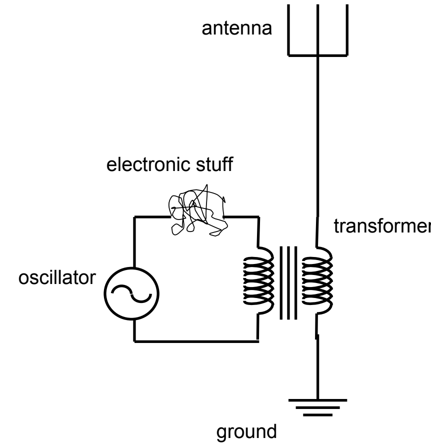
RADIOS

There are two parts of a radio system we need to talk about. The first is the sending circuit and the other is the receiving circuit. We will start with the sending circuit.

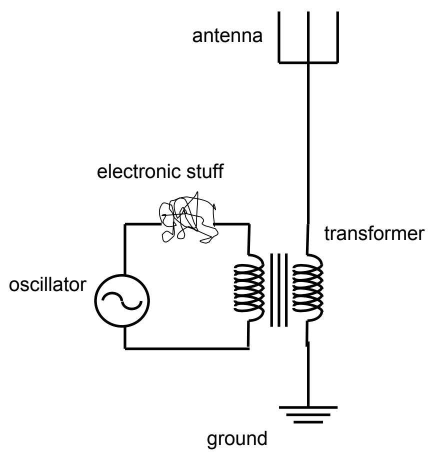
THE SENDING CIRCUIT

A sending circuit is comprised of a single frequency oscillator (with a little slop on either side of the primary frequency) to produce the carrier wave, some circuitry to put information on that carrier wave, a transformer that transfers the signal to an antenna and an antenna. This set-up is shown to the right.



The call number of a radio station denotes the single frequency the station can use to send out its information. That frequency is licensed to the station by the FCC.

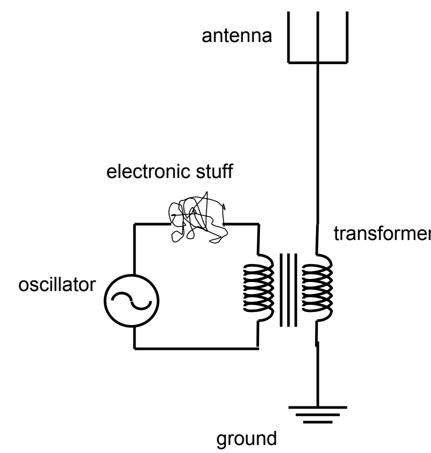
Example: KFWB, channel 98. If you look at the units on the face of a radio tuner, you will find that they are 10xkHz. What that means is that the frequency KFWB has to use is 98x10x1000 Hz, or 980,000 Hz.



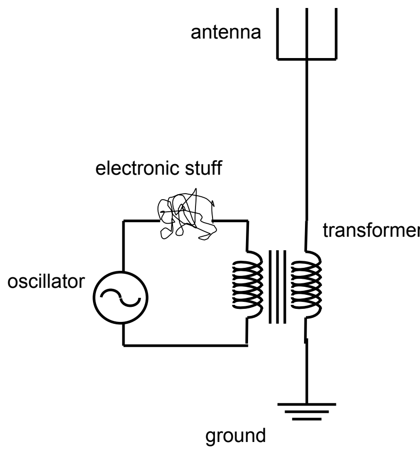
So how is the signal created?

The radio’s signal is transferred to the antenna via a transformer. Once on the antenna, a number of things happens in rapid succession.

As charge periodically runs up onto, then off of the antenna, the charge in motion produces a magnetic field that circles the antenna, is time-varying and alternates in direction.

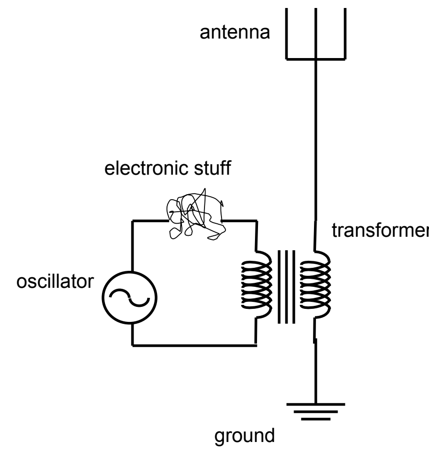


While the alternating, time-varying magnetic field is being generated, the presence of a preponderance of positive charge running onto and off of the antenna creates an electric field in the vicinity of the antenna that is directed outward. When the charge on the antenna becomes negative, the direction of the electric field turns inward. In other words, as charge becomes present on the antenna, you get a time-varying, alternating electric field around the antenna in the same region in which the magnetic field exists.



