Guide to Wireless Communications, Third Edition

Chapter 3
Radio Frequency Communications

Objectives

- List the components of a radio system
- Describe the factors that affect the design of a radio system
- Discuss why standards are beneficial and list the major telecommunications standards organizations
- Explain the radio frequency spectrum

Components of a Radio System

- Components include:
  - Filters
  - Mixers
  - Amplifiers
  - Antennas

Filters

- Filter: removes unwanted RF signals
- RF filter
  - Either passes or rejects a signal based on frequency
- Types of filters
  - Low-pass filter: maximum frequency is set and all signals below that value are allowed
  - High-pass filter: minimum frequency is set and all signals above that level are allowed
  - Bandpass filter: sets a range called a passband and signals that fall within the passband are allowed

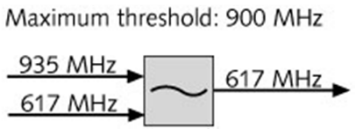

Figure 3-2 Low-pass filter

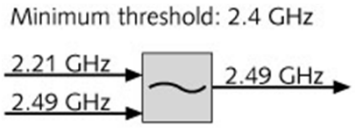

Figure 3-3 High-pass filter

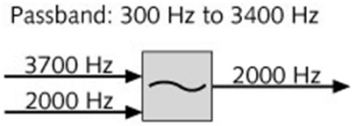

Figure 3-4 Bandpass filter

Filters

- Filters are also found in transmitters
  - Used to eliminate some unwanted frequencies called harmonic oscillations
    - Result from the process of modulating the signal before transmission
- Intermediate frequency (IF) signal
  - Resulting output from the modulation process
- IF signal is filtered through a bandpass filter
  - To remove any undesired high- or low-frequency signals

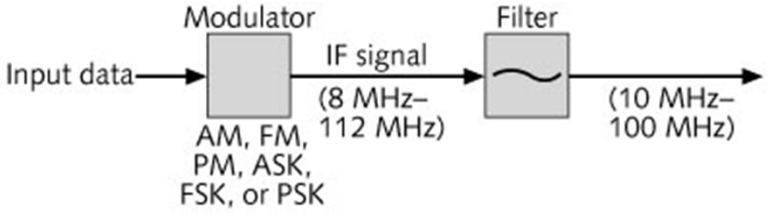

Figure 3-5 Filter function in a radio transmitter

Mixers

- Mixers: combine two radio frequency inputs to create a single output
  - Output is in the range of the highest sum and the lowest difference of the two frequencies
  - Sum and differences are known as the sidebands of the frequency carrier
    - Shield transmitted signal from “stray” signals
- Used to convert an input frequency to a specific desired output frequency

Figure 3-6 Mixer symbol

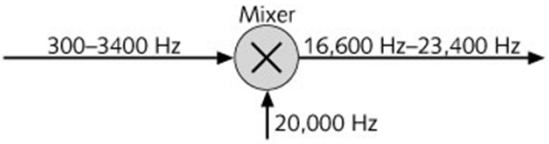

Figure 3-7 Mixer output

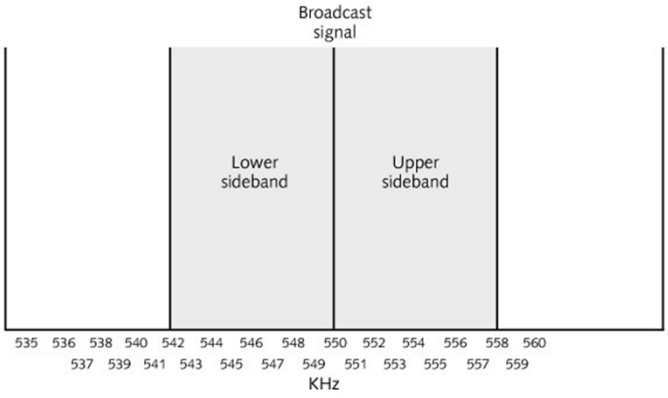

Figure 3-8 AM radio sidebands

Amplifiers

- Amplifiers: increase the amplitude of an RF signal
- RF signals tend to lose intensity (amplitude)
  - When they move through circuits, air, or space
- Amplifier is an active device
  - Must be supplied with electricity
  - Uses this electricity to increase a signal's intensity or strength
    - Then output an exact copy of the input signal with a higher amplitude

