Guide to Wireless Communications, Third Edition

Chapter 2
Wireless Data Transmission
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Objectives

- Discuss the two types of wireless transmissions
- Explain the properties of a wave, such as amplitude, wavelength, frequency, and phase
- Describe the basic concepts and techniques related to the transmission of data by radio waves

Wireless Signals

- Wireless data signals travel on electromagnetic waves
  - Through space at the speed of light
    - 186,000 miles per second (300,000 kilometers per second)
- Two basic types of waves
  - Infrared light
  - Radio waves

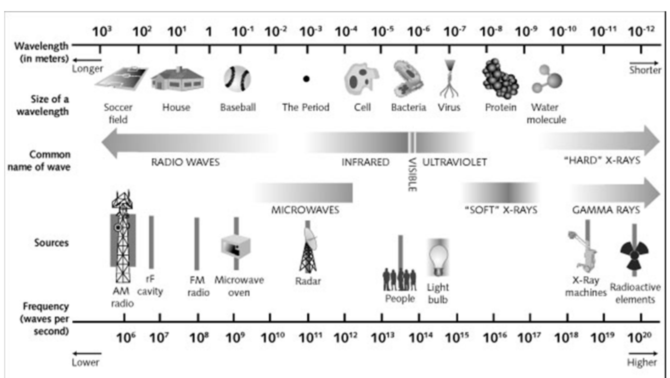

Figure 2-1 Electromagnetic spectrum

Infrared Light

- It is easy to transmit information with light
  - Because computers and data communication equipment use binary code
  - Light has two properties: off and on
  - A 1 in binary code could result in a light quickly flashing on; a 0 could result in the absence of light
- Light spectrum
  - Types of light that travel from the Sun to the Earth
- Infrared light
  - Adjacent to visible light (although invisible)
  - A much better medium for data transmission
  - Less susceptible to interference

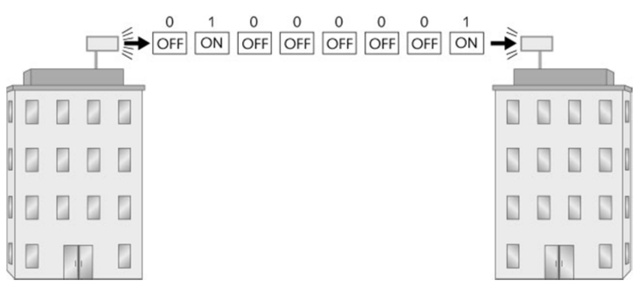

Figure 2-2 Transmitting a message using visible light

Infrared Light

- Infrared wireless systems require:
  - – Emitter that transmits a signal (LED)
  - – Detector that receives the signal
- Infrared wireless systems send data by the intensity of the light wave
  - – Detector senses the higher intensity pulse of light
    - And produces a proportional electrical current
- Infrared wireless transmission types
  - – Directed transmission (called line-of-sight or LOS)
  - – Diffused transmission – relies on reflected light