If these alternating fields happening at a frequency below 500,000 cycles per second, the fields will have time to collapse before the new fields going the other way are generated.

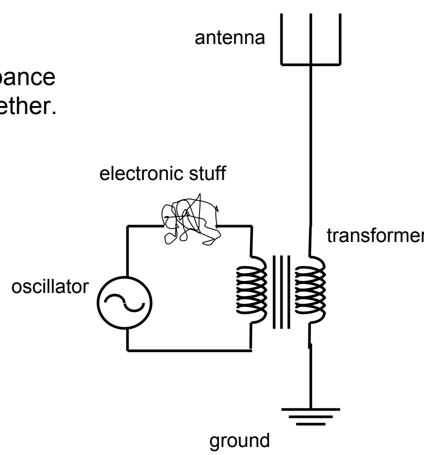
If these alternating fields happening at a frequency above 500,000 cycles per second, there won't be time for the fields to collapse before the new fields going the other way are generated, so the electrical and magnetic disturbances will *flip off* the antenna and leave at the speed of light (300,000,000 m/s).



This is what a radio wave is: an electromagnetic wave--an electric disturbance and a magnetic disturbance that propagates through space together.

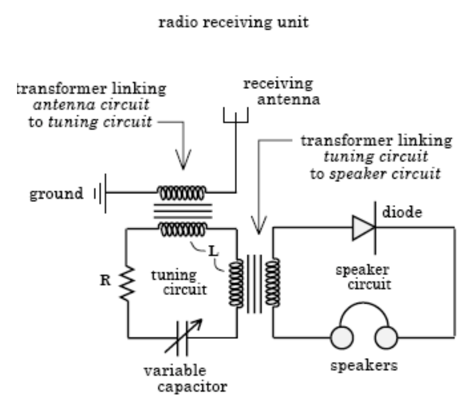
Note that KFWB's EM wave has a frequency of 980,000 Hz, well above the 500,000 Hz required for this "flip off" phenomenon to occur.

That is how AM radio signals are produced. We still haven't talked about how information is put on the signal, but that will come shortly. For now, we turn to the receiving circuit.

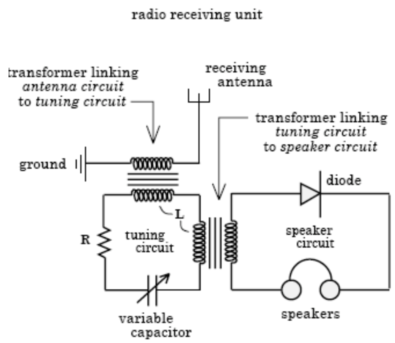


THE RECEIVING CIRCUIT

A receiving circuit has to do several things. It needs an antenna circuit to catch the radio station's EM wave, a tuning circuit that excludes extraneous stations and zeros in on the station you want to listen to and a speaker circuit to extract the information encoded on the radio station's signal. All of these circuits pieces, as they relate to one another, are shown to the right.



The Antenna Circuit:

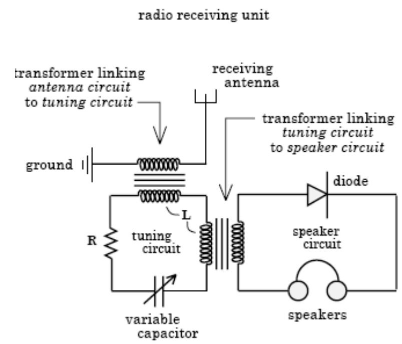


If you use a *rabbit ears* receiving antenna, the charge carriers in the antenna will be motivated to oscillate back and forth on the antenna as the alternation electric field component of the EM wave passes by.

If you use a *round* receiving antenna, the charge carriers in the antenna will be motivated to oscillate back and forth around the antenna as the alternation magnetic-field component of the EM wave passes through the coil.

In both cases, it is the energy wrapped up in the electromagnetic wave that motivates charge in the antenna to move.

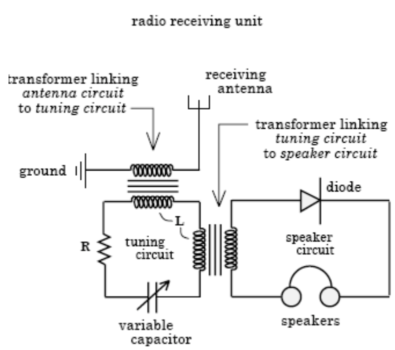
The Tuning Circuit:



The obvious problem with our set-up is that as it stands, the signal from every radio station in the area will impinge upon your receiving antenna. The signals will superimpose and the free charge on the antenna will jiggle chaotically.

