



## Build Your Own Crystal Radio

[https://www.sciencebuddies.org/science-fair-projects/project-ideas/Elec\\_p014/electricity-electronics/crystal-radio](https://www.sciencebuddies.org/science-fair-projects/project-ideas/Elec_p014/electricity-electronics/crystal-radio) ([http://www.sciencebuddies.org/science-fair-projects/project-ideas/Elec\\_p014/electricity-electronics/crystal-radio](http://www.sciencebuddies.org/science-fair-projects/project-ideas/Elec_p014/electricity-electronics/crystal-radio))

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### Experimental Procedure

#### Building Your Crystal Radio

1. The first step in building your crystal radio is to wind the receiver coil using the 22 AWG (American Wire Gauge) enamel-coated magnet wire and the cardboard tube.
  - a. The cardboard tube has a total of six holes punched in it, three at each end. The larger holes are to attach the cardboard tube to the wooden base with screws. The smaller pairs of holes are to thread the magnet wire through.
  - b. Put two pieces of double-sided tape lengthwise in the middle of your cardboard tube, one on each side (opposite each other), as shown in Figure 5. This will help keep your coil in place as you wrap it.
  - c. Thread one end of the magnet wire through a pair of holes, as shown in Figure 5. Pull about 12 inches of wire through the holes.
  - d. Now, begin to carefully and tightly wrap the magnet wire around the cardboard tube, starting just above the holes you just threaded. Each new wrap should be pushed up against, but not overlapping, the previous wrap, as shown in Figure 5.
  - e. Continue tightly wrapping the coil until you reach the set of holes on the other end of the cardboard tube. Keep approximate count as you go; you should be able to fit approximately 75 complete turns of wire.
  - f. Cut the wire, leaving about 12 inches extra dangling off the tube. Thread this end of the wire through the open set of holes at the opposite end of your coil from where you started.



**Figure 5.** Steps for making the receiver coil for your AM radio receiver. Be sure to leave at least 12 inches of wire sticking out on both ends of the coil, after threading it through the holes.

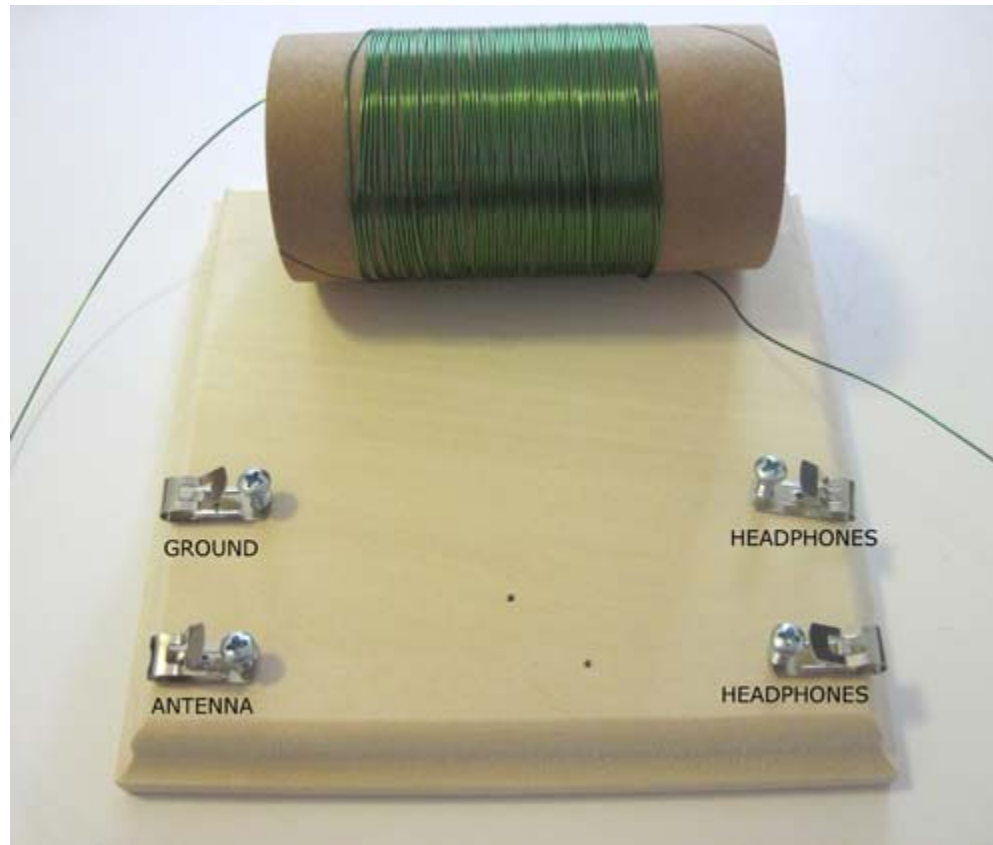
2. Optional: before you continue with the rest of the project, you can decorate your wooden base board using paint, markers, or other materials. Customize your radio! See Figure 20 for an example.
3. Attach the cardboard tube to the wooden base board using two #6 x ½ inch screws (these are the smaller screws that came with your kit; notice how the other types of screws are larger) and your Phillips head screwdriver. The wooden mounting board has multiple pre-drilled holes; be sure to use the correct ones for the cardboard tube, as shown in Figure 6.



**Figure 6.** A diagram of Attach the cardboard tube to the wooden baseboard. Be sure to use the correct holes, as labeled in the figure.

