CHAPTER THREE

HOW WIRELESS WORKS

After completing this chapter you should be able to do the following:

- Explain the principles of radio wave transmissions
- Describe RF loss and gain, and how it can be measured
- List some of the characteristics of RF antenna transmissions
- Describe the different types of antennas

Real-Life Wireless

How do you supply Internet and network access to more than 80 rock bands, thousands of workers, and over 130,000 spectators spread out over a 650-acre farm? You guessed it: use a wireless LAN.

For four days in June fans from around the world came to hear Bob Dylan, Dave Matthews, The Dead, Patti Smith, Wilco, and dozens of others perform at the 2004 Bonnaroo Music Festival south of Nashville, Tennessee. During the festival the equivalent of a small city was temporarily erected on the site, with administrative offices, six sound stages, general stores, concession stands, campsites, and parking facilities. The challenge was how to manage electronic tickets, shipping and receiving, issuing paychecks, and other functions that typically require a network. The solution was to deploy a WLAN. With a coverage area of over five square miles, it was the largest temporary WLAN in U.S. history. Although the festival itself lasted only four days, it took over six months to plan, design, construct, set up, and tear down the wireless network.

Utility poles located throughout the farm were fitted with access points (APs) powered by diesel generators, resulting in hundreds of hotspots that provided wireless network and Internet access to all administrators, service employees, ticket takers, as well as musicians and their crews. Attendees with a laptop or PDA with a wireless NIC could use the network to stay connected with friends in the camping area or download songs from a huge library of music supplied by the performing artists. There was also an Internet café, where 40 laptop computers were available to check e-mail, download music, and access the Internet.

As might be expected, there were a few problems. The sound mixers consumed a large portion of the wireless bandwidth as they recorded and then mixed the music for each band onto 8 terabytes (TB) of local storage before streaming it to servers located off site. Future plans call for live streaming of audio and video to local servers for immediate sharing and downloading by attendees. Another challenge was delivering the wireless signal to the aluminum trailers set up for musicians and their crews. Antennas had to be placed in front of the trailers' windows and doors because wireless signals do not always pass through metal walls. And just like in many offices, attendees brought in rogue access points that conflicted with the main wireless network.

Is not uncommon to hear the question, "Why do I have to know *how* it works? I only want to *use* it!" This is a valid question. For individuals who are only occasional end users of a technology there is little need to invest the time and energy to understand the underlying technology. Also, if the device is a basic commodity item, such as a standard handheld calculator or desktop telephone, there is little advantage to understanding the technology in order to troubleshoot if the device should fail. The easiest and cheapest solution is simply to buy another one.

For end users who spend a lot of time working with a device that requires significant capital to purchase, like a car or a computer, understanding the technology can be a tremendous advantage for troubleshooting. Imagine the frustration of a help desk support person who receives a telephone call from a user who says, "My computer won't work; come fix it." If the user can perform basic troubleshooting techniques that can isolate the problem ("When I start my computer the monitor does not come on but I do hear one beep") it greatly facilitates solving the problem quickly.

The same holds true with understanding wireless technology. Knowing how wireless works can become an important tool in troubleshooting a WLAN that is not functioning correctly. Although access points (APs) are no longer expensive items to purchase, often the problem with a wireless network does not lie with the equipment but instead with the signal that is being transmitted and obstructions to that signal. Knowing how a wireless signal is transmitted can help in isolating and correcting problems.

In this chapter you explore the fundamentals of how wireless technology works. Although wireless transmissions can take place using infrared or radio waves as discussed in Chapter 2, radio transmission is the preferred method used today and is the focus of this chapter. You begin by looking at the principles behind sending voice and data through radio wave transmissions. Next, you learn how radio frequency waves actually behave and how this behavior can be measured. Finally, you find out about one of the most important elements of a radio wave system, namely the antenna.

Radio Wave Transmission Principles

Understanding the principles of radio wave transmission is important not only for troubleshooting wireless LANs but also to create a context for understanding wireless terminology. In this section you explore the fundamentals of radio waves and how they can transmit data.

What Are Radio Waves?

Traditional wired communications use copper wires or fiber optic cables to send and receive data. Wireless transmissions, of course, do not use these or any other visible media. Instead, data travels on invisible radio waves.

If you stand next to a campfire at night you can see the light from the fire as well as feel its heat. The light and heat from the fire move through space from the burning logs to you as a special type of wave known as an **electromagnetic wave**. These waves require no special medium for movement. They travel freely through space in all directions at the speed of light, or approximately 3 million meters (186,000 miles) per second.

NOTE

Some 17th-century scientists theorized that there was a special medium in space called the "ether" through which light and heat travel. This was later proven to be incorrect. The network type Ethernet was named for the ether that was proposed in these early theories.

Suppose you pick up a garden hose to put out the campfire. If you move your hand up and down the water will create what look like waves that move up and down, as seen in Figure 3-1. This movement of water from a garden hose is similar to the movement of electromagnetic waves.

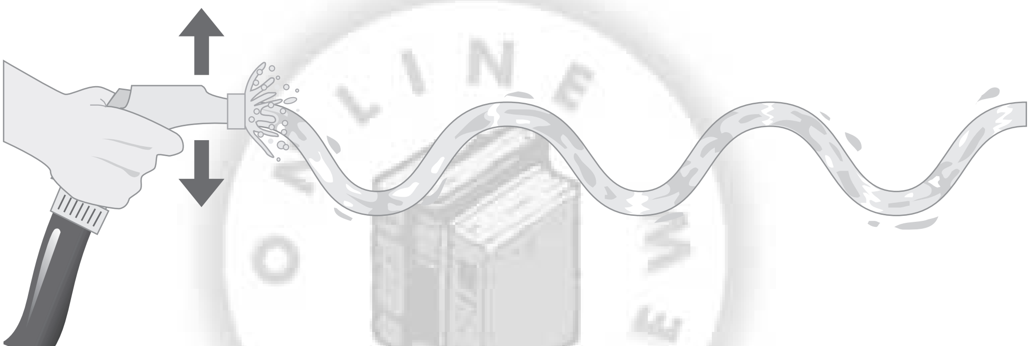

Figure 3-1 Garden hose waves

Light and heat waves, however, have limitations regarding their movement. Light waves, for example, cannot penetrate through materials like wood or concrete, and heat waves are absorbed by surrounding objects. Thus the distance that light and heat waves can travel is limited.

Light and heat are not the only kinds of electromagnetic waves. Another type is called a **radiotelephony wave** or **radio wave**. 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 an electromagnetic radio wave that spreads out through space in all directions.

NOTE

All forms of electromagnetic energy, from gamma rays to radio waves, travel through space in waves.

Radio waves do not have the limitations that light and heat waves do. Unlike heat waves, radio waves can travel longer distances because they are not absorbed by objects. Radio waves can also penetrate non-metallic objects, whereas light waves cannot. And visible light waves and heat waves can be seen and felt, but radio waves are invisible. These characteristics are summarized in Table 3-1. Because of these characteristics, radio waves are a superior means of transmitting data without wires over other types of waves.

NOTE

Guglielmo Marconi first used radio waves to transmit a Morse code signal across the Atlantic Ocean in 1901. This type of transmission was originally called "wireless." An international conference in Berlin in 1906 officially changed the name "wireless" to "radio," from the Latin word *radius* meaning a ray or beam.

Table 3-1 Comparison of wave characteristics

Type of Wave	Travels Long Distances	Invisible	Imperceptible	Penetrates Solid Objects
Light	No	No	No	No
Heat	No	Yes	No	No
Radio	Yes	Yes	Yes	Yes

Analog vs. Digital Transmissions

Consider again standing out in your yard with a garden hose to put out the campfire. As you move your hand up and down, the water will create what look like waves that move up and down. The waves are continuous, as long as the water is turned on. These waves represent an **analog signal**. An analog signal is a continuous signal with no "breaks" in it. This means that no individual element of an analog signal can be uniquely identified from another element of the signal. Figure 3-2 illustrates an analog signal. Audio, video, and even light are all examples of analog signals.

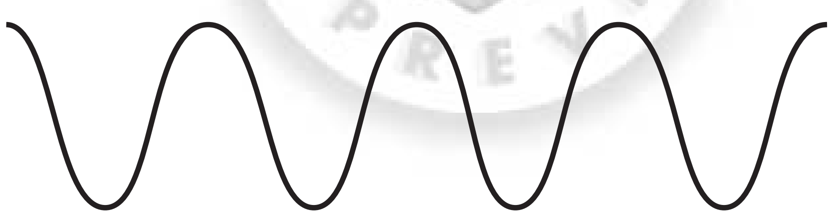

Figure 3-2 Analog signal

Yet what if you took your thumb and placed it over the end of the garden hose for a second and then removed it? Water would stop flowing (while your thumb was over the hose) and then would squirt out (when you moved your thumb). This is illustrated in Figure 3-3. This on-off activity is similar to a **digital signal**. A digital signal consists of data that is discrete or separate, as opposed to an analog signal, which is continuous. A digital signal has numerous starts and stops throughout the signal stream. Morse code with its series of dots and dashes with space between is an example of a digital signal. Figure 3-4 illustrates a digital signal.

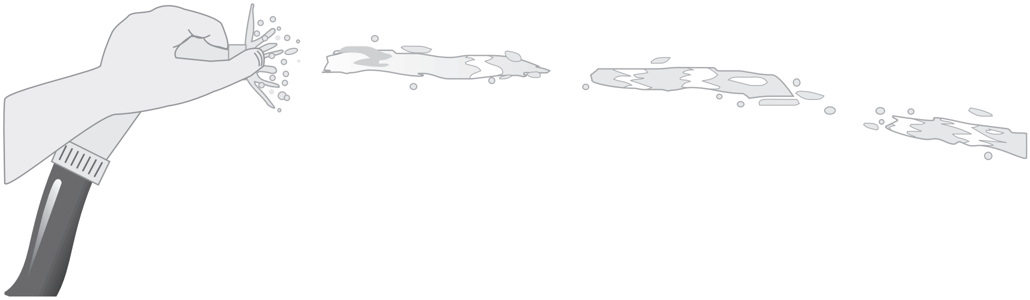

Figure 3-3 Squirting garden hose

Figure 3-4 Digital signal

NOTE

Computers operate using digital signals (binary code is discrete, thus it is digital). When analog data, such as a video image or an audio sound, needs to be stored on the computer, it must be first converted into a digital format.

When a digital signal needs to be transmitted over an analog medium, such as when a computer needs to send digital signals over an analog telephone line or TV cable, a device known as a **modem** (for MOdulator/DEModulator) is used. On the originating end a modem converts the distinct digital signals into a continuous analog signal for transmission. Likewise, on the receiving device end a modem will reverse the process, converting the analog signal back into digital.

Unlike telephone lines or TV cables, wireless LANs do not use analog signals for their transmission. This would require a modem device on each laptop or desktop computer that was part of the wireless network. Instead, WLANs use digital transmissions.

Frequency

Think about standing out in your yard with a garden hose again. If you move your hand up and down slowly while holding the hose you will create long waves, as seen in Figure 3-5. If you move your hand up and down rapidly, the waves become shorter, as seen in Figure 3-6. Depending upon how fast you move your hand the waves will vary, from several inches to several feet in length.

