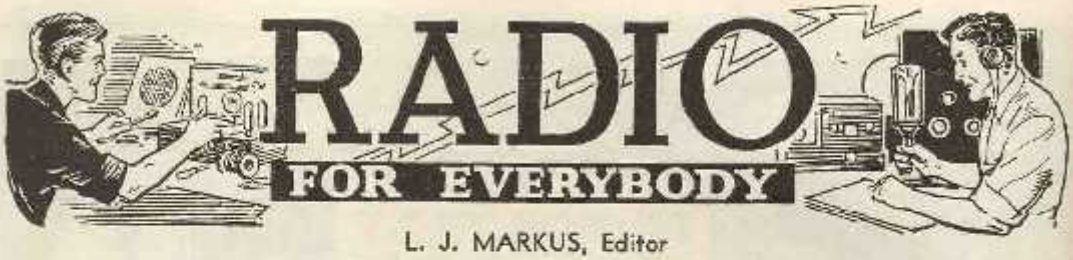
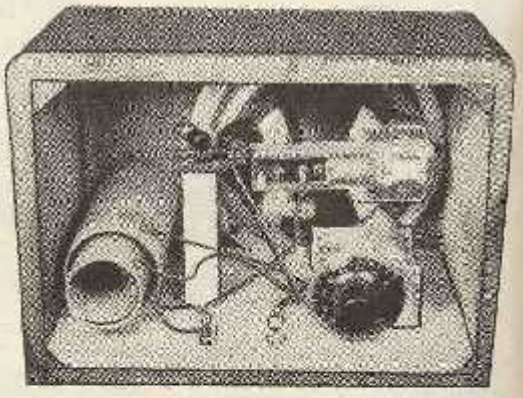


L. J. MARKUS, Editor

How to Build a Loudspeaker Crystal Receiver

Figs. 1-2. This loudspeaker crystal receiver, front and rear views of which are shown here, will bring in programs day and night on the loudspeaker with amazing clarity and volume if you live reasonably near a radio station. No batteries are needed. Features include a two-gang tuning condenser, new type ultra-sensitive magnetic loudspeaker, beautiful walnut veneer cabinet, indefinitely long life with no operating cost, variable selectivity and sensitivity adjustments, no panel controls, optional fixed crystal and optional headphone connections. The set is ideal for forest rangers in look-out towers.



A CRYSTAL set powerful enough to operate a loudspeaker—that's what radio fans have been clamoring for since the very first days of wireless. Radio engineers said it couldn't be done, and gave long lists of reasons why the power needed to operate a loudspeaker just couldn't be snatched out of the ether merely by tickling a hunk of shiny rock with a wire cat's-whisker.

This spring we came across a most interesting paragraph, on this subject, in a letter from SCIENCE AND MECHANICS reader Michael B. Young of Phoenix, Arizona, added as if an afterthought:

"One of our local stations is being received on a crystal set with a loudspeaker. The station wakes me up each morning at 6 o'clock and is

loud enough to really enjoy. Am using over 500 feet of aerial and a series of 10 grounds, which I give more credit for the amount of volume than I do the set itself, an ordinary crystal receiver circuit."

This letter definitely indicated that a loudspeaker crystal set could be made. We wrote immediately to Mr. Young for more details, and received by return mail a highly interesting letter telling about his crystal set experiments. Here are excerpts from his second letter:

"I was located about 15 blocks from KTAR, operating on 620 kc. with 1000 watts of power. I used a simple set consisting merely of a single small coil, crystal and cat's-whisker. I added more and more aerial, with better results each time. Both the direction and the length of the aerial seemed to affect volume.

"Next I tried adding grounds. Although the addition of one ground could not be noticed, there was an improvement when I changed from one to five grounds, and another small improvement when I went from five to ten grounds.

"The first loudspeaker I tried was a borrowed 16-inch cone unit. This really worked better than the smaller magnetic loudspeaker I now have.

"I taught Sunday School for a while, and started many of the boys to making crystal sets. None of these worked quite as well as mine, probably because the boys couldn't get up enough aerial. All were able to use loudspeakers, though; if they couldn't, I went out and experimented with the installation until we secured results.