Antennas

- Antennas: transmit or receive an RF signal
  - Antennas will be discussed in greater detail in Chapter 4

Figure 3-11 Antenna symbol

Component Name	Function	Block Diagram Symbol
Filter	Accept or block RF signal	
Mixer	Combine two radio frequency inputs to create a single output	
Amplifier	Boost signal strength	
Antenna	Send or receive an electromagnetic wave	

Table 3-1 Radio system components and their symbols

Design of a Radio System

- Designers of radio communications systems
  - Need to consider how the systems will be used
  - Other considerations:
    - Multiple user access
    - Transmission direction
    - Switching
    - Signal strength

Multiple Access

- Only a limited number of frequencies are available for radio transmission
  - Conserving the use of frequencies is important
- Conserving a frequency
  - Share a frequency among multiple users
- Methods that allow multiple access
  - Frequency Division Multiple Access (FDMA)
  - Time Division Multiple Access (TDMA)
  - Code Division Multiple Access (CDMA)

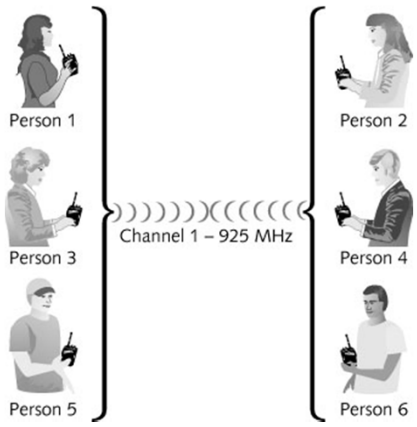

Figure 3-12 Multiple access

Multiple Access

- Frequency Division Multiple Access (FDMA)
  - Divides the bandwidth of a channel into several smaller frequencies bands
  - Most often used with analog transmissions
  - Cable television is transmitted using FDMA
  - Drawback of FDMA: Crosstalk
    - Causes interference on the other frequency and may disrupt the transmission

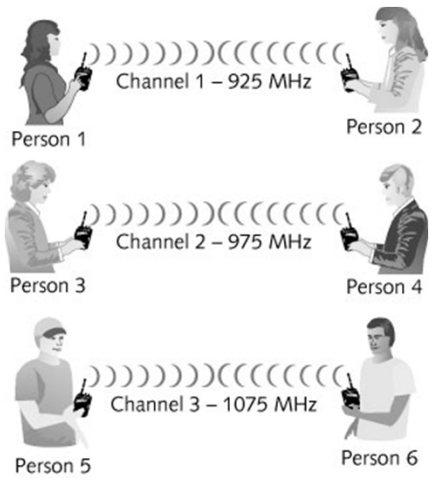

Figure 3-13 Frequency Division Multiple Access (FDMA)

Multiple Access

- Time Division Multiple Access (TDMA)
  - Divides the transmission time into several slots
  - Each user is assigned the entire frequency for the transmission
    - For a fraction of time on a fixed, rotating basis
  - Advantages
    - Uses the bandwidth more efficiently
    - Allows both data and voice transmissions to be mixed using the same frequency

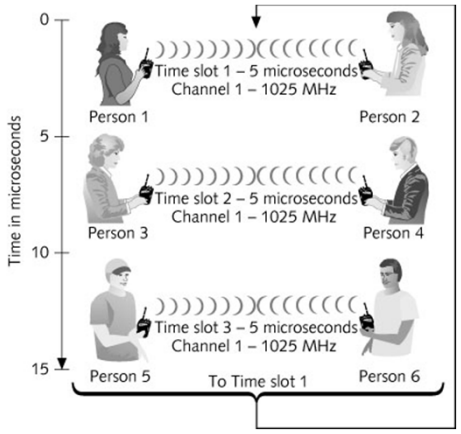

Figure 3-14 Time Division Multiple Access (TDMA)

Multiple Access

- Code Division Multiple Access (CDMA)
  - Used primarily for cellular telephone communications
  - Uses direct sequence spread spectrum (DSSS)
    - With a unique digital spreading code (PN code)
  - Before transmission occurs
    - High-rate PN code is combined with the data to be sent
      - Spreads the signal over a wide frequency band
  - The longer the code is, the more users will be able to share the same channel
  - Number of chips in the code
    - Determines the amount of spreading or bandwidth

