Tishk International University
Science Faculty
Information Technology Department

Data Communication &
Computer Networks II

Modulation and Modems

3rd Grade Spring Semester 2020-2021

Instructor: Bilal Ahmed

Chapter 10

Modulation And Modems

Topics Covered

- 10.1 Introduction
- 10.2 Carriers, Frequency, And Propagation
- 10.3 Analog Modulation Schemes
- 10.4 Amplitude Modulation
- 10.5 Frequency Modulation
- 10.6 Phase Shift Modulation
- 10.7 Amplitude Modulation And Shannon's Theorem
- 10.8 Modulation, Digital Input, And Shift Keying
- 10.9 Modem Hardware For Modulation And Demodulation
- 10.10 Optical And Radio Frequency Modems
- 10.11 Dialup Modems
-

10.1 Introduction

- This chapter
  - focuses on the use of high-frequency signals to carry information
  - discusses how information is used to change a high-frequency electromagnetic wave
  - explains why the modulation is important
  - describes how analog and digital inputs are used

10.2 Carriers, Frequency, And Propagation

Many long-distance communication systems use a oscillating electromagnetic wave, called a carrier

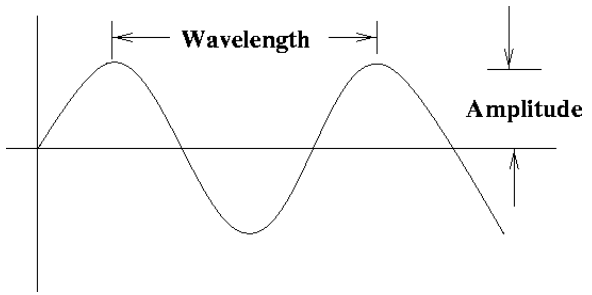
The system makes small changes to the carrier that represent information being sent

The frequency of electromagnetic energy determines how the energy propagates

One reason to carriers is to select a frequency that will propagate well

10.3 Analog Modulation Schemes

- We use the term modulation to refer to changes made in a carrier
  - according to the information being sent
- Modulation takes two inputs
  - a carrier signal, and
  - an information signal
- Then it generates a modulated carrier as output
- A sender must change one of the fundamental characteristics of the wave
- There are three primary techniques that modulate an electromagnetic carrier according to an information signal:
  - Amplitude modulation (AM)
  - Frequency modulation (FM)
  - Phase modulation (PM)