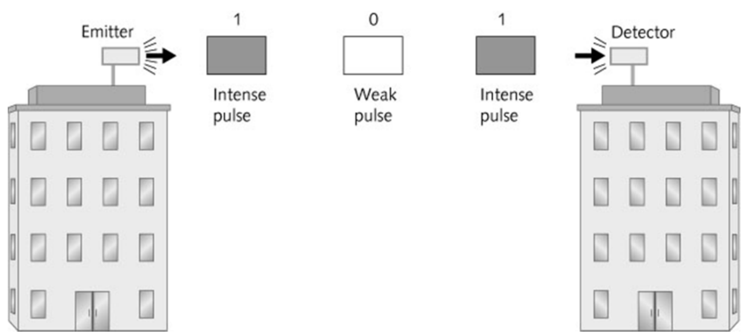

Figure 2-3 Light pulses

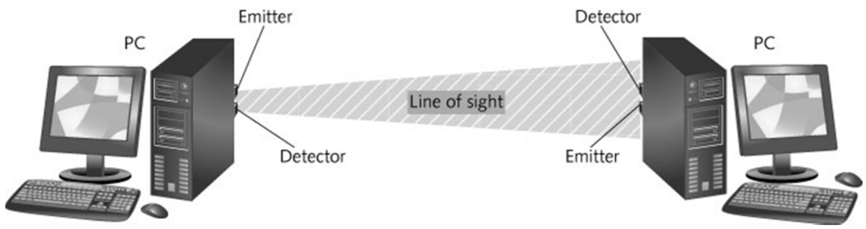

Figure 2-4 Directed infrared transmission

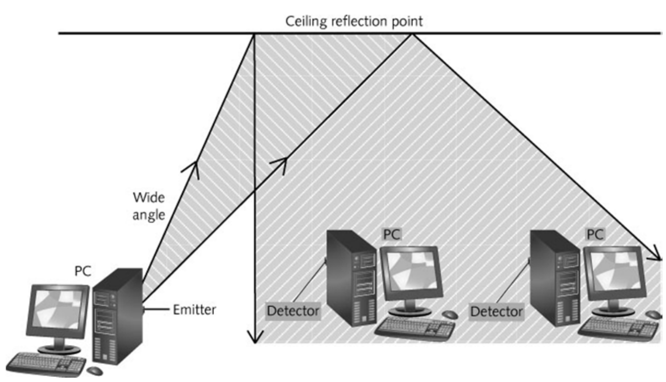

Figure 2-5 Diffused infrared transmission

Infrared Light

- Advantages
  - It does not interfere with other types of communication signals
  - It is not affected by other signals (except light)
  - Infrared light does not penetrate walls
    - Signals are kept inside a room
- Limitations
  - Lack of mobility
  - Range of coverage
    - Can cover a range of only 50 feet (15 meters)
    - Diffused infrared can only be used indoors
  - Speed of transmission

Infrared Light

- Some specialized wireless local area networks are based on the infrared method
  - Used in situations where radio signals would interfere with other equipment
- Light waves cannot penetrate through materials like wood or concrete
  - Heat rays are absorbed by most objects
  - Solid objects, dust and humidity can limit the distance that light and infrared waves can travel

Radio Waves

- Radio waves provide the most common and effective means of wireless communications today
- Energy travels through space or air in electromagnetic waves
- Radio (radiotelephony) waves
  - When an electric current passes through a wire, it creates a magnetic field
    - In the space around the wire
  - As this magnetic field radiates or moves out, it creates radio waves

Frequency (continued)

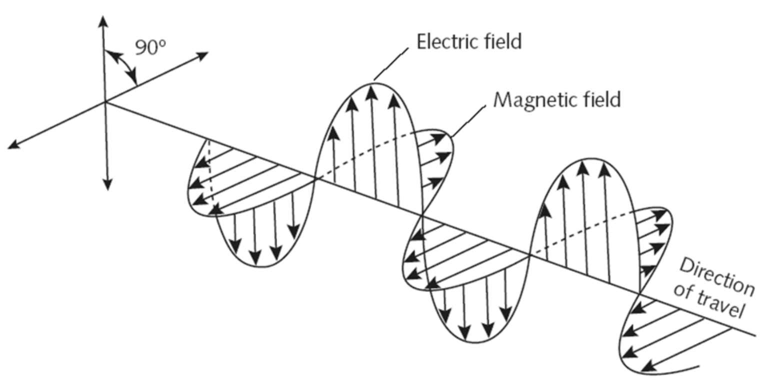

Figure 2-17 Electromagnetic wave consisting of electrical and magnetic fields

Figure 2-8 Simulating a radio wave using a garden hose

Radio Waves

- Advantages of radio waves
  - Can travel great distances
  - Can penetrate most solid objects
    - With the exception of metallic ones
  - Invisible

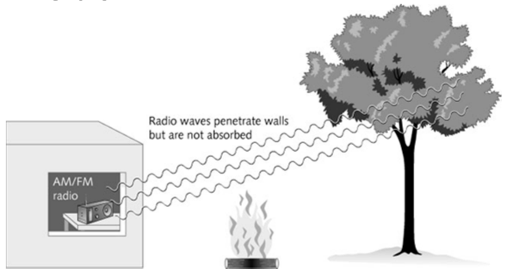

Figure 2-9 Radio waves can penetrate most solid objects

How Radio Data is Transmitted

- Radio waves can be used to transmit data
  - Over long distances
  - Without the need for wires
- Types of data
  - Analog data
  - Digital data

Analog and Digital

- Analog signal
  - The intensity of the waves (voltage or amplitude) varies
  - It is broadcast continuously
  - Examples:
    - Audio, video, voice, and light

Figure 2-10 Analog signal

Analog and Digital

- Digital signal
  - Consists of discrete or separate *pulses*
  - Has numerous starts and stops throughout the signal stream
- Computers operate using digital signals
  - Analog signal must be converted into a digital format
    - Before it can be stored and processed or interpreted by a computer