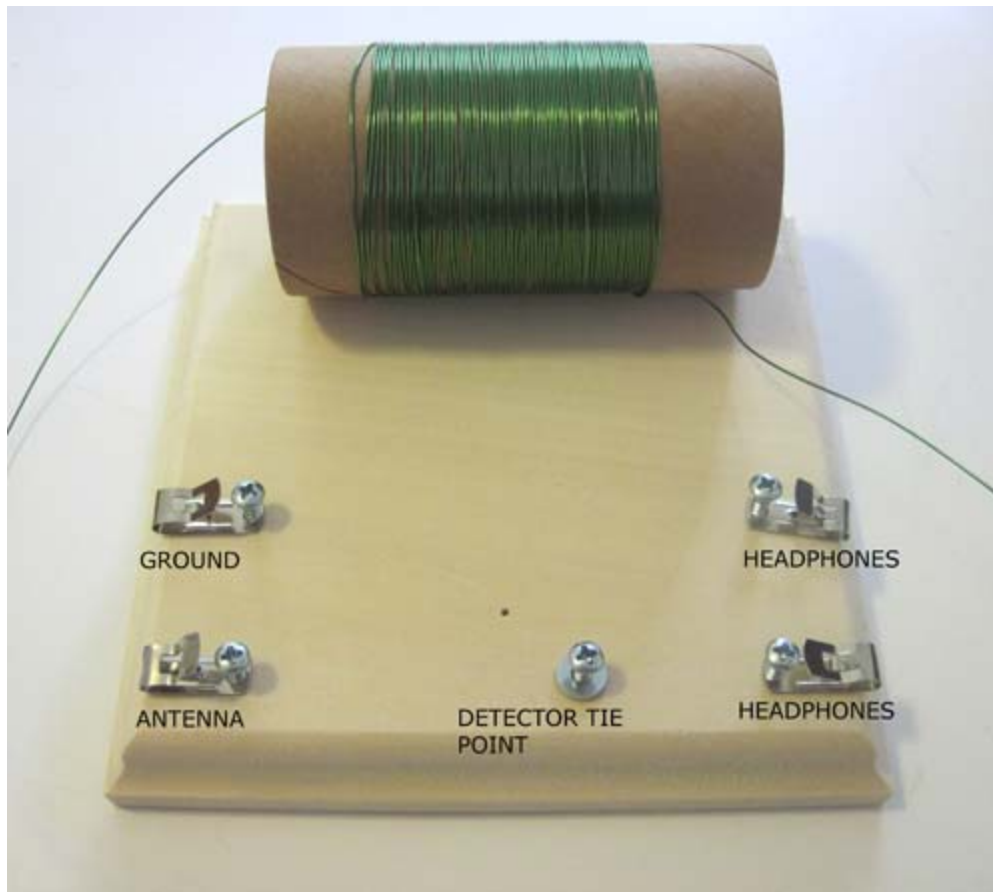
4. Attach the Fahnestock clips to the base.
  - a. Loosely mount the four Fahnestock clips to the wooden base using four #6 x ½ inch screws, as shown in Figure 7. Do not tighten the screws all the way yet.
  - b. Use scissors to cut apart the "ANTENNA," "GROUND," and two "HEADPHONE" labels. Peel off the adhesive backing and place them on the board, as

shown in Figure 7.



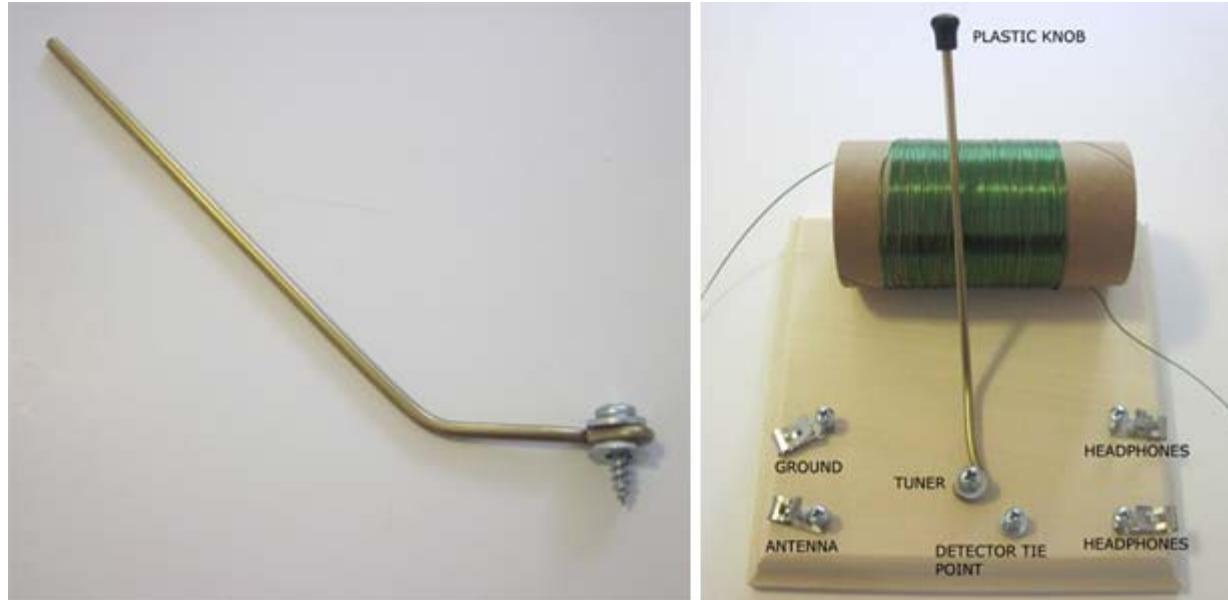
**Figure 7.** Attach the Fahnestock clips and the labels to the wooden mounting board.

5. Install the detector tie point.
  - a. Attach the final #6 x 1/2 inch screw and the #6 washer to the wooden mounting board in the open hole closest to the edge, as shown in Figure 8. Note this is the smaller washer that came with your kit. Do not tighten the screw all the way.



**Figure 8.** Attach a screw and a washer to the detector tie point.

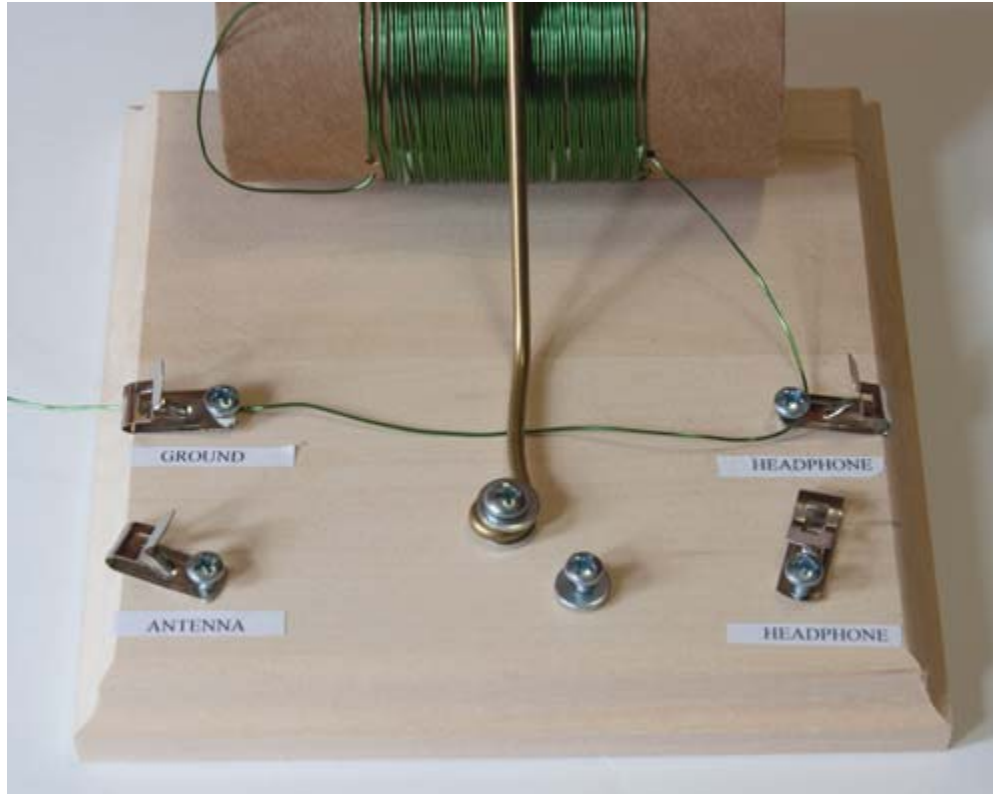
6. Mount the tuning rod to the wooden board.
  - a. Slide the loop at the end of the brass rod and two #8 washers onto the #8 x  $\frac{3}{4}$  inch screw (these are the *bigger* screws and washers that came with your kit), as shown in Figure 9.
  - b. Insert the screw into the remaining open hole in the wooden mounting board, as shown in Figure 9. Do not tighten the screw all the way yet.
  - c. **Important:** *Carefully* and *gently* press the black plastic knob onto the end of the brass rod. You may need to gently wiggle the knob or twist it back and forth to get it to slide onto the rod. Using a file to round down the end of the rod, or water to lubricate it slightly, might be helpful. The end of the rod might be sharp, so be *very careful* and get an adult to help if necessary.