"After the local station went off the air at night, I could get KPO in San Francisco, KFI in Los Angeles and KOA in Denver on the headphones but not on the loudspeaker.

"I generally left the loudspeaker connected all night. Occasionally KTAR would come back on the air about 2 a.m. for tests, waking me up. This station never failed to get me up in the morning when it came on the air for the day.

"Have tried a fixed crystal but so far have not had as good results as with an adjustable unit."

With this encouraging information to start with, an application of radio theory to the problem soon brought forth the fundamental principles involved. Then came experimentation with various circuits, followed by field trials in various locations. From all this was evolved the highly successful SCIENCE AND MECHANICS loudspeaker crystal set presented for the first time in this article.

Rare indeed is the person who cannot find some use for a radio set which costs only a few dollars initially, yet operates a loudspeaker day and night, year after year, with no batteries or power connections whatsoever and no operating costs.

Place the set on your bedside table and let it lull you to sleep at night. In the morning, it will wake you up again as faithfully as any alarm clock but with none of the ear-splitting clatter to spoil an entrancing dream.

A loudspeaker crystal set is ideal for use in a basement workshop or darkroom. Place it at the back of the bench and listen to favorite programs and to news flashes while pursuing your favorite hobby.

And what could be more perfect than this set for those who must keep lonely vigil in some roadside booth, forest ranger look-out station, gate house or other place fairly near a radio station but not on a power line? The set can be operated continually or turned off at times, as you prefer; either way, there are no battery charging or replacement problems and no worries about the size of next month's electric bill.

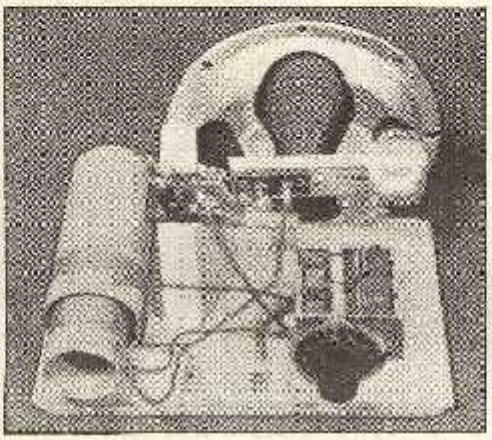


Fig. 3. Rear view of completed loudspeaker crystal set. Note that the crystal detector is mounted on the wood block which supports the loudspeaker. All parts needed will cost only a few dollars. You can wind the coils yourself by following instructions given in this article.

This set was designed primarily for those living in the outskirts of cities and on farms fairly near a radio station, for considerable room is required in which to erect the required length of antenna. It is principally a personal radio for use by one person or at most a small group of quiet persons. Obviously, you cannot expect the volume to be comparable to that of a 6-tube electric set feeding 3 watts or more of audio power into a loudspeaker. In our tests, however, the volume was found to be entirely adequate for the average room in a fairly quiet location.

How It Works

Although this crystal set is considerably more efficient than the single-circuit receiver used by Mr. Young in his experiments, the pictures and diagrams indicate that it is by no means complex. With the pictorial wiring diagram as a guide, any one who knows how to solder should have no trouble whatsoever in building this crystal set.

As the schematic circuit diagram indicates, the set is designed for use with what is known as a

half-wave antenna, with a voltage feed connection to the lead-in. In other words, the lead-in wire is connected to the end of the antenna wire in the usual manner, and the total length of the antenna system from the far end to ground is made equal to one-half the wavelength of the station which is to be received with loudspeaker volume.

With a half-wave antenna, *maximum signal voltage exists at the ends*, with zero voltage and maximum current at the center. Keep these facts in mind, for they are essential to the success of your installation.

As you can see from the circuit diagram, a parallel resonant circuit is used at the input of this crystal circuit. Having a very high resistance at resonance (when tuned to the frequency of an incoming signal), this resonant circuit matches the high resistance of the antenna. This match insures that the maximum possible amount of signal voltage will be transferred from the antenna to the receiver.

