Lot's of things in our lives transmit signals. From your cell phone when it's making a call, to your computer when it's sending an email, to your local radio station when it's broadcasting.

Here you see two objects that receive signals - they are radio receivers. Have you ever wondered how they pick out the signal they want out of all of the radio waves around them? In this video, we're going to find out.

This video is part of the information flow video series. A system is shaped and changed by the nature and flow of information into, within, and out of the system.

Hi, my name is Elena Glassman, and I am a graduate student in the Electrical Engineering and Computer Science Department at MIT.

Before watching this video, you should be familiar with basic electrical circuits, and how inductors, capacitors, and AM radio transmitters work.

After watching this video, you will be able to explain how a basic radio receiver circuit functions to select particular radio frequencies.

This Hammarlund HQ120 communications receiver was introduced in 1938. It tunes in radio waves ranging from 540 thousand cycles per second to 30 million cycles per second. It can decode signals encoded with Amplitude Modulation, abbreviated as AM, or "continuous wave" modulation, abbreviated as CW.

This Drake R-4 was introduced later, in 1964, and is optimized for amateur radio bands within the same frequency range covered by the HQ120. Both of these radios were popular with amateur radio operators. Amateur radio operators are radio enthusiasts who pass U.S. Federal Communications Commission tests to receive official government call signs and the right to broadcast on select bands.

Amateur radio operators are anything but amateur, serving as part of an important worldwide network. When cell phones, the internet, or other communication networks are down, amateur radio operators can help pass along important information. Amateur radio operators have historically experimented with and advanced cutting-edge radio technologies. (viewers hear radio making some noise) Let's delve deeper into how these radios receive information.

Recall that radio waves are electromagnetic waves whose frequencies fall in a certain range. A variety of data types can be transmitted over radio waves by systematically modulating some property of the wave.

The information we want to transmit--say speech or music--has a much lower frequency than the carrier radio wave. We can encode this lower frequency by modulating the amplitude of the carrier wave. This is called Amplitude Modulation, which is used in AM radio.

CW radio stands for continuous wave modulation and is traditionally used to transmit Morse code by switching the carrier signal on and off.

All of the signals being transmitted around the globe are superimposed on to each other.

Our goal is to understand how a basic radio circuit, called the regenerative circuit, works to pick out one frequency. This circuit was a breakthrough in radio technology both in terms of amplification and selectivity.

It was invented in 1914 by American electrical engineer Edwin Armstrong when he was an undergraduate at Columbia University.

This circuit was widely used in radio receivers, called regenerative receivers, between 1920 and World War II. They are still used in low-cost electronic equipment such as garage door openers.

Our Hammerlund and Drake radios use more sophisticated circuitry, also invented by Armstrong. However, we're going focus on the more basic and still powerful regenerative circuit.

The regenerative circuit seen here is a classical, elegant electrical circuit that amplifies while selecting a particular radio wave frequency.

Let's start by identifying the elements from this diagram in our actual radio. This is the antenna for the radio. And this is the symbol for that antenna in our diagram. This dial allows us to control the frequency we're selecting. And this is the variable capacitance element that determines which frequency this basic regenerative receiver circuit will select for.

This is a vacuum tube in the radio.

And in the diagram. It is going to act as an amplifier.

Together the volume control and the speaker enable us to hear the information decoded from the radio signal.

These are represented by a variable resistor and the headphone cartoon in our diagram.

Now let's understand how this circuit works! Radio waves induce waves of alternating current through the antenna. By the phenomenon of inductive coupling, the radio wave energy is picked up by this tuned circuit, which is just an inductor and variable capacitor in parallel. This circuit acts like an echo chamber for radio waves.

To get a better sense of how this parallel inductor and capacitor work, let's look at a system with which you may be more familiar--brass instruments.

Brass players create lots of sound frequencies when they blow through their mouthpieces.

[sound of buzzing] The brass tube acts as a resonant cavity or echo chamber. Sound waves bounce back and forth between each end of the tube.

