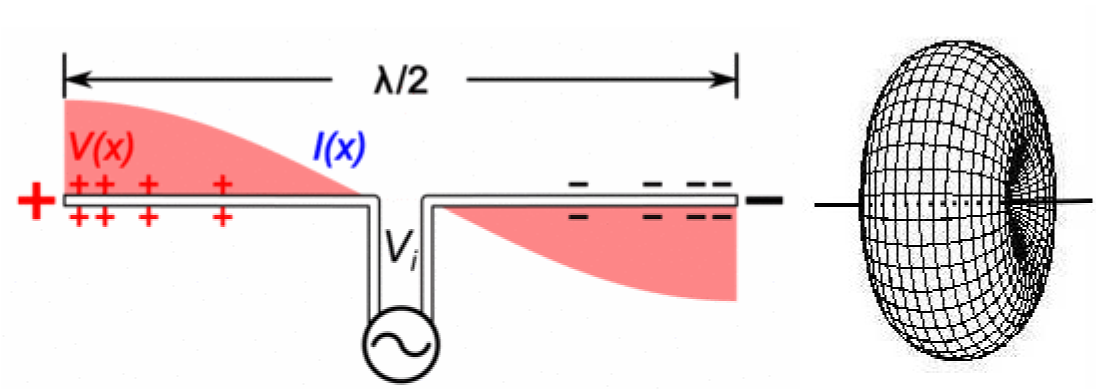
How To Make A Radio Wave

Back on the Intro Page, we introduced to the idea of frequency and saw that

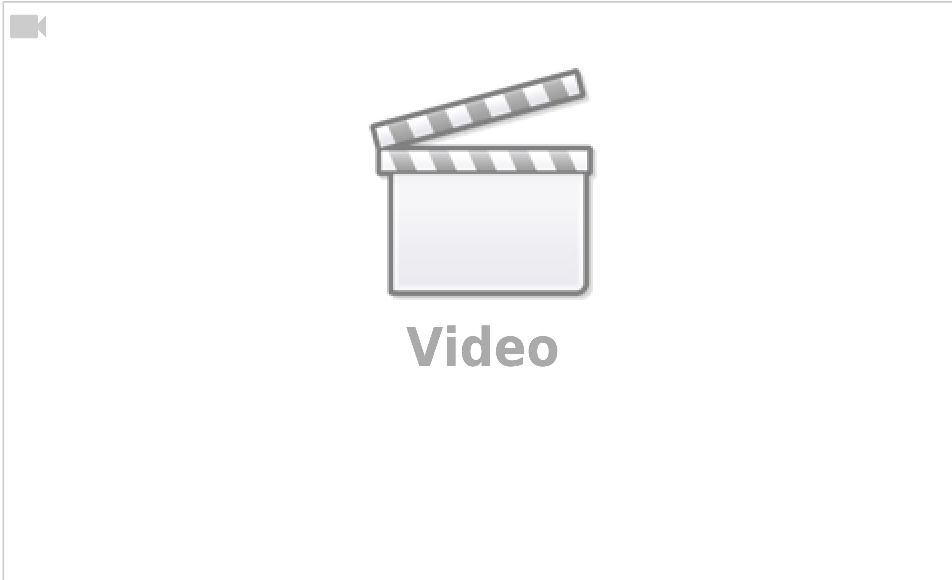
> A Hertz (Hz) is a measure of how fast something vibrates […]
>
> Just seeing "Hz" doesn't tell you anything about what it is that's oscillating in the same way that seeing "°C" doesn't tell you anything about what it is that has temperature. "Hz" is a unit of measure, not a thing itself.
>
> Radio waves are created by oscillating electric currents. How many times this current oscillates per second is called the frequency, which is measured in Hz.

It's now time to add a few more details to this story. Here is a basic recipe for making a radio wave:

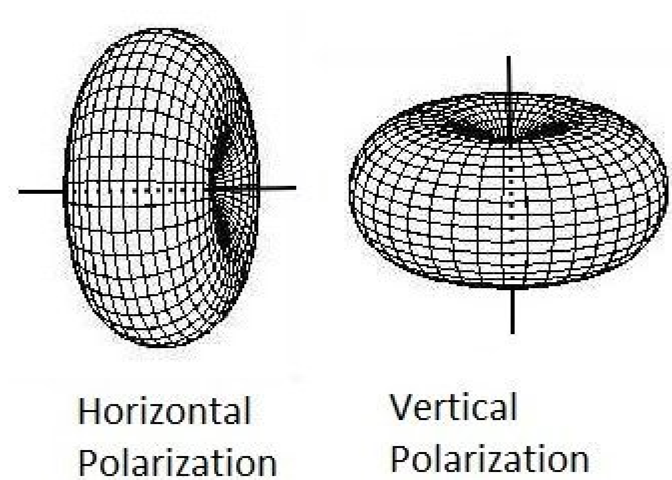
1. Get a length of conducting wire and lay it in a straight line.
2. Cut it in half right in the middle and bend both ends at right angle.
3. Connect the two middle ends to each side of an alternating current generator.



Voila! The antenna we've made is called a *dipole*. Assuming that its length matches the frequency of the current generator (more on this shortly), and that the antenna is high enough above the ground, you've created a radio wave.[1] As electrons move up and down the length of the wires, they create varying electric and magnetic fields that couple together according to Maxwell's Equations and propagate outward in a doughnut shape.[2]



Horizontal vs Vertical Polarization



Here's the critical part though: In the same way that an alternating current through an antenna creates a radio wave, a radio wave hitting an antenna induces an alternating current through it if the radio wave hitting the antenna is in the same "direction" as the antenna.

This "direction" is called polarization.

Effect on Communication

The polarization of an antenna is determined by the orientation of the electric field relative to the Earth's surface. So a horizontal antenna will produce a radio wave that has an horizontal electric field. The magnetic field part of the wave is always perpendicular to both the electric field and the direction of propagation, so in this case, it would be vertical.

In practice, polarization is more important for VHF and UHF communication because signals travel more or less directly from the transmitting antenna to the receiving one. For skywave HF communications, however, the ionosphere can change the polarization of the signal from moment to moment as the radio wave refracts, reflects, or goes through magnetic fields in the atmosphere. As such polarization of the antennas on HF frequency doesn't matter much because you never know what polarization your signal will end up having once it arrives at its destination.

Wavelength and Antenna Length

As we saw previously, the wavelength (λ) in metres of the wave is dictated by the frequency (f) in MHz and the speed of light:

$$ \lambda = \frac{300}{f} \qquad \text{or} \qquad f = \frac{300}{\lambda} $$

This explains the Band name in the table on the intro page. For example, the frequency range of the 2m band is 144 Mhz – 148 Mhz. If we calculate the wavelength of 146 Mhz, we get: 300 ÷ 146 = 2.05 m

Now it turns out that the size of the antenna is very closely related to the wavelength of the signal we wish to transmit or receive. For a dipole, the total length is roughly half of the wavelength. So an antenna for the 2m band should be roughly 1m long, while an antenna for the 160m band would be roughly 80m long!

We say "roughly" here because as we'll see later, the speed of electricity in a conductor is a bit less than the speed of light, so the antenna length end up a being roughly 5% shorter than calculated here.

Cellphone Antenna

LTE band 1 operates roughly at 2100 MHz.[3] How long would a dipole have to be?

- The wave length is: 300 ÷ 2100 = 0.14m = 14cm
- Half of the wave length would be 7cm, which is small enough to fit in the cellphone.

Questions

[1] GIF from Wikipedia Dipole Antenna

[2] Picture modified from Wikipedia Dipole Antenna

[3] Wikipedia LTE