Electromagnetic Waves

Using Electromagnetic Waves

Read to Learn

How do you use electromagnetic waves?

Almost everything you do involves some type of electromagnetic wave. Perhaps a clock radio wakes you with music in the morning. You are warm under your blanket because infrared radiation from your body changed into thermal energy. When you crawl out of bed, you turn on a lamp and use light to see which clothes to wear.

Radio Waves

The signals sent from radio and television stations are radio waves. Radio waves can pass through many buildings, yet they don't carry enough energy to harm humans. The wavelengths of radio waves are long enough to go around many obstacles. Radio waves travel through air at the same speed as all electromagnetic waves.

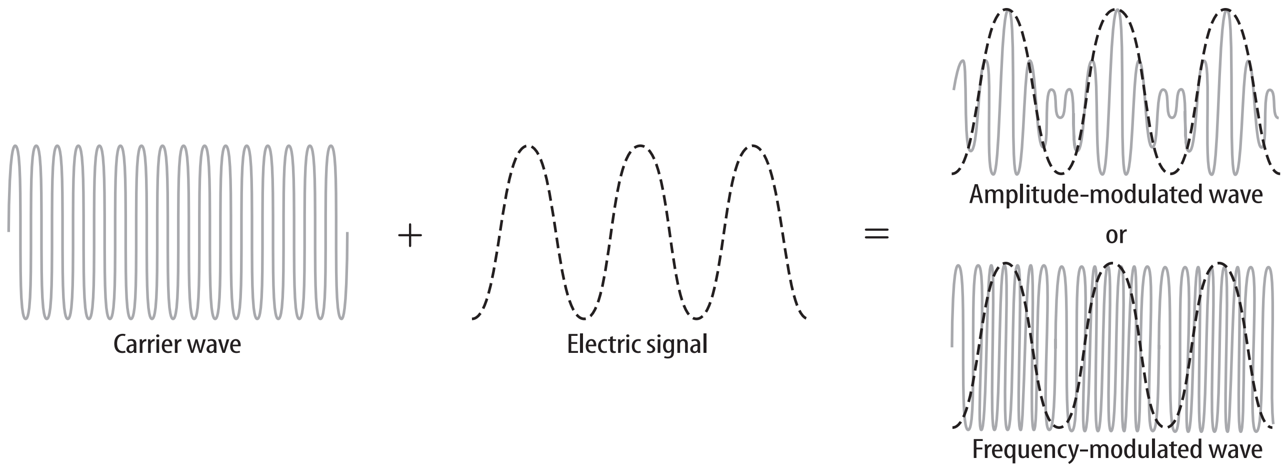
In the past, it might have taken days for news to travel from one part of the United States to another. Today, you can watch and listen to events around the world as they happen! **Broadcasting** *is the use of electromagnetic waves to send information in all directions*. Broadcasting became possible when scientists learned how to use radio waves.

Radio and Television

How do your radio and television receive information to produce sounds or images? A radio or TV station uses radio waves to carry information. Each station sends out radio waves at a certain frequency. The station converts sounds or images into an electric signal. Then, the station produces a **carrier wave**—*an electromagnetic wave that a radio or television station uses to carry its sound or image signals*. The station modulates, or varies, the carrier wave to match the electric signal. The signal then gets converted back into sound or images when it reaches your radio or television.

Two ways of changing a carrier wave to send information are shown in the figure below. **Amplitude modulation** (AM) *is a change in the amplitude of a carrier wave*. Amplitude is the maximum distance a wave varies from its rest position. **Frequency modulation** (FM) *is a change in the frequency of a carrier wave*. Changes in frequency match changes in sounds or images.