**Figure 9.** Sandwich the loop of the brass rod in between two #8 washers on the #8 x  $\frac{3}{4}$  inch screw. Then insert the screw into the wooden board, but do not tighten it all the way yet.

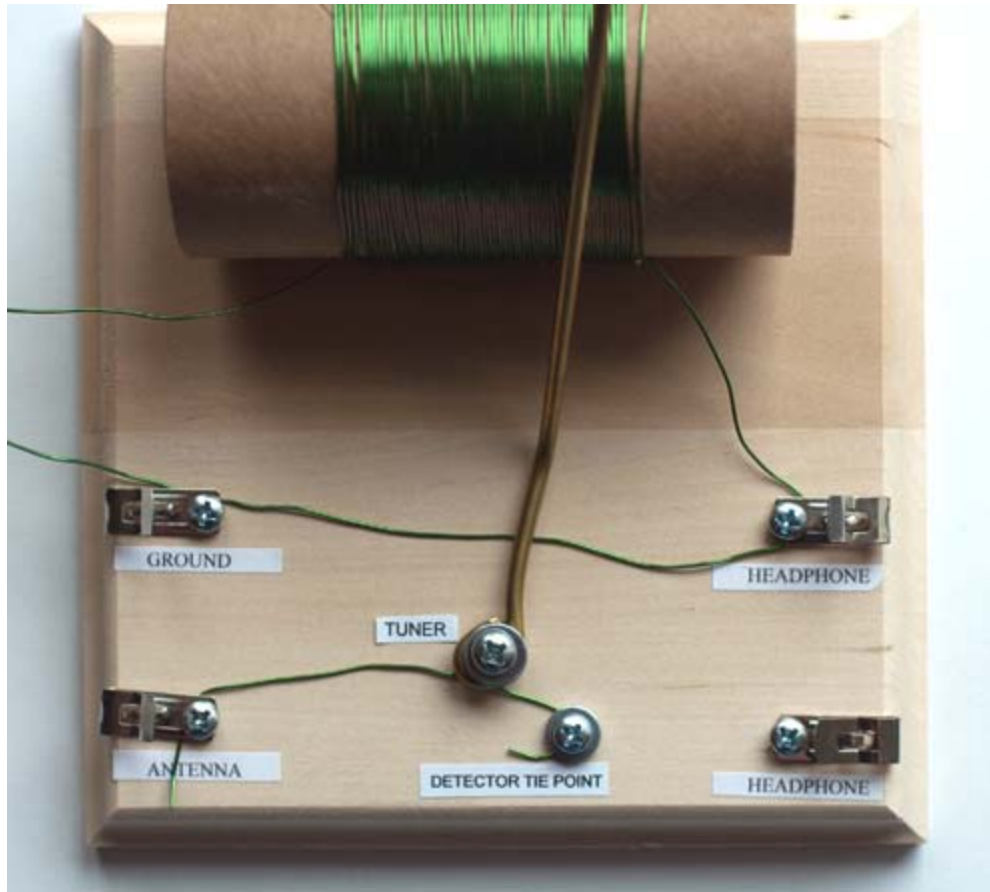
7. Connect the tuning coil to the "HEADPHONE" and "GROUND" clips.

- a. As a general rule of thumb, in the following steps, whenever you wrap a wire or a component's lead around a screw, wrap it in the *clockwise* direction. That way, when you tighten the screw, the wire will be pulled tighter instead of being pushed loose and coming unwound.
- b. With the wooden mounting board in front of you and the tuning coil farthest from you, loop the extra wire on the right-hand side of your tuning coil around the screws *under* the top "HEADPHONE" and "GROUND" clips, as shown in Figure 10. Make a mental note or use your finger to mark approximately where the wire is under the "HEADPHONE" screw. This will give you an idea of where you need to remove insulation from the wire, so it can be electrically connected to the clips.
- c. Unwrap the wire and use the sandpaper supplied with the kit to rub insulation off a short (about 1 inch) section of the wire where it loops under the "HEADPHONE" clip. Be sure to remove the insulation around the entire perimeter of the wire.
- d. Loop the wire back under the headphone clip (wrap it completely around the screw at least once so it stays in place), ensure the stripped piece of wire is wrapped around the screw, and stretch the end out to opposite side of the wooden mounting board to the "GROUND" clip. Again, make a mental note or use your finger to mark approximately where the wire is under the screw.
- e. Unwrap the wire from the "GROUND" screw (you can leave it under the "HEADPHONE" screw) and use the sandpaper to remove insulation from a short (about 1 inch) section of the wire where it will loop under the "GROUND" clip.
- f. Once you have removed the insulation, loop the wire back under the "GROUND" clip. Wrap the wire completely around the "GROUND" screw at least once so it stays in place. Do not tighten the screws yet.