The same is true with radio waves. The rate at which an event occurs (like moving the garden hose up and down) will result in different radio waves being created. This creates a radio wave's **frequency**. That is, how *frequently* an event occurs can create different

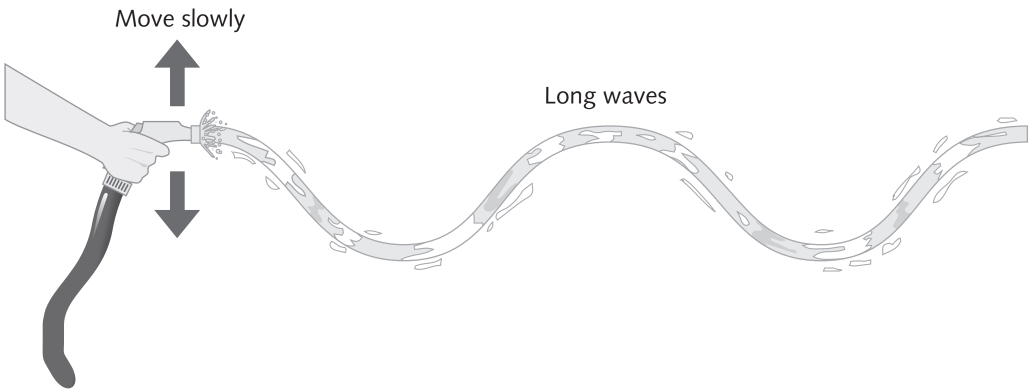

Figure 3-5 Long waves

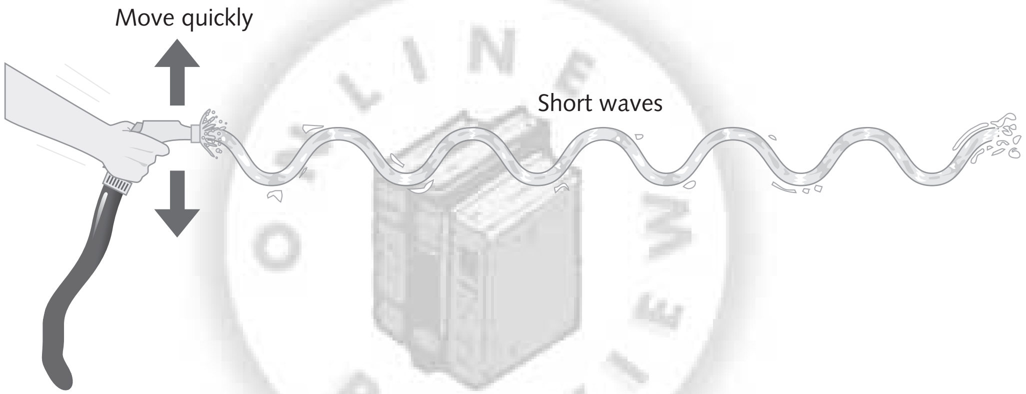

Figure 3-6 Short waves

frequencies. The changing event that creates the different radio frequencies is called a **cycle**. If you start with your hand level at your waist holding the garden hose and then bring it up, then down and finally back to where you started, you have completed one cycle. Whenever the wave completes its trip and returns back to the starting point it has finished one cycle. Frequency is the number of times that a wave completes a given cycle. Although radio frequencies are based on the number of cycles per second, today the term **hertz (Hz)** is used for the unit of measurement instead of cycle. Because of the high number of cycles required, metric prefixes are used when referring to frequencies. A **kilohertz (KHz)** is a thousand hertz, a **megahertz (MHz)** is a million hertz, and a **gigahertz (GHz)** is one billion hertz. The wave measured as 710,000 Hz, or 710,000 cycles per second, would more properly be listed as 710 KHz.

Cycles are illustrated by an up-and-down wave called an **oscillating signal** or a **sine wave**. This is illustrated in Figure 3-7. Notice that the wave starts at zero, and then moves up to the maximum voltage (+), then down to the minimum voltage (-), and finally returns back to its starting point (0) before beginning all over again.

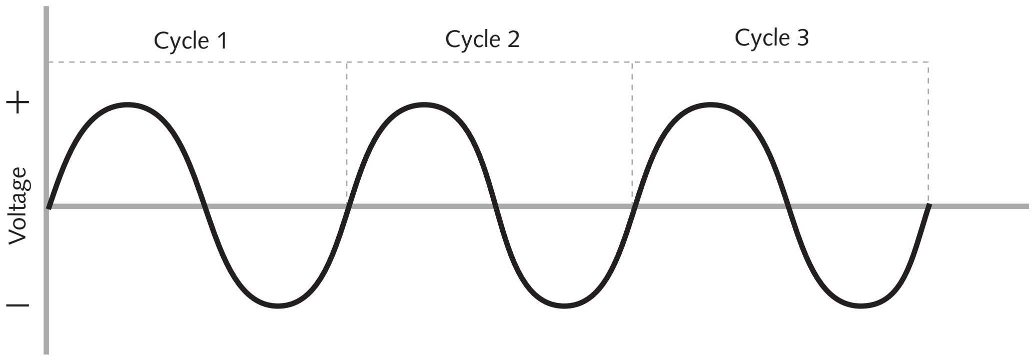

Figure 3-7 Sine wave

NOTE

In electrical terms the cycle produces what is known as an alternating current (AC) because it flows between positive (+) and negative (-). AC is the type of current that runs to the electrical outlets in a house. Direct current (DC) is found in batteries. With DC the current flows only from one terminal (+) to the other (-) and does not alternate.

How can the frequency be changed? Consider the garden hose once again. The pressure on the water line (typically 80 pounds per square inch) represents the **voltage (V)** in an electrical circuit and is measured in **volts**. The water flow (typically 9.5 liters or 2.5 gallons per minute) would represent the **current (I)** and is measured in **amperes** or **amps**. To increase the diameter of the garden hose from 1.2 cm (.5 inch) to 2.5 cm (1 inch) would reduce the **resistance (R)** and cause more water to flow.

Resistance is measured in **ohms** and the total amount of resistance is called the **impedance**. In electrical terms, voltage is equal to current times resistance, or V=I*R. Electrical power (P) is the voltage multiplied by the current (P=V*I) and is measured in **watts**. These electrical terms are summarized in Table 3-2.

NOTE

The formula for voltage (V=I*R) was first proposed in 1827 by German physicist George Ohm and is called Ohm's Law. Although Thomas Edison relied upon the principle of Ohm's Law in his development of the incandescent light, he later said, "At the time I experimented I did not understand Ohm's Law. Moreover, I do not want to understand Ohm's law; it would prevent me from experimenting."

Table 3-2 Electrical terminology

Electrical Term	Abbreviation	Description	Garden Hose Analogy	Unit of Measurement
Voltage	V	Electrical pressure on wire	Water pressure	Volts
Current	I	Rate of electrical flow	Water flow rate	Amperes (amps)
Resistance	R	Impedance of electrical flow	Diameter of hose	Ohms
Electrical power	P	Amount of energy	Total amount of water coming out of hose	Watts

The frequency of the radio wave can be changed by modifying the voltage or electrical pressure on the wire (remember that when electrical energy passes through a wire it creates a magnetic field in the space around the wire and as this field radiates it creates a radio wave). Radio transmissions send what is known as a **carrier signal**. Increasing the voltage will change the frequency of the carrier signal, which can be illustrated by a sine wave. In Figure 3-8 two different frequencies are illustrated. Notice that the lower frequency and the higher frequency still alternate to the same maximum and minimum voltage. A change in frequency is a result of how long it takes to reach the maximum, fall back to the minimum, and then return to neutral to complete a cycle.

NOTE

Frequency is an important part of music also. Each musical note vibrates at a particular frequency. The note A above middle C is 440 Hz and middle C is 263 Hz.

Modulation

The carrier signal sent by radio transmissions is simply a continuous electrical signal; the signal itself carries no information. How then can data be transmitted by a carrier signal? There are three types of modulations or changes to the signal that can be made to enable it to carry information: the height of the signal, the frequency of the signal, or the relative starting point. The height, frequency, and relative starting point are sometimes called the "three degrees of freedom." Modulation can be done on either analog or digital transmissions.

NOTE

Although WLAN transmissions are digital, understanding analog modulation helps in the understanding of digital modulation.

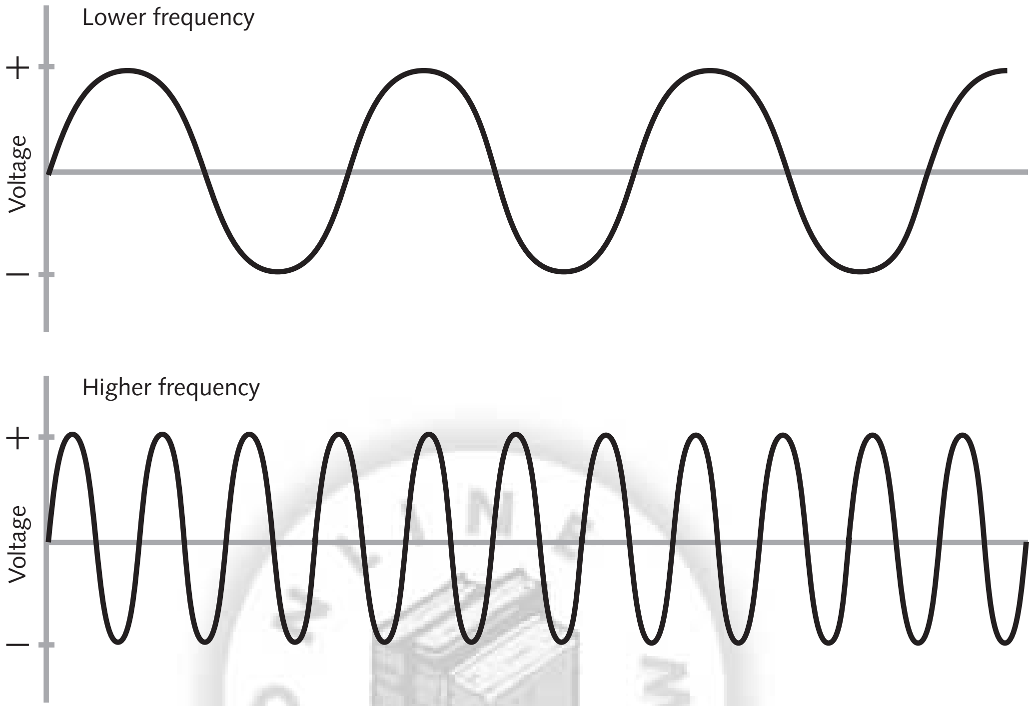

Figure 3-8 Lower and higher frequencies

Analog Modulation

As mentioned, there are three types of analog modulation. The first is known as **amplitude modulation (AM)**. The height of a carrier wave is known as the **amplitude**, as illustrated in Figure 3-9 with a typical sine wave. The height of the carrier can be changed so that a higher wave represents a 1 bit while a lower wave represents a 0 bit. Amplitude modulation (AM) changes the amplitude so that the highest peaks of the carrier wave represent a 1 bit while the lower waves represent a 0 bit. Figure 3-10 illustrates the letter "A" (ASCII 65 or 01000001) being transmitted by amplitude modulation.

NOTE Amplitude modulation is most frequently used by broadcast radio stations. However, AM is often susceptible to interference from outside sources such as lightning from a thunderstorm, and is not generally used for data transmissions.

Whereas amplitude modulation varies the height of the signal, **frequency modulation (FM)** changes the number of waves representing one cycle. When using frequency modulation, the number of waves needed to represent a 1 bit are more than the number of waves needed to represent a 0 bit. Figure 3-11 illustrates the letter "A" (ASCII 65 or 01000001) being transmitted by frequency modulation. Notice that the number of waves to represent a 1 bit are double that of the number of waves to represent a 0 bit.

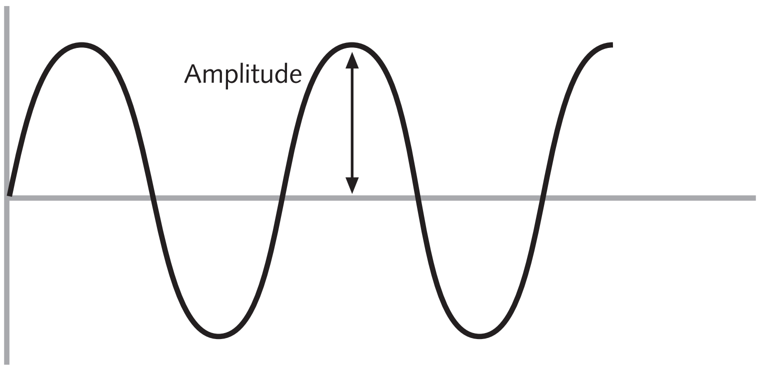

Figure 3-9 Amplitude

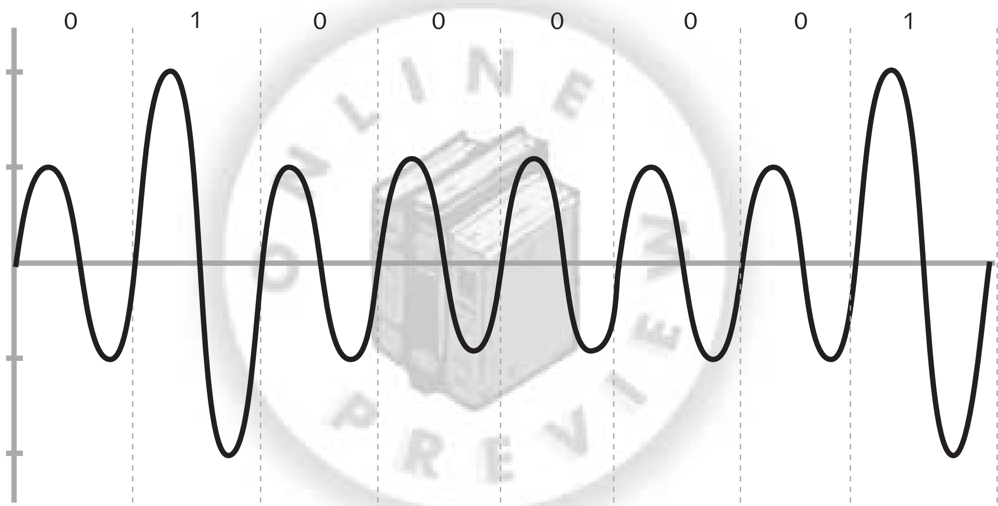

Figure 3-10 Amplitude modulation (AM)

NOTE

Like amplitude modulation, frequency modulation is often used by broadcast radio stations. However, unlike AM, FM is not as susceptible to interference from outside sources.