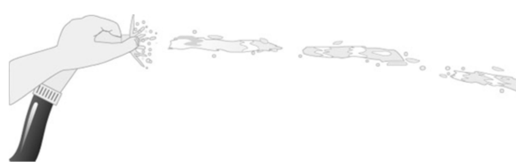

Figure 2-11 Simulating a digital signal with a garden hose

Figure 2-12 Digital signal

Analog and Digital

- To transmit a digital signal over an analog medium, a **modem** is used
  - Modem (Modulator/Demodulator)
    - Converts the distinct digital signals from a computer
    - Encodes them into a continuous analog signal
      - For transmission over analog phone lines
- Modulation
  - Process of encoding the digital signals (bits) onto an analog wave

Frequency and Wavelength

- Wavelength – distance between any point in one wave cycle and the same point in the next wave cycle
- Frequency – Rate at which a radio circuit creates the waves
  - The number of times a cycle occurs within one second
- Carrier signal
  - Sent by radio transmitters
  - Continuous wave (CW) of constant amplitude (also called voltage) and frequency
  - An up-and-down wave called an oscillating signal or a sine wave

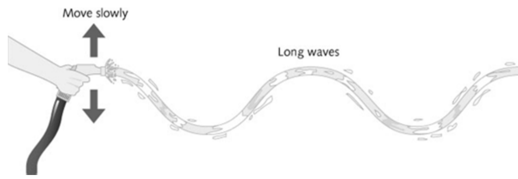

Figure 2-13 Long waves

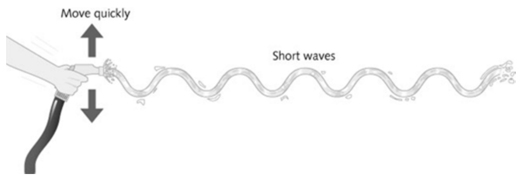

Figure 2-14 Short waves

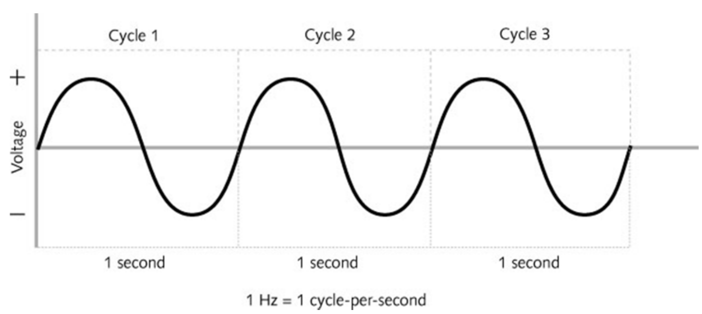

Figure 2-15 Sine wave (analog wave) and frequency

Frequency and Wavelength

- A change in voltage does not create a change in frequency
- The term Hertz (Hz) is used to measure frequency
  - A Kilohertz (KHz) is 1,000 Hertz
  - A Megahertz (MHz) is 1,000,000 Hertz
  - A Gigahertz (GHz) is 1,000,000,000 Hertz
- The wave measured as 710,000 Hz is referred to as 710 KHz

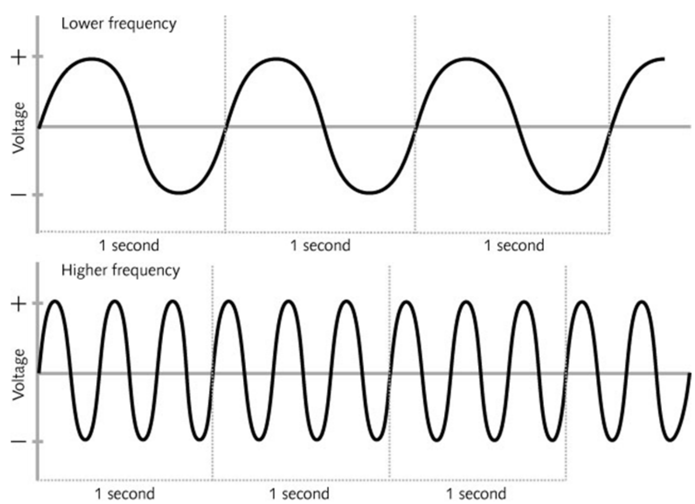

Figure 2-16 Two different frequencies; same amplitude

Frequency and Wavelength

- Antenna
  - Length of copper wire, or similar material with one end free and the other end connected to a receiver or transmitter
- Electrical current moves the antenna
  - At the same frequency as the radio waves
- Electromagnetic wave (EM wave) – continuous (analog) combination of magnetism and electrical pressure moving away from an antenna

