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CONSTRUCTION AND OPERATION OF A SIMPLE HOMEMADE RADIO RECEIVING OUTFIT

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ABSTRACT

The apparatus used for the reception of radio messages may be a homemade affair, very simple and inexpensive, or may be elaborate and expensive. All that is necessary for receiving radio messages is a device for collecting power from the incoming radio waves, a suitable circuit adjusted or "tuned" electrically to the frequency of the incoming waves, and apparatus for changing the received power into audible sounds.

The device for collecting power from the incoming waves is the "antenna." The adjustment of the receiving circuit to the frequency of the incoming waves may be made by a variable inductor or by a variable condenser. In a very simple set it is conveniently made by a variable inductor. The apparatus for changing the received power into audible sounds may consist simply of a crystal detector, and a telephone receiver specially wound with a large number of turns.

This Circular describes the method of constructing in the home a very simple and inexpensive receiving outfit from materials which can be easily secured. The cost of the materials need not exceed $10. Satisfactory results have been obtained from sets constructed according to these instructions by persons having no previous experience with radio.

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1. INTRODUCTION

Frequent inquiries are received at the Bureau of Standards for information regarding the construction of a simple receiving set which any person can construct in the home from materials which can be easily secured. This publication has been prepared to meet these inquiries.

This is the first of a series of publications on the construction of radio receiving equipments. Subsequent publications will describe the construction of sets with which messages sent over longer distances can be received.

The primary function of the Bureau of Standards is the development and maintenance of standards of many different kinds, and includes scientific and technical measurements and investigations in a wide variety of fields of science and industry. Most of the publications of the Bureau describe the results of such investigations, and are primarily of interest to the specialist. A few publications of the Bureau, such as the present one, are devoted to methods of making simple apparatus in the home.

The preparation of this publication had its origin in work undertaken by the Bureau of Standards in cooperation with the Bureau of Markets and Crop Estimates of the Department of Agriculture in connection with the broadcasting by radio of Government news and information. This broadcasting service has proved to be very useful to farmers, bankers, dealers, and many others, and a considerable demand arose for information regarding simple receiving equipment.

Persons desiring an elementary book covering the principles and apparatus of radio communication can purchase for $1 a book prepared at the Bureau of Standards, "The Principles Underlying Radio Communication" (Signal Corps Radio Communication Pamphlet No. 40). This book contains over 600 pages and 300 illustrations. Orders should be sent to the Superintendent of Documents, Government Printing Office, Washington, D. C.

A convenient means of keeping in touch with the radio work of the Government is to subscribe to the "Radio Service Bulletin," published monthly by the Department of Commerce (Bureau of Navigation). This contains announcements regarding new Government radio publications and short news items. The subscription price is 25 cents per year for subscribers in the United States. Orders should be sent to the Superintendent of Documents.

This Circular describes the construction and operation of a very simple and inexpensive radio receiving outfit. The outfit will enable anyone to hear radio code messages or music and voice sent out from medium-power transmitting stations within an area about the size of a large city, and from high-power stations within 50 miles, provided the waves used by the sending stations have wave frequencies between 500 and 1500 kilocycles per second; that is, wave lengths between 600 and 200. This equipment will not receive uninterrupted continuous waves. Occasionally much greater distances can be covered, especially at night. Sets constructed according to these instructions have given clear reception of music transmitted by radiotelephone from stations

300 miles distant. The total cost of the outfit can be kept below $10, or if an especially efficient outfit is desired, the cost may be about $15.

2. ESSENTIAL PARTS OF RECEIVING STATION

The five essential parts of the station are the antenna, lightning switch, ground connections, receiving set, and telephone receiver or "phone." The received signals come into the receiving set through the antenna and ground connection. The signals are converted into an electric current in the receiving set and the sound is produced in the phone. Either one telephone receiver or a pair, worn on the head of the listener, is used.

The lightning switch, when closed, protects the receiving set from damage by lightning. It is used to connect the antenna directly to ground when the receiving station is not in use. When the antenna and the connection to the ground are properly made and the lightning switch is closed, the antenna is not a hazard to a building and may act somewhat as a lightning rod to supplement the protection given to a building by lightning rods of standard construction.

The principal part of the station is the "receiving set." In the set described herein it consists of two parts, the "tuning coil" and the "detector," and in more complicated sets still other elements are added.