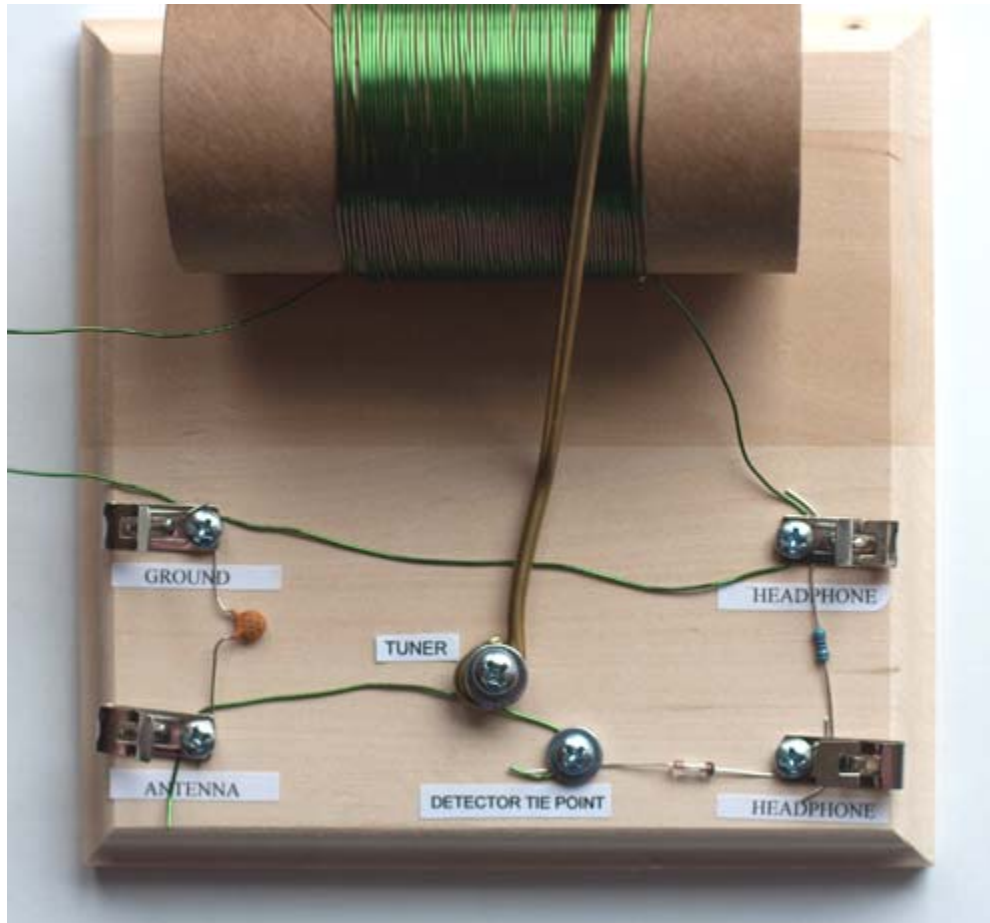
**Figure 10.** Loop the stripped portions of the tuning coil wire under the top "HEADPHONE" and "GROUND" clips. Remember to loop the wires around the screws in a clockwise direction.

8. Connect the antenna clip to the tuning rod and detector tie point.
  - a. Cut a segment of the enamel-coated magnet wire about 6 inches long.
  - b. Loop the wire under the "ANTENNA" screw, the tuning rod screw, and the detector tie point screw, as shown in Figure 11. This will give you an idea of where you need to sand off insulation.
  - c. Remove the wire from under the screws, and sand off roughly a 1 inch strip of insulation from where the wire will connect to each of the three screws. It is OK to sand off some extra insulation, so you have a little room for error when lining up the wire.
  - d. Loop the wire back under the three screws again, as shown in Figure 11, ensuring the stripped sections are under the screws. Be sure to wrap the wire around each screw at least once so it stays in place. Do not tighten the screws yet.



**Figure 11.** Connect the "ANTENNA" screw, the tuning rod screw, and the detector tie point screw with an extra piece of 6 inch wire. Be sure to sand off insulation in the appropriate spots first. Note that the kit does not come with labels for the "TUNER" and "DETECTOR TIE POINT" screws. You can print and cut your own labels if you want.

9. Attach the capacitor, resistor, and diode to the circuit. *Note:* No insulation stripping is needed in this step.
  - a. Slightly bend the ends of the leads of the capacitor, and loop these around the screws for the "GROUND" and "ANTENNA" clips, as shown in Figure 12. The direction of the capacitor does not matter. Tighten the screws to hold the capacitor in place.
  - b. Slightly bend the ends of the leads of the resistor, and loop these around the screws for the two "HEADPHONE" clips, as shown in Figure 12. The direction of the resistor does not matter. Tighten *only* the top "HEADPHONE" screw to hold the resistor in place for now.
  - c. Slightly bend the ends of the leads of the diode, and loop these around the screw for the "HEADPHONE" clip and the detector tie point screw, as shown in Figure 12. *Important.* Make sure the black stripe on the diode is facing toward the "HEADPHONE" clip.
  - d. Double check and tighten all of the screws *except* the tuning rod screw.