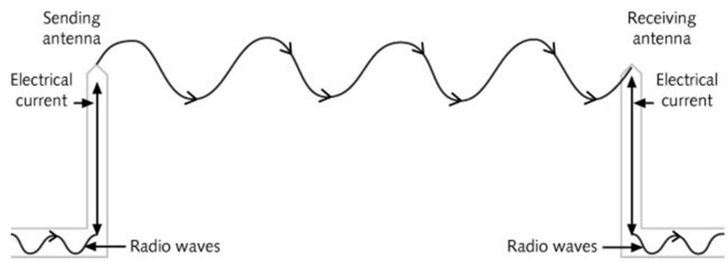

Figure 2-18 Radio antennas transmitting and receiving signals

Transmission Speed

- Speed of transmission is usually shown in bits per second (bps)
- Baud rate
  - Another term used in measuring the speed of radio transmission
  - Number of signal units per second that are required to represent the bits transmitted
  - Baud is a change in the carrier signal
- It is possible to have a change in signal (a baud) represent more than 1 bit

Signal Change (Baud)	Bit Combination Represented
Signal W	00
Signal X	01
Signal Y	10
Signal Z	11

Table 2-2 Bit representation of four signal changes

Transmission Speed

- Analog modems transmit at a rate of 4,800 baud
  - Maximum number of signal changes per second that a phone line can support
- Current modems can transmit up to 33,600 bps
  - Using more complex modulation techniques
    - Along with compression of the data
- When a signal unit can represent:
  - Two bits, it is known as a dibit
  - Three bits, it is known as a tribit
  - Four bits, it is known as a quadbit

Transmission Speed

- Bandwidth
  - Range of frequencies that can be transmitted by a particular system or medium
  - Refers to the maximum data transmission capacity
  - Accurate only when referring to purely digital systems

Analog Modulation

- Representation of analog information by an analog signal
- Analog modulation types
  - Amplitude modulation
  - Frequency modulation
  - Phase modulation
- Amplitude modulation (AM)
  - Height of a carrier wave is known as the amplitude
    - Can be measured in volts (electrical pressure)
  - Height of the carrier wave is changed in accordance with the height of the modulating signal

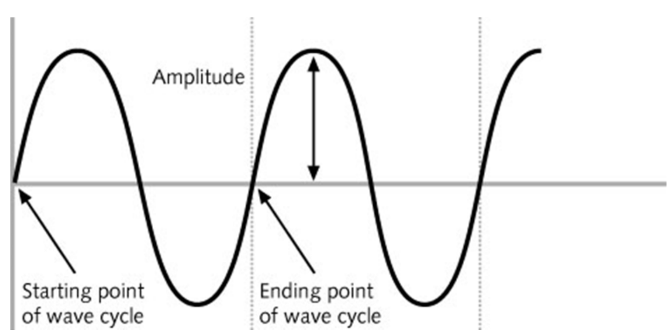

Figure 2-19 Amplitude of a signal

Analog Modulation (continued)

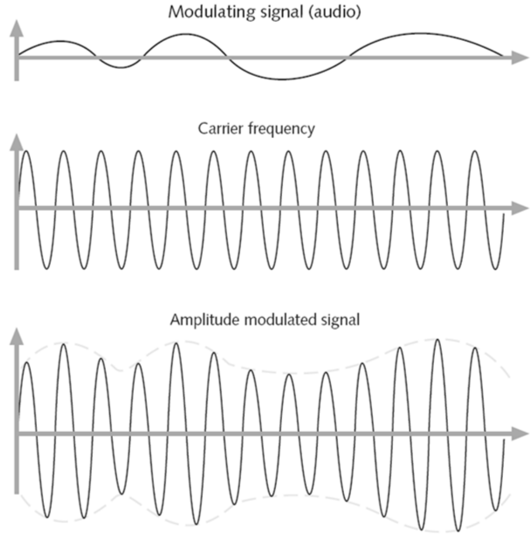

Figure 2-20 Amplitude modulation (AM)

Analog Modulation

- Amplitude modulation (AM)
  - Used by broadcast radio stations
  - Very susceptible to interference from outside sources
- Frequency modulation (FM)
  - Number of waves that occur in one second undergoes change based on the amplitude of the modulating signal
  - Often used by broadcast radio stations
  - Not as susceptible to interference from outside sources
  - FM carrier has a wider bandwidth
    - Allows it to carry Hi-Fi as well as stereophonic signals