10.3 Analog Modulation Schemes

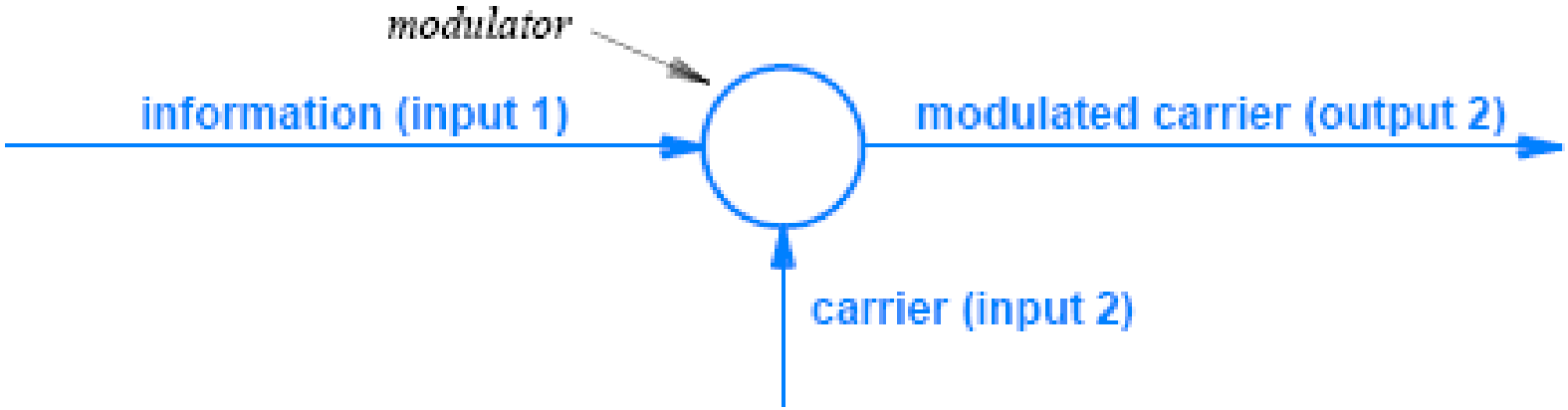


Figure 10.1 The concept of modulation with two inputs.

10.4 Amplitude Modulation (AM)

- AM varies the amplitude of a carrier in proportion to the information being sent
- The carrier continues oscillating at a fixed frequency
  - but the amplitude of the wave varies
- Figure 10.2 illustrates
  - an unmodulated carrier wave
  - an analog information signal
  - and the resulting amplitude modulated carrier
- As it is seen from the figure:
  - only the amplitude (i.e., magnitude) of the sine wave is modified
  - a time-domain graph of a modulated carrier has a shape similar to the signal that was used
  - Envelope curve (that connects the peaks of a sine wave) as shown in Figure 10.2c has the same shape as the signal in Figure 10.2b

