Chapter 4

How Antennas Work

Guide to Wireless Communications, 4th Edition
© 2017, Cengage Learning

Review – Antenna

- Type
  - Passive antennas
  - Active antennas
    - With an amplifier built-in, not common, much higher cost
- Size
  - Inversely proportional to the frequency of the signal it is designed to transmit or receive
    - Lower frequency signals require larger antennas
- Shapes
  - Vary according to their specific applications

Topics

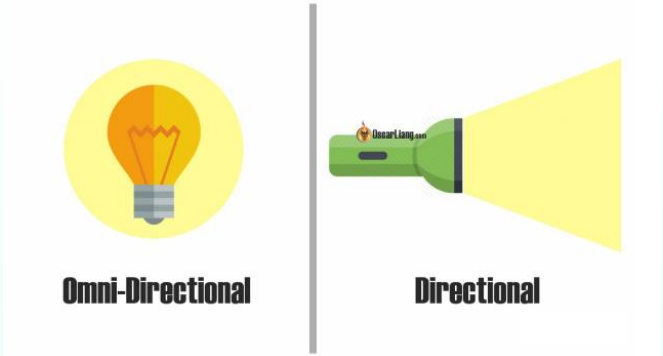
1. Gain and Loss
2. Antenna Characteristics
3. Antenna Performance
4. Antenna System Implementation

Antenna Performance

- A measure of how efficiently an antenna can radiate an RF signal
- Design, installation, size, and type of antenna can affect its performance
- How antennas work
  - Radiation Patterns
  - Antenna Polarization
  - Antenna Dimensions

Signal Strength and Direction

- Distance between the transmitter and receiver determines the strength of the signal
  - Most antennas are passive type, transmitters produce a finite amount of RF energy
- Free space loss
  - Signals lose energy as EM wave travels away from antenna
- Omnidirectional antenna divides strength of signal in a 360-degree circle around the antenna
- Directional antenna sends most energy in the direction the antenna is pointed
  - RF wave travels farther

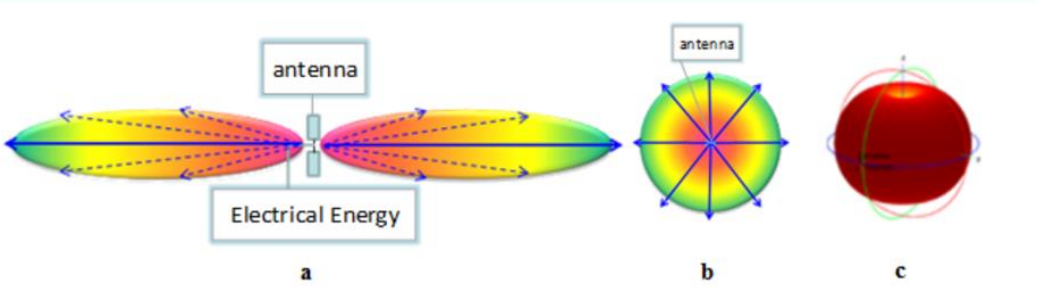


Wavelength

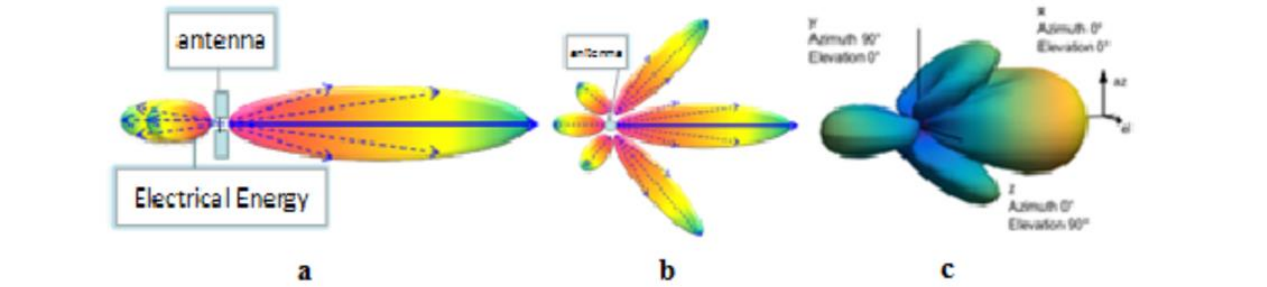
- Wavelength: length of a single RF sine wave
  - Determines the size of an antenna
- Full-wave antenna
  - Antenna transmits and receives a signal most efficiently at a specific frequency
    - When it is as long as the full length of the wave
  - In most cases, this is not practical
- Half-wave antennas, quarter-wave antennas, or eighth-wave antennas are more commonly for practical reasons

