The EASY COURSE in HOME RADIO

MAJ. GEN. GEO. O. SQUIER, EDITOR-IN-CHIEF

LESSON VII—INSTALLING THE HOME SET

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ONE OF THE FOLLOWING SET OF SEVEN LESSONS

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LESSON SEVEN

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LESSON SEVEN

Installing the Home Set

INSTALLING your own radio telephone receiver offers the distinct advantage that it is both interesting and instructive. There is no reason why any one with a little skill and a few simple tools cannot install most of the units employed in reception. We have in mind especially such parts as the antenna and ground system, the tuner, crystal detector and condensers.

Such parts as the head telephone receivers, vacuum tubes and batteries, however, must be bought. It is beyond any untrained person to make them especially without the proper equipment of tools. This is especially true of the head telephones and vacuum tubes. For this reason, it is much simpler and certainly much cheaper to buy such parts outright. The theory of their operation, however, should be well understood and to this end reference must be made to other books of this series.

The Five Receiver Requirements

In all receiving equipment, it may be said that there are five general requirements. In other words, five distinct functions must be performed. Briefly they are:

(a) **The aerial** for picking up or absorbing the wireless waves as they travel through the ether.

(b) **The ground** system, which functions in conjunction with the aerial to form a return circuit for the waves.

(c) **The tuner,** which places the entire receiver in tune with the distant transmitter.

(d) **The detector,** which may be either of the crystal or vacuum tube type, and which detects waves in the circuit and rectifies them from a rapidly vibrating state to a slower vibrating state suitable for sound reproduction.

(e) **The reproducer,** which may be either a head telephone or a loud speaker, and which converts electrical waves into sound waves.

The aerial picks up the waves sent out into the ether by the distant transmitter, after which they are led down to the tuner and placed in resonance with the receiver, from which point they are led back and forth to ground in rapidly oscillating form. After the waves have been properly tuned, they are passed through the detector and rectified in such manner as to move the diaphragms of the head telephone receivers. While these five functions illustrate in a general way the foremost instrument, required for reception, in practice it will be found that there are many minor accessories employed in conjunction with them. For instance, and especially in vacuum tube reception, we have such devices as the grid leak, the grid condenser, "A" and "B" batteries, rheostats, etc.

The Necessary Tools

Now that we understand what is required in a receiving set and why these various parts are required, we can proceed with the business of obtaining the parts.

We must first provide ourselves with a few simple tools. These are usually found in the average tool chest or can be borrowed. We require:

A small hand drill equipped with varying sizes of drill points,
A center punch,
A small hammer,
A pair of electrician's pliers,
A soldering set,
A brace and bit,
A hack saw,
A screw driver.

Four General Types of Receiving Sets

There are four general types of receiving sets in use today. Each fills a definite purpose at a given cost.

1. **Simple Crystal Receiver.**—We have first, the simple crystal-receiving set which will be found quite effective for the reception of radio telephone broadcasting within the radius of a few miles and especially for use in cities where are located powerful broadcasting stations. If we wish to construct this type of set at home, we need not spend more than $8.00 to $12.00 for a complete installation. When, on the other hand, we wish to purchase the complete outfit outright, we need not spend more than $15.00 to $40.00.

2. **Simple Vacuum Tube Receiver.**—The next type of receiving set is practically the same as the first except that we employ a vacuum tube for the detector instead of a crystal. By doing this, we gain the immediate advantage of increasing the receiving range by some few miles. We may also easily enough construct such simple vacuum tube receiving sets at home at a cost of from $20.00 to possibly $30.00. We may purchase the complete set at a nearby radio store at prices ranging from $50.00 to $100.00 for the complete installation.

3. **Regenerative Receiver.**—The third type of set is that employing a tuner of the regenerative type in conjunction with a vacuum tube detector, so that we secure an increased sensitiveness as well as a slight amplification of the waves *after* they have been detected, all this by the simple use of one vacuum tube. Such a set, built at home, will cost about the same as set No. 2, except that it requires a little more patience and a few more operating details. 'A complete set of this kind may also be purchased for about $75.00.

