4.3: Antenna

Tutorial 4.3: Antenna

In the previous simulation you saw the electromagnetic waves created by an oscillating electric charge. In this simulation we look at only the wave traveling in the x-direction and its effect on a second charge inside a receiving antenna. Only the y-component of the *change* in the electric field is shown (so an oscillation frequency of zero will show nothing, because there is only a constant electric field).

The simplest type of receiving antenna can be approximated by free charges (electrons) constrained by a metal wire. For a receiving antenna oriented in the y-direction, an oscillating field traveling in the x-direction will cause the charges in the receiver to oscillate in the y-direction with the same frequency as the wave (the charges cannot move in the x-direction because they are confined to the wire). This oscillating current can then be analyzed by electronic circuitry to extract the transmitted signal. A general rule of thumb is that for strongest reception, the receiving antenna should be roughly the same length as the wavelength of the wave it is trying to receive.

For simplicity this simulation has oscillating positive charges in the sending and receiving antennas. (Electrons feel a force in the opposite direction of the applied field.) Time is measured in microseconds (10^{-6} s).

Antenna

Questions:

Exercise 4.3.1

Run the simulation and describe what you see. Does the receiving antenna charge start oscillating immediately? Why not?

Exercise 4.3.2

In the previous simulation you learned that sending antennas give the strongest signal perpendicular to the antenna and so are usually mounted vertically. This is so that the signal is equal in all horizontal directions where the receiving antennas will be located. Why are receiving antennas generally oriented vertically?

Exercise 4.3.3

Try different oscillation frequencies. How does the frequency of the sending charge compare with the frequency of oscillation of the charge in the receiving antenna?

Exercise 4.3.4

Use the step button to find the time lapse between when the source charge starts to oscillate and when the receiver starts oscillating. If the receiving antenna is $1.6 \times 10^3\ \mathrm{m}$ away, what is the speed of the wave?

Exercise 4.3.5

Repeat the previous exercise with different oscillation frequencies. Does changing the oscillation frequency change the speed the wave travels in the x-direction? What does change if the oscillation speed changes? (Hint: Recall that $v = \lambda f$ where v is the speed of the wave.)

Exercise 4.3.6

What do you notice about the amplitude of the wave as it travels away from the antenna? Explain.

Exercise 4.3.7

Why are cell phone antennas small (for modern cell phones they are hidden inside the phone itself) but FM and AM radio antennas and TV antennas typically around a meter in length? Why are short wave radio antennas much larger?

The simulation is incomplete in one sense because we know that a moving charge also creates a magnetic field. The Biot-Savart law and Ampere's law tell us that for positive charge flowing in one direction (for example upwards in the translation case) a magnetic field will be formed in a circle around the electric flow in a right hand sense (if your thumb points in the direction of positive charge flow, your curled fingers give the direction of the magnetic field).

Exercise 4.3.8

What direction will the magnetic field point in the vicinity of the sending antenna if the charge is moving upward? (Hint: Describe the field to the left and right the charge flow as well as behind the screen and in front of the computer screen.)