Whereas AM changes the height of the wave and FM increases the number of waves per cycle, **phase modulation (PM)** changes the starting point of the cycle. This change takes place only when the bits being transmitted change from a 1 bit to a 0 bit or vice versa. The change in starting point indicates that a different bit is now being sent. Figure 3-12 illustrates the letter "A" (ASCII 65 or 01000001) being transmitted by phase modulation.

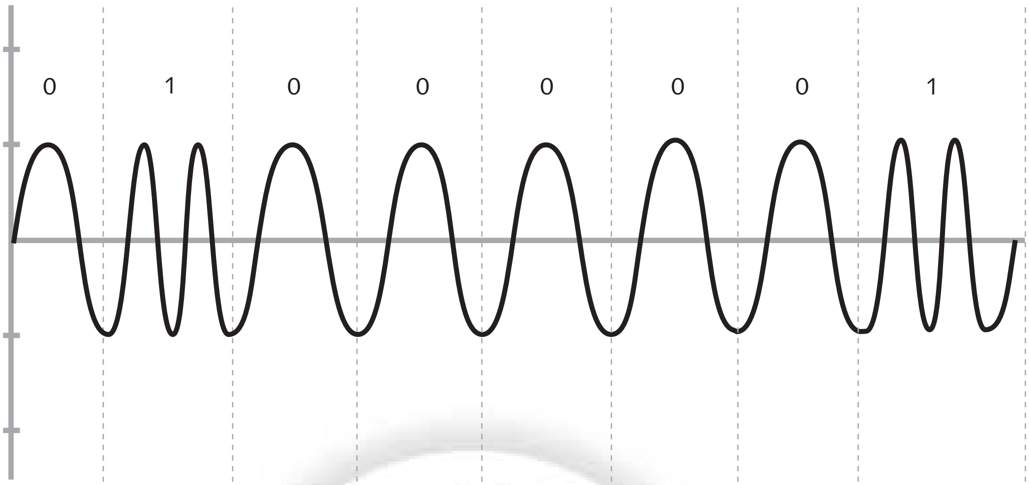

Figure 3-11 Frequency modulation (FM)

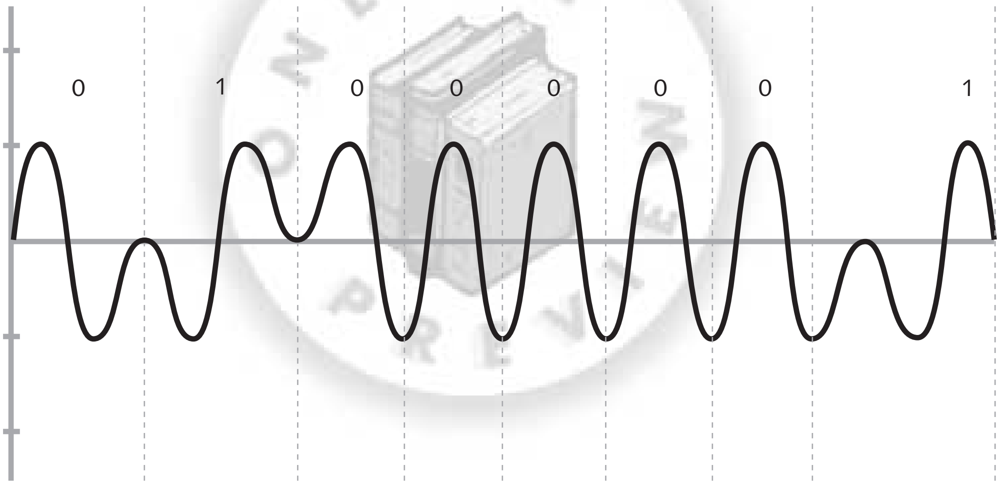

Figure 3-12 Phase modulation (PM)

NOTE

Although radio broadcasts use either amplitude modulation (AM) or frequency modulation (FM), television broadcasts actually use AM, FM, and phase modulation (PM). Television video uses AM, the sound uses FM, and the color information uses PM.

Digital Modulation

Although analog modulation could be used for data communications, almost all wireless systems use digital modulation. There are several advantages of digital modulation over analog modulation:

- Digital modulation makes better use of the bandwidth.
- It requires less power to transmit digital modulation than analog modulation.
- Digital modulation performs better when there is interference from other signals.
- Digital modulation error-correcting techniques are more compatible with other digital systems.

In an analog system the carrier signal is continuous, and amplitude, frequency, and phase changes also occur continuously. With a digital system, on the other hand, the changes are in distinct or discrete steps using binary signals. Digital modulation, like analog modulation, uses three types of modulation: the height of the signal, the frequency of the signal, and the relative starting point.

Amplitude shift keying (ASK) is a binary modulation technique similar to amplitude modulation, in that the height of the carrier can be changed to represent a 1 bit or a 0 bit. However, instead of both a 1 bit and a 0 bit having a carrier signal as with amplitude modulation, the ASK 1 bit has a carrier signal (positive voltage) while a 0 bit has no signal (zero voltage). Figure 3-13 illustrates the letter “A” (ASCII 65 or 01000001) being transmitted by ASK.

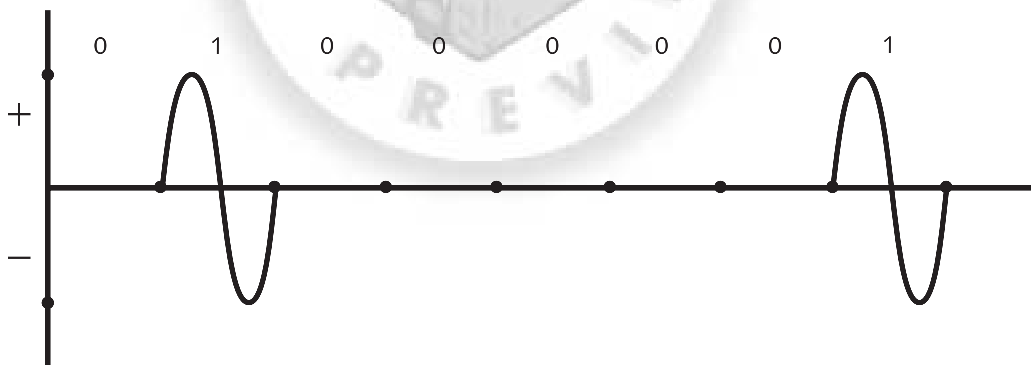

Figure 3-13 Amplitude shift keying (ASK)

NOTE Digital (binary) modulation is still shown as a standard sine wave.

Similar to frequency modulation, **frequency shift keying (FSK)** is a binary modulation technique that changes the frequency of the carrier signal. Because it is sending a binary signal, the carrier signal starts and stops. Figure 3-14 illustrates the letter "A" (ASCII 65 or 01000001) being transmitted by FSK.

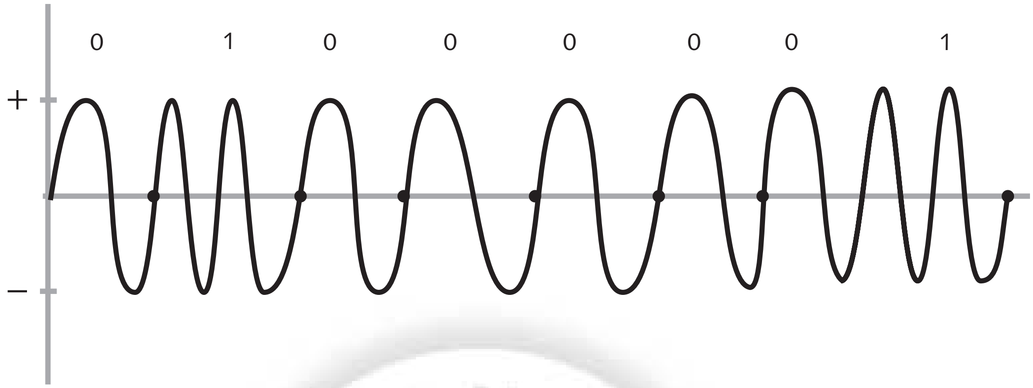

Figure 3-14 Frequency shift keying (FSK)

Phase shift keying (PSK) is a binary modulation technique similar to phase modulation. The difference is that the PSK signal starts and stops because it is a binary signal. Figure 3-15 illustrates the letter "A" (ASCII 65 or 01000001) being transmitted by PSK.

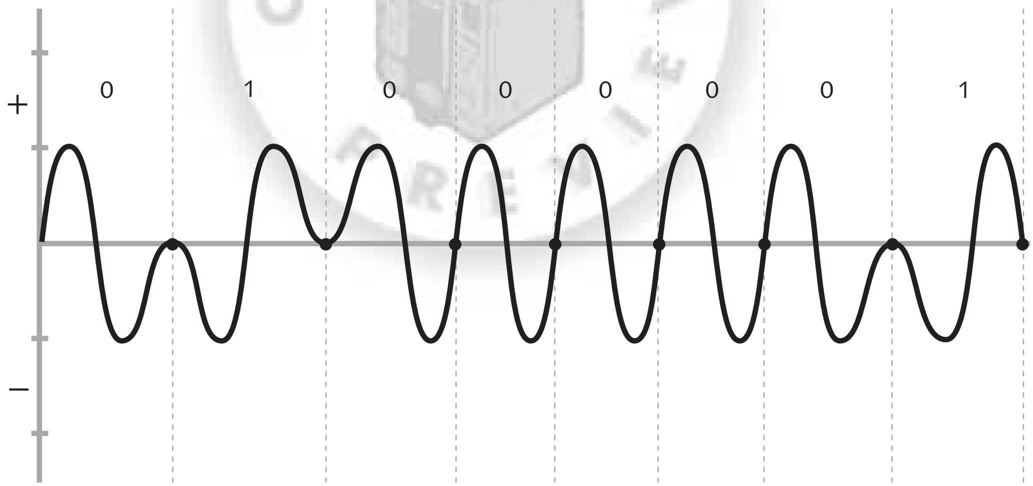

Figure 3-15 Phase shift keying (PSK)

Radio Frequency Behavior and Measurement

One of the key elements of managing a wireless LAN is understanding how radio frequency (RF) signals behave. Unlike signals that speed down a network cable with a minimum of outside interference, RF signals can be affected by the environment—walls, doors, street signs, and even the weather can have an impact on the signals. Understanding the unique behavior of RF signals and how this behavior can be measured is important for setting up and troubleshooting a WLAN.

RF Behavior

The behavior of an RF signal can be categorized by whether something adds power to the signal or takes power away from the signal. Known as gain and loss, these are now discussed in detail.

Gain

Gain is defined as the positive difference in amplitude between two signals. Gain is achieved by an **amplification** of the signal. Sometimes gain is used synonymously with amplification. However, gain is technically the measure of amplification. Figure 3-16 illustrates gain. Gain can occur intentionally from an external power source that amplifies the signal, or unintentionally when an RF signal bounces off an object and combines with the original signal to amplify it.