Radiation Patterns

- Antennas emit signals in two dimensions
  - Horizontally and vertically



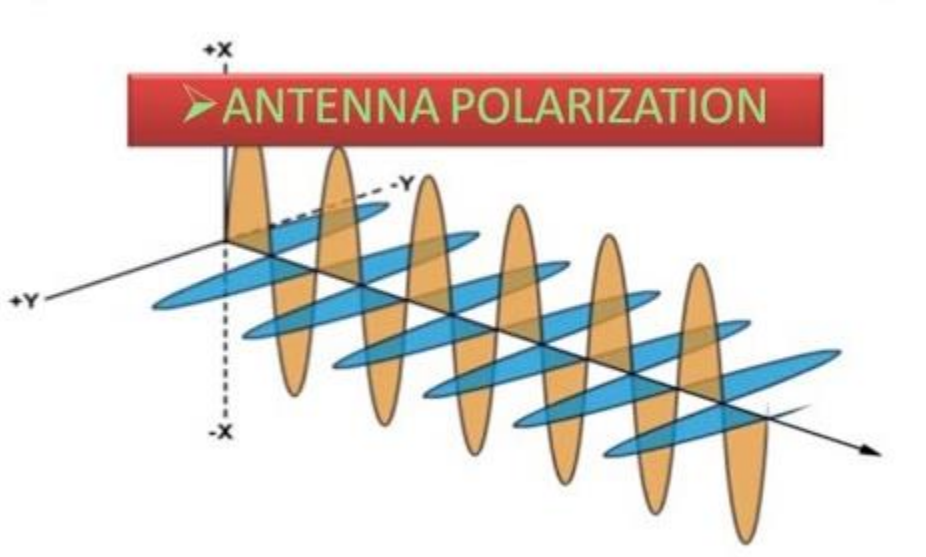
Radiation pattern of omnidirectional antenna: a - vertical plane, b - horizontal plane, c - 3D image



Radiation pattern of directional antenna: a - vertical plane, b - horizontal plane, c - 3D image

Antenna Polarization

- Antenna polarization: orientation of the wave leaving the antenna
  - Vertical polarization
    - Sine waves travel up and down when leaving antenna
  - Horizontal polarization
    - Sine waves travel from side to side on a horizontal plane



- Most efficient signal transmission and reception is experienced when both antennas are equally polarized

Antenna Dimensions

- One-dimensional antennas
  - Basically, a length of wire or metal
  - Monopole antenna
    - Straight piece of wire or metal, usually a quarter of the wavelength, with no reflecting or ground element
  - Dipoles are commonly built as two monopoles
    - Mounted together at the base
  - A monopole antenna is less efficient than a dipole

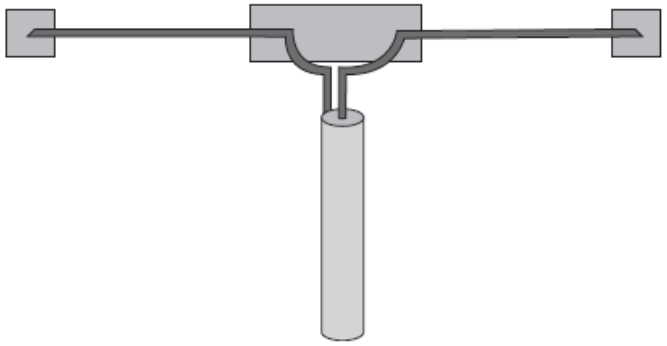


Figure 4-13 Common dipole antenna

Antenna Dimensions

- Two-dimensional antennas
  - Antennas organized in a two-dimensional pattern
- Examples: horn antenna
  - Resembles a large horn with wide end bent to one side
  - Common in telephone networks
  - Used to transmit microwave signals between two distant towers

Figure 4-14 Telephone transmission tower showing two horn antennas

Smart Antennas

- Used primarily in cellular telephony and WiMAX
- "Learn" where the mobile receiver is
  - Can track and focus RF energy in specific direction
  - Uses several narrow beam antennas pointing in different directions
  - Has the effect of sending the energy beam in a particular direction

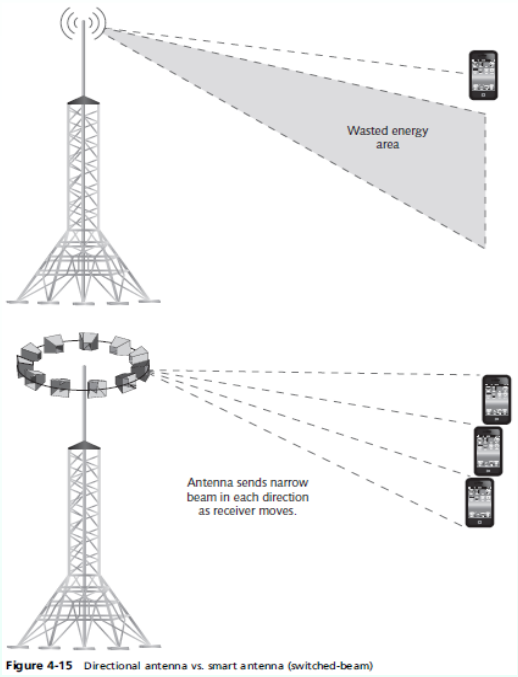


Figure 4-15 Directional antenna vs. smart antenna (switched-beam)