With so little signal loss, practically the entire antenna voltage is developed across resonant circuit L1-C1. The resulting current through primary coil L1 induces a voltage in secondary coil L2. This voltage undergoes resonant step-up in secondary resonant circuit L2-C2, and the output voltage across the circuit is applied to the loudspeaker in series with the crystal detector.

The crystal rectifies the incoming modulated r.f. carrier signal, as it allows current to flow in only one direction. The condenser across the loudspeaker by-passes r.f. pulses to ground, so that only the desired audio signals pass through the loudspeaker and are converted into sound.

The two-gang tuning condenser permits adjusting both tuned circuits simultaneously. Provisions are made for varying the amount of coupling between the coils, as this varies both the selectivity and the sensitivity of the receiver. When two stations interfere, the coils can be moved apart to improve selectivity; when a weak station is desired and there is no interference, the coils can be brought together to give maximum sensitivity.

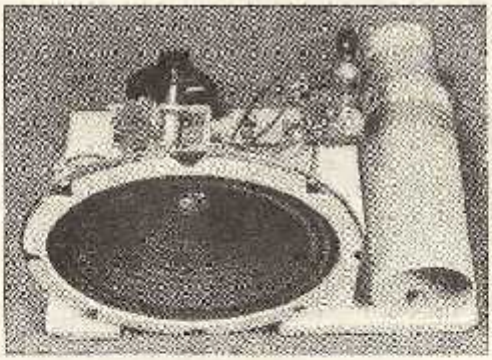


Fig. 4. Front view of completed set. Note the mounting bolt for the large coil, and the method of notching the base so the loudspeaker sets into it.

Building the Set

First of all, let me emphasize that there are many possible arrangements for the parts in this set, all giving equally good results. You can use the cabinet and mounting arrangement shown here, or can rearrange the parts to fit into a cabinet of your own design, as you prefer. The important thing to keep in mind, however, is that stray capacities between parallel resonant circuit L1-C1 and ground should be kept at a minimum. In other words, keep this coil well away from any grounded object such as a metal chassis or metal cabinet, and keep its ungrounded lead a half-inch or so away from grounded leads and parts.

A 6" x 9" piece of ⅜" plywood serves as the base on which all parts are mounted. Trim the sides at an angle so they will fit neatly into the cabinet, if you decide to use the attractive walnut veneer cabinet shown in the photos.

Mount the loudspeaker first, cutting a notch for it at the front of the base, and mounting a 3½" x 3½" x ¾" block on the base with wood screws for use as a vertical support. Two screws, one into the base and one into this block, will support the loudspeaker rigidly. Because of the rounded top of the cabinet, it will be necessary to cut away a small amount of wood inside the cabinet at the top in order to get the loudspeaker flush against the back of the panel.

Although almost any good magnetic loudspeaker can be used, best results will be obtained with one of the new high-impedance units like that specified on the diagram, having a rated impedance of 10,000 ohms or higher, and having a screw adjustment which controls the position of the armature or moving element. The permanent magnet in this unit is made from the new high-strength magnet alloy, far superior to that used in older magnetic loudspeakers.

Any desired type of crystal detector can be used. Mount it on the loudspeaker supporting block with a single wood screw.

It is best to use a new two-gang .000365 mfd. tuning condenser with this set, but a unit of the correct size taken from an old radio set should give acceptable results if in good condition. Mount the unit in back of the loudspeaker, using either wood screws or countersunk bolts inserted from the bottom of the base as required. Any small knob or tuning dial can be placed on the condenser shaft for convenience in tuning. A calibrated dial is not necessary.

Fahnestock clips mounted on the base with wood screws will serve nicely as antenna and ground terminals.

Winding the Coils

Commercial coils are not available for this set, but it is a simple matter to wind your own. Get two 5" long coil forms, one 2⅛" in diameter and the other 1⅜" in diameter. (Specify inside

diameters when ordering; these will be 2" and 1½" respectively.) In addition, you will need about 100 feet of No. 32 double silk-covered copper wire, a small piece of beeswax, and a 10-cent roll of 1" wide gummed brown paper (sold at dime stores).