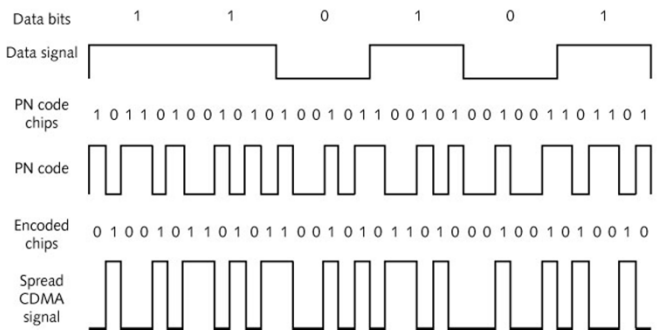

Figure 3-15 CDMA spreading of a data signal by a PN code

Multiple Access

- Code Division Multiple Access (cont'd)
  - Spreading process is reversed at the receiver
    - Code is de-spread to extract the original data bit transmitted

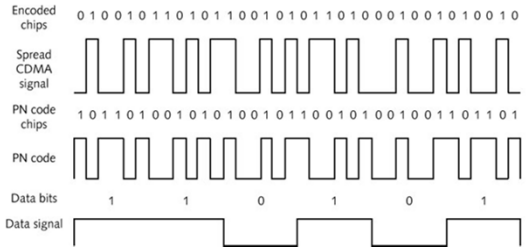

Figure 3-16 De-spreading a CDMA signal to recover the data bits

Multiple Access

- Code Division Multiple Access (cont'd)
  - Advantages
    - Can carry up to three times the amount of data as TDMA
    - Transmissions are much harder to eavesdrop on
    - A would-be eavesdropper must also know the exact chip in which the transmission starts

Transmission Direction

- Simplex transmission
  - Occurs in only one direction
  - Rarely used in wireless communication today
    - Except for broadcast radio and television
- Half-duplex transmission
  - Sends data in both directions
    - But only one way at a time
  - Used in consumer devices such as citizens band (CB) radios or walkie-talkies
    - User must hold down the “talk” button while speaking

Figure 3-18 Simplex transmission

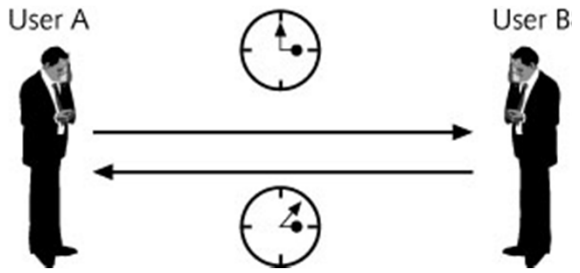

Figure 3-19 Half-duplex transmission

Transmission Direction

- Full-duplex transmission
  - Allows data to flow in both directions simultaneously
  - Example: A telephone system
  - If the same antenna is used for wireless transmission and reception
    - A filter can be used to handle full-duplex transmissions
  - Full-duplex wireless communications equipment
    - Sends and receives on different frequencies

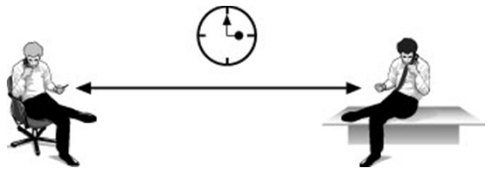

Figure 3-20 Full-duplex transmission

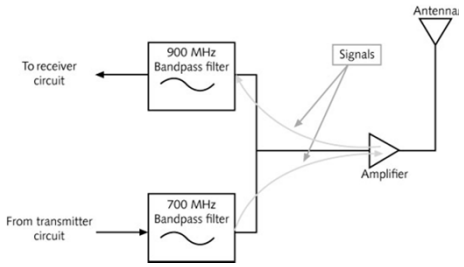

Figure 3-21 Using a single antenna in full-duplex RF communications

Switching

- Involves moving the signal from one wire or frequency to another
- Circuit switching
  - Type of switching used by telephone systems
  - A dedicated and direct physical connection is made between the caller and the recipient
    - Direct connection lasts until the end of the call
- Packet switching
  - Used by data networks
  - Data transmissions are broken into packets
  - Each packet is sent independently