10.4 Amplitude Modulation (AM)

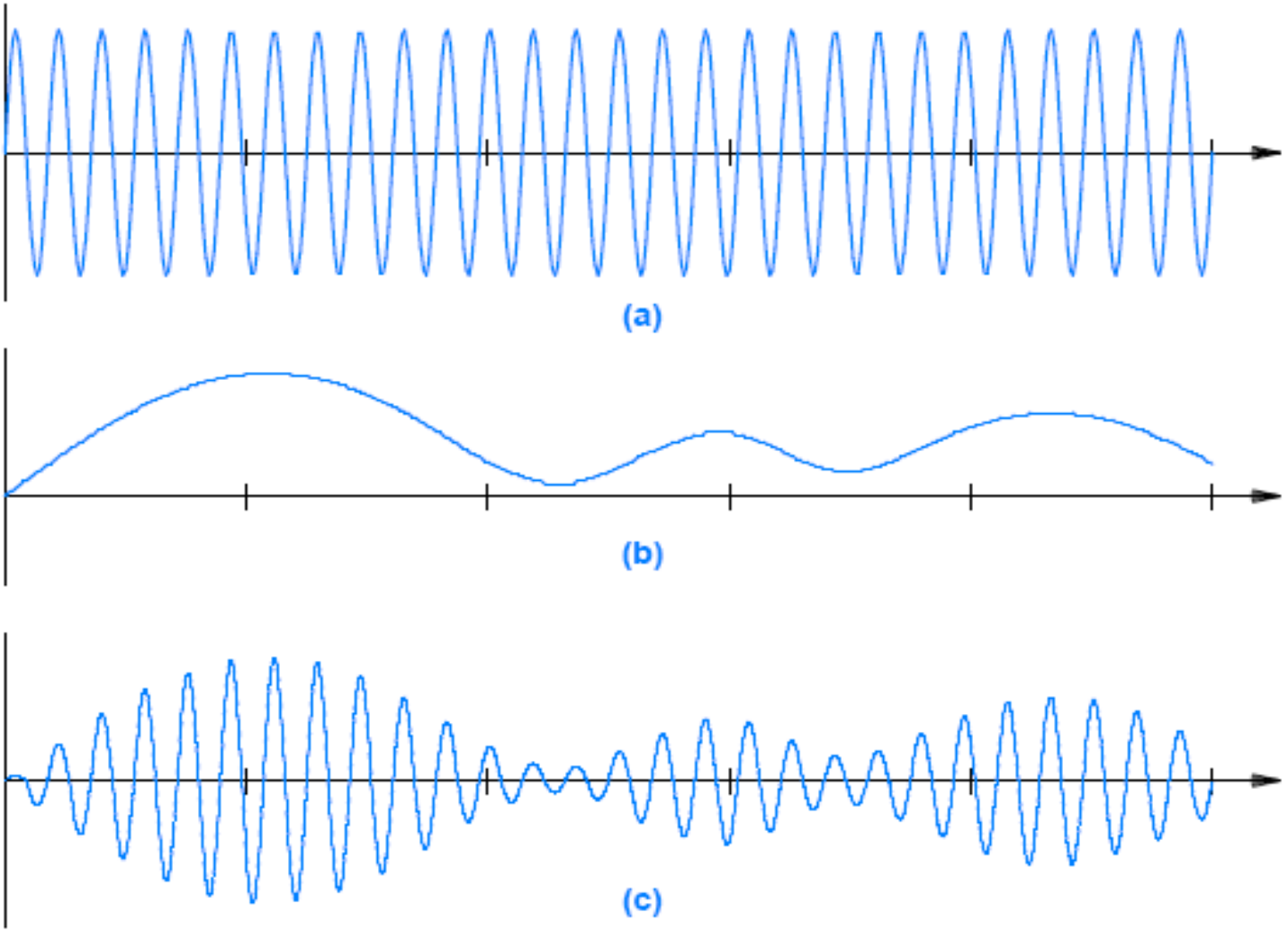


Figure 10.2 Illustration of (a) an unmodulated carrier wave, (b) an analog information signal, and (c) an amplitude modulated carrier.

10.5 Frequency Modulation (FM)

- In FM, the amplitude of the carrier remains fixed
- Frequency changes according to the signal:
  - when the signal is stronger, the carrier frequency increases,
  - and when the signal is weaker, the carrier frequency decreases
- Figure 10.3 illustrates an example of FM
- FM is more difficult to visualize
  - because slight changes in frequency are not as clearly visible
  - However, one can notice that the modulated wave has higher frequencies when the signal used for modulation is stronger