3. THE ANTENNA, LIGHTNING SWITCH, AND GROUND CONNECTION

The antenna is simply a wire suspended between two elevated points. The antenna should not be less than 30 feet above the ground and its length should be about 75 feet (see Fig. 1). This figure indicates a horizontal antenna, but it is not important that the antenna be strictly horizontal. It is in fact desirable to have the end where the pulley is used as high as possible. The "lead-in" wire or drop wire from the antenna itself should run as directly as possible to the lightning switch. If the position of the adjoining building or trees is such that the distance between them is greater than about 85 feet, the antenna can still be held to a 75-foot distance between the insulators by increasing the length of the piece of rope *D* to which the far end of the antenna is attached. The rope *H* tying the antenna insulator to the house should not be lengthened to overcome this difficulty, because by so doing the antenna "lead-in" or drop wire *J* would be lengthened.

(*a*) Details of Parts.—The parts will be mentioned here by reference to the letters appearing in Figs. 1 and 2.

A and *I* are screw eyes sufficiently strong to anchor the antenna at the ends.

B and *H* are pieces of rope ¼ or ⅜ inch in diameter, just long enough to allow the antenna to swing clear of the two supports.

D is a piece of ¼ or ⅜ inch rope sufficiently long to make the distance between *E* and *G* about 75 feet.

C is a single-block pulley which may be used if readily available. The pulley should not allow the rope to catch.

E and *G* are two insulators which may be constructed of any dry hardwood of sufficient strength to withstand the strain of the antenna; blocks about ¾ by 1 by 10 inches will serve. The holes should be drilled as shown in Fig. 1, sufficiently far from the ends to give proper strength. If wood is used, the insulators should be boiled in paraffin. Precautions in regard to melting the paraffin are given in the paragraph under "Accessories." If porcelain insulators are available, they may be substituted for the wood insulators. Porcelain cleats can be used. Regular antenna insulators are available on the market, but the two improvised types mentioned will be satisfactory for an amateur receiving antenna.

F is the antenna about 75 feet long between the insulators *E* and *G*. The wire may be No. 14 or 16 copper wire either bare or insulated. The end of the antenna farthest from the receiving set may be secured to the insulator *E* by any satisfactory method, but care should be taken not to kink the wire. Draw the other end of the antenna wire through the insulator *G* to a point where the two insulators are separated by about 75 feet and twist the insulator *G* so as to form an anchor, as shown in Fig. 1. The remainder of the antenna wire *J*, which now constitutes the "lead-in" or drop wire, should be just long enough to reach the lightning switch.

K is the lightning switch. For the purpose of a small antenna this switch may be the ordinary porcelain-base, 30-ampere, single-pole double-throw battery switch. These switches as ordinarily available have a porcelain base about 1½ by 4 inches. The "lead-in" wire *J* is attached to this switch at the middle point. The switch blade should always be thrown to the lower clip when the receiving set is not actually being used, and to the upper clip when it is desired to receive signals.