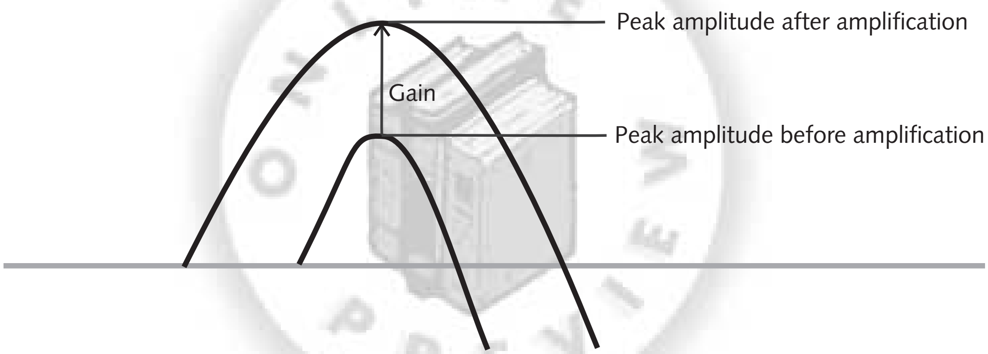

Figure 3-16 Gain

Loss

Loss, also known as **attenuation**, is the negative difference in amplitude between signals, as seen in Figure 3-17. Like gain, loss can be either intentional or unintentional. Intentional loss may be necessary to decrease the strength of the signal to comply with standards or to prevent it from interfering with other RF signals.

More often, however, loss is unintentional. There are several factors that may result in RF loss. These include:

- *Absorption*—Certain types of materials can absorb the RF signal. This is known as **absorption**. The types of materials that will absorb an RF signal include concrete, wood, and asphalt. Absorption is illustrated in Figure 3-18.

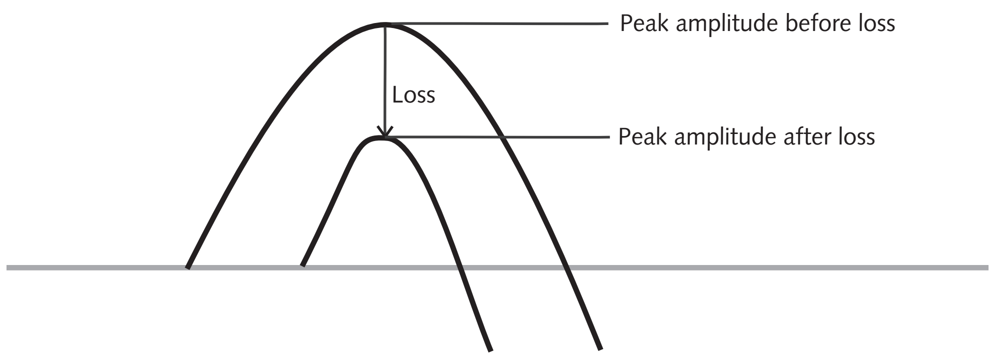

Figure 3-17 Loss

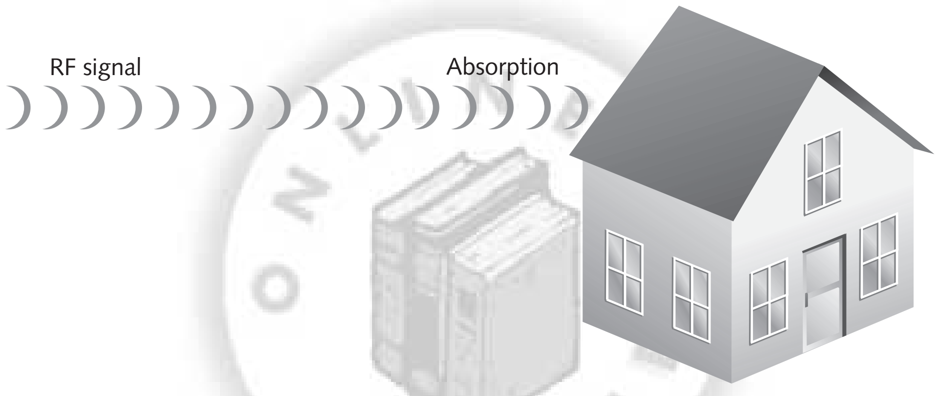

Figure 3-18 Absorption

- *Reflection*—**Reflection** is the opposite of absorption. Instead of the signal being "soaked up," it is "bounced back." Reflection generally is caused by objects that are very large (in relation to the size of the **wavelength** of the signal, or the distance between successive amplitude peaks) and relatively smooth, such as walls, buildings, and the surface of the earth. Also, objects that are made out of metal will reflect a signal. These can include metal roofs, metal walls, and elevator shafts. A signal is generally weaker after it is reflected. Reflection is seen in Figure 3-19.
- *Scattering*—Whereas reflection is caused by large and smooth objects, **scattering** is caused by small objects or rough surfaces. Objects that can cause scattering include foliage, rocks, and sand. Scattering can also occur when the RF signal comes in contact with elements in the air, such as rain or heavy dust particles. Scattering is illustrated in Figure 3-20.
- *Refraction*—Over a long distance an RF signal may move through different atmospheric conditions. For example, it may start out in a relatively transparent condition, such as in bright sunshine, then go through a much denser condition, such as cold damp air. When an RF signal moves from one medium to another of a different density the signal actually bends instead of traveling in a straight line. This is known as **refraction** and is seen in Figure 3-21.

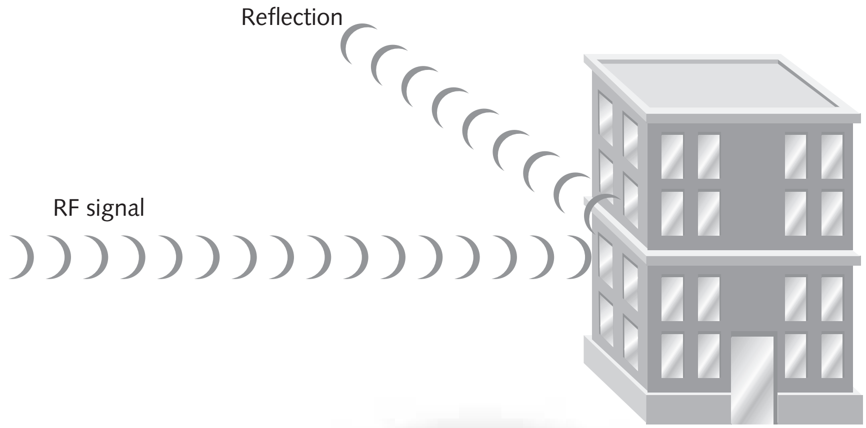

Figure 3-19 Reflection

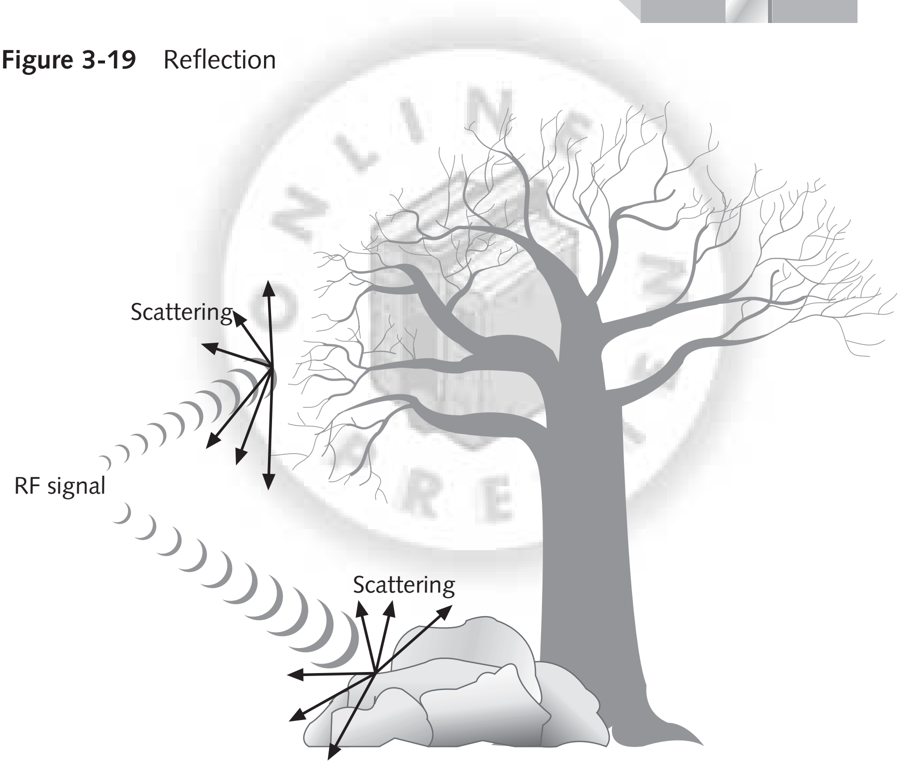

Figure 3-20 Scattering

NOTE

Refraction is the reason why a swimming pool appears deeper than it actually is. When you look into a pool, the light from the bottom is refracted away from the perpendicular because the index of refraction in air is less than in water.

Figure 3-21 Refraction

- *Diffraction*—Unlike refraction, in which the medium through which the signal passes causes the RF signal to bend, **diffraction** is bending caused by an object in the path of the transmission. Diffraction is illustrated in Figure 3-22.

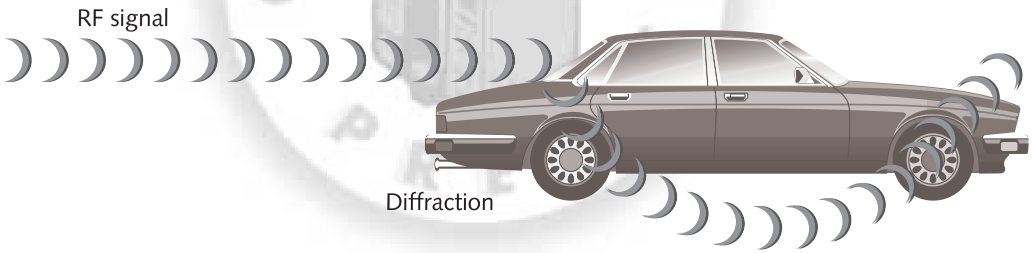

Figure 3-22 Diffraction

- *Voltage Standing Wave Ratio (VSWR)*—Unlike the previous examples in which external objects caused RF signal loss, **Voltage Standing Wave Ratio (VSWR)** is caused by the equipment itself. If one part of the equipment has different impedance than another part, the RF signal may be reflected back within the device itself. Not only does this cause a loss of signal strength, the reflected power can actually burn out the electronics of the device. VSWR is illustrated in Figure 3-23.

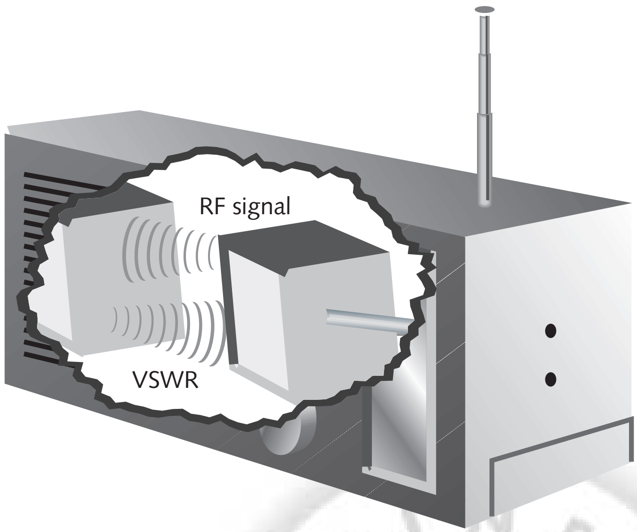

Figure 3-23 VSWR

RF Measurement

Because RF signals can be affected by the environment, it is sometimes necessary to be able to calculate the gain or loss of the signal. For RF engineers the measurements must be very precise. For WLAN network managers, that same degree of precision is not always required; approximations can often be sufficient. However, gain and loss can be important when identifying WLAN transmission difficulties between mobile devices and the access point.

RF Math

RF power can be measured by two different units on two different scales. The first is on a linear scale using **milliwatts (mW)** or thousandths of a watt of power. Most linear scales have a reference that is fixed at zero, or the absence of what is being measured. The speedometer in a car is an example of a linear scale: when the needle is pointing to zero, the car is not moving. RF power (gain or loss) can be measured by the number of mWs that are being transmitted.

However, linear scales do not reveal the relation to the whole. Consider an RF system that was experiencing a loss. Expressed on a linear scale, it can be said that the loss is 50 mW. However, this does not reveal what the loss is in relation to the whole. Is 50 mW a small loss or a large loss? If the total power transmission is 30,000,000 mW, then 50 mW is small, whereas if the total power transmission is only 100 mW, the loss is very large.