4. **Amplifying Receiver.**—Set No. 4, starts off with the same qualifications as set No. 3, but with the difference that we include external amplification. In this case, it is the common practice to employ a two-stage amplifier, so that the entire receiver requires three vacuum tubes, one for detection and two for amplification at audible frequencies. This class of complete receiving outfit is purchased from approximately $200.00 to $300.00. In this class of apparatus we may also include other types of receivers, somewhat more elaborate, which in-

corporate not only amplification at audio* frequencies, but amplification at radio† frequencies as well. That is to say, the received energy is first tuned, then amplified at its original radio frequency directly as received from the ether by means of one or two stages of vacuum tube amplification. After the signals have been boosted up to a much greater intensity than can ordinarily be obtained by any other means, they are then detected by a third vacuum tube which functions simply as a detector. This process of detection rectifies the received energy from radio frequencies down to audio frequencies. From this point, one or two more vacuum tubes are employed for the purpose of further amplifying the received energy, and this is called "audio frequency amplification." Such types of receivers, while somewhat complicated and expensive to operate, find very useful application in receiving from long distances (1,000 miles or more) with the customary outdoor antenna, or for receiving comparatively shorter distances with the indoor loop antenna.

This same class of apparatus is frequently made up in cabinet form similar to that of the phonograph, and by employing a loud-speaking device, it is a comparatively easy task to fill a large room with broadcasted news and music so as to entertain a large number of people at one time without the necessity of employing individual head-telephone receivers. The set-up of a two-stage amplifier is explained in a later chapter.

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* Meaning to amplify after the signal has been detected and rectified to audible tones.

† Meaning to amplify before detection, and at the original rate of vibration (frequency) the waves are picked up by the aerial.

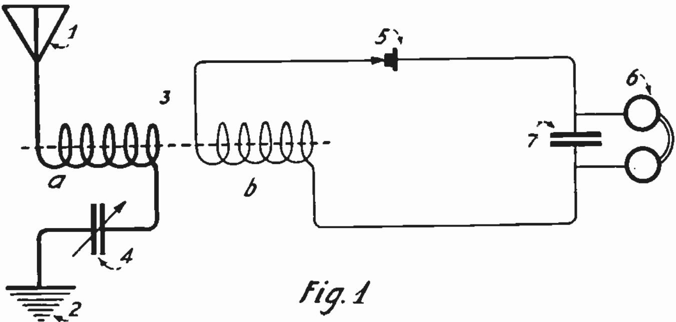


Fig. 1

A Simple Crystal Receiver Circuit Diagram.

Simple Crystal Receiver

Parts	*Approximate Cost*
1. Aerial outfit, consisting of 150 feet No. 14 copper, silicon bronze or aluminum wire, 50 feet No. 14 insulated copper "ground" wire, 3 porcelain aerial insulators, 1 lead-in insulator, 1 lightning protector, 1 ground clamp..	$5.00
2. Ground (included above).	
3. Tuner (Fig. 1-*A*), where *a* is a tuned primary coil and *b* a secondary, to build as per accompanying instructions	3.00
4. Variable Tuning Condenser of .0005 microfarad capacity	3.00
5. Crystal Detector to build as per accompanying instructions, unmounted type for back of panel mounting	1.00
6. Head Telephone Receivers, 2000 ohms, pair.	6.00
7. Small Telephone Condenser, .002 microfarad (or can be made as per Fig. 1-*B*)	.35
Total	$18.35

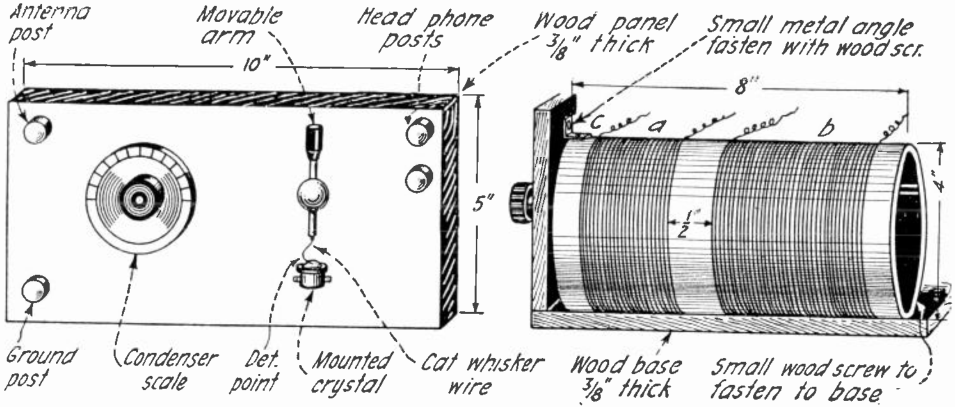


Fig. 1-A

Directions for Tuner.