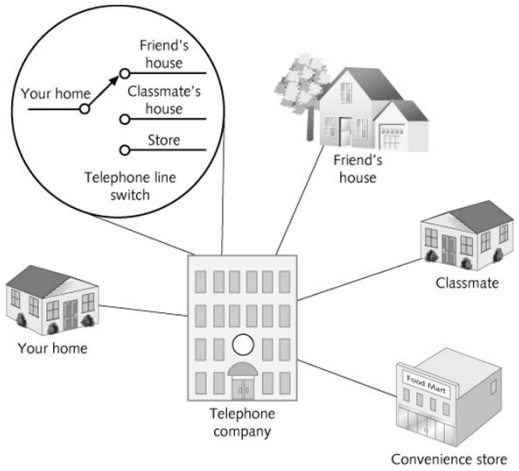

Figure 3-22 Telephone call switching

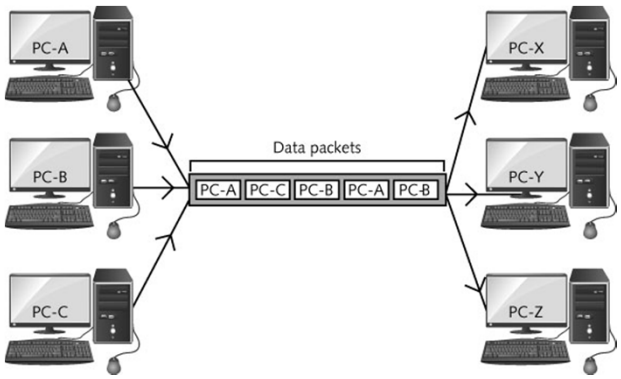

Figure 3-23 Packet switching

Switching

- Packet switching advantages
  - Allows better utilization of the network
  - Allows multiple computers to share the same line or frequency
  - If a transmission error occurs
    - It usually affects only one or a few packets
    - Only packets affected must be resent, not entire message

Signal Strength

- Strength of the signal in a radio system
  - Must be sufficient for the signal to reach its destination
    - With enough amplitude to be picked up by the antenna
    - And for the information to be extracted from it
- Electromagnetic interference (EMI)
  - Affects radio signal strength
  - Also called noise
- Signal-to-noise ratio (SNR)
  - Compares signal strength with background noise
  - When strength of a signal is well above the noise, interference can be filtered out

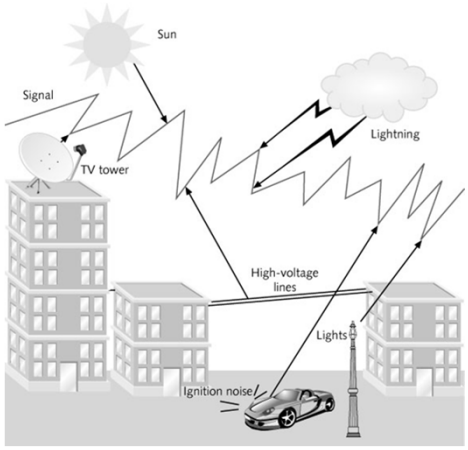

Figure 3-24 Sources of EMI or noise (interference)

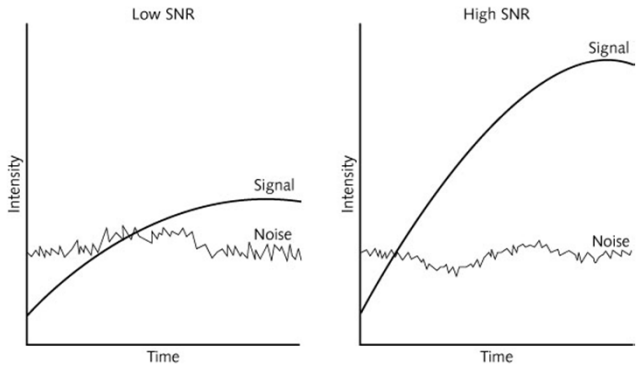

Figure 3-25 Signal-to-noise ratio (SNR)