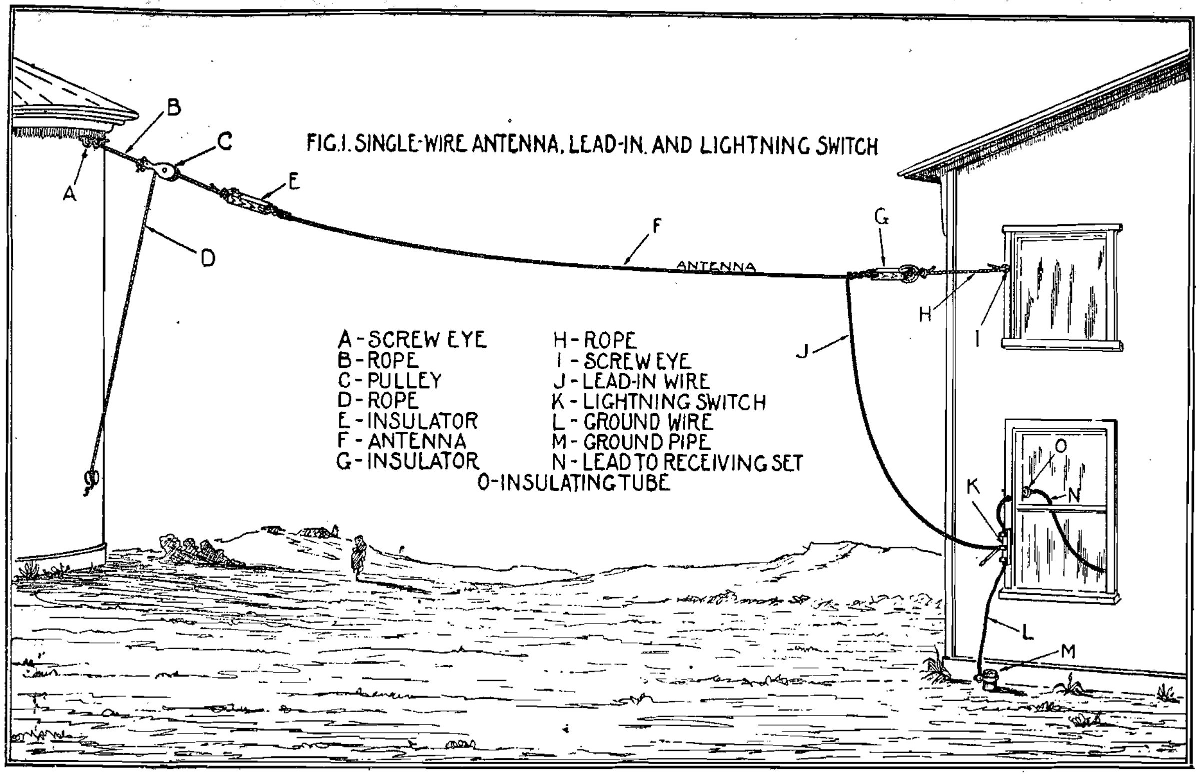

FIG. 1. SINGLE-WIRE ANTENNA, LEAD-IN, AND LIGHTNING SWITCH

In some stations there is no lightning switch outside the building, but instead a lightning arrester is connected to the antenna lead-in just inside the building; that is, as close as possible to the point where the lead-in leaves the porcelain tube. This lightning arrester has two binding posts, one of which is connected to the antenna lead-in, and the other is connected to a suitable ground connection. The type of lightning arrester used should be a protective device approved by the Underwriters Laboratories, Chicago and New York. Information as to the types of devices which are approved may be obtained from the Underwriters Laboratories or from local insurance inspection departments. For the ground connection a water pipe or a steam pipe may be used; a gas pipe should not be used. The use of the lightning switch outside the building as above described is perhaps a little preferable to the use of the lightning arrester inside the building.

L is the ground wire for the lightning switch. The ground wire may be a piece of copper wire, No. 14 or larger, and should be of sufficient length to reach from the lower clip of the lightning switch *K* to the clamp on the ground rod *M*. The use of a large size of copper wire, such as No. 6, or of copper strap, will give added mechanical strength and minimize the danger of accidental breakage of the ground wire.

M is a piece of iron pipe or rod driven 3 to 6 feet into the ground, preferably where the ground is moist, and extending a sufficient distance above the ground so that the ground clamp may be fastened to it. The pipe should be free from rust or paint. Special care should be taken to see that the pipe is clean and bright where the ground clamp is connected.

N is a wire leading from the upper clip of the lightning switch through the porcelain tube *O* to the receiving set binding post marked "antenna."

O is a porcelain tube of sufficient length to reach through the window casing or wall. This tube should be mounted in the casing or wall so that it slopes down toward the outside of the building. This is done to keep the rain from following the tube through the wall to the interior.

Fig. 2 shows the radio receiving set installed in some part of the house.

P is the receiving set which is described in detail below.

N is a wire leading from the antenna (upper) binding post of the receiving set through the porcelain tube to the upper clip of the lightning switch. This wire, as well as the wire shown at *Q*, should be insulated and preferably flexible. Unbraided lamp cord will serve for these two leads.