A = 45 turns #24 D.C.C. magnet wire.
B = 75 turns #24 D.C.C. magnet wire.
(both coils wound same direction.)
C = Small brass strip angle with two holes.
D = Cardboard tubing 8" long by 4" outside diameter, by 1/8" thick.
100 feet #24 D.C.C. Magnet wire required for all purposes—tuner coils, connections, etc.

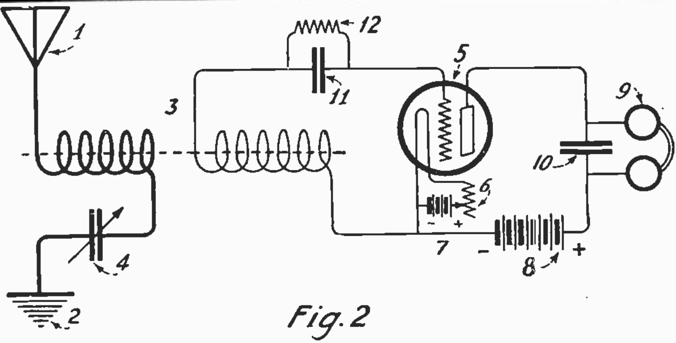


Fig. 2

A Simple Vacuum Tube Receiver Circuit Diagram.

Simple Vacuum Tube Receiver

	Parts to Purchase	*Approximate Cost*
1.	Aerial (same as Fig. 1)	$5.00
2.	Ground (included above)	
3.	Tuner (same as Fig. 1)	3.00
4.	Variable Tuning Condenser (same as Fig. 1)	3.00
5.	Vacuum Tube Detector and Socket	6.00
6.	Rheostat for controlling vacuum tube filament temperature	2.00
7.	6-volt, 80-ampere hour "A" Storage Battery for lighting vacuum tube filament	25.00
8.	22-volt "B" Block cells for actuating plate of vacuum tube, tapped for 18 volts	2.00
9.	Head Telephone Receivers, 2000 ohms, pair	6.00
10.	Small Telephone Condenser, .002 microfarad	.35
11.	Small Grid Condenser, .0005 microfarad	.35
12.	Grid Leak Resistance, 1 megohm	.50
	Total	$53.20

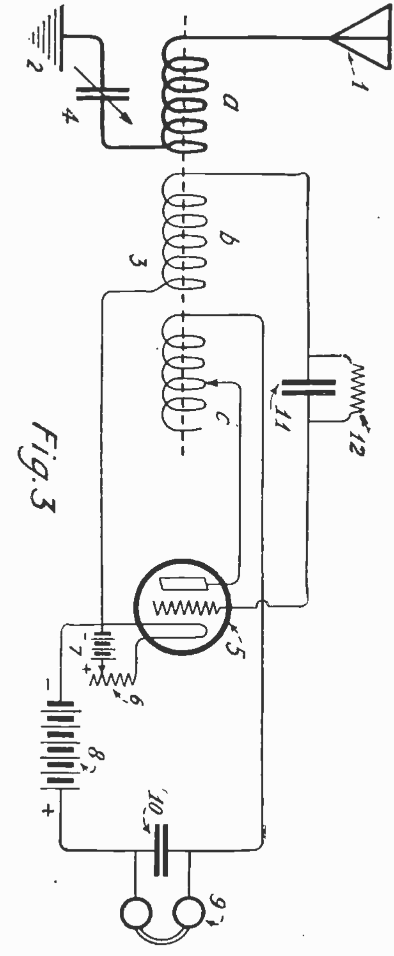


Fig. 3

A Simple Vacuum Tube Regenerative Receiver Circuit Diagram.