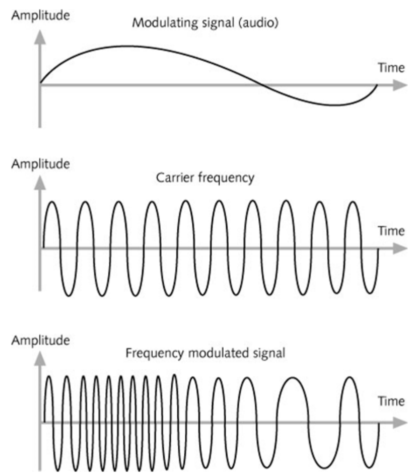

Figure 2-21 Frequency modulation (FM)

Analog Modulation

- Phase modulation (PM)
  - Changes the starting point of the cycle
  - It is not generally used to represent analog signals
  - A signal composed of sine waves has a phase associated with it
  - Phase is measured in degrees
    - One complete wave cycle covers 360 degrees
  - A phase change is always measured with reference to some other signal
  - PM systems almost always use the previous wave cycle as the reference signal

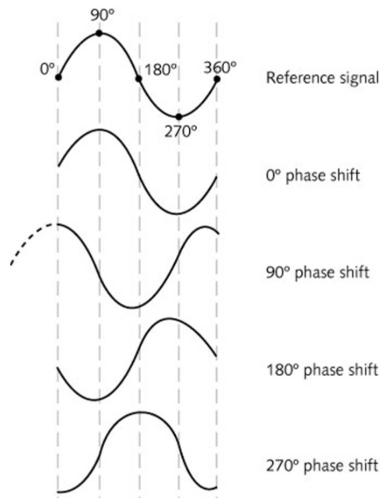

Figure 2-22 Visual representation of phase shift

Digital Modulation

- Method of encoding a digital signal onto an analog wave
  - For transmission over a medium that does not support digital signals
- In a digital system, the changes are distinct using binary signals
  - Which exist in one of two states, a 1 or a 0
- For a computer to be able to understand these signals
  - Each bit must have a fixed duration to represent 1 or 0

Digital Modulation

- Advantages
  - Makes better use of the bandwidth available
  - Requires less power to transmit
  - Performs better when the signal experiences interference from other signals
  - Error-correcting techniques are more compatible with other digital systems
- There are three basic types of digital modulations:
  - Amplitude, frequency, and phase
- Users demand more transmission speed
  - Today there are dozens of different types of modulation

Digital Modulation

- Binary signals
  - Digital data transmissions are typically sent in bursts of bits
  - Three types of binary signaling techniques can be used:
    - Return-to-zero (RZ)
    - Non-return-to-zero (NRZ)
    - Polar non-return-to-zero (polar NRZ)
      - Also known as non-return-to-zero-level (NRZ-L)
  - A variation of NRZ-L is non-return-to-zero, invert-on-ones (NRZ-I)

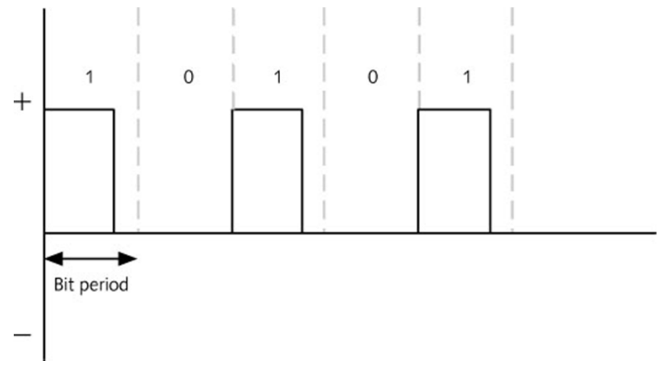

Figure 2-23 Return-to-zero (RZ)

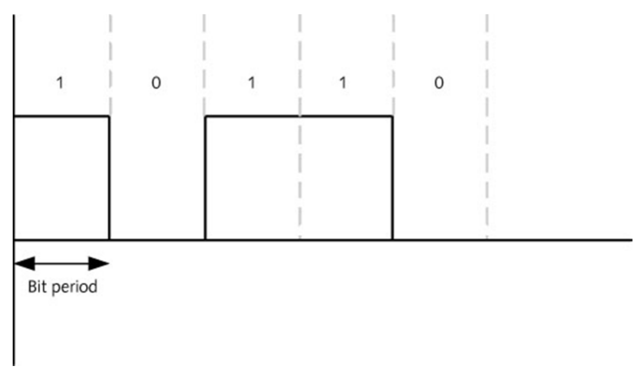

Figure 2-24 Non-return-to-zero (NRZ)