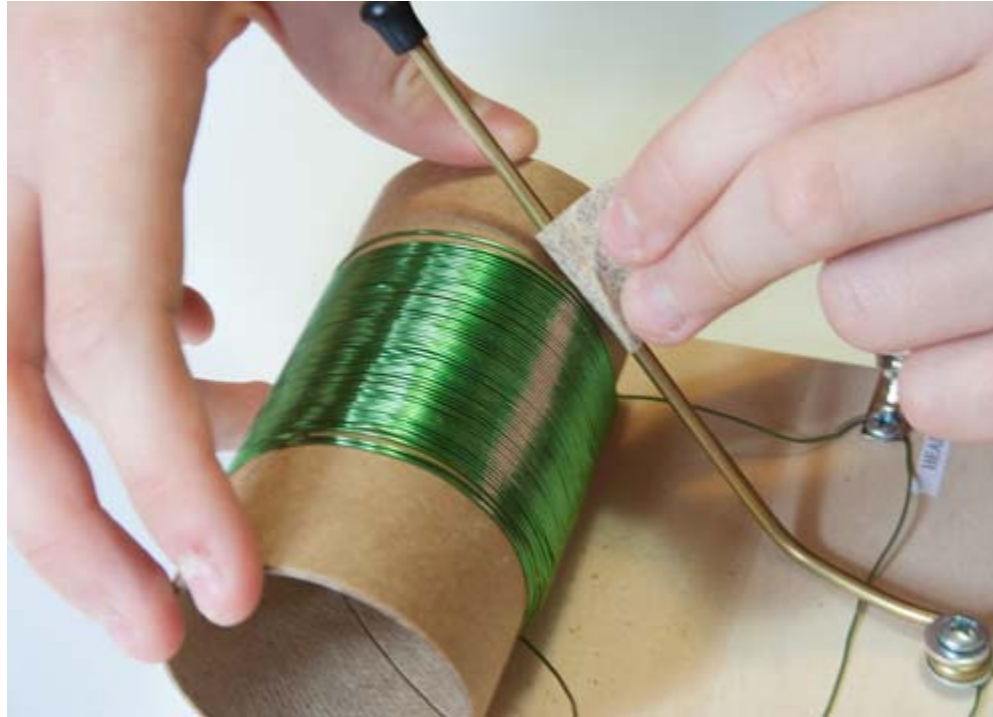


**Figure 12.** Wrap the capacitor, resistor, and diode leads around the screws under the appropriate clips, as pictured.

10. Sand insulation off the tuning coil where the brass tuning rod contacts it.
  - a. Move the tuning rod all the way to one side of the coil.
  - b. Test the tuning rod's contact with the tuning coil by sliding the tuning rod back and forth across the coil, making sure it always touches the coil and applies even pressure. If it presses too hard, or loses contact with the coil, you may need to bend the tuning rod slightly using pliers (do this near the base, where it is already bent).
  - c. Place your sandpaper between the brass rod and the coil wire, and pinch it around the tuning rod, as shown in Figure 13. Move the tuning rod back and forth in order to remove the enamel insulation where it contacts the coil.
  - d. When you are done, you should see exposed, shiny copper, which is a different color than the enamel insulation, as shown in Figure 13.
  - e. For now, you are done working on the wooden mounting board, and your circuit is complete. Double check that your crystal radio circuit looks like the one shown in Figure 12, and that you have sanded off insulation like in Figure 13. You can use scissors to trim any excess lengths of magnet wire that



are dangling off your wooden board, then move on to step 10 to go outside and set up your ground rod and antenna.



**Figure 13.** The tuning coil, showing exposed copper, after sanding off insulation where the tuning rod contacts it.

11. Set up your antenna. **Warning:** Never work outside during a thunderstorm. Do **not** install your antenna near power lines.
  - a. Use plastic zip ties to string up a length of the enamel-coated magnet wire from the Science Buddies kit that is as long and as high off the ground as possible. Try to make the antenna as long as possible, but do not use all of your remaining wire. You will need a few feet to connect the ground rod (see step 12). If possible, have an adult use a ladder to attach the ends of the antenna to high places like rain gutters. *Important.* Leave enough wire at one end of your antenna to reach the ground and connect to your radio.
  - b. The plastic zip ties will ensure that the antenna does not "ground out," or become electrically connected to the ground, if some of the insulation wears off (for example, if you have the antenna connected to a sharp corner on a metal fence).
  - c. Figure 14 shows an example antenna strung up in a back yard, connected to a rain gutter and a wooden fence using plastic zip ties.
  - d. **Safety note:** Thin wires hanging in midair can be hard to see. If your antenna is close enough to the ground that someone might walk into it, you should hang "flags" on it to make it more visible. The flags do not need to be anything fancy; you can just fold pieces of paper in half and tape them to the antenna.

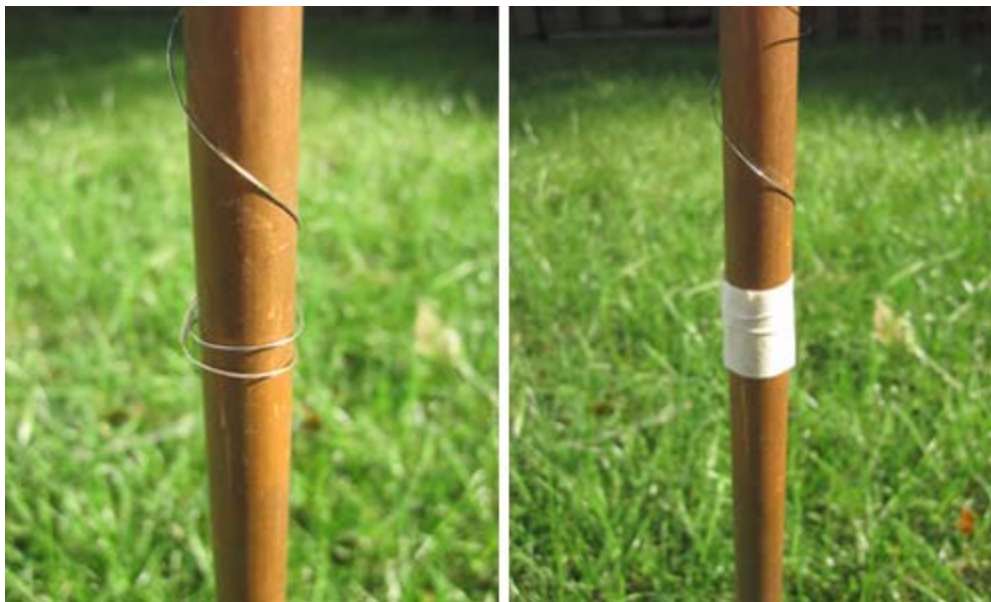




**Figure 14.** An antenna strung up between a tree and a fence in a back yard (the antenna is highlighted with a red line in the bottom photo, since the wire is too thin to see easily).

12. Install the ground rod.

- a. If you have a metal fence or exposed metal water pipe in your yard, it will work as a ground rod *only* if it is not rusted or painted.
- b. If you purchased a ground rod, have an adult use a mallet to pound it at least 2–3 ft. into the ground, preferably near the end of the antenna that has extra wire to attach to your radio.
- c. Cut a segment of enamel-coated magnet wire that will be long enough to reach from your ground rod to your radio, with an extra 2 ft. to wrap around the ground rod. Use the sandpaper to sand the insulation off of 2 ft. at the end of the wire.
- d. *Tightly* wrap the un-insulated end of the magnet wire around the ground rod, and tie a tight knot so it doesn't fall off. You can also wrap the wire in masking tape to make sure it stays in good contact with the ground rod. Figure 15 shows a ground rod with the wire wrapped and secured around it.