Signal Strength

- To reduce the interference of noise
  - Boost the strength of the signal
  - Use of filters on the receiving end
- Attenuation
  - A loss of signal strength
- Multipath distortion
  - As a radio signal is transmitted, the electromagnetic waves spread out
  - Waves travel different paths between transmitter and receiver
    - Arrive at different times and out of phase

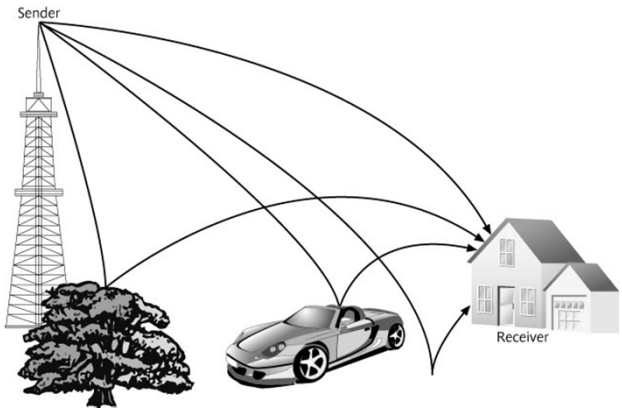

Figure 3-26 Multipath interference or distortion

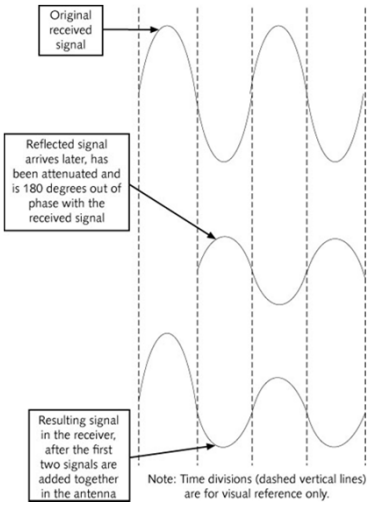

Figure 3-27 Effect of multipath distortion in a signal

Signal Strength

- Directional antenna
  - Used to minimize multipath distortion
  - Radiates electromagnetic waves in one direction only
- Other methods to reduce multipath distortion
  - Use an amplifier in front of receiver to increase SNR
  - Transmit the same signal on separate frequencies

Understanding Standards

- Standards for telecommunications have been in place almost since the beginning of the industry
  - Standards have played an important role in the rapid growth of the industry

The Need For Standards

- Standards
  - Commonly accepted technical specifications
- Telecommunications requires standards exist for the design, implementation, and operation of the equipment
- A lack of standards between devices would prevent communications from taking place

Advantages and Disadvantages of Standards

- Advantages
  - Guarantee device interoperability
  - Create competition
    - Competition results in lower costs for consumers and improvements in products
    - Competition also results in lower costs for manufacturers
  - Help consumers protect their investment in equipment
- Disadvantages
  - Can be a threat to industries in large countries
  - Although standards are intended to create unity
    - They can have the opposite effect

Types of Standards

- De Facto Standards
  - Not official standards
  - Common practices that industry follows
- De jure Standards
  - Also called official standards
  - Controlled by an organization or body
  - Process for creating standards can be very involved
- Consortia
  - Industry-sponsored organizations that promote a specific technology

Telecommunications Standards Organizations

- United States Standards Groups
  - American National Standards Institute (ANSI)
  - Telecommunications Industries Association (TIA)
  - Internet Engineering Task Force (IETF)
  - Internet Architecture Board (IAB)
  - Internet Society (ISOC)
  - Institute of Electrical and Electronics Engineers (IEEE)
- Multinational Standards Groups
  - European Telecommunications Standards Institute (ETSI)

Telecommunications Standards Organizations

- International Standards Groups
  - International Telecommunications Union (ITU)
  - International Organization for Standardization (ISO)

Regulatory Agencies

- Enforcing telecommunications regulations is important
- Regulations must be enforced by an outside agency
- Federal Communications Commission (FCC)
  - Primary regulatory agency for telecommunications in the United States
  - Responsibilities
    - Develops and implements regulatory programs
    - Processes applications for licenses and other filings
    - Analyzes complaints and conducts investigations
    - Take part in congressional hearings
    - Represents the United States in negotiations
    - Regulates radio and television broadcast stations