Q is a flexible wire leading from the receiving set binding post marked "ground" to a water pipe, heating system, or some other

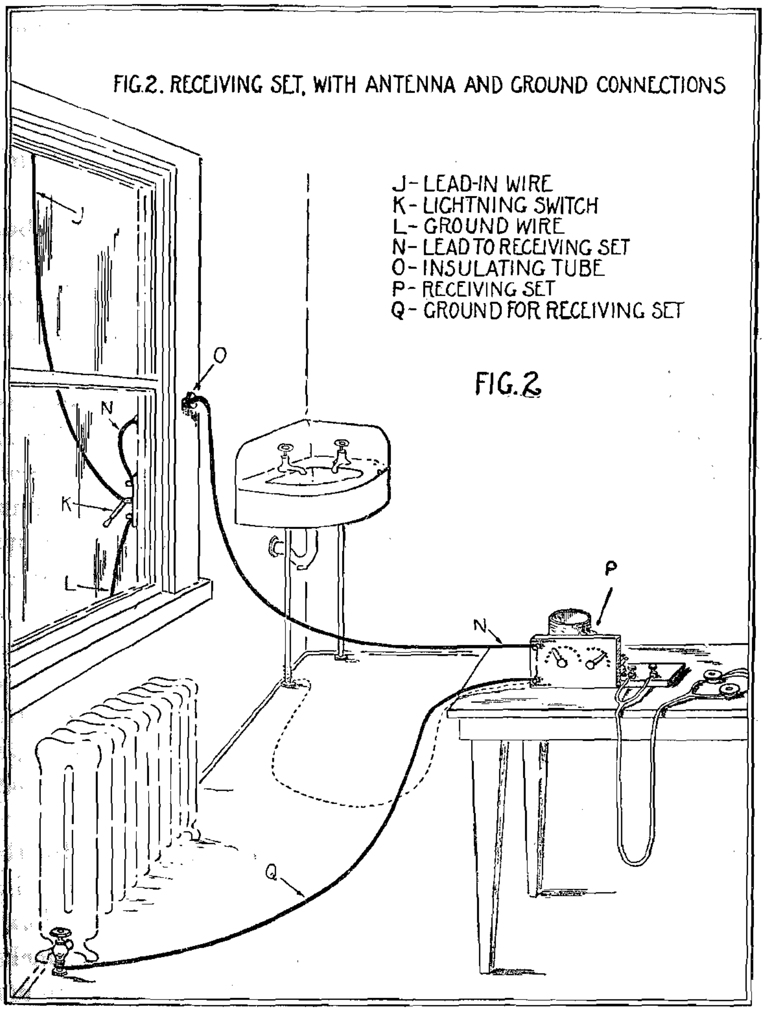

FIG. 2. RECEIVING SET, WITH ANTENNA AND GROUND CONNECTIONS

metallic conductor to the ground. If there are no water pipes or radiators in the room in which the receiving set is located, the wire should be run out of doors and connected to a special ground below the window. The ground for the lightning switch should not be used for this purpose. It is essential that for the best operation of the receiving set this ground be of the very best type. If the soil near the house is dry, it will be necessary to drive one or more pipes or rods sufficiently deep to encounter moist earth. The distance between the pipes will ordinarily not exceed 6 feet. Where clay soil is encountered the distance may be 3 feet; in sandy soil it may be 10 feet. Some other metallic conductor, such as the casing of a drilled well, not far from the window will be a satisfactory ground.

4. TUNING COIL, DETECTOR, AND PHONE

The phone and certain parts of the apparatus will have to be purchased. The other parts may be obtained at home.

(*a*) TUNING COIL (*R*, Fig. 3).—This is a length of cardboard tubing with copper wire wound around it. The cardboard tubing may be an oatmeal box. Its construction is described in detail below. A cylinder of wood or other nonmetallic substance may also be used.

(*b*) CRYSTAL DETECTOR (*S*, Fig. 3).—The crystal detector may be of very simple construction. A number of different kinds of crystals are suitable for use as detectors; these are discussed in detail in the book "The Principles Underlying Radio Communication." A galena crystal which will be satisfactory can usually be conveniently secured. Silicon is usually not as sensitive as galena, but is sometimes more easily obtained, and sensitive spots are often more easily located on silicon. It is important that a selected tested crystal be used.

The crystal detector can be made up of the tested crystal, three wood screws, a short piece of No. 16 copper wire or a nail, a piece of fine copper wire such as No. 28 or 30, a set-screw type binding post, and a wood knob or cork.

The crystal may be held in place on the wood base by three brass wood screws as shown at *1*, Fig. 3. A bare copper wire is wrapped tightly around the three brass screws for connection.

