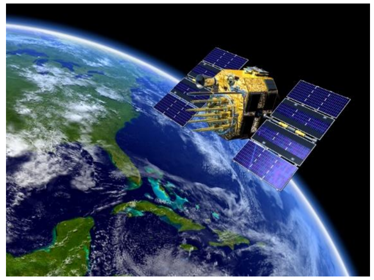
Reflect



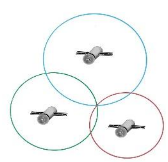
Have you ever wondered what GPS, cellular phones, and remote controls have in common? They all work using electromagnetic waves to encode and transmit information. Each device has limitations based in part on the properties and behaviors of electromagnetic waves.

GPS relies on a combination of satellites and receivers. The Global Positioning System (GPS) operates using a minimum of 24 GPS satellites orbiting Earth. The orbit of each satellite is known precisely. Each satellite contains an atomic clock and a radio wave transmitter. These satellites are spaced evenly over the globe so that at any point on Earth's surface, at least four satellites are 'visible' above the horizon at any time.

GPS receivers are built into many consumer devices, such as cellular telephones and tablet computers. Dedicated GPS units are also available. Each receiver has a clock and a radio receiver. To determine where it is, a receiver takes the radio signals it receives from multiple satellites and calculates how far it is from each satellite, which gives it its location on Earth. In order to do this, the satellite signal has to include the precise location of the satellite and the time it sends its signal. Distance is determined by measuring the time it takes a radio signal from the satellite to reach the receiver. For example, a satellite may send a radio transmission starting at exactly 12:00 am. The receiver records when it receives the transmission and uses the time difference to determine the distance between itself and the satellite. The distance from each satellite puts the receiver on a circle of a particular radius. Using geometry, the receiver determines its precise location.

Look Out!

Albert Einstein discovered that time passes differently on Earth compared to space. Therefore, clocks work differently in space. GPS receivers have to take this into account when calculating distance.

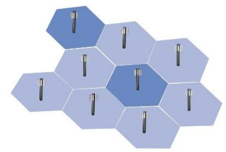


Once the receiver has calculated its distance from three different satellites, it uses the process of trilateration to determine its location. If there appears to be significant error in the location, information from a fourth satellite will be used. Although the diagram shows trilateration in two dimensions, most GPS units can also determine altitude.

Cell phones also rely on radio signals. Several innovations have influenced the rise of cell phones. The 'brains' of computers, called computer chips, have become both small and very powerful. Battery technology has improved such that small batteries are both inexpensive and long lasting. Using low power signals increases battery life even further.

Look Out!

Cell phones require a network of radio towers. Each cell phone tower handles the calls for a specific area. This area, called a cell, is shaped like a hexagon, which creates a hexagonal grid pattern in urban areas. Cells next to each other in the grid use different frequencies to avoid interfering with each other. Non adjacent cells can use the same set of frequencies, so companies can improve coverage without needing more channels.



Cell phones have IDs that identify the phone, its owner, and the service provider. Each cell phone call requires two frequencies, one to talk and one to listen. Control frequencies are used by the Mobile Telephone Switching Office to keep track of which cell the phone is located in and when to hand off the call from one cell to the next.

What Do You Think?

Signal strength is usually displayed on cell phone screens using a series of bars. Cell phones usually won't work in parking garages or basements. If you experience poor cell phone reception, what strategies might you try to improve it?

Everyday Life: Cell Phones in Developing Nations
According to Robert Hahn and Peter Passel (http://www.usnews.com/opinion/blogs/economic-intelligence/2012/04/12/how-cell-phones-are-boosting-kenyas-economy), in 1999 only 3% of people living in Kenya had access to any phone. In 2012 the number had jumped to 93%. Cell phone towers are much cheaper to build than running wires to every home, so the cost of cell phone use is low. Cell phones in many developing countries are used not only to communicate with other people but also to provide access to reading material and the ability to transfer money easily without the need for a bank account. Cell phones are called a 'disruptive innovation' for their ability to radically change people's lives.

Reflect

Remote controls use infrared light, or heat. The remote control transmitter sends out a pulse of light that corresponds to a particular binary code (a series of 0s and 1s). For example, there is a code for turning the power on or off, and changing the volume. The receiver in the TV changes the light pulse back into binary code and provides it to a computer in the TV to respond.

Infrared has several limitations, including range, line-of-sight, and interference. Its range is only about 10 m. Infrared waves don't go through walls or around corners, so the remote has to be able to 'see' the TV to work. Many different objects give off electromagnetic radiation in the infrared range, such as the Sun, fluorescent light bulbs, and even the human body. TV receivers use filters to block out wavelengths that aren't the wavelength sent by the transmitter.

Electromagnetic Waves in Communication Devices

Connecting With Your Child

Building a Periscope
A periscope is a tool in which several mirrors at opposite ends of a long tube allow people to see around objects. Designing and building a periscope is an excellent way for your child to learn about line-of-sight and the fundamental laws of reflection. Remember that light travels in straight lines, and the angle of incidence (where it hits) equals the angle of reflection (how it bounces off). In other words, the angle at which a light ray approaches a mirror is the same as the angle the light ray bounces off the mirror. Plans and instructional videos for building a periscope can easily be found on the Internet. Use search terms such as “periscope plans.”

For most designs, you will need these items:

- Long, square box or enough cardboard to make such a box
- Two small pocket mirrors
- Protractor
- Sharp knife
- Duct tape

The other end of this periscope is inside a submarine underwater, where someone is observing events above the surface.

As you and your child position the mirrors at either end of the box, explain the significance of the angles at which the mirrors are set. (The first mirror must reflect light entering the periscope toward the mirror at the other end of the periscope. This mirror must then reflect light toward the eyepiece of the periscope.) Perhaps also watch videos of how a periscope is used onboard a submarine. Encourage your child to find other uses for the periscope. For example, a periscope can let someone look around a corner or above a couch.