Drill two holes in the large coil form for the mounting bolts, each 5/16" in from an end. Starting ⅝" in from one end, wind on 65 turns of No. 32 wire. Anchor the start of the winding with a small piece of beeswax pressed over the wire, allowing about 8" of wire to project for connections. Anchor the end of the winding with beeswax in the same manner, leaving another 8" for connections.

Wind 130 turns on the smaller form in exactly the same manner, starting the same distance from one end. Now cover both windings with beeswax, using your soldering iron to melt and spread the wax. You'll be surprised at the ease and speed with which you can spread a neat covering of wax over the entire winding, anchoring the turns and making them moisture-proof. Extra wax at each end of a winding, heated only slightly so it will not spread too much, will provide ample anchorage for the fine wire used in the coils.

Although the photos show heavy hook-up wire going to the coils, this is by no means necessary. It was done simply to make the wires show more clearly in the photos.

The method used for providing variable coupling is truly simple. Moisten the end of your strip of gummed paper, then wind it neatly over the unused end of the smaller coil form, until the diameter is exactly equal to the inside diameter of the larger coil form. Cut the paper strip now, and anchor the end by moistening. The smaller form should now slide freely inside the larger, without wobbling. Remove or add gummed paper as required to get a good sliding fit.

Mounting the Coils

Mount the large coil next. Insert the rear bolt first, after drilling and countersinking a hole for it in the base. Use washers or a dry cell terminal nut to support the coil about ¼" above the base board. Cut or file off the projecting end of the bolt inside the coil after the nut has been tightened, for the small coil must clear the bolt. Insert the small coil from the front, then insert and tighten the front bolt (nearest the loudspeaker). The mounting bolts will prevent the inner coil from being pushed out in either direction, while still permitting ample movement away from the maximum-coupling position (when the centers of the windings coincide).

Connections come next. For convenience, use solid push-back hook-up wire. Solder each connection, using rosin-core solder. Coil leads can be soldered directly to their respective terminals. Use soldering lugs on the Fahnestock clips if they do not already have lugs. Allow enough extra length in the leads from the small coil so these leads will not break when the coil is pulled all the way out.

An on-off switch is not essential, for the set can be silenced simply by detuning the variable tuning condenser. If you prefer, however, you can insert a s.p.s.t. toggle switch in the crystal detector lead for this purpose.

Erecting the Antenna

Length, direction and height are all important factors in the erection of a satisfactory antenna

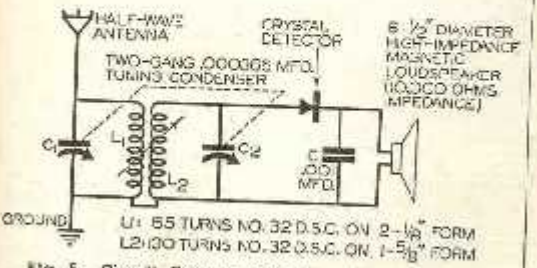


Fig. 5. Circuit diagram of loudspeaker crystal set.

for this loudspeaker crystal set. The length is determined by the frequency of the station which is to be received with loudspeaker volume. To be more specific, the length of the antenna system in feet should be equal to 490,000 divided by the station frequency in kilocycles. This length should be measured from the far end of the antenna to the ground rod along the antenna proper, the lead-in wire and the ground wire.

Extreme accuracy in the length is not essential, for variations of a few per cent either way will have no noticeable effect upon performance. The table in this article gives examples of correct antenna lengths for various station frequencies.

The antenna wire can be of any size and type insofar as performance is concerned. For initial tests, No. 24 enamelled wire is inexpensive and entirely satisfactory, but for a weather-proof permanent installation it is best to use regular antenna wire. Seven-strand No. 22 bare or enamelled wire is standard for antennas, and is ideal for this set. You can also consider solid No. 14 enamelled wire. If you cannot purchase the entire antenna as a single length, be sure to

Station	Frequency	Computation	Ant. Length
KOY	550 kc.	490,000 ÷ 550	891 ft.
WMAL	630 kc.	490,000 ÷ 630	778 ft.
WLW	700 kc.	490,000 ÷ 700	700 ft.
WLS	870 kc.	490,000 ÷ 870	564 ft.
KDKA	980 kc.	490,000 ÷ 980	500 ft.
KSL	1130 kc.	490,000 ÷ 1130	433 ft.
KSTP	1460 kc.	490,000 ÷ 1460	335 ft.
WQPC*	1610 kc.	490,000 ÷ 1610	304 ft.
KGIX*	1712 kc.	490,000 ÷ 1712	286 ft.