Fig. 3

Simple Vacuum Tube Regenerative Receiver

	Parts to Purchase	*Approximate Cost*
1.	Aerial (same as Fig. 1)	$5.00
2.	Ground (included above)	
3.	Tuner, same as Fig. 1 with the addition of an extra third coil called the "feed back" coil and consisting of an additional 12 turns of the same wire, separated by ½ inch from the secondary coil. See Fig. 3-*A*	3.00
4.	Variable Tuning Condenser	3.00
5.	Vacuum Tube Detector and Socket	6.00
6.	Rheostat for controlling vacuum tube filament temperature	2.00
7.	6-volt, 80-ampere hour "A" Storage Battery for lighting vacuum tube filament	25.00*
8.	22-volt "B" Block Cells for actuating Plate of vacuum tube, tapped for 18 volts	2.00
9.	Head Telephone Receivers, 2000 ohms, pair	6.00
10.	Small Telephone Condenser, .002 microfarad	.35
11.	Small Grid Condenser, .0005 microfarad...	.35
12.	Grid Leak Resistance, 1 megohm	.50
	Total	$52.20

* For initial economy, three standard dry cells may be used instead but for operating periods of short duration only, at a cost of $1.20.

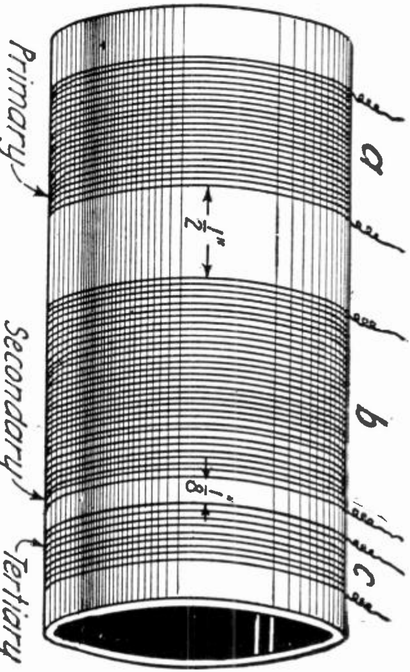


Fig. 3-A

Directions for Regenerative Tuner.

A = 45 turns #24 D.C.C. Magnet Wire.
B = 75 turns #24 D.C.C. Magnet Wire.
C = 15 turns #24 D.C.C. Magnet Wire.

Fig. 4

Regenerative Receiver, Variometer Type

Parts to Purchase	*Approximate Cost*
1. Aerial (same as Fig. 1)..................	$5.00
2. Ground (included above)	
3. Tuner, vario-coupler type, see directions given in Lesson Six. for building, to cost...	3.00
4. Variable Tuning Condenser (same as Fig. 1)	3.00
5. Vacuum Tube Detector and Socket........	6.00
6. Rheostat for controlling vacuum tube filament temperature	2.00
7. 6-volt, 80-ampere hour "A" Storage Battery for lighting vacuum tube.................	25.00*
8. 22-volt "B" Block Cells for actuating Plate of vacuum tube, tapped for 18 volts........	2.00
9. Head Telephone Receivers, 2000 ohms, pair	6.00
10. Small Telephone Condenser, .002 microfarad	.35
11. Small Grid Condenser, .0005 microfarad...	.35
12. Grid Leak Resistance, 1 megohm.........	.50
13. Grid Variometer for Regenerative Tuning.	3.00
14. Plate Variometer for Regenerative Tuning. (These two Variometers can be made or bought ready made.)	3.00
Total	$59.20

* For initial economy, three standard dry cells may be used instead but for operating periods of short duration only, at a cost of $1.20.

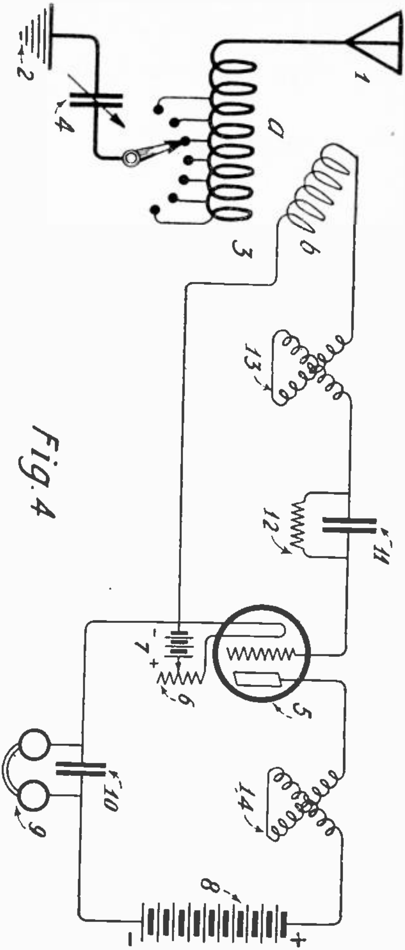


Fig. 4

A Short Wave Amateur Regenerative Receiver of the Variometer Type.