Amplitude Modulation and Frequency Modulation



Digital Signals

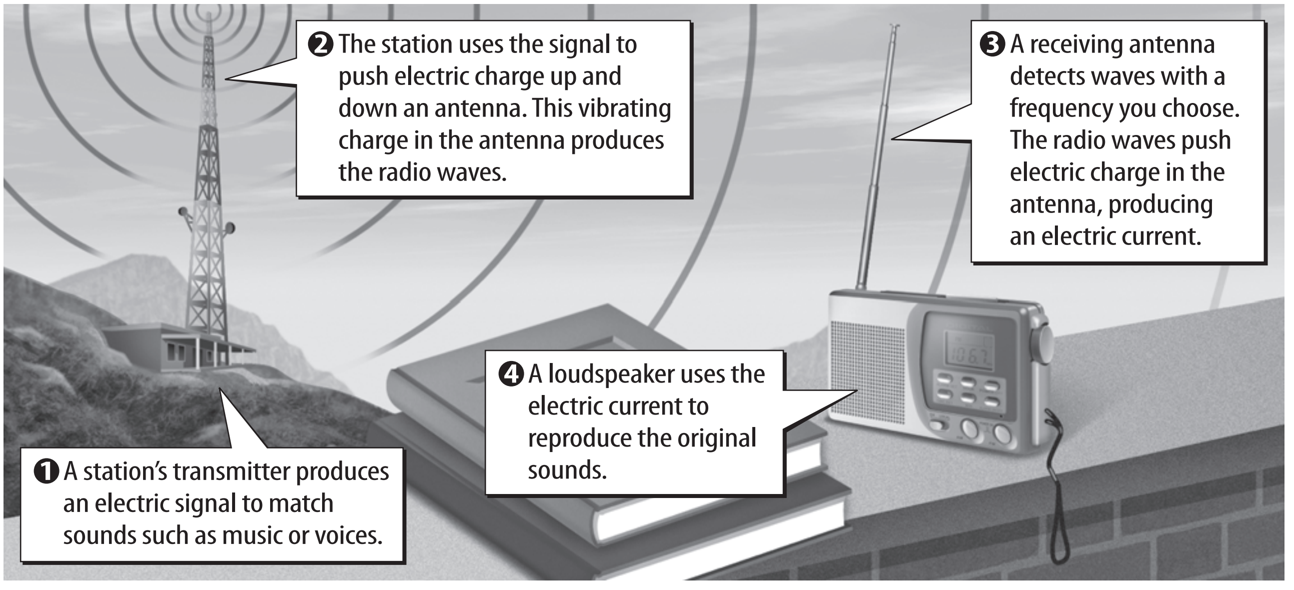
Television stations and some radio stations broadcast digital signals. Look at the amplitude-modulated wave in the figure above. Notice how the wave changes smoothly from high to low. This type of change is called analog. A digital signal, however, changes in steps. Stations can produce a digital signal by changing different properties of a carrier wave. For example, the station might send the signal as pulses, or a pattern of starting and stopping. The wave might have a code of high and low amplitudes. Sounds and images sent by digital signals are usually clearer than those sent by analog signals.

Transmission and Reception

The figure below describes how a radio station broadcasts a signal. A transmitter produces and sends out radio waves. An antenna receives the waves and changes them back to sound. Television transmission is similar. However, for cable television, the waves travel through cables designed to carry radio waves.

The wavelength of an AM carrier wave is typically much longer than the wavelength of an FM carrier wave. A long wavelength means that AM signals can pass around obstacles and travel farther than FM waves. AM waves also are long enough to reach Earth's upper atmosphere without scattering. FM waves typically have higher frequencies and more energy than AM waves. Therefore, FM waves usually produce better sound quality than AM waves.

Radio Transmission



Microwaves

You've probably used a microwave oven to heat food. Did you know that you also use microwaves when you use watch a television show that uses satellite transmission?

Like radio waves, microwaves are useful for sending and receiving signals. However, because microwaves have a shorter wavelength, they carry more information than radio waves. Microwaves also pass easily through smoke, light rain, snow, and clouds.