A metal called "Wood's metal," which has so low a melting point that it will melt in boiling water, may be purchased in many stores. If this metal is available, it may be used for mounting the crystal, but a metal of higher melting point, such as ordinary solder, should not be used because it may seriously injure the crystal. A shallow hole of size suitable to hold the crystal and leave most of the crystal projecting may be bored in the wooden base, and melted Wood's metal poured into the hole so that the crystal is held in place. The wire which is to make connection with the crystal should terminate in the hole so that it will be embedded in the Wood's metal. Instead of being mounted in a hole bored in the base, the crystal may be mounted in a small brass cup such as is found on the positive terminal of some kinds of dry batteries.

The binding post may be mounted on the back of the upright panel near its edge, as shown in Fig. 4. It may be found more convenient to mount the binding post on a small vertical piece of wood screwed to the base at another point, so that the detector will be more accessible. A long slender nail, or a piece of copper wire of a size such as No. 16, about 2 inches long, is bent as shown about ½ inch from one end, with an offset depending on the size of the crystal used. Ordinarily the offset may be about ¼ inch. This nail or piece of wire is inserted in the binding post as shown. To the upper end a small cork or wooden knob is attached. To the lower end a short piece of fine copper or brass wire is attached and the free part of the wire is wound into a small spiral of several turns. For this fine wire it will be found best to use No. 26, No. 28, or No. 30. For galena the smaller wire such as No. 30 will usually be found best.

(*c*) Phone (*T*, Fig. 3).—It is desirable to use a pair of telephone receivers connected by a head band, usually called a double telephone headset. The telephone receivers may be any of the standard commercial makes having a resistance of between 2000 and 3000 ohms. The double telephone receivers may cost more than all the other parts of the station combined, but it is desirable to get them, especially if it is planned to improve the receiving set later. A single 1000-ohm telephone receiver with a head band may be used but with less satisfactory results.

(*d*) Accessories.—Under the heading of accessory equipment may be listed binding posts, switch arms, switch contacts, test buzzer, dry battery, and boards on which to mount the complete apparatus. The binding posts, switch arms, and switch contacts may be purchased from dealers who handle such goods or they may be readily improvised at home. The pieces of wood on which the equipment is mounted may be obtained from a dry packing box and covered with paraffin to keep out moisture. Care should be taken in melting the paraffin not to get it too hot. For this reason, it is a good plan to melt it in a pan set in boiling water. When the paraffin just begins to smoke it is at the proper tem-