* Police stations. To get one of these or any other police station in the 1610-1712 kc. police band, use 50 and 100 turns for the large and small coils respectively (instead of 65 and 130 turns).

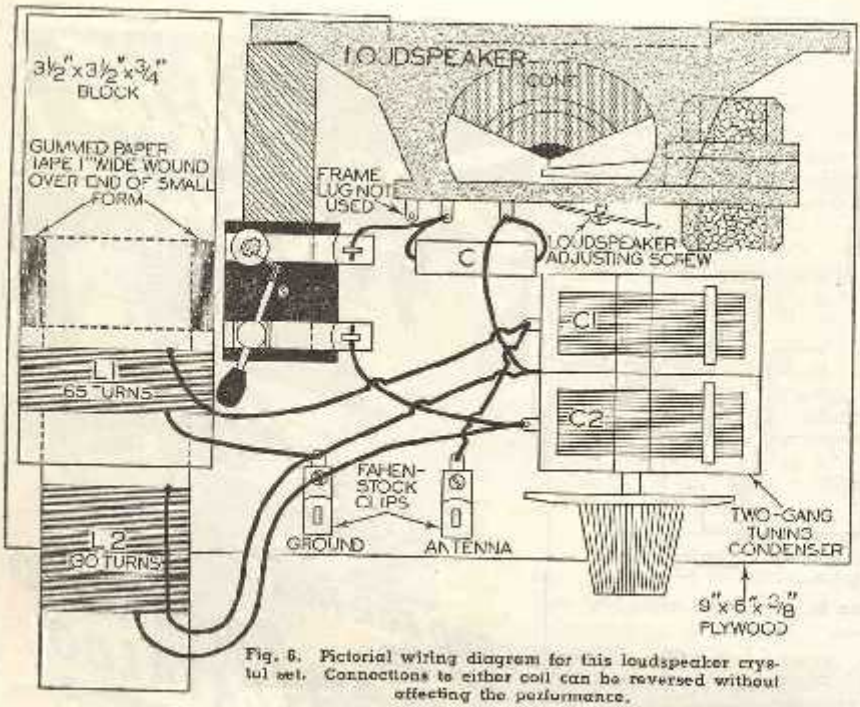


Fig. 6. Pictorial wiring diagram for this loudspeaker crystal set. Connections to either coil can be reversed without affecting the performance.

The entire lead-in wire is at high r.f. potential (high with respect to other points in the antenna system; the actual voltage will never be more than a few volts with respect to ground, and hence is perfectly harmless). Stray capacities to ground will lower this voltage, so keep the lead-in at least a foot away from buildings and trees by using long stand-off insulators. You can mount insulators on hardwood strips, projecting outward from a building. Use regular insulated copper lead-in wire such as solid or stranded No. 16 or No. 18 wire, soldering it carefully to the antenna and using as few insulators as possible. Avoid using a window strip; instead, bring the wire into the house through a porcelain tube or through a hole drilled in a glass window pane.

make strong splices between the pieces, soldering each one carefully. The heavier the wire you use, the farther can be the distance between supports without danger of breakage during high winds or sleet storms.

The half-wave inverted-L type antenna for which this set was designed will give best results when broadside to the station (at right angles to a line connecting station and antenna) and poorest results when pointing in the direction of the station. The difference in performance for the two extremes of position is not so great, however, as to warrant neglecting existing high supports which are ideal except for direction.

In our own tests, excellent results were obtained in one instance with the antenna about one mile away from 1000-watt station and pointing directly toward it. This shows that even the poorest antenna direction will work if you are sufficiently near the station.