A second way to measure RF power is to use a relative scale. In a relative scale the reference point is the measurement itself, rather than being fixed at zero. A relative scale can reveal the gain or loss in power in relation to the whole. Considering the 50 mW loss above, a relative scale might indicate that half of the total power being transmitted is lost. Although the relative scale measurement is not as precise as the linear scale, it gives a better picture of the loss or gain relative to the whole.

Relative scales often use a logarithm to express the relationship of the measurement to the whole. A logarithm is the exponent to which the number 10 must be raised to reach a given value. For example, the logarithm (or "log") of the number 1,000 is 3 ($10^3 = 1{,}000$). The log is always the exponent.

NOTE The logarithm of a negative number or of zero is undefined and is not allowed.

RF power gain and loss on a relative scale are measured in **decibels (dB)** instead of mW. This is because gain and loss are relative concepts and a decibel is a relative measurement. A basic rule of thumb in dealing with RF power gain and loss is known as the **10's and 3's Rules of RF Math**. The rules are:

- -3 dB—A loss of 3 decibels means that half of the power in mW has been lost.
- +3 dB—A gain of 3 decibels means that the power has been doubled in mW.
- -10 dB—A loss of 10 decibels means that 90 percent of the power has been lost in mW.
- +10 dB—A gain of 10 decibels indicates a tenfold increase in mW.

Table 3-3 summarizes these rules.

Table 3-3 The 10's and 3's Rules of RF Math

Rule	Explanation	Percentage of Power Lost/ Gained	Current Power Level	Example
-3 dB	Half the watt value	50% lost	Half of original	100 mW - 3 dB = 50 mW
+3 db	Double the watt value	100% gained	Double the original	10 mW + 3 dB = 20 mW
-10 dB	Decrease watt value to one tenth of original	90% lost	One-tenth of original	300 mW -10 dB = 30 mW
+10 dB	Increase the watt value by ten-fold	1,000% gained	Ten times the original	10 mW + 10 dB = 100 mW

NOTE The Certified Wireless Network Administrator (CWNA) exam does not require you to perform logarithmic calculations but does require you to understand the concepts of the 10's and 3's Rules of RF Math.

The reference point that relates the logarithmic relative decibel (dB) scale to the linear milliwatt scale is known as the **dBm**. This reference point specifies that 1 mW = 0 dBm and is a measurement of absolute power.

Another type of RF measurement on a relative scale is **Equivalent** (also called **Effective**) **Isotropically Radiated Power (EIRP)**. EIRP is the power radiated out by the antenna of a wireless system (antennas are discussed later in this chapter). This level of power includes not only the intended power output but also any antenna gain. Although RF power gain and loss are measured in decibels (dB), EIRP uses a slightly different unit of measurement known as **isotropic decibels (dBi)**. The reference point of dBi is a theoretical antenna with 100 percent efficiency. dBi measurements for RF follow the same 10's and 3's rules as above. A gain of 10 dBi to a 1W antenna results in a tenfold increase or 10W.

NOTE

The unit of measurement dBi refers only to the gain of an antenna. Unless an antenna is malfunctioning it will not negatively impact a signal.

Most of the power levels referenced by WLAN administrators will be given in either mW or dBm. These two units of measurement represent an absolute amount of power and are industry standard measurements.

WLAN Measurements

In the United States, the Federal Communications Commission (FCC) defines power limitations for wireless LANS (FCC Part 15.247). The reason for these power regulations is to limit the distance that the WLAN can transmit: a lower power results in a shorter transmission range. While EIRP measures any antenna gain, the **Transmitter Power Output (TPO)** is a measure of the power being delivered to the transmitting antenna. The TPO limitation set by the FCC for WLANs is 1,000 mW or 30 dBm. The maximum EIRP for IEEE 802.11b WLANs is 100 mW (20 dBm). The EIRP for 802.11b and 802.11g wireless networks vary by transmission speed and are listed in Table 3-4.

Table 3-4 IEEE 802.11b and 802.11g EIRP

Transmission Speed	IEEE 802.11g	IEEE 802.11b
24 Mbps and less	50 mW (17 dBm)	40 mW (16 dBm)
36 Mbps	40 mW (16 dBm)	25.1 mW (14 dBm)
48 Mbps	31.6 mW (15 dBm)	20 mW (13 dBm)
54 Mbps	20 mW (13 dBm)	20 mW (13 dBm)

Vendors of WLAN products as well as Microsoft Windows XP and Server 2003 provide tools to measure RF signal strength. The chipset in 802.11 devices provides a value called the **Receive Signal Strength Indicator (RSSI)** which is used to determine different factors, such as when transmission is allowed, when a roaming device should be associated with a different access point, and what data rate (transmission speed) should be used for transmission. Vendors use an algorithm or a look-up table to convert RSSI values to dBm, mW, or signal strength percentage. Because the conversions can be different between vendors' products, two different analysis tools may report different values for signal power even though they are sitting on the same desk.

ANTENNAS

One of the most important components of any wireless system is its antenna. Without antennas radio waves would be unable to travel long distances. In this section you explore how antennas work, their characteristics, and the various types of antennas.

Antenna Concepts

Radio waves are transmitted and received by using an **antenna**. An antenna is a copper wire or similar device that has one end up in the air and the other end connected to the ground or a grounded device. When transmitting, the radio waves are directed to strike this wire (the length of an antenna should be about ¼ of the wavelength). This will set up electrical pressure (voltage) along the wire. This pressure will cause a small electrical current to flow up and down the wire. The voltage causes the electricity in the antenna to move back and forth at the same frequency as the radio waves. Broadcasting or sending out radio waves is accomplished by forcing the electricity in the antenna to move at the same frequency as the radio waves. An antenna is also used to pick up transmitted radio signals. The electricity in the receiving antenna moves back and forth in response to the radio signals reaching it. The motion causes a voltage that leads from the antenna into the receiver. This is seen in Figure 3-24.

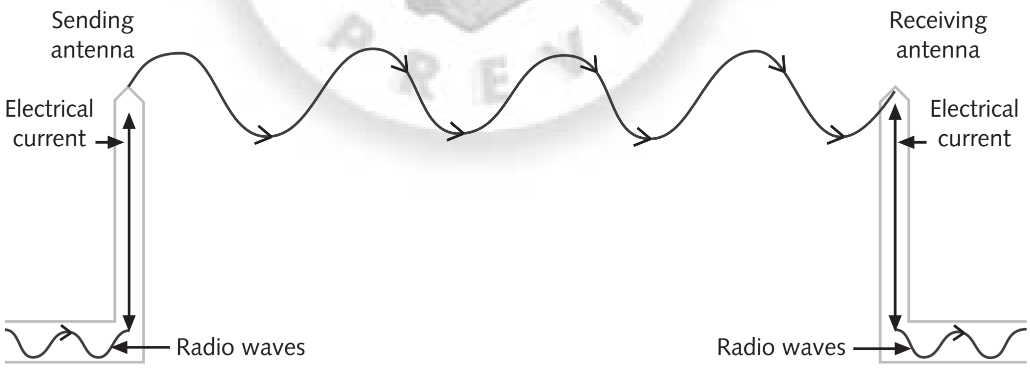

Figure 3-24 Antennas are required for sending and receiving radio signals

Although the Equivalent Isotropically Radiated Power (EIRP) is the measure of the total power radiated out by the antenna of a wireless system, the Federal Communications Commission (FCC) uses another term to describe everything in a wireless system *except* the antenna. As defined by the FCC, an **intentional radiator** is a device (minus the antenna) that is specifically designed to create and generate radio frequency signals. Just as the FCC regulates the overall power transmission of a wireless LAN, it also sets limits on the power that can be generated by an intentional radiator.

Characteristics of RF Antenna Transmissions

There are a variety of characteristics of RF antenna transmissions that play a role in properly designing and setting up a WLAN. These include polarization, wave propagation, multipath distortion, the Fresnel zone, and free space path loss.

Polarization

The orientation of the radio waves as they leave the antenna is known as **polarization**. Waves follow the plane of their electrical fields, and the electric field is parallel to the radiating elements (the antenna element is the metal part of the antenna that is doing the radiating). If the antenna is in a vertical position (perpendicular to the ground), then the polarization is said to be vertical; if it is in a horizontal position (parallel to the ground) the polarization is horizontal. Vertical polarization is typically used in wireless LANs with the dual antennas of access points pointing upward. Devices with antennas that are not polarized in the same way are not able to communicate with each other effectively. Receiving a horizontally polarized signal with a vertically polarized antenna (or vice versa) will reduce the amount of signal received. Vertical polarization is illustrated in Figure 3-25.

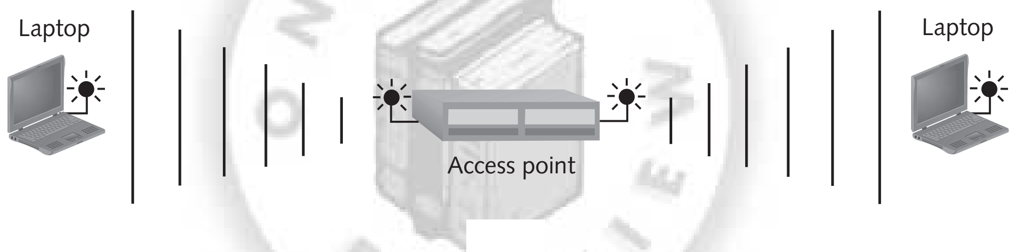

Figure 3-25 Vertical polarization

NOTE Polarization is typically referred to as being horizontal or vertical, but the actual polarization can be at any angle. Circular polarization is also possible.

Wave Propagation

Whereas polarization is the plane in which signals radiate, **wave propagation** is the pattern of their dispersal. One type of wireless radio wave propagation is known as sky wave propagation. The RF waves bounce off of the earth's ionosphere from the sending antenna to the receiving antenna. Sky wave propagation does not require the antennas to be in a straight line with one another. Sky wave propagation is illustrated in Figure 3-26.

The type of propagation associated with WLANs is called **RF line of sight (RF LOS)**. This follows the same principle as **visual line of sight**, in which the sending and receiving antennas must be in a relatively straight line with each other in order to send and receive the signals. RF LOS is illustrated in Figure 3-27.

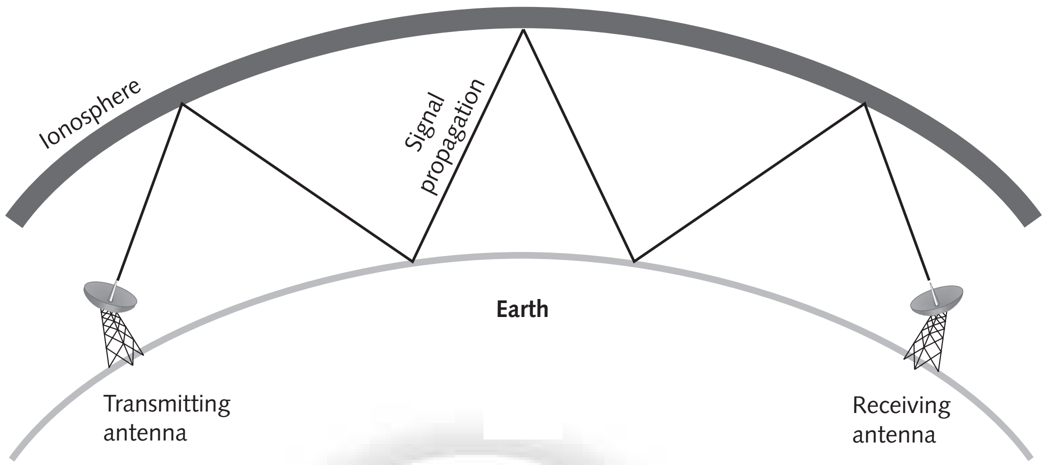

Figure 3-26 Sky wave propagation

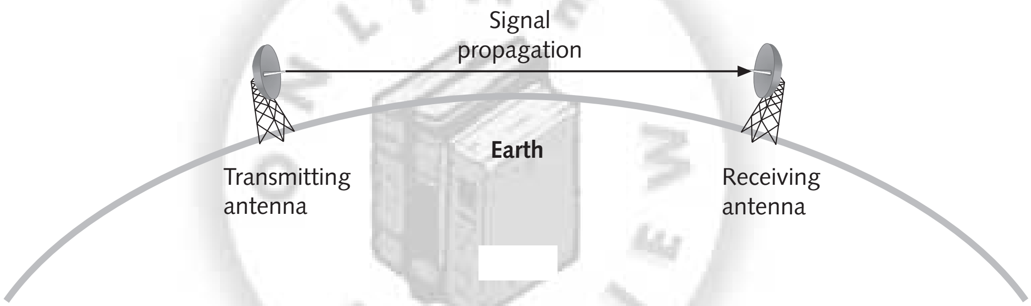

Figure 3-27 RF LOS propagation

Multipath Distortion

Sky wave propagation signals, because they're pointing towards the sky, generally are not interfered with by other objects. However, because RF LOS propagation requires alignment of the sending and receiving antennas, ground-level objects can obstruct the signals. These obstructions do not necessarily completely block the signal, but can cause refraction or diffraction. These refracted or diffracted signals may still reach the receiving antenna but will arrive later than the signals that can move in a straight line without any obstructions. This is known as **multipath distortion**.