There needs to be a way to tune out all the unwanted signals and keep the one associated with the station to which you want to listen.

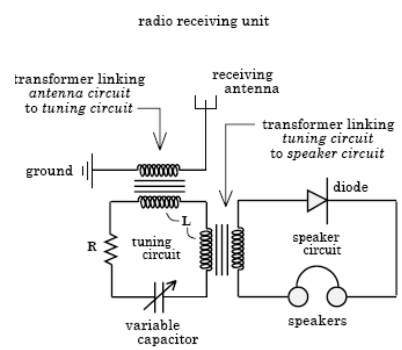
Enter the tuning circuit.



A transformer transfers the signals from the antenna circuit to the tuning circuit.

The tuning circuit is comprised of an inductor (this is really the secondary coil of the transformer that links the two circuits), a similar inductor attached to the transformer that will transfer the selected signal into the speaker circuit, a resistor (small but included as there is always resistor-like resistance in any wired circuit) and a variable capacitor.

In short, the tuning circuit is an RLC circuit that is powered by the signals that come in via the transformer from the antenna.



We've already talked about the fact that RLC circuits have one natural frequency at which they are willing to oscillate. That frequency was:

$$\nu = \frac{1}{2\pi}\sqrt{\frac{1}{LC}}$$

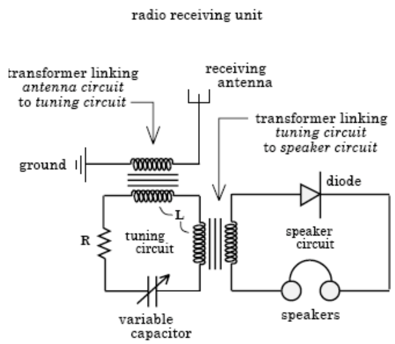
So let's suppose you want to pick up KFWB at 980,000 Hz. All you have to do is tune the variable capacitor until the resonance frequency for the circuit is 980,000 Hz, and the LC combination will allow that particular signal to proliferate within the tuning circuit while damping out all others.

In other words, if you want the information from a radio station to build within your radio, all you have to do is tune the RLC circuit's so that its natural frequency matches the frequency of the station you want to pick up.

The Speaker Circuit:

We have now selected our signal. It's time to decode the information on that signal. That means its time to look at the speaker circuit.

To understand how the speaker circuit does what it does, we have to do a quick review of how speakers work in general and we need to take a look at how radio stations put information onto their single frequency carrier wave. First, how do stations put information on their single high frequency wave?

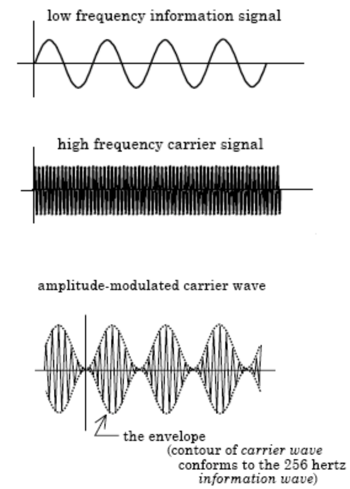


Carrier Waves, Information Waves and Envelopes:

Let's say you want to send out an information wave of middle C at 256 Hz. You are KFWB, so all you have is a high frequency carrier wave whose frequency is 980,000 Hz to work with.

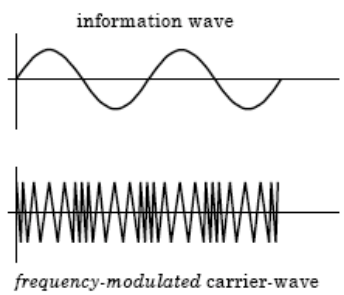
The clever thing you can do to accomplish this is to modulate (vary) the amplitude of the carrier wave (the 980,000 Hz wave) so that its envelope (its outline) has the form of the information wave (i.e., a wave at 256 Hz).

Radios that use this kind of signal encoding are called Amplitude Modulated radios, or AM radios.



MINOR NOTE: The other way radios signal encode is by modulating the frequency of the carrier wave. These are called FM radios.