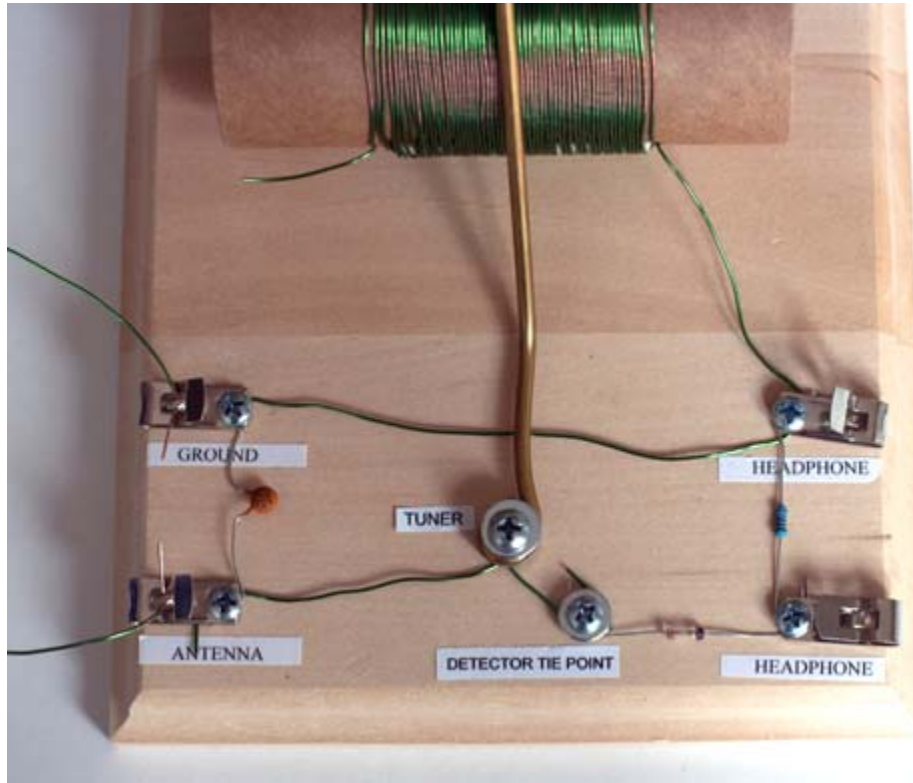


**Figure 15.** A copper pipe used as a ground rod with a ground wire attached (which will be used to connect the radio circuit to ground).

13. Take your crystal radio outside and hook it up to your antenna and ground rod. **Remember not to operate your crystal radio during a thunderstorm.**
  - a. Use sandpaper to sand insulation off 1 inch of wire at the end of the extra wire dangling off your antenna, and from the free end of the wire connected to your ground rod.
  - b. Attach the antenna and ground wires to the "ANTENNA" and "GROUND" Fahnestock clips on the wooden mounting board, respectively. Figure 16 shows a close-up of how to use a Fahnestock clip, and Figure 17 shows both wires attached to the circuit.



**Figure 16.** To connect a wire to a Fahnestock clip, first press down on the tab of the clip with your finger. Use your other hand to thread the end of the wire through the clip, as pictured, then release the tab.



**Figure 17.** Connect the antenna and ground wires to the appropriate Fahnestock clips on the wooden mounting board. The two wires leaving the left side of the picture connect to the ground rod and antenna respectively.

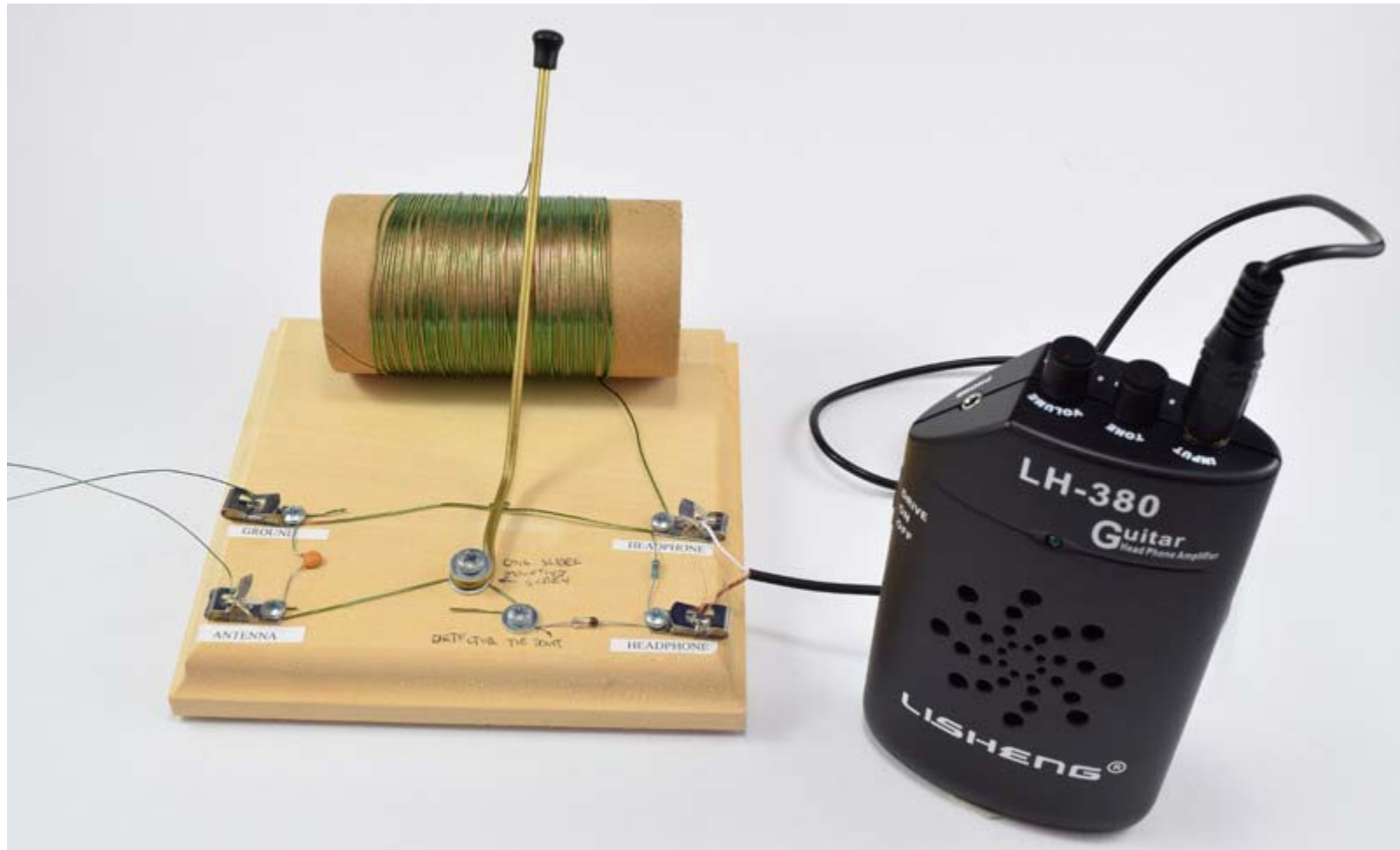
14. Attach the audio amplifier to your crystal radio.