10.5 Frequency Modulation (FM)

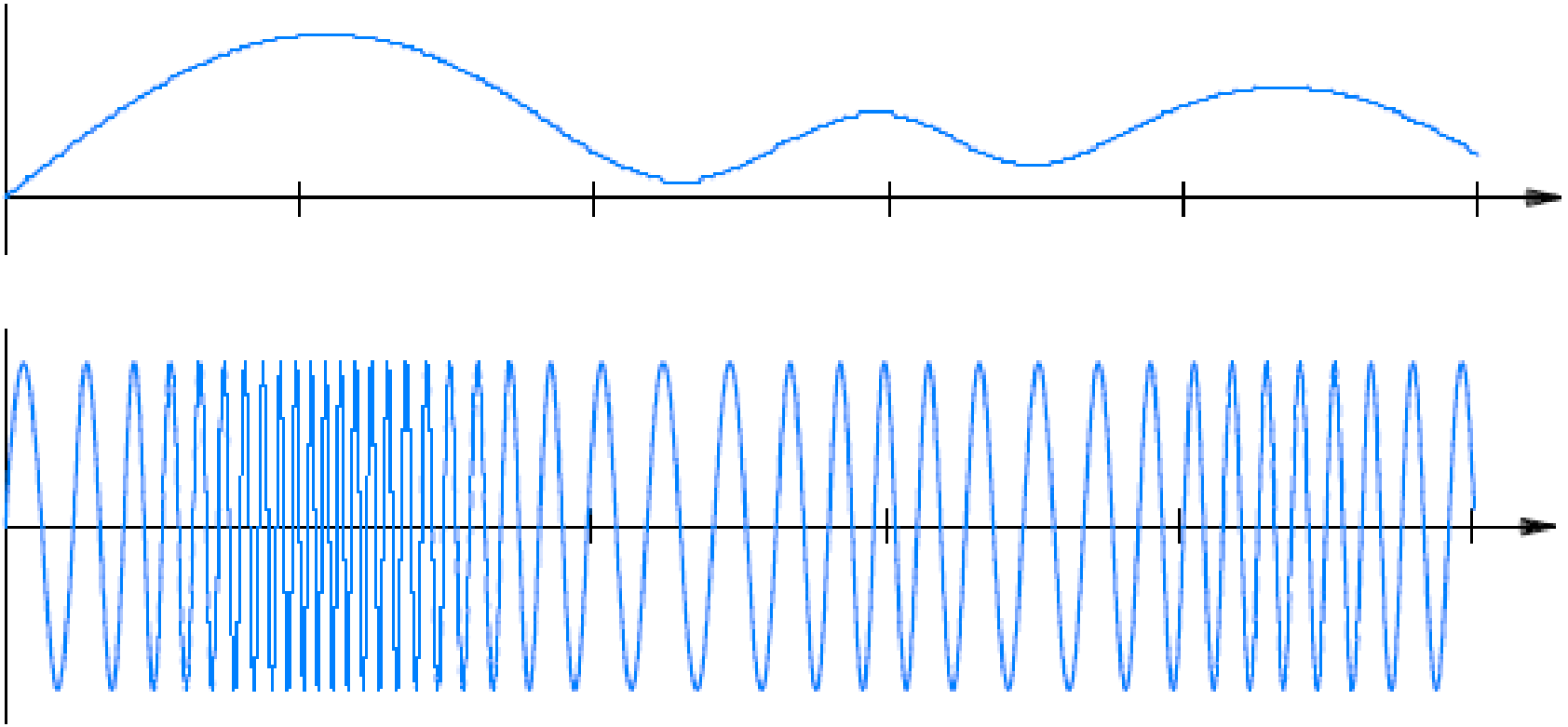


Figure 10.3 Illustration of a carrier wave with frequency modulation according to the signal in Figure 10.2b.

10.6 Phase Modulation (PM)

- One property of a sine wave is its phase
  - the offset from a reference time (at which the sine wave begins)
- It is possible to use changes in phase to represent a signal
  - Phase shift term used to characterize such changes
- If phase changes after cycle k, the next sine wave will start slightly later than the time at which cycle k completes
  - A slight delay resembles a change in frequency
- PM can be thought of as a special form of FM
  - However, phase shifts are important when a digital signal is used to modulate a carrier