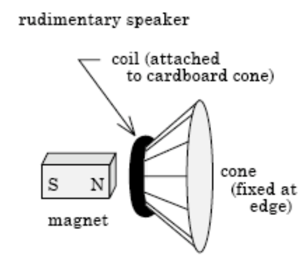
Another minor note: Whereas AM radios are prone to have static (if the sun lets loose with a 980,000 EM wave and you are tuned to KFWB, not only will your tuner circuit select KFWB's signal, it will also select the junk single from the sun). FM radios don't work that way, so FM radios have practically no static associated with them



Speakers

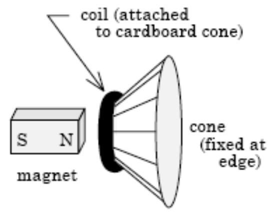
If you will remember, a speaker is really just a coil attached to a cone and a fixed magnetic field.

As current passes through the coil, the coil sets up a B- field of its own which interacts with the fixed magnet's B- field.



Example: Let's attach an AC source to the speaker. If the coil's magnetic field is such that it generates a north pole on the fixed magnet side of the coil, the repulsion between the two north poles will flex the cone outward (the cone will be fixed at its edges). The flexing will compress air adjacent to it sending the air out from the cone as a pressure ridge. When the AC source changes polarity, the coil's B-field will become a south pole near the fixed magnet and attraction will ensue. That will pull the cone back toward the fixed magnet creating a rarified region in the air adjacent to the cone.

rudimentary speaker



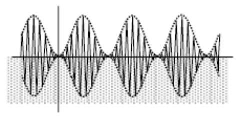
This back and forth flexing of the cone is what produces the pressure waves we associate with sound.

So we have a 980,000 Hz electromagnetic wave that is amplitude modulates so that its envelope mimics a 256 Hz wave.

If all we did was to pipe the high frequency wave into the speaker circuit, the speaker would just sit there. The cone is, after all, heavy and quite inert, and the alternating nature of the signal would go nowhere.

What's done is to make the signal into DC by placing a diode into the circuit.

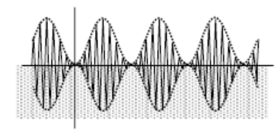
a diode in the speaker-circuit makes the amplitude-modulated carrier wave into DC



the diode wipes out the bottom-half of the wave (notice that the 256 hertz envelope is still intact)

Now, the polarity of the coil's B-field will always be the same and the amount of cone flex will be determined by what the waveform is doing *in general*. That is, if the waveform is, on average, getting bigger, the cone will, on average, flex more. And when the waveform is getting smaller, the cone will flex less. What's cool is that this variation will mimic the envelope of the carrier wave, which is the same as the information wave we are trying to reproduced (in our example, that would be a 256 Hz sound wave).

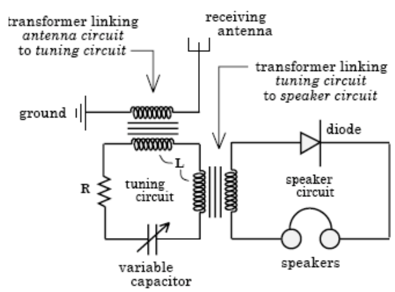
a diode in the speaker-circuit makes the amplitude-modulated carrier wave into DC



the diode wipes out the bottom-half of the wave (notice that the 256 hertz envelope is still intact)

In other words, the speaker in this circuits acts like a decoder, taking the carrier wave and turning it into an information wave.

radio receiving unit

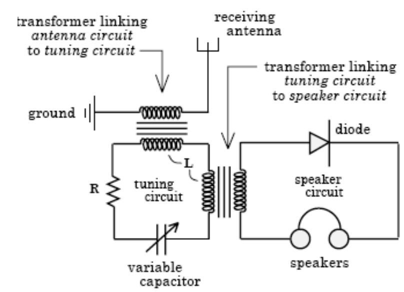


Having said all that, the overall circuit should now make sense.

The antenna circuit picks up any EM wave that impinges upon it and sends it to the tuner circuit via a transformer.

The capacitor in the tuner circuit is tuned so that that RLC circuit's resonance frequency matches the frequency of the station you want to listen to. All frequencies other than that frequency will die out in the tuner circuit with that surviving signal being transferred to the speaker circuit via another transformer.

radio receiving unit



The speaker circuit takes the high frequency carrier wave, chops it with a diode making it into DC, then has the speaker act as decoder.

There is no battery in this circuit. All the power necessary to make charge move in the circuit comes from the E/M wave from the radio station. The only downside is that the speaker in a circuit like this has to be tiny as there is very little power available to drive a speaker.

So how can you amplify the signal so that a larger speaker can be used?

An amplified circuit is shown to the right. The only difference between it and the unamplified circuit is that after transferring the signal from the tuner circuit to the speaker circuit, the signal is run through a transistor whose emitter is connected to a large battery. The transistor acts as usual with its depletion zone becoming larger or smaller depending upon the degree of positiveness of its base. With a set-up like this, you can drive ceiling-high Bosak speakers with no problem.