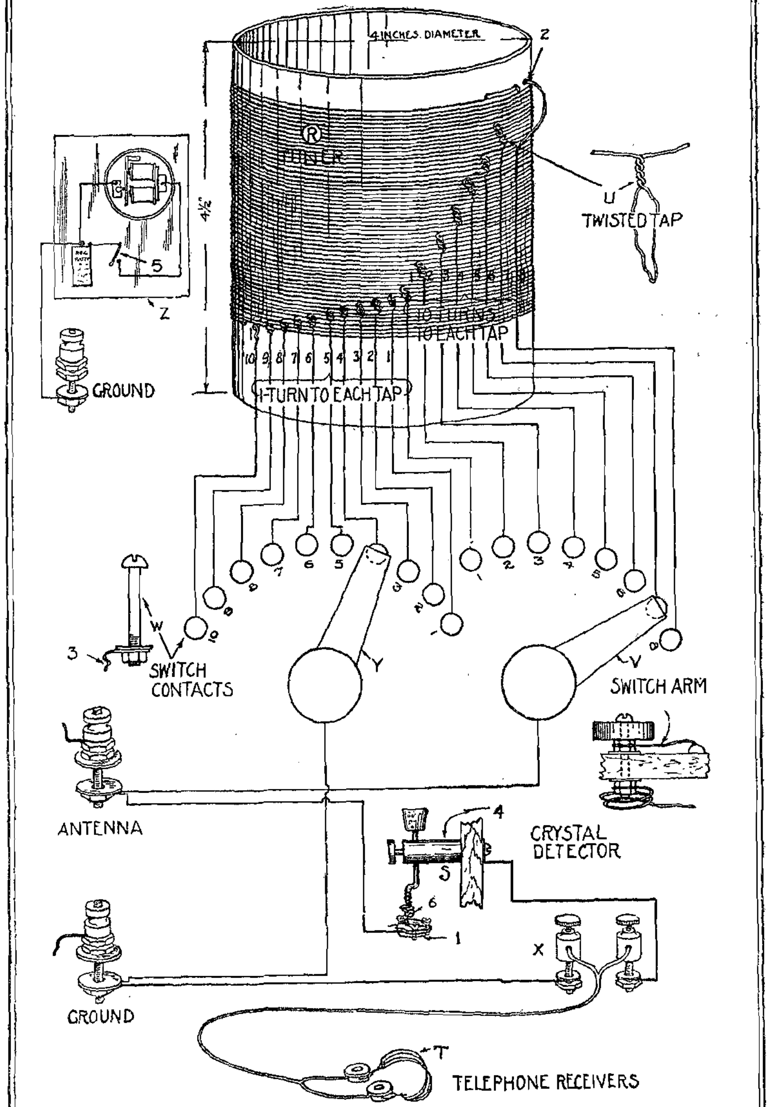

FIG.3. WIRING DIAGRAM AND DETAILS OF RECEIVING SET

perature. When the wood parts have been drilled and cut to size, they should be soaked in the melted paraffin, or the paraffin may be applied quickly with a small brush. When cold, the excess paraffin must be carefully scraped off with a straight piece of metal such as the brass strip in the edge of a ruler.

5. DETAILS OF CONSTRUCTION

The following is a description of the method of winding the tuning coil and the construction of the wood panels:

(*a*) TUNING COIL (R. Fig. 3).—The cardboard tubing is 4 inches in diameter by 4½ inches long. One end of the tube should have the cardboard cover glued securely to it. About 2 ounces of No. 24 (or No. 26) double cotton-covered copper wire is used for winding the coil. Punch three holes in the tube ½ inch from one end as shown at 2 in Fig. 3. Weave the wire through these holes in such a way that the end of the wire will be firmly anchored, leaving about 12 inches of the wire free for connecting. Start with the remainder of the wire to wind the turns in a single layer about the tube, tightly and closely together. After 10 complete turns have been wound on the tube hold these turns tight and take off a tap. This tap is made by twisting a 6-inch loop of the wire together at such a place that it will be slightly staggered from the first connection. This method of taking off taps is shown clearly at *U*, Fig. 3. Proceed in this manner until 7 twisted taps have been taken off—one at every 10 turns. After these first 70 turns have been wound on the tube, take off a 6-inch twisted tap for every succeeding single turn until 10 additional turns have been wound on the tube. After winding the last turn of wire, anchor the end by weaving it through two holes punched in the tube as at the start, leaving about 12 inches of wire free for connecting. It is to be understood that each of the 18 taps is slightly staggered from the one just above, so that the taps will not be punched along one line on the cardboard tube (see Fig. 3). It might be advisable, after winding the tuning coil, to dip the tuner in hot paraffin. This will help to exclude moisture. It is important to have the paraffin heated until it just begins to smoke, as previously explained, so that when the tuner is removed it will have only a very thin coat of paraffin.

(*b*) UPRIGHT PANEL AND BASE.—Having completed the tuning coil, set it aside and construct the upright panel shown in Fig. 4. This panel may be a piece of wood approximately ½ inch thick,

$4\frac{1}{2}$ inches wide, and 8 inches long. This panel can be used with apparatus to be described in another publication. For this reason it is desirable to have the last contact an inch from the right end of the panel (see Fig. 4). It is also desirable to have