Cell Phones

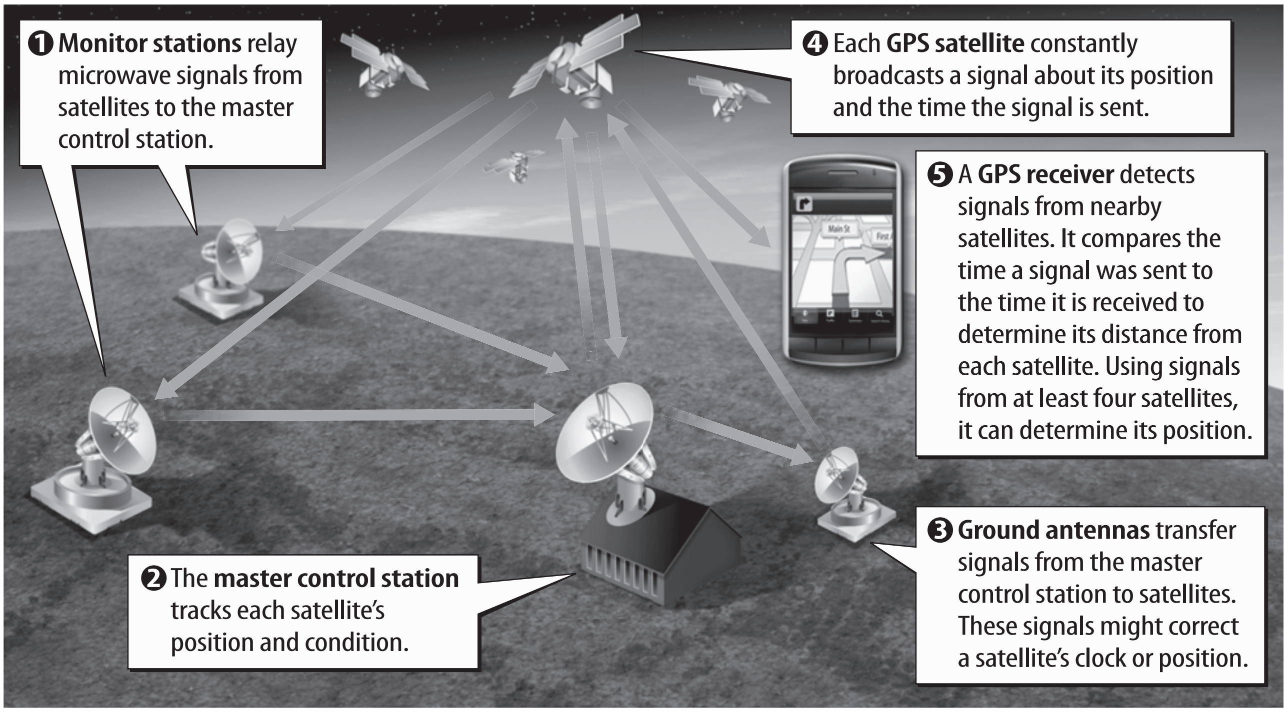
A cell phone company sets up small regions of service called cells. Each cell has a base station with antennae. When you make a call, your phone sends and receives signals to and from the cell tower. Cell towers hold antennae from one or more service providers. Electric circuits in the base station direct your signal to other towers. A signal passes from cell to cell until it reaches the phone of the person you called.

Communication Satellites

Have you watched a sports event or heard a news story from around the world on your TV? Information about the sounds and the images probably traveled by microwaves from a satellite to your TV. Some homes have a satellite dish that receive signals directly from satellites. Satellites send and receive signals much like antennae on Earth do. A transmitter sends microwave signals to the satellite. The satellite sends the signal to other satellites or to another place on Earth.

The figure below describes the use of satellite signals to find directions. *The* **Global Positioning System** (GPS) *is a worldwide navigation system that uses satellite signals to determine a receiver's location*. More than 24 GPS satellites continually orbit Earth. These satellites send signals about their orbits and the time. To calculate its position, a receiver must analyze signals from at least four of these satellites.

Global Positioning System



Infrared Waves

You read in Lesson 2 that vibrating molecules in any matter emit infrared waves. The wavelength of the infrared waves depends on the object's temperature. Hotter objects emit infrared waves with a greater frequency and shorter wavelength than do cooler objects. Scientists have developed technology that produce images showing how much thermal energy a person or a thing emits.

Infrared Imaging

Thermal cameras take pictures by detecting infrared waves rather than light waves. They convert invisible infrared waves, or different temperatures, to different colors so that your eyes can interpret the information. Medical professionals use thermal imaging to locate areas of poor circulation in the body. Thermal imaging of a building can identify areas where excessive thermal energy loss occurs.

Can you see in the dark? Night-vision goggles make buildings and other objects visible at night. The goggles use infrared waves similar to the way a normal camera uses light. Using the small amount of infrared light present, the goggles produce enough light that a person can easily see objects in the dark.

Imaging Earth

Scientists launch satellites that detect and photograph infrared waves coming from Earth. These infrared images might show variations in vegetation or snowfall. Some images can even show a fire smoldering in a forest before it bursts into flame.

Light

The Sun provides most of Earth's light, but light emitted on Earth also has important uses. Think about how difficult driving in congested areas would be without automobile headlights, street lights, and traffic signals. Without electric lights, homes and businesses would be dark at night. Televisions, computers, and movie theaters also rely on light. Some forms of communication rely on light that travels through optical fibers—thin strands of glass or plastic that transmit a beam of light over long distances.

Ultraviolet Waves

Too much exposure to ultraviolet waves can damage skin, but these same waves also can be useful. Certain materials glow when ultraviolet waves strike them. The materials absorb the energy of the waves and reemit it as light. Credit cards, for example, have invisible symbols stamped on them using this material. When a store clerk holds the card under an ultraviolet lamp, the symbol appears. Scientists also can identify some minerals in rocks by the way they glow under an ultraviolet lamp.