Fig. 5

Two-Step Vacuum Tube Amplifier

	Parts to Purchase	*Approximate Cost*
1. 2.	Two audio frequency amplifying transformers	$14.00
3. 4.	Two amplifier vacuum tubes, with two sockets	15.00
5. 6.	Two Rheostats for controlling vacuum tube filament temperatures	4.00
7.	One double circuit telephone jack, to plug in for one step of amplification	1.50
8.	One single circuit telephone jack to plug in for two steps of amplification	1.00
9.	One telephone plug for Head Telephone Receivers	1.25
10.	Six service binding posts	.90
11.	"A" Battery for vacuum tube filaments, should be a 6-volt, 80-ampere hour Storage Battery and can be used for the vacuum tube detector shown in Fig. 4, as well as for the above two-step amplifier, Fig. 5	
12.	"B" Battery for vacuum tube plates, should consist of two standard block cells, each 22½ volts, so as to furnish 45 volts. These should be separate units from the one used for the detector circuit	4.00
	A hard wood base for mounting the instruments in appropriate form	.50
	Screws, wires, nails, etc.	.50
	Total	$42.65

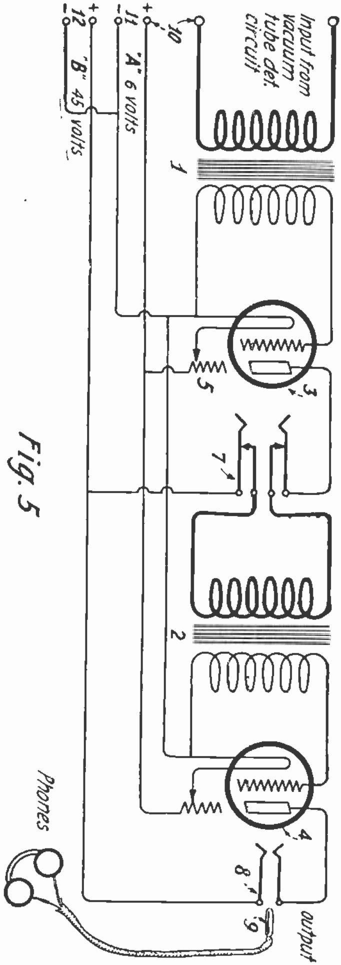


Fig. 5

A Two-Step Vacuum Tube Amplifier Circuit Diagram.

Fig. 6

Loop Receiver

Parts to Purchase	Approximate Cost
1. Loop. 100 feet No. 14 Lamp cord wire....	$3.00
4 Bakelite brackets, to be shaped as shown above, wooden support and stand for loop frame can be easily made by the operator. See Fig. 6 for size..........................	.50
2. Tuning Condenser for tuning, variable type, having capacities ranging from .00004 to .0006 microfarad	7.00
3. A Radio Frequency Amplifier unit, consisting of:	
2 radio frequency intervalve transformers designed for short wave work, to cost about.	13.00
2 amplifier vacuum tubes and sockets.......	15.00
2 Rheostats for filament control............	4.00
1 "A" Battery Potentiometer..............	2.00
4. A vacuum tube detector unit, consisting of:	
1 detector vacuum tube and socket.........	6.00
1 Grid condenser, .0005 microfarad capacity	.35
1 Grid leak, 1 megohm resistance..........	.50
1 Rheostat for filament control............	2.00
5. An audio frequency amplifier unit, consisting of 1 audio frequency transformer..........	7.00
1 amplifier vacuum tube and socket........	7.50
1 Rheostat for filament control............	2.00
6. A pair of Head Telephone Receivers, 2000 ohms at $6.00 per set, or a loud speaker at...	30.00