NOTE

These "late" multipath signals can actually reduce the power of the straight line signals.

One of the solutions to multipath distortion is **antenna diversity**. Antenna diversity uses multiple antennas, inputs, and receivers to overcome multipath distortion. In some WLAN systems with multiple antennas the signal is received in only one antenna at a time. In other WLAN systems that have multiple antennas the last antenna that received the reception is the one that is used to transmit the next signal.

NOTE: A wireless NIC can contain multiple embedded antennas.

Fresnel Zone

Often it is important to know the degree of multipath distortion. Determining the extent of the "late" multipath signals can be done by calculating the **Fresnel** (fre-NEL) **zone**. The Fresnel zone is illustrated in Figure 3-28. Each Fresnel zone is an ellipsoidal or "sausage-like" shape. The signal strength is strongest in Zone 1, a straight line from sender to receiver, and decreases in each successive zone. The rule of thumb is that 60 percent of the first Fresnel zone must be clear of obstacles.

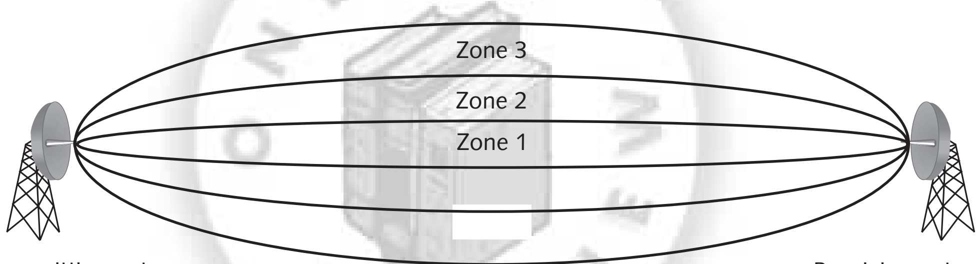

Figure 3-28 Fresnel zone

NOTE: Calculating the Fresnel zone can be done by hand using a complicated formula or by using any number of free Web-based calculators. For example, when sending a signal 8 kilometers (5 miles) with an obstruction at 1.6 kilometers (2 miles) at 2.4 GHz will result in Zone 1 being 9.4 meters (31 feet) at its widest point.

Free Space Path Loss

As the RF signal propagates from the antenna it spreads out. The further the signal spreads out, the weaker it becomes. Known as **free space path loss**, this signal dispersion represents the single greatest source of power loss in a wireless system. Although the loss can be more accurately calculated using a formula, a basic rule of thumb is that each 6 dB increase in EIRP results in a doubling of the transmission range (distance from the antenna), and a 6 dB reduction in EIRP translates into reducing the range by half. Table 3-5 illustrates the approximate free space path loss for IEEE 802.11b and 802.11g WLANs.

NOTE

The decrease in signal strength due to free space path loss is inversely proportional to the distance traveled and proportional to the wavelength of the signal.

Table 3-5 Free space path loss for IEEE 802.11b and 802.11g WLANs

Distance in Meters	Distance in Feet	Loss in dB
100	328	80
250	820	88
400	1,312	92
750	2,460	97
1,000	3,280	100

There are no means to counteract free space path loss by an *action* of the antenna. This is because an antenna by itself does not amplify or change the RF signal as it is being transmitted; it is only a piece of metal that radiates or absorbs a signal. The only way for an increase in amplification by the antenna, known as **antenna gain**, to occur is by the physical *shape* of it. The shape of an antenna can provide amplification by focusing the RF radiation into a more compact and tighter beam of energy. This focusing of the radiation is measured by **beamwidth**, which is measured in horizontal and vertical degrees. A type of antenna that normally has a 360-degree horizontal beamwidth could be remanufactured into a more focused beamwidth of 60 degrees. Generating the same power but with smaller beamwidth, the RF waves will travel further.

Antenna Types and Their Installations

There are two fundamental characteristics of antennas. First, as the frequency gets higher the wavelength becomes smaller. This means that the size of the antenna likewise is smaller. Consider a cellular telephone: it uses a high frequency so only a small antenna is required. Secondly, as the gain of an antenna increases, the coverage area narrows. High-gain antennas offer larger coverage areas than low-gain antennas at the same input power level.

There are three basic categories of antennas: omni-directional, semi-directional, and highly directional. Within each category there are multiple types of antennas, each one with different RF characteristics for appropriate uses.

Omni-Directional Antennas

The most common type of antenna for a WLAN is an **omni-directional antenna**, also known as a **dipole antenna**. An omni-directional antenna radiates its signal out in all directions equally. Figure 3-29 shows a side view and a top view of an omni-directional radiation pattern from a WLAN access point.

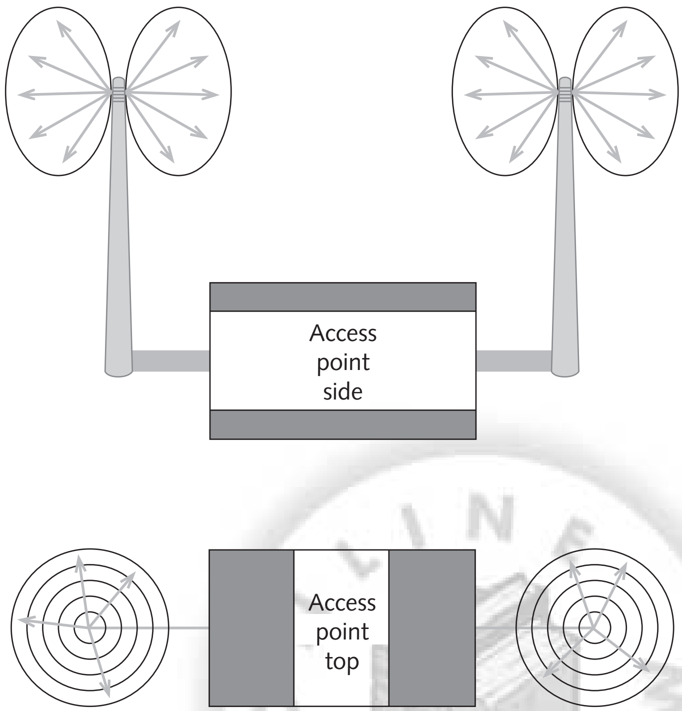

Figure 3-29 Omni-directional antenna

If a standard dipole antenna is placed in the center of Floor 2 of a three-story building, most of its signal will be radiated along the floor of Floor 2. Some of the signal will reach Floor 1 and Floor 3 rooms below and above the AP. If a high-gain dipole antenna is placed in the same position, however, the signal is "flatter" (more horizontal) and less vertical. That is, more of the rooms on Floor 2 will receive the signal but less of it radiates to Floor 1 or Floor 3.

Semi-Directional Antennas

Unlike an omni-directional antenna that evenly spreads the signal in all directions, a **semi-directional antenna** focuses the energy in one direction. Figure 3-30 illustrates one type of radiation pattern from a semi-directional antenna.

Semi-directional antennas are primarily used for short and medium range remote wireless bridge networks. Two office buildings that are across the street from one another and need to share a wireless network connection would use semi-directional antennas. They are not commonly used for WLANs.

Highly-Directional Antennas

Highly-directional antennas send a narrowly focused signal beam. Highly-directional antennas are generally concave dish-shaped devices. These antennas are used for long distance, point-to-point wireless links, such as connecting buildings that are up to 42 kilometers (25 miles) apart. They are not commonly used for WLANs.

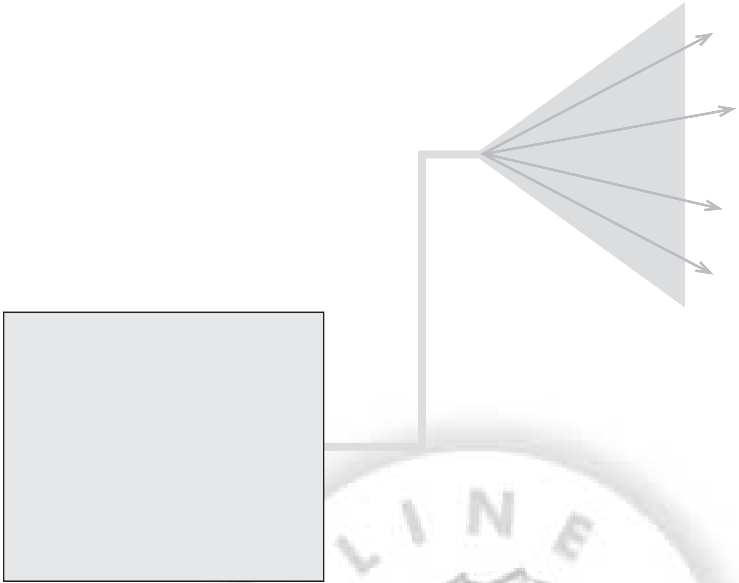

Figure 3-30 Semi-directional antenna

WLAN Antenna Locations and Installation

Because WLAN systems use omni-directional antennas to provide the broadest area of coverage, access points should be located near the middle of the coverage area. Also, the antenna should be positioned as high as possible, such as in a plenum ceiling or affixed to the ceiling, in order to increase coverage area. If a high-gain omni-directional antenna is used, it is important to determine that users located below the antenna area still have reception. Outdoor antennas should be mounted above obstructions such as trees and buildings so that no objects encroach on the Fresnel zone to ensure that multipath transmissions can get through.

Chapter Summary

- Light, heat, and other forms of energy move through space as electromagnetic waves. Another type of electromagnetic wave that travels in the same fashion is called a radiotelephony wave or radio wave. 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 a radio wave that spreads out in all directions. Because radio waves can travel longer distances they are ideal for the transmission of data.
- Radio waves can be transmitted using either an analog or digital signal. An analog signal is a continuous signal with no breaks in it. A digital signal consists of data that is discrete or separate, as opposed to continuous. The rate at which an event occurs like the electrical current striking an antenna will result in different radio waves being created. This creates

a radio wave's frequency. The changing event that creates the different radio frequencies is called a cycle. Cycles are measured in hertz and illustrated as a wave called an oscillating signal or a sine wave.

- The carrier signal sent by radio transmissions is simply a continuous electrical signal and the signal itself carries no information. There are three types of modulations or changes to the signal that can be made to enable it to carry information: the height of the signal, the frequency of the signal, or the relative starting point. Modulation can be done on either analog or digital transmissions.
- Gain is defined as a positive difference in amplitude between two signals. Gain is achieved by an amplification of the signal. Loss, or attenuation, is a negative difference in amplitude between signals. Most loss is unintentional. There are several factors that may result in RF loss, including absorption, reflection, scattering, refraction, diffraction, and Voltage Standing Wave Ratio.
- RF power can be measured by two different units on two different scales. Milliwatts are based on a linear scale, while decibels are measured on a relative scale. A set of basic rules of thumb in dealing with RF power and loss is known as the 10's and 3's Rules of RF Math and is summarized in Table 3-3.
- Radio waves are transmitted and received by using an antenna. An antenna is a copper wire or similar device that has one end in the air and the other end connected to the ground or a grounded device. There are a variety of characteristics of RF antenna transmissions that play a role in properly designing and setting up a WLAN. These include polarization, wave propagation, multipath distortion, the Fresnel zone, and free space path loss.