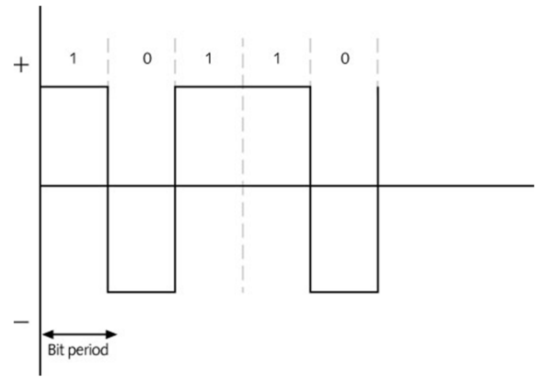

Figure 2-25 Polar non-return-to-zero (non-return-to-zero level or NRZ-L)

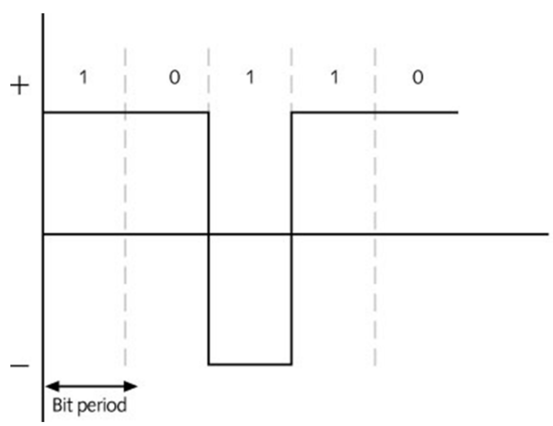

Figure 2-26 Non-return-to-zero, invert-on-ones (NRZ-I)

Digital Modulation

- Amplitude Shift Keying (ASK)
  - Binary modulation technique similar to amplitude modulation
  - Height of the carrier signal can be changed to represent a 1 bit or a 0 bit
  - ASK uses NRZ coding
- Frequency Shift Keying (FSK)
  - Binary modulation technique that changes the frequency of the carrier signal
  - More wave cycles are needed to represent a 1 bit

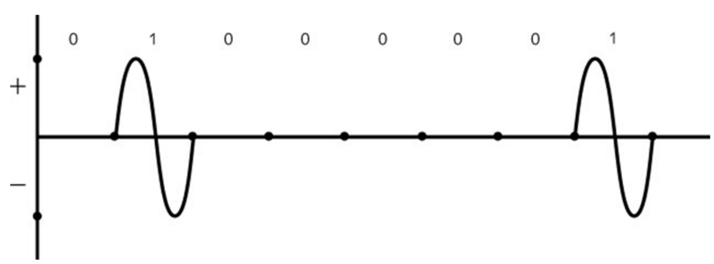

Figure 2-27 Amplitude shift keying (ASK)

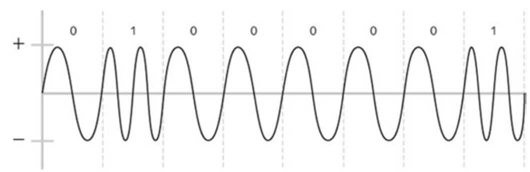

Figure 2-28 Frequency shift keying (FSK)

Digital Modulation

- Phase Shift Keying (PSK)
  - Binary modulation technique similar to phase modulation
  - Transmitter varies the starting point of the wave
  - PSK signal starts and stops because it is a binary signal
  - Quadrature amplitude modulation (QAM)
    - Technique of combining amplitude and phase modulation
  - Receivers can detect phase changes much more reliably than a frequency or amplitude change
    - In the presence of electromagnetic noise

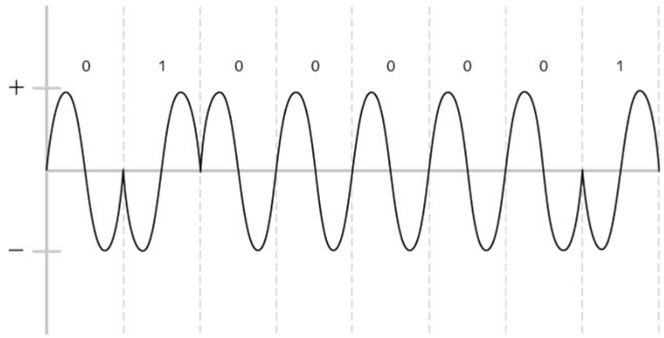

Figure 2-29 Phase shift keying (PSK)