Particular frequencies constructively interfere or reinforce each other, while other frequencies destructively interfere, and therefore have their amplitude diminished.

As the slide is moved, the length of the tube changes, and that changes which frequencies are reinforced and which frequencies are damped. This parallel inductor and capacitor act the same way for radio waves. Changing the capacitance of the capacitor is equivalent to changing the length of the trombone's tube by moving the slide.

The noise produced by buzzing into the mouthpiece and filtering it with the brass tube is sufficient to produce audible sound.

But radio waves may be coming from transmitters very far away, and may have very small amplitudes by the time they reach us. It's not uncommon for these receivers to pick up radio stations part way around the globe. How are we going to deal with this? We need amplification!

The radio waves echoing in the tuned circuit here are applied to the input of this vacuum tube, which acts as an amplifier. An amplifier reproduces the signal applied to its input, but with greater magnitude. The added energy comes from a local power source, like a battery.

That might be enough amplification, but we can do even better using positive feedback!

The tickler, located here, takes the amplified radio signal from the vacuum tube and feeds it back into the echo chamber, to reinforce new radio waves coming in from the antenna at that same frequency!

A frequency is strengthened by the echo chamber alone, so it becomes even larger in amplitude after amplification and positive feedback into the same echo chamber! Likewise, any frequencies that did not resonate well in the echo chamber will be diminished further with each circulation back through the loop. This echo chamber with its output amplified and fed back into itself is what is responsible for achieving our stated goal of selecting only one frequency to tune in to, in the presence of all the other frequencies carrying information.

Now that we have selected and amplified the carrier frequency, we still need to extract the original information.

You might expect our signal after amplification to look like this. But the information encoded in the amplitude would be hard to decode because the average amplitude is constant everywhere.

Luckily for us, the vacuum tube is a nonlinear amplifier.

It accentuates the lower half of the signal and diminishes the top half, giving us a signal that looks more like this. Since headphones are natural smoothing filters that convert variations in current to air pressure waves, the user hears the original information encoded in the AM signal. If we hadn't accentuated the lower half of the signal before smoothing, you wouldn't hear anything. There's one last aspect of this simple regenerative receiver we'd like to point out.

After all this selective amplification of the carrier frequency, we must still extract the information carried by the envelope of its amplitude.

We take advantage of the imperfect amplification of the vacuum tube to accentuate the lower half of the signal.

Since headphones are natural smoothing filters that convert variations in current to air pressure waves, the user hears the original information encoded in the AM signal.

It was extremely clever to use a single tube to amplify, provide selectivity, and demodulate an AM signal at a time when tubes were very expensive and considered cutting edge.

This Drake R-4 radio uses more sophisticated circuitry but even modern radio receivers are built with digital circuits that operate on the same basic principles!

Radio is a cool, handy way to disseminate information, so humans have created lots and lots of electromagnetic waves and transmitted them into the air at various frequencies.

We've even standardized who can transmit and at what frequency.

Here's the radio spectrum that is available. You see AM and FM broadcast within this spectrum.

This radio spectrum has been divided up even further for different uses: mobile phones, amateur astronomy, satellites, space research, amateur radio, and Earth research.

Zooming out further we see that lots of different communities have their own spot allocated.

Out of all of that radio activity, we can now pull out what we personally want. Maybe it's finding a friend or fellow amateur radio operator transmitting from another continent, or maybe it's the BBC, broadcasting international news.

To summarize, in this video, we have explained how the components in the regenerative receiver circuit work together to dampen unwanted frequencies, while selectively amplifying and demodulating a desired AM signal. This is no small feat, given the amount of radio waves humans broadcast!

We've also demonstrated the tuning process with a Drake R-4 radio receiver built for amateur radio operators in the 1960s. Learning about these radio receivers with my dad when I was a kid was instrumental in developing my own interest in electrical engineering!

It was really fun to share some of the circuitry with you. If you want to try something a little more hands-on, I recommend checking out the local amateur radio community or signing up for a course in electrical engineering!