Key Terms

10's and 3's Rules of RF Math — Basic rules of thumb for measuring RF power and loss. Refer to Table 3-3.

absorption — The assimilation of RF signals into a material.

amperes (amps) — The measure of the flow of electrical current.

amplification — The action that causes a gain.

amplitude — The height of the carrier waves.

amplitude modulation (AM) — An analog modulation that changes the height of the carrier waves.

amplitude shift keying (ASK) — A binary modulation technique similar to amplitude modulation that changes the height of the carrier.

analog signal — A continuous signal.

antenna — A copper wire or similar device that has one end up in the air and the other end connected to the ground or a grounded device that transmits or receives radio signals.

antenna diversity — The use of multiple antennas, inputs, and receivers to overcome multipath distortion.

antenna gain — An increase in amplification by the antenna shape.

attenuation — The negative difference in amplitude between signals.
beamwidth — A measure of focus of a RF signal.
carrier signal — The signal on which a radio transmissions is sent.
current (I) — The flow of electrical energy.
cycle — The changing event that creates different radio frequencies.
dBm — The reference point that relates the logarithmic relative decibel (dB) scale to the linear milliwatt (mW).
decibels (dB) — The measurement of RF power gain and loss on a relative scale.
diffraction —When RF signals bend because of striking a rough surface.
digital signal — A signal in discrete or separate units.
dipole antenna — An antenna that radiates its signal in all directions equally.
electromagnetic waves — Waves of energy through which light, heat, and radio signals move through space.
Equivalent (or **Effective) Isotropically Radiated Power (EIRP)** — The power radiated out by the antenna of a wireless system.
free space path loss — The weakening of signal strength as it disperses.
frequency —The rate at which an electrical current alternates creating different radio wave transmissions.
frequency modulation (FM) — An analog modulation that changes the number of waves used to represent one cycle.
frequency shift keying (FSK) — A binary modulation technique that changes the frequency of the carrier signal.
Fresnel zone — An area in which the RF signal strength can be calculated.
gain — The positive difference in amplitude between two signals.
gigahertz (GHz) — One billion hertz.
hertz (Hz) — The unit of measure for a radio frequency cycle.
highly-directional antenna — An antenna that sends a narrowly focused signal beam.
impedance — The total amount of resistance to the flow of electrical current.
intentional radiator — A device (minus the antenna) that is specifically designed to create and generate radio frequency signals.
kilohertz (KHz) — One thousand hertz.
loss — The negative difference in amplitude between signals.
megahertz (MHz) — One million hertz.
milliwatt (mW) — One thousandth of a watt of power.
modem — A device that converts analog signals to a digital format or digital to analog format for transmission.
multipath distortion — Refracted or diffracted signals that reach the receiving antenna late.
ohms — The measure of the restriction of the flow of current.
omni-directional antenna — An antenna that radiates its signal equally in all directions.
oscillator signal — A waveform that illustrates cycles or changes in frequency.

phase modulation (PM) — An analog modulation that changes the starting point of the cycle.
phase shift keying (PSK) — A binary modulation technique that starts and stops the signal to represent a binary digit.
polarization — The orientation of radio waves as they leave the antenna; usually horizontal or vertical.
radio wave — An electromagnetic wave through which radio transmissions are sent and received.
radiotelephony wave — Same as radio wave.
Receive Signal Strength Indicator (RSSI) — The value transmitted by chipsets in 802.11 devices that can be used to determine signal strength.
reflection — When RF signals bounce back after striking a material**.**
refraction — When RF signals bend due to a change in atmospheric condition.
resistance (R) — Measure of the restriction of the flow of electrical current.
RF line of sight (RF LOS) — A straight line transmission of an RF signal.
scattering — The reflection of an RF signal by small objects, such as raindrops.
semi-directional antenna — An antenna that focuses RF signals in one direction.
sine wave — A wave that illustrates cycles or changes in frequency.
Transmitter Power Output (TPO) — A measure of the power being delivered to the transmitting antenna.
visual line of sight — A line between two points so that vision is unobstructed between the points.
voltage (V) — Electrical pressure on a wire.
Voltage Standing Wave Ratio (VSWR) — Impedance caused by a reflected signal.
volts — The measure of electrical pressure on a wire.
watts — The measure of electrical energy.
wavelength — The distance between successive amplitude peaks.
wave propagation — The pattern of RF radio wave dispersal.

Review Questions

1. Light, heat, and other forms of energy move through space in
   a. electromagnetic waves
   b. the ether
   c. modulated electroenergy (MEE)
   d. digital binary refraction
2. Waves that are continuous with no breaks represent a(n) ______________ signal.
   a. digital
   b. analog

c. modulated
d. transfer

3. How often an event occurs can create different
   a. modulations
   b. frequencies
   c. cycles
   d. gigapops (GPS)
4. A ________________ is a million hertz.
   a. kilohertz
   b. megahertz
   c. gigahertz
   d. millihertz
5. Changes in frequency are illustrated by an up-and-down wave called a(n)
   a. sine wave
   b. oscillation modulation
   c. X-Z point graph
   d. AC/DC time line
6. Voltage is equal to current times resistance, or V=I*R. True or False?
7. Resistance is measured in watts. True or False?
8. Radio transmissions send what is known as a carrier signal. True or False?
9. Wireless LAN transmissions are analog and not digital. True or False?
10. Modulation cannot be performed on analog transmissions. True or False?
11. ________________ is a digital modulation technique that changes the height of the carrier to represent a 1 bit or a 0 bit.
12. ________________ is defined as the positive difference in amplitude between two signals.
13. Attenuation is another term for ________________ .
14. A thousandth of a watt of power is a ________________ .
15. A ________________ is the exponent to which the number 10 must be raised to reach a given value.
16. Explain The 10's and 3's Rules of RF Math.
17. Explain how an antenna functions.
18. What is polarization and why is it important to WLANs?
19. What is multipath distortion and how can it be corrected?
20. What is the Fresnel zone?

HANDS-ON PROJECTS

Project 3-1: Download and Install Cisco Wireless Utilities

Cisco provides a variety of utilities for managing wireless clients. In this project you will download and install those utilities. Note that you need a Cisco wireless network interface card to use these utilities. If you are using the same wireless device that you used in Project 2-1 you have already installed these utilities; if you are using a different wireless device that has a Cisco wireless card but is lacking these utilities, be sure to install them following these steps.

1. On a laptop computer point your browser to *http://www.cisco.com*.
2. Under **Direct Access** click the arrow next to **Downloads** and select **Wireless Software**.

> NOTE: It is not unusual for the location of these utilities to change on Cisco's site. It may be necessary to search for them.

3. Click **Aironet Wireless Software Selector**.
4. There are five questions that you must answer on five separate screens:
   - Step 1 – Under **Product Type** select **Client Adapter** and click **Submit**.
   - Step 2 – Select the model number of your Cisco product, which is probably **802.11a/b/g**, and click **Submit**.
   - Step 3 – Select your adapter type and click **Submit**.
   - Step 4 – Select your operating system and click **Submit**.
   - Step 5 – Select the latest Software Release and click **Submit**.
5. Click the file to download and follow the instructions for entering your personal information to access the file.
6. Once the file has completed downloading click **Open** to install it.
7. The **Cisco Aironet Installation Program** window will appear, as seen in Figure 3-31. Click **Next**.

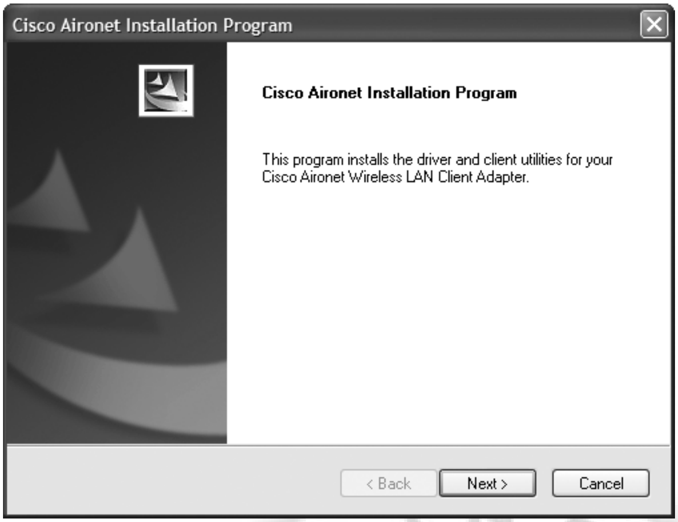

Figure 3-31 Cisco Aironet Installation Program

8. Select **Install Client Utilities and Drivers (Recommended)** and click **Next**.
9. Complete the steps to install the software utilities.

Project 3-2: Evaluating Radio Frequency Loss

HANDS-ON PROJECTS

The two factors that have the greatest impact on WLAN RF loss are distance from the access point (AP) and objects between the AP and the client. In this project you will evaluate the RF loss in your environment.

1. On a laptop computer click **Start** and **All Programs** and **Cisco Aironet** and **Aironet Client Utility**.
2. Click the **Current Status** tab.
3. A graph appears showing the signal strength between the laptop computer and the Cisco AP. Note the strength based on the current location of the laptop computer.
4. With a partner monitor the strength of the Link Status meter as you move away from the AP. It is best if one person carries the laptop while the other person takes notes.

NOTE

Note that in an area with multiple access points your signal could be picked up by another access point as you roam closer to it. Your instructor or lab supervisor may be able to temporarily disable the other access points while you are performing this activity. If that is not possible then note on your Link Status meter where the signal falls and then suddenly receives an increase in strength. You have probably moved from one area of coverage to another.

5. Continue roaming until you no longer can receive the signal. Note the location where the signal can no longer be found and estimate the distance from the AP, both as a straight line and also the distance you traveled (down hallways, around corners, etc.).

NOTE

Ceiling tiles can be a good unit by which to measure distance. Observe the length of the tiles (generally 18-24 inches) and then count the number of tiles for an approximation of distance.

6. Move back towards the AP and stop whenever there is a significant increase in signal strength. Note and record the obstacles that are now between the laptop and the AP and the distance.
7. Once you have moved back to the AP switch tasks with your partner. Now go in the opposite direction or down another hallway and monitor the signal strength and obstacles.
8. Create a map that will illustrate the signal strength in your building. Start with the AP as the "bulls eye" and draw circles away from the AP of "Excellent," "Good," "Fair," and "Poor." Also draw the obstacles (walls, elevators, etc.) on your map.

HANDS-ON PROJECTS

Project 3-3: Modifying AP Transmit Power and Antenna Diversity

The maximum power output of an AP is regulated by standards set by the Federal Communications Commission. In this project you will adjust the power output of the AP and its antenna settings and then note its impact. Be sure to make a written record of any settings before changing them so that they can be set back once the activity is completed.

1. Access the Cisco access point by pointing your browser to its IP address that you identified in the Hands-on Projects in Chapter 2, such as *http://192.168.2.30*.
2. Enter the username and password; the default is **Cisco** for both username and password.
3. Click **Network Interfaces** on the menu on the left side.
4. Click **Radio0-802.11*x***, where *x* is the letter of the IEEE standard on which the AP is based.

NOTE

Depending on the IEEE standard your Cisco AP is using your menu may be *Radio0-802.11b*, *Radio0-802.11a*, or *Radio0-802.11g*.

5. Click the **Settings** tab to display the radio options, as seen in Figure 3-32.
6. Note the **Transmit Power (mW)** (that sent from the AP to the clients) and the **Limit Client Power (mW)**. Record these on the map that you created in Project 3-2.

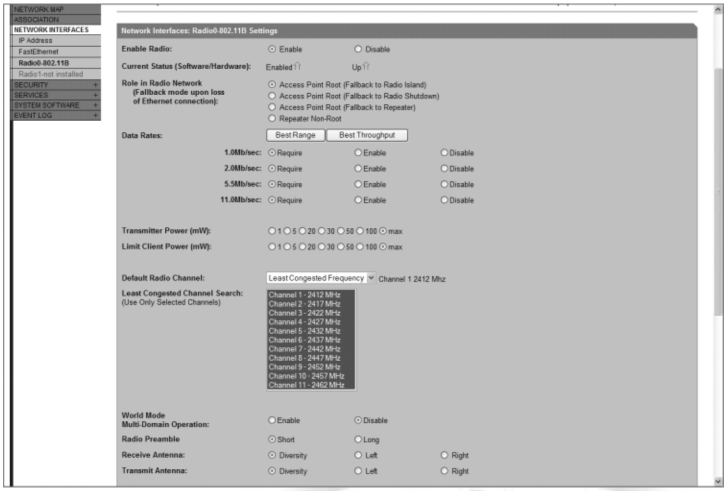

Figure 3-32 Network interfaces

7. Modify the **Transmit Power** to half of what it was set to. For example, if it was set to 100 mW (or Max) set it to **50 mW**.
8. Run the same test as in Project 3-2 and note any changes. Redraw your map indicate the Transmit power.
9. Modify the **Transmit Power** to the minimum and run the same test. Redraw the map once again.
10. Return to the same AP screen and scroll down to see **Receive Antenna** and **Transmit Antenna** and note the settings. Change these settings to **Left** and recreate your map, noting any differences.
11. Change the **Receive Antenna** and **Transmit Antenna** to **Right** and run the same tests once again, noting any differences.
12. Write a one-page paper that details the coverage of your building and the impact of changing the power levels and antenna diversity.
13. Adjust the settings in the Cisco AP back to their original state.
14. Close all windows.