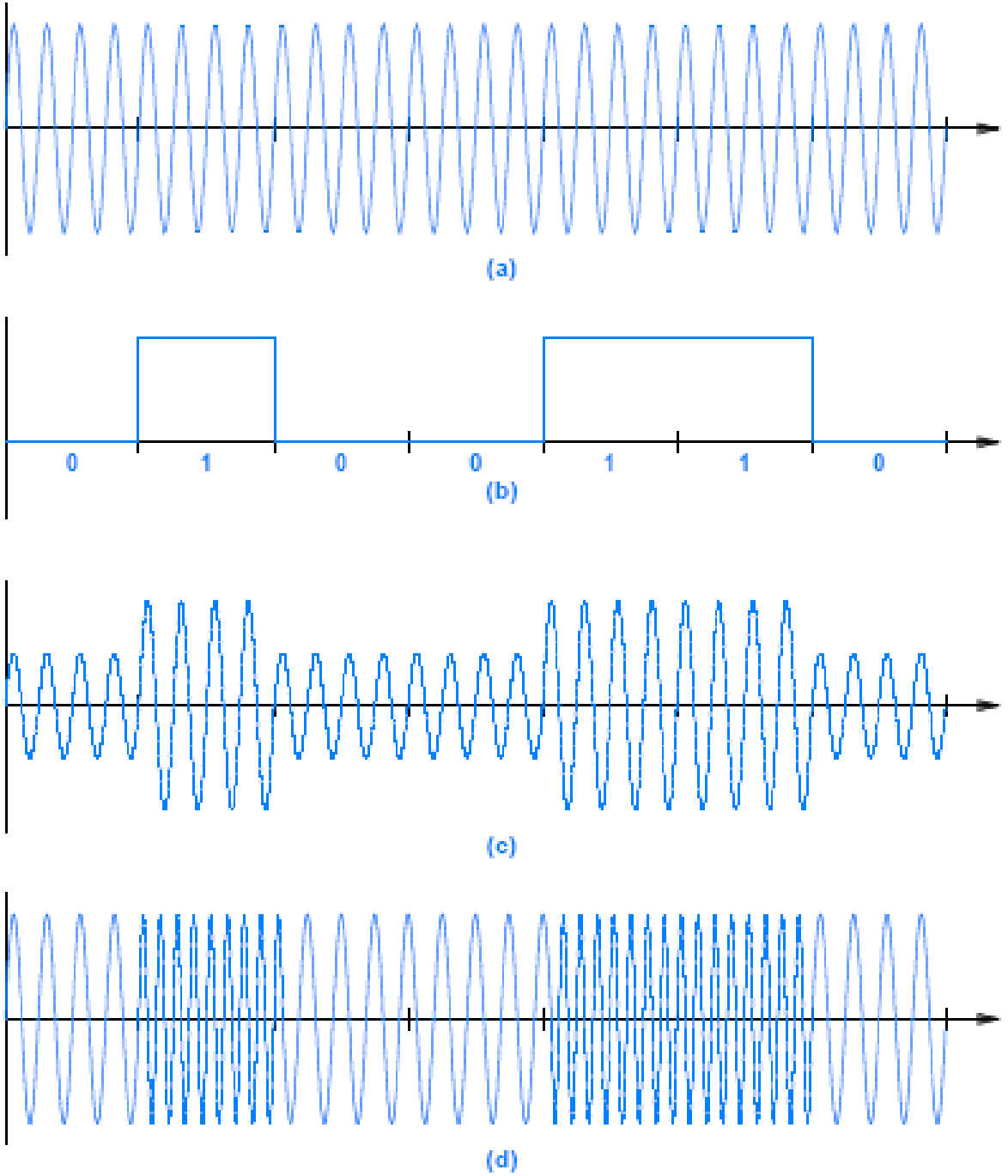
10.7 AM and Shannon's Theorem

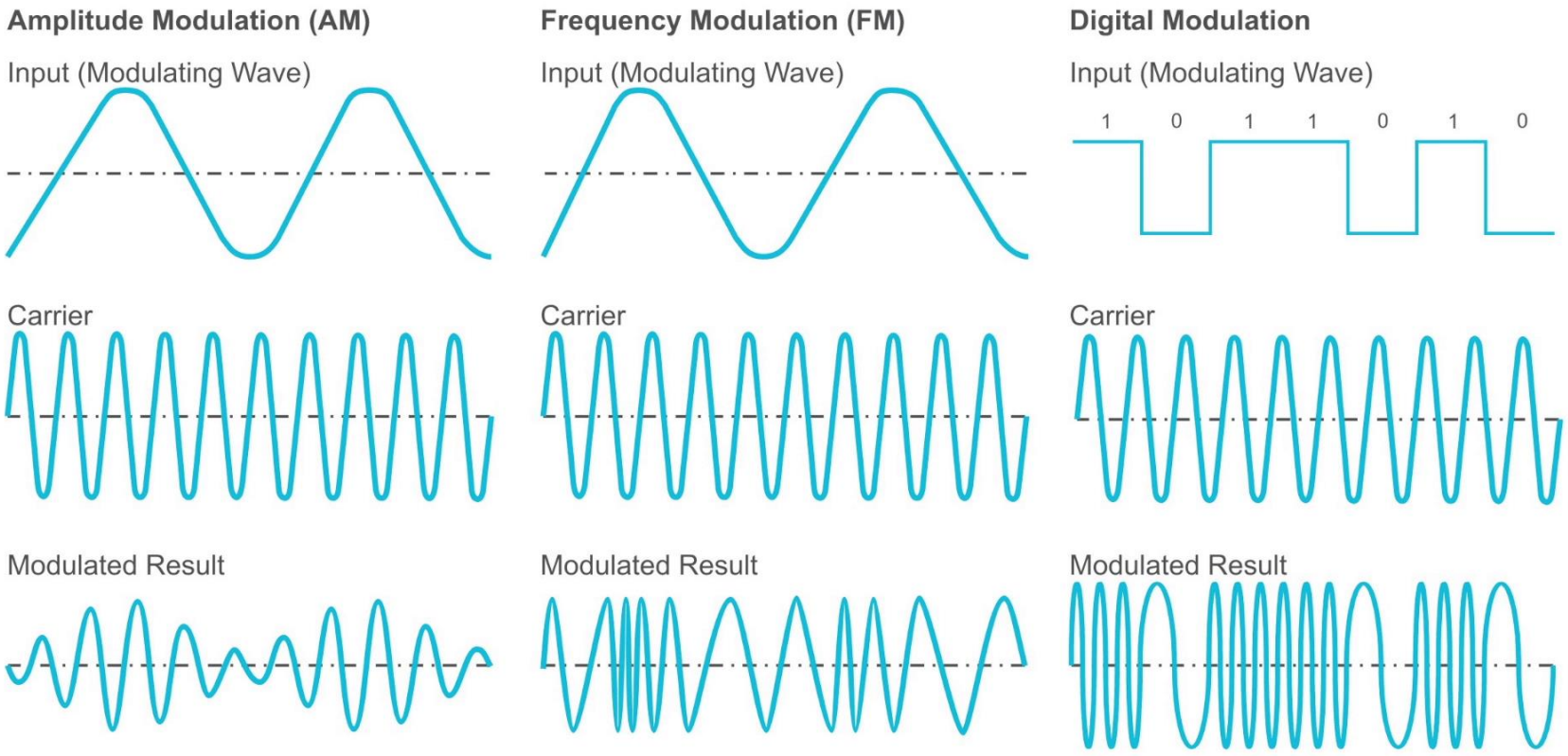
- Figure 10.2c shows the amplitude varying from a maximum to almost zero
- The figure is slightly misleading:
  - in practice, modulation only changes the amplitude of a carrier slightly, depending on a constant known as the modulation index
- Practical systems do not allow for a modulated signal to approach zero
- Consider Shannon's Theorem
  - assuming the amount of noise is constant
    - the signal-to-noise ratio will approach zero as the signal approaches zero
- Keeping the carrier wave near maximum insures that the signal-to-noise ratio (SNR) remains as large as possible
  - This permits the transfer of more bits per second

10.8 Modulation, Digital Input, And Shift Keying

- How can digital input be used in modulation?
- Modifications are needed:
  - instead of modulation that is proportional to a continuous signal, digital schemes use discrete values
- To distinguish between analog and digital modulation
  - we use the term shift keying rather than modulation
- Shift keying operates similar to analog modulation
  - Instead of a continuum of possible values, digital shift keying has a fixed set
  - For example, AM allows the amplitude of a carrier to vary by arbitrarily small amounts in response to a change in the signal
    - In contrast, amplitude shift keying (ASK) uses a fixed set of possible amplitudes
- Figure 10.4 illustrates concept for ASK and FSK

Figure 10.4
Illustration of
(a) a carrier wave
(b) a digital input signal
(c) ASK
(d) FSK




Amplitude Modulation (AM)
Input (Modulating Wave)
Carrier
Modulated Result
Frequency Modulation (FM)
Input (Modulating Wave)
Carrier
Modulated Result
Digital Modulation
Input (Modulating Wave)
1 0 1 1 0 1 0
Carrier
Modulated Result

10.9 Modem HW For Modulation And Demodulation

- Modulator
  - a mechanism that accepts a sequence of data bits and applies modulation to a carrier wave according to the bits
- Demodulator
  - a mechanism that accepts a modulated carrier wave and recreates the sequence of data bits that was used to modulate the carrier
- Transmission of data requires a modulator at one end of the transmission medium and a demodulator at the other
- Most communication systems are full duplex