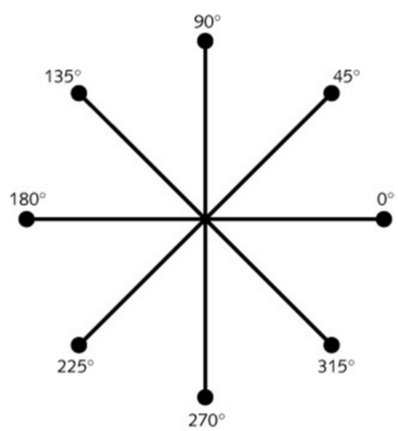

Figure 2-30 Phase modulation angles

Digital Modulation

- Binary phase shift keying (BPSK)
  - Can be used to transmit dibits (four signal changes equals 2 bits per signal change)

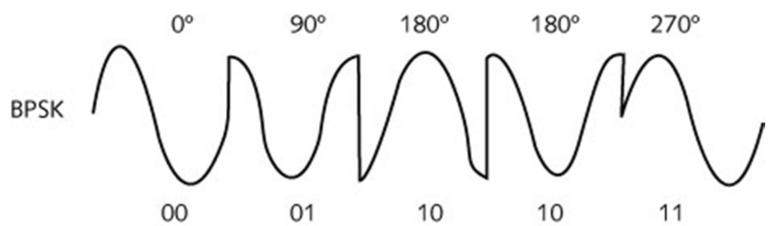

Figure 2-32 Transmitting dibits using BPSK

Spread Spectrum

- Narrow-band transmissions
  - Each signal transmits on one radio frequency
    - Or a very narrow range of frequencies
  - Vulnerable to outside interference from another signal
  - Radio signal transmissions are narrow-band
- Spread spectrum transmission
  - Takes a narrow band signal and spreads it over a broader portion of the radio frequency band
  - Results in less interference and fewer errors
  - Two common methods
    - Frequency hopping and direct sequence

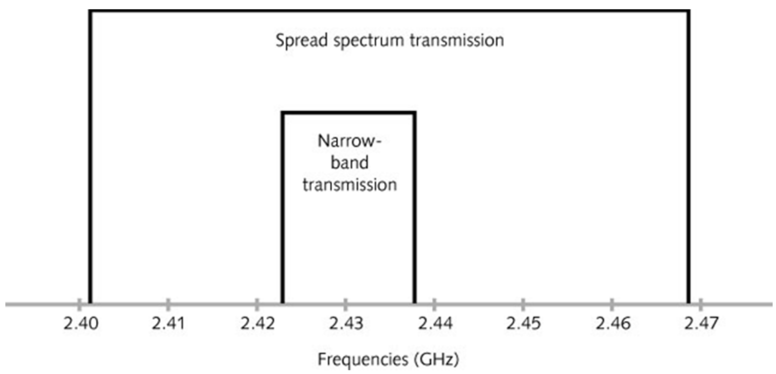

Figure 2-33 Spread spectrum vs. narrow-band transmission

Frequency Hopping Spread Spectrum (FHSS)

- Uses a range of frequencies
  - Changes frequencies several times during transmission
- Hopping code
  - The sequence of changing frequencies
  - The receiving station must also know the hopping code
  - Multiple radios can each use a different sequence of frequencies within the same area
    - And never interfere with each other
- If interference is encountered on a frequency
  - Only a small part of the message is lost

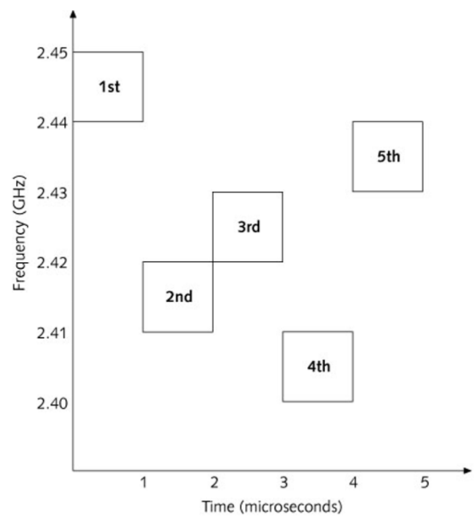

Figure 2-34 Frequency hopping spread spectrum (FHSS) transmission

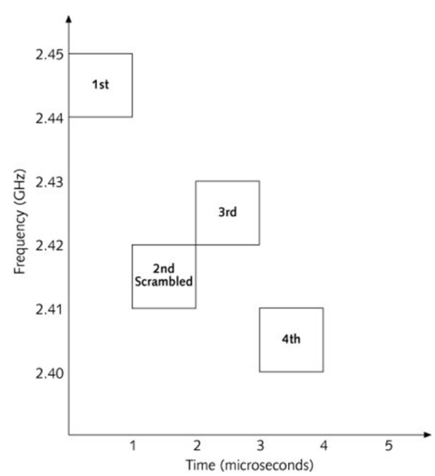

Figure 2-35 FHSS error detection

Frequency Hopping Spread Spectrum (FHSS)