Project 3-4: Compute RF Behavior

HANDS-ON PROJECTS

Determining the behavior of an RF signal can be an aid when troubleshooting a WLAN that does not function properly. In this project you will use several online calculators to compute RF behavior.

1. Point your browser to *http://www.swisswireless.org/wlan_calc_en.html*.
2. Scroll down to the **Power** section. Recall that the reference point that relates the logarithmic relative decibel (dB) scale to the linear milliwatt scale is known as the dBm, and this reference point specifies that 1 mW = 0 dBm and is a measurement of absolute power. This calculator will convert from watts to dBm.
3. Enter **1** in **Watts**, which is the maximum power level for an IEEE WLAN.
4. Click **dBm <-w** to convert from watts to dBm. What is the dBm of 1 W?
5. Scroll down to **Antenna**. Remember that dBi refers to the gain of an antenna. Select **2.41-2.48 GHz (WiFi 802.11b; 802.11g; Bluetooth)** under **Frequency Band**.
6. What would be the gain of an antenna that is .1 meters (3.9 inches) in diameter, the size of an optional antenna that could be added to a wireless gateway? This Web site will help determine that answer. Under **Antenna diameter in meters** enter **.1**.
7. Click **D-> dB**. What is the maximum theoretical gain?
8. Scroll down to **Free space loss**. Remember that as the RF signal propagates out from the antenna it spreads out and results in the signal weakening in power known as Free Space Path Loss.
9. Select **2.41-2.48 GHz (WiFi 802.11b; 802.11g; Bluetooth)** under **Frequency Band**.
10. The maximum distance of an IEEE 802.11b WLAN is 114 meters (375 feet). Enter **.114** under **Kilometers**.
11. Click **dB<-km**. What is the free space path loss?
12. Scroll down to **Propagation: Fresnel ellipsoid**. Using your data from Project 3-2, enter the maximum distance between the AP and the farther point you were able to reach by roaming with the laptop computer.

NOTE

Note that this value must be in meters. If you need to convert from feet to meters locate an online metric conversion calculator.

13. Enter the distance in meters between the AP and a main barrier in your setting, such as an elevator or brick wall.
14. Click **Compute radius** to calculate the value, as seen in Figure 3-33. Using this information attempt to draw a Fresnel zone ellipsoid for your building.
15. Scroll down to **Propagation: Diffraction.**
16. Consider two APs that are affixed to ceilings that are communicating with each other. What type of power loss might they encounter if an obstacle is between them that is .5 meters (1.6 feet) above them? Under **Height "h" between antenna top and obstacle top** enter **.5**.

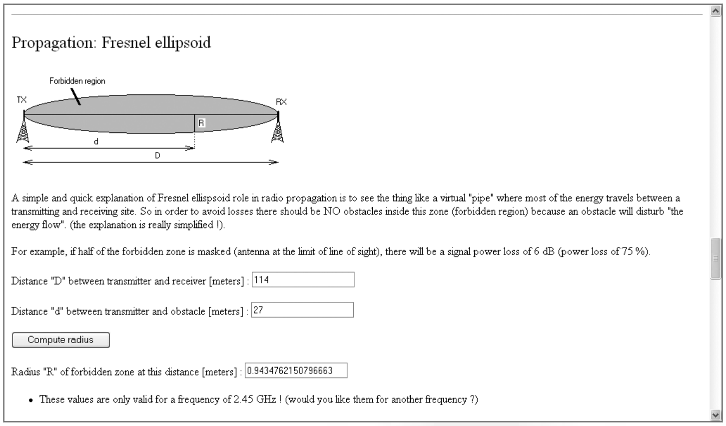

Figure 3-33 Fresnel zone calculations

17. Under **Distance "D1" between transmitter and obstacle** enter **70**.
18. Under **Distance "D2" between receiver and obstacle** enter **35**, as seen in Figure 3-34.

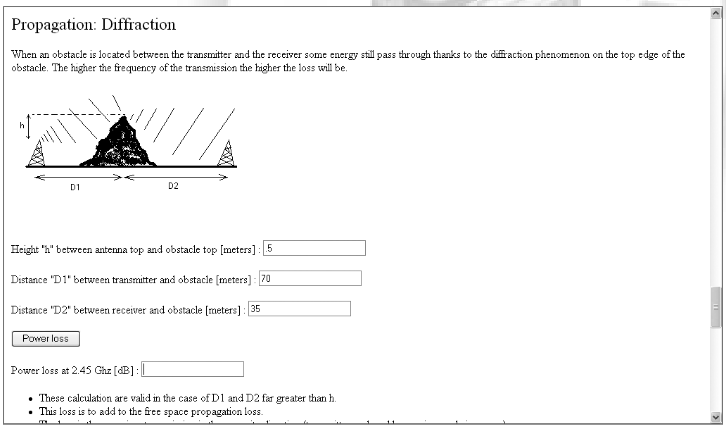

Figure 3-34 Diffraction calculations

19. Click **Power loss**. What was the amount of power loss?
20. Using the figures that you calculated from Project 3-2 above, determine the power loss for your building.
21. Close your browser.

Project 3-5: Using Windows Wireless Zero Configuration

Microsoft Windows XP can be used to manage the wireless client. In this project you explore the features of Windows Wireless Zero Configuration.

1. Click **Start** and **Connect To** and **Show all connections** to open the Network Connections window.
2. Double click on **Wireless Network Connection** in order to launch the Windows Wireless Zero Configuration Wireless Network Configuration Status window, as seen in Figure 3-35.

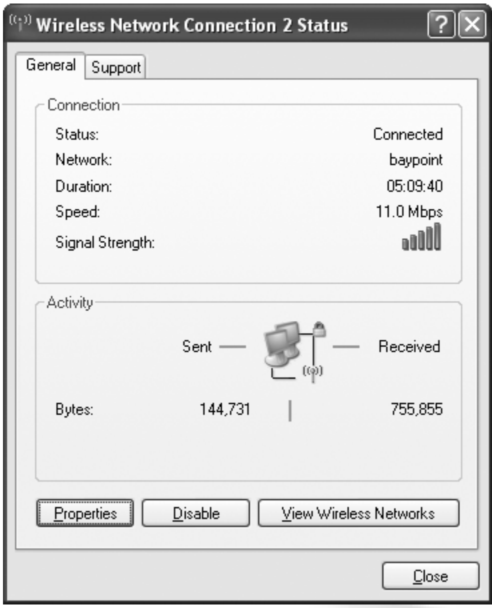

Figure 3-35 Wireless network configuration status

> **NOTE** If you are unable to launch the Windows Wireless Zero Configuration Wireless Network Configuration Status window, click the Wireless Network tab, then click Use Windows to configure my wireless network settings. You may have to restart your wireless device.

3. Note that this window displays summary information about the connection as well as activity information.
4. Click **Properties**.
5. At the Wireless Network Connection Properties window click the **General** tab if it is not already selected.
6. Be sure that the options **Show icon in notification area when connected** and **Notify me when this connection has limited or no conductivity** are selected.

7. Click the **Wireless Networks** tab.
8. Be sure that the option **Use Windows to configure my wireless network settings** is selected.
9. Notice that the preferred order in connecting to a wireless network is displayed under **Preferred Networks**.
10. Click the **View Wireless Networks** button. This will display a summary of all of available wireless networks, as seen in Figure 3-36.

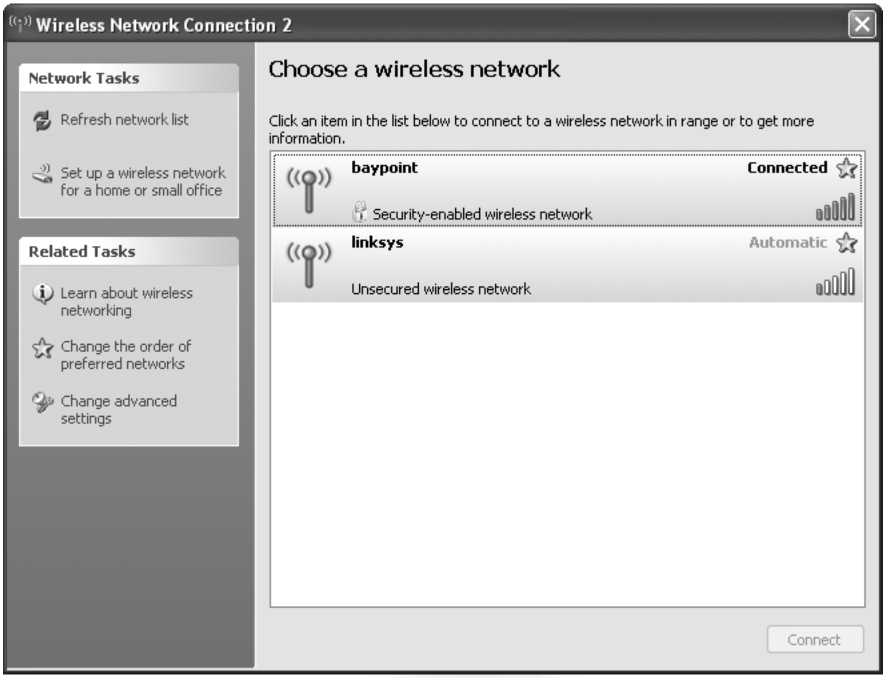

Figure 3-36 Wireless network connection

11. Close all windows.

Case Projects

Case Project 3-1: Antenna Types

Using the Internet and other resources, research the different types of antennas that are included under the three main categories: omni-directional, semi-directional, and highly-directional. Draw or print an example of each type and summarize when it is used, what is its maximum transmission distance, and its advantages and disadvantages.

Case Project 3-2: RF Measurements

What are the power output levels of other types of wireless devices, such as cellular telephones, portable (cordless) telephones, garage door openers, etc.? How do they compare with WLANs? Create a table that compares RF measurements of different wireless devices.

Case Project 3-3: Wireless Pioneers

The history of wireless development is filled with great men and women who dramatically changed communication around the world, including Edwin Howard Armstrong, Guglielmo Marconi, Reginal Fessenden, Lee De Forest, and others. Using books and the Internet, research some of the great developers of wireless technology. What contributions did they make?

Case Project 3-4: Modulation Techniques

Analog amplitude modulation, frequency modulation, and phase modulation, along with their digital counterparts of AFK, FSK, and PSK, all have their advantages and disadvantages. Research these types of modulations along with their respective strengths and weaknesses. Include coverage regarding how they are used today.

Case Project 3-5: RF Math

1. Using Table 3-3 as a reference, what is the dB of 1 watt of power?
2. A wireless device has output of 200 mW. It is connected to a cable with a 9 dBi gain and a 6 dB loss. What is the EIRP?

Northridge Consulting Group

Northridge Consulting, a local firm that assists businesses and organizations to solve their IT problems, has hired you to help them on a WLAN project. Cards, Cards, Cards! is a franchise retail chain for greeting cards. During the last Christmas season computer problems plagued the regional distribution center so they are now considering replacing it with a wireless network that will allow them to better serve their customers. However, some of Cards, Cards, Cards! IT staff is not comfortable with wireless technology and are concerned about RF interference in the warehouse. Northridge has hired you to help.

1. Prepare a PowerPoint presentation for the IT staff of at least 12 slides that covers RF loss and the factors that can influence it. Because these employees have a technical background your presentation should be technical in its nature.
2. After the presentation Cards, Cards, Cards! is now considering both a WLAN for internal warehouse use as well as a remote wireless gateway. However, they want more information regarding the Fresnel zone. Using the Internet and other sources, dig deeper into the Fresnel zone and create another presentation that gives more detail. Your PowerPoint presentation should be 8–10 slides in length.