Topics

1 Gain and Loss

2 Antenna Characteristics

3 Antenna Performance

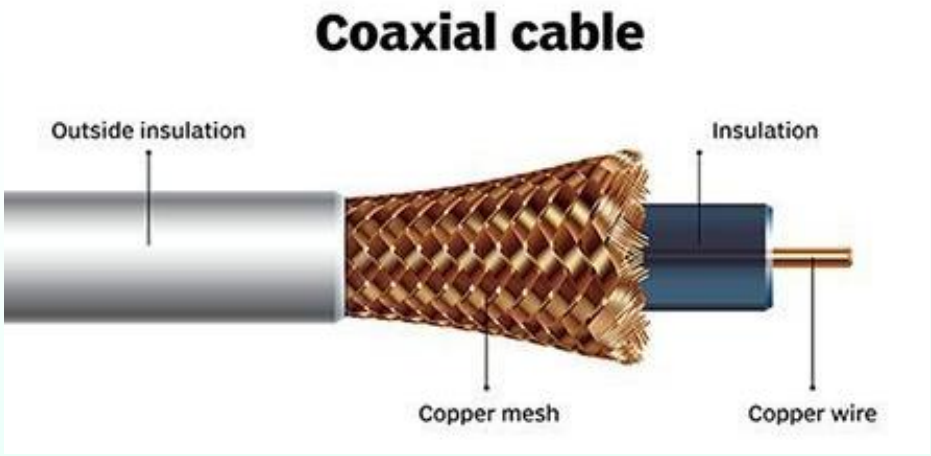
4 Antenna System Implementation

Antenna System Implementation

- Proper installation of antennas
  - Knowledge of the user's requirements
  - Deal with various challenges such as physical obstacles, municipal building codes, and other regulatory restrictions
- Major concerns for the RF technician
  - System's performance
  - Reliability
  - Security

Antenna Cables

- Most antennas are connected to the transmitter or receiver using coaxial cable
- You must consider the signal loss caused by the connector and by the cable itself
- Cable loss is measured in relation to the length of the cable
  - Use special low-loss antenna cables to minimize signal loss



RF Wave Propagation Groups

Group	Frequency Range
Ground waves	3KHz to 2MHz
Sky waves	3KHz to 2MHz
Line-of-sight waves	30MHz to 300GHz

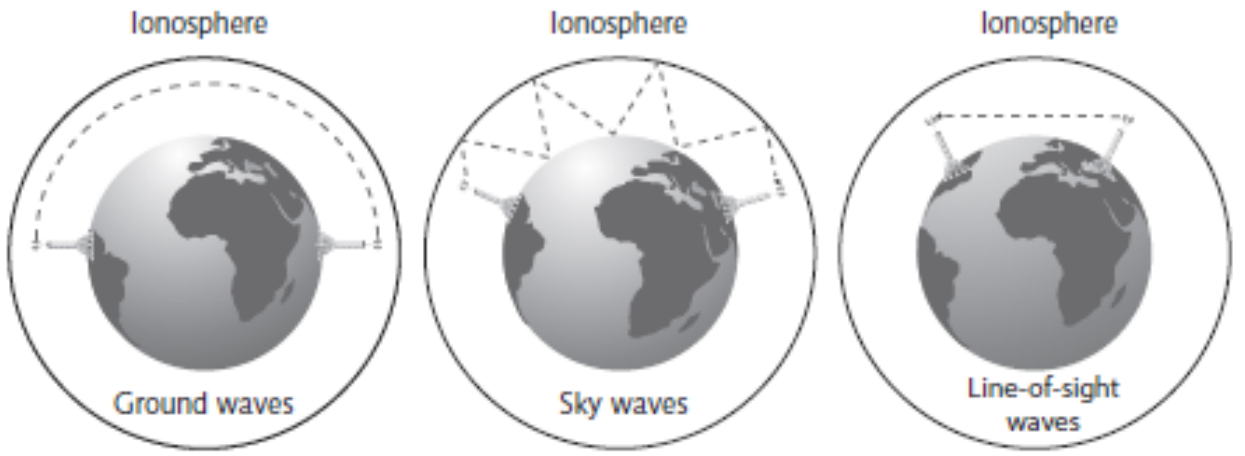


Figure 4-20 How radio waves propagate

Links

- Point-to-multipoint wireless link
  - One transmitter communicates with several mobile clients
  - Maximize the signal distance by
    - Using an omnidirectional antenna at the central location
    - Using directional, higher-gain antennas at the remote locations
- Point-to-point wireless link
  - Connects two computer networks in different buildings
  - Directional antennas provide the most reliable method of transmitting RF waves