The end supports for your antenna should be as high as possible, particularly if you are using long spans between supports. Keep the antenna well above objects such as trees and buildings, and at least 20 feet above the ground at its lowest point if at all possible. Since a wire will sag considerably at the center of a long span, an extra support will generally be necessary at the center of a half-wave antenna designed for a broadcast band frequency. For stations below 1000 kc., two or even more extra supports may be needed.

Insulators should be used at all supports, and should be of particularly good quality at the ends, where r.f. voltage is a maximum.

Loading Coils

If there is not sufficient room available between supports for the required length of antenna, erect as long an antenna as you can, connect it to the lead-in as usual, then wind the left-over antenna wire on a large form to make a loading coil, and insert this in the lead-in wire near the receiver. This "loads" the antenna, making it in effect a half-wavelength long and giving very nearly the efficiency of the correct longer antenna. The turns of wire on the loading coil should be spaced apart a distance equal to twice the wire diameter. A smaller size of wire can be used for the loading coil than for the antenna if desired, for length rather than diameter is the important factor here. A large cylindrical paper container such as is used for oatmeal makes a good coil form; any paper box about 10" square could also be used.

The loading coil should be mounted at least a foot away from all walls and grounded metal objects. A loading coil should not contain more than about one-fourth the total required length, for the greater the proportion of wire in it, the lower will be the efficiency of your antenna system.

Experimentation with a temporary antenna will tell whether a given combination of antenna and loading coil will give sufficient signal pick-

up for a particular antenna direction in your locality.

Making the Ground

A clean water or gas pipe about 10 feet long, driven almost entirely into the earth in a location where it will contact moist earth continually, makes an ideal ground for this receiver. Use a good ground clamp for connecting the ground wire to the pipe. The ground wire should be of an insulated type, but no special care need be taken in mounting it on the house.

Be sure to use an approved type of lightning arrester. An inexpensive unit employing an air gap is entirely satisfactory. Mount it outside the building at the point where antenna and ground enter the building. Connect one terminal to the ground wire, the other to the lead-in, without cutting either wire.

You can try extra grounds if you like, connecting them all to the same ground wire. In the average fairly moist location, however, the improvement in reception will hardly be enough to warrant the extra trouble and expense if your first ground is properly made.

Operating the Receiver

It is a good idea to use headphones when first trying out your receiver. Simply connect them across the loudspeaker terminals; this can be done most easily by slipping one phone tip into the Fahnestock ground clip, and the other phone tip into that crystal detector clip which goes to the loudspeaker. Slightly greater phone volume will be obtained by disconnecting the loudspeaker; this can be done by removing the loudspeaker lead from the crystal detector temporarily.

To tune in a station after antenna and ground wires have been connected to the proper terminals, adjust the cat's-whisker until it just touches the crystal. With the small coil entirely inside the larger (maximum coupling), rotate the gang tuning condenser slowly. If no station is heard, try different settings for the crystal detector and for the coil. When a station is heard, readjust each control carefully for maximum volume, then disconnect the phones and reconnect the loudspeaker to see if you are getting sufficient loudspeaker volume.

If two stations are heard together when the small coil is all the way in, pull it out a small amount and retune the condenser. Repeat until you hear only the desired station. Separating the coils reduces volume, but at the same time improves the selectivity (station-separating abil-

WHERE TO GET PARTS

For information as to where you can secure, at unusually low prices, the various parts needed for crystal sets, just drop a letter to Radio Editor, Science and Mechanics, 800 North Clark St., Chicago, Ill., asking for a free copy of the data sheet on loudspeaker crystal sets. This contains a complete list of parts needed, along with data on catwhiskers and fixed crystals. Enclose a stamp for the reply.

ity). Experiment with various coil and condenser settings until you are thoroughly familiar with the operation of your set.

Front-Panel Controls

Since this crystal set was designed primarily for loudspeaker reception from a single station, no controls were mounted on the front of the cabinet. Once the set has been properly tuned to the chosen station, it will remain in tune indefinitely, so there is really no need for panel controls except possibly for an on-off switch.