10.9 Modem Hardware For Modulation And Demodulation

- Users would like keep cost low and make the pair of devices easy to install and operate
- Manufacturers combine modulation and demodulation mechanisms into a single device called a modem
  - Modem (modulator and demodulator)
- Figure 10.9 illustrates how a pair of modems use a 4-wire connection to communicate
- Modems are designed to provide communication over long distances

10.9 Modem HW for Modulation and Demodulation

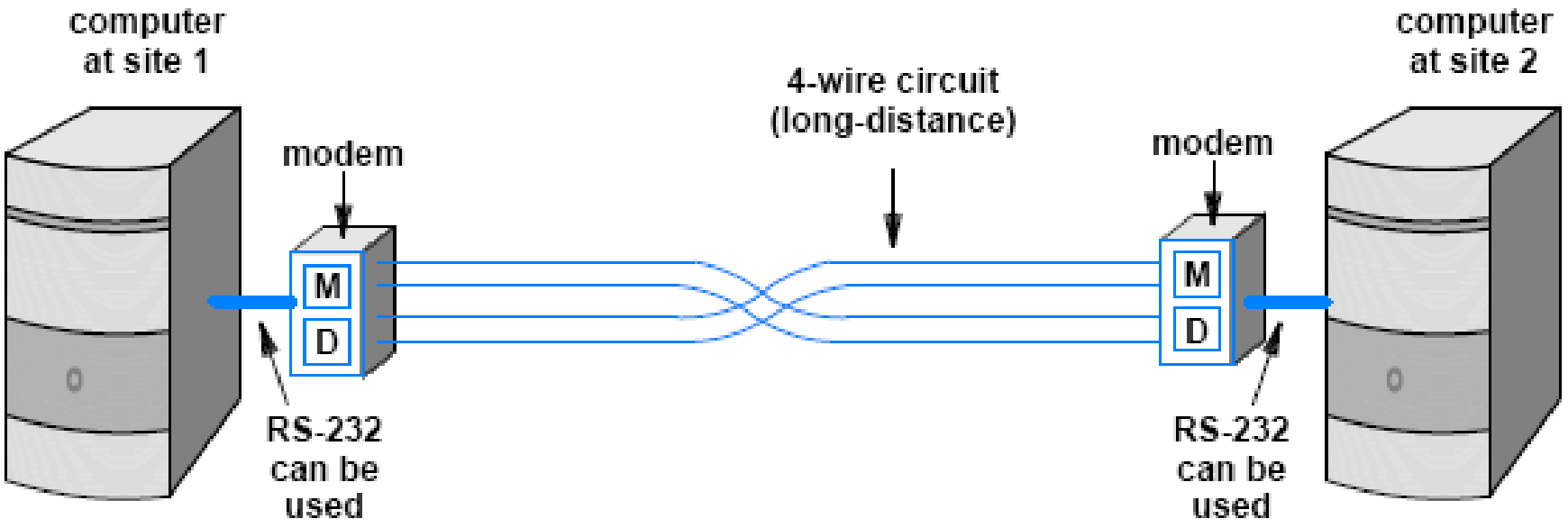


Figure 10.9 Illustration of two modems that use a 4-wire connection.

10.10 Optical And Radio Frequency Modems

- Modems are also used with other media
  - including Radio Frequency (RF) transmission and optical fibers
- A pair of RF modems can be used to send data via radio
- A pair of optical modems can be used to send data across a pair of optical fibers

10.11 Dialup Modems

- A dialup modem uses an audio tone
- A dialup modem uses data to modulate an audible carrier
  - which is transmitted to the phone system
- Difference between dialup and conventional modems is that audible dialup modems uses lower bandwidths
- Interior of a modern telephone system used today is digital
  - The phone system digitizes the incoming audio
  - Internally, transports a digital signal
  - Converts the digitized version back to analog audio for delivery
  - The receiving modem demodulates the analog carrier
  - Extracts the original digital data

Dialup Modems