Ultraviolet waves also are useful for killing germs. Just as ultraviolet waves can damage your skin, these waves can also damage germs. Food manufacturers might use ultraviolet lamps to kill germs in some foods. Campers might use ultraviolet lamps to purify lake water.

Medical Uses

In hospitals and clinics, having a germ-free environment might be the difference between life and death. Medical facilities sometimes clean tools and surfaces by bringing them near an ultraviolet lamp. Some air and water purifiers use ultraviolet light to kill germs and reduce the spread of disease.

Ultraviolet light has other medical uses. For example, exposure to ultraviolet waves can help control or cure certain skin problems, such as psoriasis. The patient's skin is exposed to ultraviolet light. The waves carry enough energy to slow the growth of the diseased skin cells.

Dentists use ultraviolet light to harden adhesives quickly. The adhesive hardens in just a few seconds. Without ultraviolet light, adhesives might take several minutes to harden.

Fluorescent Lightbulbs

Fluorescent lightbulbs use the energy from ultraviolet waves to produce light. The process is similar to the way a symbol on a credit card glows under ultraviolet light. Certain chemicals inside the lightbulb glow when they are exposed to ultraviolet light.

When you flip a switch and provide electricity to the bulb, an electric current flows through a gas inside the bulb. The heated gas emits ultraviolet light. This light strikes a chemical that coats the inside of the bulb. The chemical absorbs the energy of the ultraviolet waves and reemits it as light.

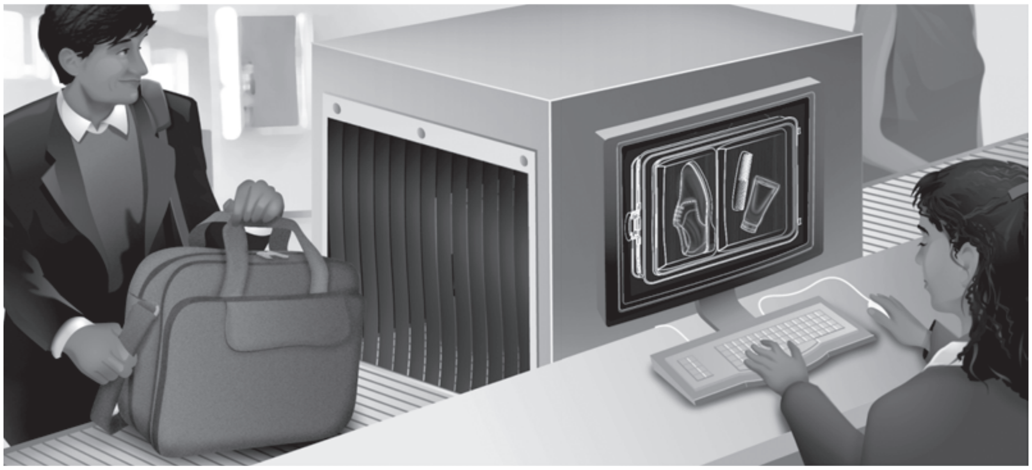
X-Rays

X-rays have even more energy than ultraviolet waves and can pass through skin and muscle. Although this property makes X-rays dangerous, it also makes them useful. Two important uses of X-rays are security and medical imaging.

Detection and Security

X-rays are used for security scanning because they can pass through many materials, but metal objects block them. Airport security scanners, like the one in the figure below, can form images of the contents of luggage. Scanners do this by measuring how different materials transmit the X-rays.

Airport Security



Medical Detection

Doctors and dentists use X-rays to examine bone. X-rays pass through soft parts of the body, but bone stops them. When X-rays strike photographic film, the film turns dark. Light parts of the film show where bone absorbed the X-rays. A computed tomography (CT) scanner provides even more detailed images. It is an X-ray machine that rotates around a patient, producing a three-dimensional view of the body.

Gamma Rays

Because of their extremely high energy, gamma rays can be used to destroy diseased tissue. Gamma rays also can be used to diagnose medical conditions. Recall that gamma rays are produced when an atom's nucleus breaks apart or changes. In a positron emission tomography (PET) scan, a detector monitors the breakdown of a chemical injected into a patient. The procedure uses a chemical that is attracted to diseased parts of the body. The detector can locate the disease by detecting the gamma rays emitted by the chemical.