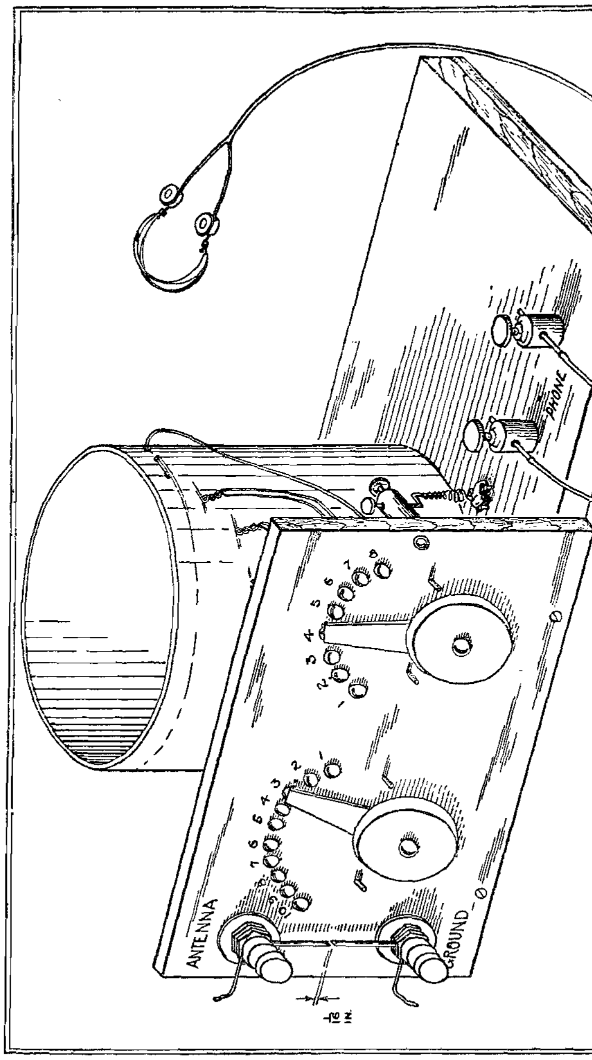

FIG. 4. ASSEMBLED RECEIVING SET

the contact points near the top of the panel. The position of the several holes for the binding posts, switch arms, and switch contacts may first be laid out and drilled. The antenna and ground binding posts may be ordinary $\frac{8}{32}$ brass machine screws about $1\frac{1}{2}$ inches long with three nuts and two washers. The first nut binds the bolt to the panel, the second nut holds one of the short pieces of stiff wire, while the third nut holds the antenna or ground wire, as the case may be. The switch arm with knob shown at *V*, Fig. 3, may be purchased in the assembled form or it may be constructed from a 3/8-inch slice cut from a broom handle and a bolt of sufficient length equipped with four nuts and two washers, together with a strip of thin brass somewhat as shown. The end of the switch arm should be wide enough so that it will not drop between the contact points, but not so wide that it can not be set to touch only a single contact. The switch contacts (*W*, Fig. 3) may be of the regular type furnished for this purpose, or they may be $\frac{6}{32}$ brass machine screws with one nut and one washer each; they may even be nails driven through the panel with the individual tap fastened under the head or soldered to the projection of the nail through the panel. The base is of wood approximately 3/4 inch thick, 5½ inches wide, and 10½ inches long.

The telephone binding posts should preferably be of the set-screw type as shown at *X*, Fig. 3.

6. INSTRUCTIONS FOR WIRING

After the several parts mentioned have been constructed and (with the exception of the tuning coil) mounted on the wood base, the wires may be connected to the switch arms and binding posts, and the taps may then be connected to the switch contacts. A wire is connected to the back of the left-hand switch-arm bolt (*Y*, Fig. 3), twisted into a spiral of one or two turns like a clock spring, and then led to the back of the binding post marked "ground." Connection is made to the binding post by removing the insulation from the wire and clamping between the nut and washer. The same wire is now passed through a small hole and run underneath the base to the left-hand binding post marked "phone." A wire is then run from underneath the right-hand binding post marked "phone" to the binding post *4*, Fig. 3, which is part of the crystal detector. The copper wire, which was wrapped tightly about the three brass wood screws that hold the crystal in place, is led underneath the base, up through a small hole, and is then connected to the back of the binding post marked "antenna." Another wire is connected to the back of the right-hand switch-arm bolt (*V*), twisted into a spiral of one or two turns like a clock spring, and then connected to the back of the same binding post.

The taps leading from the tuner should now be connected to the switch contacts. Scrape the cotton insulation from the loop ends of the 16 twisted taps as well as from the ends of the two single wire taps coming from the first and last turns. Fasten the bare ends of these wires to the proper switch contacts as shown by the corresponding numbers in Fig. 3. Be careful not to cut or break any of the looped taps. The connecting wires may be fastened to the switch contacts by binding them between the washer and the nut as shown at *3*, Fig. 3. After all the wires from the tuner have been connected, the tuner should be fastened to the base by two or three small screws passing through the cardboard end. The screws should be provided with washers.