If front-panel control is desired in order to change from one station to another conveniently while using headphones, mount the tuning condenser where the coil now is, with its shaft projecting through the panel. Mount the crystal detector above the condenser on a small shelf, with its handle projecting through a one-inch hole drilled in the front panel. Mount the coil crosswise across the back of the base, with a wood dowel rod attached to the sliding coil and projecting out through one side of the cabinet to give push-pull control of the coupling. The loudspeaker can remain where it now is.

Volume-Increasing Hints

Sharpening the point of the cat's-whisker carefully with a nail file or small metal file will make it easier to find a sensitive spot on your crystal.

Grease or dust on a crystal impairs its sensitivity. Washing the crystal in denatured alcohol will remove any grease left by your fingers when handling the crystal.

After a crystal has been used for some time and has been scratched up considerably, try chipping off a portion of it to expose fresh rough surfaces.

The loudspeaker specified for this set has an adjusting screw. Rotate this slowly a half-turn or so in either direction while the set is in operation, until you find the setting which gives maximum loudspeaker volume.

DX Reception with Headphones

Excellent distant reception on headphones can be obtained with this crystal set provided the antenna is tuned to resonance for each station. The antenna is naturally resonant (is one-half wavelength long) at only one frequency, but can be tuned to resonance at any other frequency in the broadcast band by inserting either a coil or condenser of the proper size in series with the lead-in wire.

If the antenna is too long for the frequency you wish to receive, insert an ordinary .000365 or .0005 mfd. variable condenser in the lead-in wire and adjust this for maximum volume. If too short, insert an ordinary broadcast band coil (or any other coil you have on hand) in the lead-in along with the variable condenser, and adjust the condenser for maximum volume. A coil and a condenser have opposite types of reactance, so that one cancels out part or all of the other, depending upon their relative sizes. Variable coils are not easy to make, hence we use the condenser to vary the amount of inductance which is effective in the circuit.

Always readjust the crystal set controls after tuning the antenna, for there will be some interaction between the various adjustments. Keep the antenna tuning units away from grounded objects. If volume is a maximum with the antenna condenser either all the way in or all the way out, try other sizes of coils to see if you can get still better results. This antenna tuning procedure will improve loudspeaker volume if the antenna is shorter or longer than the required length for a station.

If you plan to use headphones frequently, mount two extra Fahenstock clips or tip jacks on the plywood base. Connect one to the ground terminal, the other to the loudspeaker terminal of the crystal detector. A single-pole, double-throw toggle switch can be connected for instant change-over from phones to loudspeaker.

Limitations of Crystal Sets

If you will be satisfied with headphone reception, you can set up this crystal set practically anywhere and receive at least one station. If you are within 100 miles of a station having a power of 1000 watts or more, and design your antenna specifically for it, you can be sure of good headphone reception of that station.

If you are within a few miles of a station having at least 1000 watts power, you can also expect good loudspeaker volume. The closer you are to a station and the greater its power, the greater will be the volume.

In general, signal strength varies inversely as the square of the distance from a station, at points within its service range. This means that if there is a given signal strength at one point the signal will be only about one-fourth as strong at a point twice as far away.

Loudspeaker reception with a crystal set can be enjoyed only in a relatively quiet room. Any number of persons can gather around the set to enjoy a broadcast provided they remain quiet, but when several begin talking or there are disturbing noises outside, you require more volume (more power) than can possibly be secured with a crystal set.

A fixed crystal will, as a general rule, have slightly less sensitivity than an ordinary crystal detector. Once you get everything properly adjusted and find that you are getting ample volume, try connecting a fixed crystal in place of the crystal detector. It will eliminate the need for resetting the cat's-whisker each time someone bumps the receiver. Some fixed crystals are better than others, so try several if you can.

Adjustable crystals likewise vary in sensitivity, but are sufficiently low in price so you can order several, try them all out, and choose the best.

If you don't expect too much right at the start, and have the patience to make all the experiments and adjustments needed to snatch the very

last micro volt of signal strength out of the ether, you'll be agreeably surprised with the performance of this little receiver. Remember, however, that you must be at least within ten miles of a high-power station, and preferably within one or two miles, before you can expect good volume.