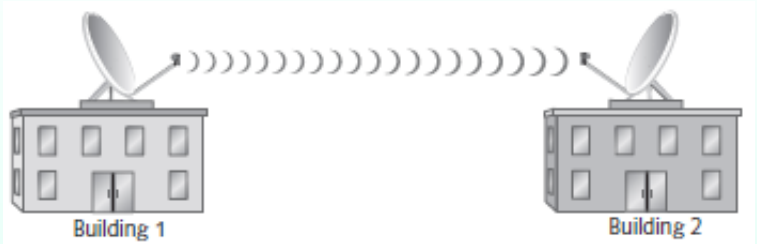


Figure 4-22 Point-to-point link using directional antennas

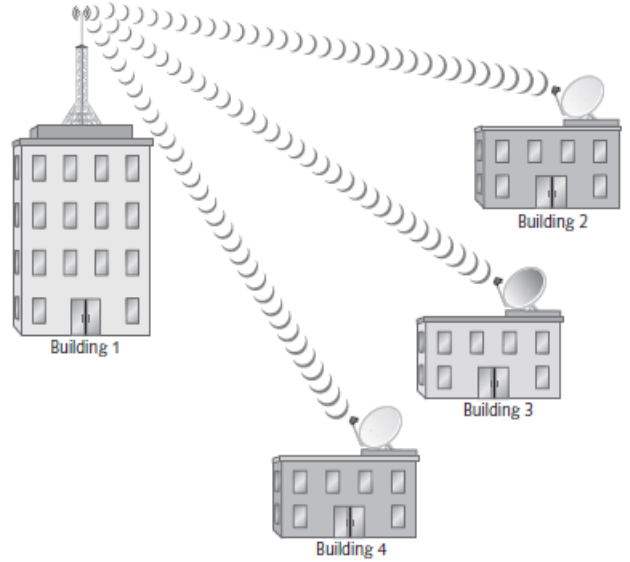


Figure 4-21 Point-to-multipoint links using a combination of omnidirectional and direct

Fresnel Zone

- RF waves have a tendency to spread out
  - Space between two antennas would be more accurately represented by an ellipse
    - Called the **Fresnel zone**
- When planning a wireless link
  - At least 60% of the Fresnel zone must be kept clear of obstructions
  - May affect the height of the antenna tower

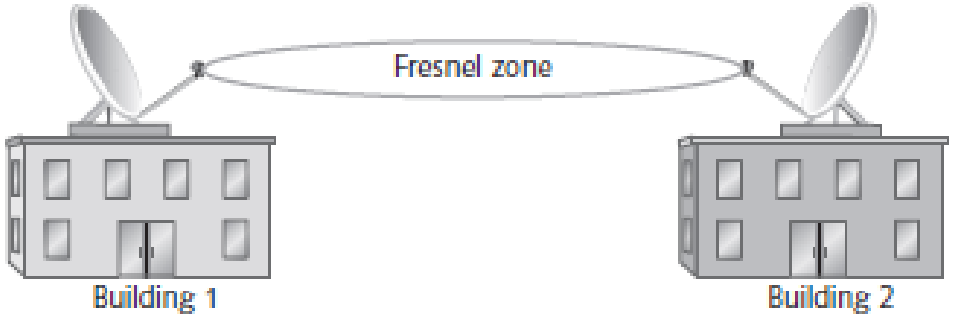


Figure 4-23 Fresnel zone

Link Budgets

- Link budgets
  - Calculate whether you have enough signal strength to meet the receiver's minimum requirements
- Information needed to calculate link budget includes:
  - Gain of the antennas
  - Cable and connector losses for receiver and transmitter
  - Receiver sensitivity
  - Free space loss figure
- Many link budgeting tools available on the Internet

Challenges of Outdoor Links

- Radio waves can reflect, diffract, or be absorbed by some materials
- Weather phenomena can affect the performance and reliability of wireless links
  - Examples: heavy fog, rain, dust, or snowstorms
- Air disturbances and changes in temperature can also affect wireless links
- Seasonal changes can impact a wireless link
  - An antenna that was setup in winter (when there were no leaves on trees) may not work as well in the spring (when leaves can block a percentage of the Fresnel zone)

Challenges of Outdoor Links

- While planning an outdoor link:
  - Always consider environmental conditions
    - Check the history of the region's weather
  - Check for short- and long-term plans that may interfere with your intended link
  - Consider the possibility of another link that may interfere with your link