- a. Slide the battery cover off the back of the amplifier (in the direction of the arrow), and install a 9 V battery. Replace the back cover.
- b. Insert the 1/4 inch plug end of your audio cable into the port labeled "Input" on the audio amplifier, as shown in Figure 18.
- c. Connect the ends of the audio cable to the two "HEADPHONE" Fahnestock clips, as shown in Figure 18. It does not matter which of the two wires you plug into which clip.



**Figure 18.** Attach the split ends of your audio cable to the two "HEADPHONE" Fahnestock clips, and plug the other end into the audio amplifier's "Input" jack.

15. As a last step, install the felt footpads on the bottom of your crystal radio. Congratulations! You have finished building your crystal radio. It should look like the completed radio shown in Figure 19. You are now ready to move on to the next section, *Testing Your Crystal Radio*.
  - a. Optional: if you haven't already, you can decorate the wooden base of your radio, as shown in Figure 20.



**Figure 19.** A picture of a completed crystal radio. The two wires leaving the left side of the picture connect to the ground rod and antenna respectively.



**Figure 20.** A decorated crystal radio.

## Testing Your Crystal Radio

*Note:* The experiments you can do with your radio may vary greatly depending on where you live and how many AM radio stations there are in your area. This procedure is a suggestion, but you may need to modify it based on your location.

1. Turn on your audio amplifier using the switch on the side. Adjust the volume to a comfortable level.
2. Now, adjust your tuning rod to see if you can get clear reception of different stations. Take your time adjusting the rod to different positions on the tuning coil, and make sure that the tuning rod always makes physical contact with the coil. Check the full range of the coil, from one end to the other.
3. If you check the full range of your coil but cannot receive any clear stations, try re-orienting your antenna (for example, rotating it by 90 degrees). The orientation of your antenna relative to the AM broadcast towers can have a big impact on reception.
4. Once you have identified stations that you can receive, put a strip of masking tape lengthwise on your coil. Use a permanent marker to mark the location where you heard the station, and write down the station's **call sign** (for example, you may hear the DJ say "You're listening to WHCU", which is the call sign). You may also hear a number associated with the station, such as "WHCU 870." The number is the frequency at which the station broadcasts in kilohertz (kHz). You can



also write this number down, as shown in Figure 21. This will help you find stations again easily. *Note:* Depending on the strength of a station, there may be a wide range (a couple centimeters) on which you can receive it using your tuning coil. If this happens, make a mark in the middle of the range.



**Figure 21.** Use a strip of masking tape and a permanent marker to help you identify stations more easily on your coil.

4. Once you have identified some stations using your tuner, you can also use the Federal Communication Commission (FCC)'s **AM Query Broadcast Station Search** (<https://www.fcc.gov/media/radio/am-query>) to search for AM radio stations in your area.
  - a. Search for AM radio stations by city and/or state using the FCC's AM Query link. If you search by city, remember to search neighboring cities as well, not just the one you live in.
  - b. This will bring up a list of results that list each station's call sign, frequency, and some other information, as shown in Figure 22. You can click on a station's call sign to bring up more detailed information, including the coordinates (**latitude** and **longitude**) of their broadcast tower, as shown in Figure 23.
  - c. Use an online mapping program like Google Maps™ to look up the location of the towers relative to your house. Note that you will have to check for the specific format to search for latitude and longitude in the mapping program you are using. For example, as of May 2013, in Google Maps the latitude and longitude 42° 27' 54.00" N, 76° 22' 23.00" W (from Figure 23), must be entered as a single line of text with spaces between the numbers and no symbols: 42 27 54 N 76 22 23 W.
  - d. Print out a paper map of your area, or use an online mapping tool like Google Maps or Google Earth™, and mark the locations of your house and all the

radio stations in your area. Figure 24 shows an example map.

<a href="#">WHCU</a>	AM 870 kHz DAN	Daytime	B B LIC	ITHACA	NY US
<a href="#">WHCU</a>	AM 870 kHz DAN	Nighttime	B B LIC	ITHACA	NY US
<a href="#">WNYY</a>	AM 1470 kHz DAN	Daytime	B B LIC	ITHACA	NY US
<a href="#">WNYY</a>	AM 1470 kHz DAN	Nighttime	B B LIC	ITHACA	NY US

**Figure 22.** The search results for Ithaca, NY show two stations. The stations' call signs are hyperlinks that bring up more information about each individual station.

Licensee: SAGA COMMUNICATIONS OF NEW ENGLAND, LLC

**870 kHz Licensed**

Domestic Station Class: B Region 2 Station Class (corresponds to W. Hemisphere): B  
 Coordination Status: Canada: - Mexico: - Region 2: -  
 File No: BL-20111031ALH Facility ID No.: 18048  
 CDBS Application ID No.: 1457632

42° 27' 54.00" N Latitude  
 76° 22' 23.00" W Longitude

Power: 5.0 kilowatts (kw) Daytime

**Broadcast tower  
 latitude and longitude**

DAN - Directional Antenna: Nighttime only  
 Number of Augmentations to standard directional pattern: 0  
 RMS Standard: 0.00 mV/m at 1 kilometer  
 RMS Theoretical: 318.65 mV/m at 1 kilometer

1 tower CDBS Ant. System ID: 116643

Tower information:

Tower No.	Field Ratio	Phase (deg)	Spacing (deg)	Orientation (degrees)	Electrical Height (deg)	Twr Ref.	-No Top Loaded or Sectionalized Tower(s)- (#0)	A	B	C	D	Antenna Structure Registration Number
1	1.000	0.00	0.00	0.00	110.50	0	0.00	0.00	0.00	0.00	0.00	1048236

Additional Individual Tower Information from the Antenna Structure Registration database.  
 Use the Registration Number links for detailed information

Tower No.	ASRN	Site Elevation (meters)	Overall Height Above Ground (meters)	Overall Height Above Mean Sea Level (meters)	NAD 83 Tower Coordinates		Convert to FAA Study Number NAD 27
					Latitude	Longitude	
1	1048236	543.4	108.2	651.6	N 42° 27' 54.0"	W 76° 22' 22.0"	To NAD27 1973-EA-129-OE

FAA: [Obstruction / Airport Airspace searches](#)