- Frequency hopping can reduce the impact of interference from other radio signals
- An interfering signal will affect the FHSS signal only when both are transmitting at the same frequency and at the same time
  - Because FHSS transmits short bursts over a wide range of frequencies, the extent of any interference will be small
    - The error can be detected through error checking
    - Message can be easily retransmitted

Direct Sequence Spread Spectrum (DSSS)

- Uses an expanded redundant code to transmit each data bit
  - And then a modulation technique such as QPSK
  - A DSSS signal is effectively modulated twice
- Barker code (or chipping code)
  - A particular sequence of 1s and 0s
  - Ideal for modulating radio waves
    - As well as for being detected correctly by the receiver
  - It is also called a pseudo-random code
- Before transmission, add the original data bit to the chipping code

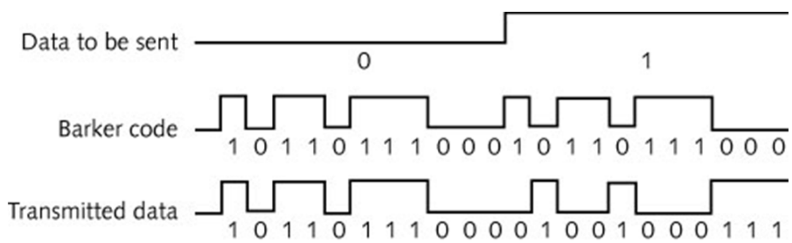

Figure 2-36 Encoding before modulation in a DSSS transmission

Direct Sequence Spread Spectrum (DSSS)

- DSSS system transmits combinations of multiple chips
  - 11 chips are transmitted at a rate 11 times faster than the data rate
- Characteristics
  - Frequency of the digital component of the signal is much higher than that of the original data (chip rate)
  - A plot of the frequency spectrum of this signal would look similar to random noise
  - All of the information contained in the original signal (a 0 or a 1 bit) is still there!

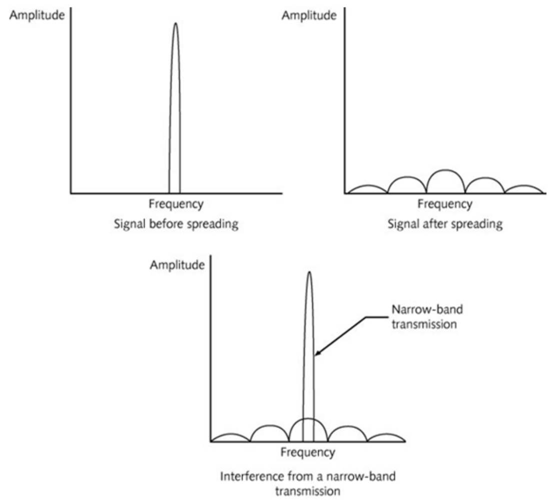

Figure 2-37 Spreading the signal over a wider range of frequencies

Direct Sequence Spread Spectrum (DSSS)

- Advantages
  - DSSS signal appears to an unintended narrow-band receiver to be low-powered noise
  - Noise can cause some of the chips to change value
    - Receiver can recover the original data bit
      - Using statistical techniques and mathematical algorithms
      - Thus avoiding the need for retransmission
- DSSS devices are typically higher-end products
  - Because they are more expensive to manufacture than FHSS systems

Summary

- American Standard Code for Information Interchange (ASCII)
  - Coding scheme that uses numbers from 0 to 127 to represent symbols
- Wireless transmissions do not use wires or any other visible media
- Infrared wireless transmission can be either directed or diffused
- Radio transmissions use a carrier signal
  - A continuous wave (CW) of constant amplitude (voltage) and frequency

Summary

- Carrier signal can undergo three types of modulation:
  - Amplitude, frequency, and phase
- Digital modulation basic techniques
  - Amplitude, frequency and phase
- Radio signals are by nature a narrow-band type of transmission
  - Transmit on one radio frequency or a very narrow spectrum of frequencies

Summary

- Spread spectrum
  - Takes a narrow signal and spreads it over a broader portion of the radio frequency band
- Spread spectrum common methods
  - Frequency hopping spread spectrum (FHSS)
  - Direct sequence spread spectrum (DSSS)