)

NRZ-L

Figure 2-12 in textbook



Differential Manchester

14

- Used in most transceivers
- Ensure that each bit has some type of signal change (solve the synchronization problem)

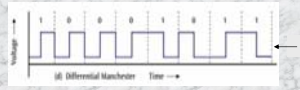


Figure 2-12 in textbook

- Disadvantage: For transmitting a series of 0s, the signal has to change at the beginning of each bit, as well as in the middle of each bit.

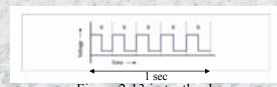


Figure 2-13 in textbook

Baud rate = 10
Bit Rate = 5
=> To send 100 0s, the signal changes 200 times
=> Devices more elaborate

Converting Digital Data into Analog Signals

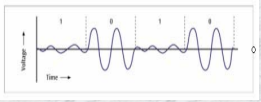
15

- Technique for converting digital data to Analog signal is called **modulation** or **Shift Keying**.
- Three current techniques:
  - Amplitude Modulation
  - Frequency Modulation
  - Phase Modulation

Amplitude Modulation

16

- A data value of 1 and a data value of 0 represented by two different amplitudes of the signal
- During each bit period the amplitude is constant.



← Figure 2-15 in textbook

- Some systems use multiple amplitudes

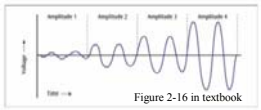


Figure 2-16 in textbook

- Each amplitude level represents 2 bits
- Every time the signal changes 2 bits are transmitted
- => Bit Rate = Twice the Baud Rate

- Noise can increase or decrease the amplitude

Frequency Modulation

17

- A data value of 1 and a data value of 0 represented by two different Frequency range
- During each bit period the frequency is constant.

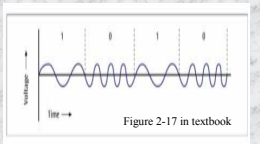


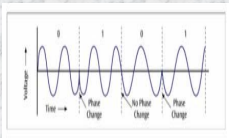
Figure 2-17 in textbook

- More robust than Amplitude Modulation, but subject to intermodulation distortion

Phase Modulation

18

- A data value of 1 and a data value of 0 represented by two different Phase changes



- 0 represented by No Phase change
- 1 represented by a Phase change

- More robust than Amplitude Modulation and Frequency Modulation

Summary Questions

19

1. What is the main advantage of digital signals over analog signals with regard to noise?

2. What are the three main components (characteristics) of signals ?

3. What is the bandwidth of signals? The spectrum?

4. (a) Name one technique for converting digital data into digital signals. (b) Name 3 techniques for converting digital data into analog signals