Approximate Sunrise & Sunset Times => [Eastern](#) time zone

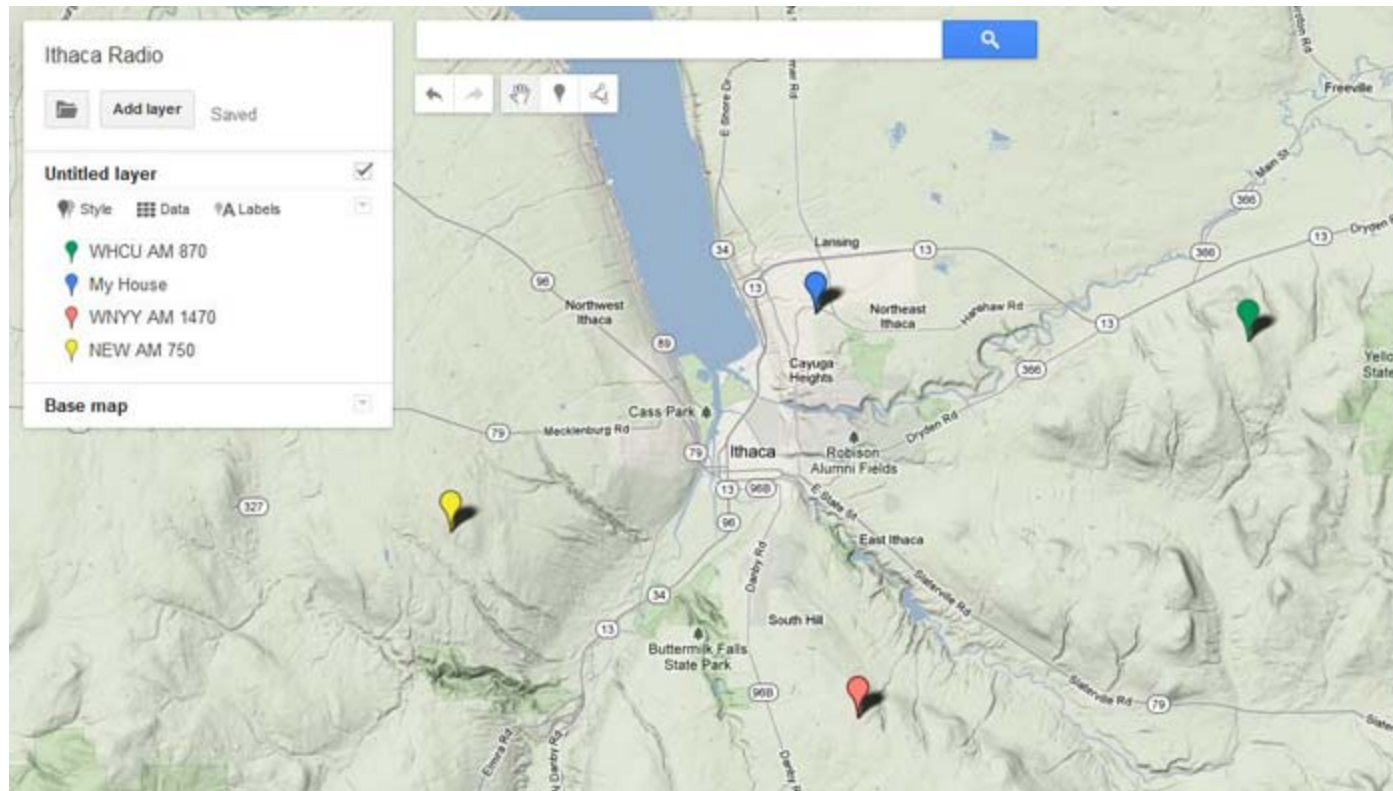
CDBS: [Station Info](#) [Application Info](#) [Mailing Address](#) [Assignments and Transfers](#)  
[Application List](#) [CDBS Search Page](#) [Ownership Info](#) [EEO](#) [Call Sign Changes](#)  
[Correspondence for WHCU](#) [Correspondence for application BL-20111031ALH](#)

Site Map: [USGS Topographic map for WHCU's transmitter site \(MSRMaps\)](#)

ULS: [Related facilities in ULS](#)

[ASRNs within 0.5 km radius](#)

Figure 23. Detailed station information, including the latitude and longitude of the broadcast tower.



**Figure 24.** This custom map shows the location of three radio towers relative to a house (this map was made using Google Maps Engine Lite in May 2013).

5. Now, compare the stations listed on your map to the stations you marked on your strip of masking tape. Ask yourself a couple questions:
  - a. Is there any correlation between location on the map and how loud/clear the stations sound on your radio? For example, does your radio do a better job picking up stations that are closer to your house? Or does distance not seem to matter?
  - b. Are there any stations listed on the map that you could *not* pick up with your radio? If so, do you see any potential reasons, such as a mountain between your house and the broadcast tower (it may help to view a terrain or elevation map to determine this)?
6. Now, try to adjust the position, orientation, and/or shape of your antenna to get better reception. **Warning:** Remember not to put your antenna near power lines.
  - a. For ideal reception, your antenna should be *perpendicular* to a line drawn on the map between your house and the radio tower. So, if your antenna is pointed straight toward a radio tower, you may get poor reception for that station. What happens if you rotate your antenna, and then try adjusting the tuner again? Can you pick up new stations that you couldn't hear before, or do you lose stations that used to be clear?
  - b. What happens if you change the location of your antenna; for example, move it from your back yard to your front yard? Does this affect the reception of different stations?
  - c. What happens if you change the *shape* of the antenna? For example, instead of stringing it out in a straight line, you could tie it to different fence posts (remember to use zip ties) to form a square. You could even coil it around something like a barrel or a roll of paper towels.
  - d. Can you find an "optimal" antenna configuration that gets you the best reception on the most stations?
7. AM radio reception can be very different at night. Try using your radio at night — can you pick up any stations that you could not detect during the day, or vice

versa? Do stations you can detect during the day sound clearer or fainter at night? Do some background research to find out why this happens.

8. **Important:** When you are done using your radio, disconnect the antenna and ground wire from the Fahnestock clips, and bring your radio inside (it is not waterproof, so should not be left outside). Then, *connect the antenna directly to your ground rod*. This will protect the antenna from lightning and static charge buildup.

## Frequently Asked Questions (FAQ)

FAQ for this Project Idea available online at [https://www.sciencebuddies.org/science-fair-projects/project-ideas/Elec\\_p014/electricity-electronics/crystal-radio#help](https://www.sciencebuddies.org/science-fair-projects/project-ideas/Elec_p014/electricity-electronics/crystal-radio#help)  
([http://www.sciencebuddies.org/science-fair-projects/project-ideas/Elec\\_p014/electricity-electronics/crystal-radio#help](http://www.sciencebuddies.org/science-fair-projects/project-ideas/Elec_p014/electricity-electronics/crystal-radio#help)).