Radio Frequency Spectrum

- Radio frequency spectrum
  - Entire range of all radio frequencies that exist
  - Range extends from 10 KHz to over 30 GHz
  - Spectrum is divided into 450 different sections (bands)
- Radio frequencies of common devices include:
  - Garage door openers, alarm systems: 40 MHz
  - Baby monitors: 49 MHz
  - Radio-controlled airplanes: 72 MHz
  - Radio-controlled cars: 75 MHz
  - Wildlife tracking collars: 215 MHz–220 MHz
  - Global positioning system: 1.227 GHz and 1.575 GHz

Band (Acronym)	Frequency	Common Uses
Very low frequency (VLF)	10 KHz to 30 KHz	Maritime ship-to-shore
Low frequency (LF)	30 KHz to 300 KHz	Radio location such as LORAN (Long Range Navigation) Time signals for clock synchronization (WWVB)
Medium frequency (MF)	300 KHz to 3 MHz	AM radio
High frequency (HF)	3 MHz to 30 MHz	Short wave radio, CB radio
Very high frequency (VHF)	30 MHz to 144 MHz 144 MHz to 174 MHz 174 MHz to 328.6 MHz	TV channels 2–6, FM radio Taxi radios TV channels 7–13
Ultra high frequency (UHF)	328.6 MHz to 806 MHz 806 MHz to 960 MHz 960 MHz to 2.3 GHz 2.3 GHz to 2.9 GHz	Public safety: Fire, Police, etc. Cellular telephones Air traffic control radar WLANs (802.11b/g/n)
Super high frequency (SHF)	2.9 GHz to 30 GHz	WLANs (802.11a/n)
Extremely high frequency (EHF)	30 GHz and above	Radio astronomy

Table 3-3 Radio frequency bands

Radio Frequency Spectrum

- International spectrum allocations are established by the ITU
- License exempt spectrum
  - Unregulated bands
    - Radio spectra available without charge to any users without a license
  - Devices from different vendors may attempt to use the same frequency (disadvantage)

Unlicensed Band	Frequency	Total Bandwidth	Common Uses
Industrial, Scientific and Medical (ISM)	902–928 MHz 2.4–2.4835 GHz 5.725–5.875 GHz	259.5 MHz	Cordless phones, WLANs, wireless public branch exchanges
Unlicensed Personal Communications Systems	1910–1930 MHz	20 MHz	WLANs, wireless public branch exchanges
Unlicensed National Information Infrastructure (U-NII)	5.15–5.25 GHz 5.15–5.25 (Low) 5.25–5.35 GHz (Mid) 5.47–5.725 (Worldwide) 5.725–5.825 GHz (Upper)	555 MHz	WLANs, wireless public branch WLANs wireless public branch exchanges, campus applications, long outdoor links
Millimeter Wave	59–64 GHz	5 GHz	In-home networking applications

Table 3-4 Unregulated bands

Radio Frequency Spectrum

- Recent developments that have had an impact on the crowded radio frequency spectrum
  - Adaptive array processing
    - Replaces a traditional antenna with an array of antenna elements
  - Ultra-wideband transmission (UWB)
    - Uses low-power, precisely timed pulses of energy that operate in the same frequency spectrum as low-end noise
    - Currently used in limited radar and position-location devices

Summary

- Radio frequency system hardware components
  - Filters, mixers, amplifiers, and antennas
- Filter is used either to accept or block a radio frequency signal
- Mixer combines two inputs to create a single output
- Amplifier increases a signal's intensity or strength
- Multiple access methods
  - FDMA
  - TDMA
  - CDMA

Summary

- Types of data flow
  - Simplex
  - Half-duplex
  - Full-duplex
- Switching involves moving the signal from one wire or frequency to another
- Electromagnetic interference (EMI) is sometimes called noise
  - Signal-to-noise ratio (SNR)
    - Measure of signal strength relative to background noise

Summary

- Standards for telecommunications
  - In place almost since the beginning of the industry
- Radio frequency spectrum
  - The entire range of all radio frequencies that exist
- Recent developments that have had an impact on the crowded radio frequency spectrum
  - Adaptive array processing
  - Ultra-wideband transmission