7. DIRECTIONS FOR OPERATING

After all the parts of this crystal-detector radio receiving set have been constructed and assembled, the first essential operation is to adjust the fine wire so that it rests on a sensitive point on the crystal. This may be accomplished in several ways; one method is to use a buzzer transmitter. Assuming that the most sensitive point on the crystal has been found by the method described in paragraph below, "The Test Buzzer," the rest of the operation is to adjust the radio receiving set to resonance or in tune with the station from which the messages are sent. The tuning of the receiving set is accomplished by adjusting the inductance of the tuner. That is, one or both of the switch arms are rotated until the proper number of turns of wire of the tuner are made a part of the metallic circuit between the antenna and ground, so that together with the capacity of the antenna the receiving circuit is in resonance with the particular transmitting station. It will be remembered that there are 10 turns of wire between adjacent contacts of the 8-point switch and only 1 turn of wire between adjacent contacts of the 10-point switch. The tuning of the receiving set is best accomplished by setting the right-hand switch arm on contact (1) and rotating the left-hand switch arm over all its contacts. If the desired signals are not heard, move the right-hand switch arm to contact (2) and again rotate the left-hand switch arm throughout its range. Proceed in this manner until the desired signals are heard.

It will be advantageous to know the wave frequencies (wave lengths) used by the radio transmitting stations in the immediate vicinity. A lower frequency (greater wave length) requires more turns of the coil.

(*a*) THE TEST BUZZER (*Z*, Fig. 3).—As stated, the more sensitive spots on the crystal can be found by using a test buzzer. The test buzzer is used as a miniature local transmitting set. This is shown at *Z*, Fig. 3. The buzzer, dry battery, and switch (*5*) may be mounted on the table or a separate board. The binding post marked "ground" may be one terminal of the dry cell. The current produced by the buzzer will be converted into sound by the telephone receivers and the crystal, the loudness of the sound depending on what part of the crystal is in contact with the fine wire. To find the most sensitive spot, connect the binding post marked "ground" of the receiving set to the test buzzer binding post marked "ground," close the switch (*5*, Fig. 3), and if necessary adjust the buzzer so that a clear note is emitted; set the right-switch arm on contact point No. 8 and connect the telephone receivers to the binding posts. Loosen the set screw of the binding post (*4*) slightly and change the position of the fine wire (*6*, Fig. 3) to several positions of contact with the crystal until the loudest sound is heard in the phones; then slightly tighten the binding post set screw (*4*). The single wire connection between the test buzzer and the receiving set is all that is necessary to give a good test signal when the crystal detector is adjusted to a sensitive spot.

After the construction of the set has been completed, a test should be made for broken wires or poor contacts. Connect one terminal of the dry battery to the binding post marked "antenna." Connect the other battery terminal to one terminal of the buzzer, and from the other buzzer terminal run a wire to the binding post marked "ground." Turn the left-hand switch arm to the extreme left and the right-hand switch arm to the extreme right. If the buzzer operates, the metallic circuit of the coil is complete.

To make sure that the cords of the telephone receiver are all right, put the telephone receivers over the ears and touch the two cord tips to the two terminals of the dry battery. If a click is heard in both receivers, the cord is all right.

8. APPROXIMATE COST OF PARTS

The following list shows the approximate cost of the parts used in the construction of the receiving station. The total cost will depend largely on the kind of apparatus purchased and on the number of parts constructed at home.

Antenna:	
Wire, copper, bare or insulated, No. 14 or 16, 100 to 150 feet	$0.75
Rope, 1/4 or 3/8 inch, 2 cents per foot.	
2 insulators, porcelain	.20
1 pulley	.15
Lightning switch, 30-ampere battery switch	.30
1 porcelain tube	.10
Ground connections:	
Wire (same kind as antenna wire).	
2 clamps	.30
1 iron pipe or rod	.25
Receiving set:	
3 ounces No. 24 copper wire, double cotton covered	.75
1 round cardboard box	
2 switch knobs and blades complete	1.00
18 switch contacts and nuts	.75
3 binding posts, set screw type	.45
2 binding posts, any type	.30
1 crystal, tested	.25
3 wood screws, brass, 3/4 inch long	.03
2 wood screws for fastening panel to base	.02
Wood for panels (from packing box).	
2 pounds paraffin	.30
Lamp cord, 2 to 3 cents per foot.	
Test buzzer	.50
Dry battery	.30
Telephone receivers	4.00
Total	10.70

If the switches are constructed as directed and a single telephone receiver be used, the cost may be kept well below $10.

If a head set consisting of a pair of telephone receivers instead of a single telephone receiver is used, the cost of this item may be about $8 instead of $4. Still more efficient and expensive telephone receivers are available at prices ranging up to about $20.

WASHINGTON, March 27, 1922.