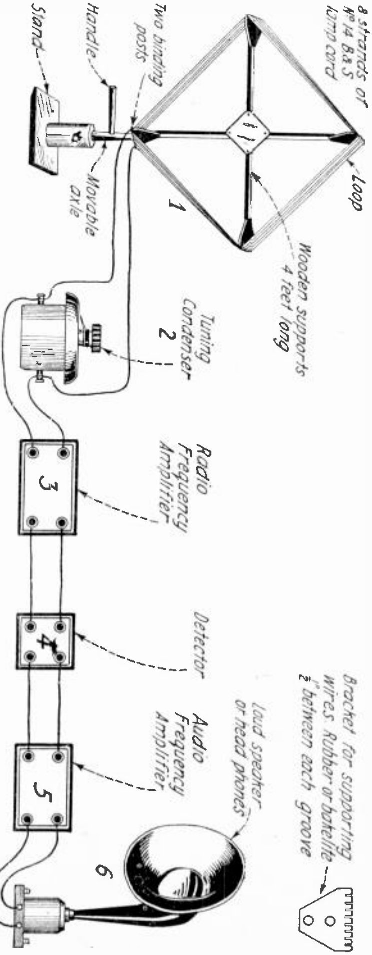


Fig. 6

Diagram of the necessary parts for a Loop Broadcast Receiver.

Assuming the "A" and "B" batteries were not available and had to be purchased, the first at $25.00, and the second (two block cell units) at $4.00.	29.00
Total	$108.85

Note: See Fig. 7 for proper method of circuit connection.

The Simple Crystal Receiving Set

The following is a list of materials required to build this set and a description of each item. The numbers given in this list correspond with the numbers shown on the diagrams.

1. First, we must consider the aerial or antenna as it is also called which is to be erected out of doors and which picks up the broadcasted radio waves. This aerial may consist of a single wire stretched in a horizontal position, about 125 to 150 feet long. Two insulators are necessary at each end, and these should be fastened to a suitable elevated support. The lead-in wire must form part of this aerial. It is led from one end down to the receiving instruments. This lead-in wire enters the house by means of the lead-in insulator. When it enters the house, it is led to a lightning protector and then to the tuner.
2. The ground which, as we have previously explained, forms the other end of the radio circuit, consists of a length of insulated copper wire led to the nearest water pipe or steam radiator system. If neither are available, it should be led to a metal pipe, six feet long, buried in moist ground, care being taken

to solder or otherwise securely fasten the copper wire to the pipe. A so-called "ground clamp" may be employed as an alternative for this purpose.

3. The tuner may be constructed according to the directions given in our sketch. This type of tuner is especially designed for the reception of broadcasted signals. It differs from other instruments in that it requires no slider or movable contacts of any kind. When used with the antenna it will receive radio telegraph signals or broadcasted speech and music between the wave-lengths of 175 to 500 meters. Tuning is done by the simple operation of the variable condenser shown in Fig. 1. The tuner consists of a primary and a secondary wound on a single tube. The coupling between this primary and secondary is of a predetermined value corresponding in this instance to a ½ inch separation between each section. Follow the construction details of the accompanying sketch closely.
4. The Variable Condenser. It is not especially recommended that this instrument be made by the beginner. It can be purchased at the nearest radio store for about $3.00. The size recommended for our purpose has a maximum capacity of .0005 mfd. It may be of the unmounted type; that is to say, the knob end protrudes through a quarter-inch hole of the wooden panel shown in the sketch, and the plates are mounted on the reverse side.
5. The Detector. It is recommended that the parts necessary for a crystal detector be purchased at the nearest radio shop. These are:

   (a) A movable joint with "cat-whisker" point.

(b) A mounted galena crystal.
(c) A holder for the mounted crystal.
These parts should be assembled on the panel in the vertical position shown in our sketch. Next connect a small piece of wire from the movable joint post to the inside end of coil *B* and at a point marked *E*. Connect another wire from the mounted crystal-holder to the top binding-post placed in the right-hand top corner of the front panel.

6. Telephone Receivers. As previously mentioned, these are not easy to construct by the beginner. They can be furnished by the nearest radio store for about $6.00, and each receiver should be of the 1000 ohm type, so that the pair will have a combined resistance of 2000 ohms.
7. The Fixed Telephone Condenser. This unit can also be purchased at the very small cost of about 35c. and should have a capacity of .002 mfd. It should be connected directly across the head telephone receiver binding post as shown in our sketch.

If the radio enthusiast wishes to make his own he can easily do so by following the instructions given in Lesson 6.

The Simple Vacuum Tube Receiver

From the simple crystal receiver we make the natural step into the vacuum tube receiver class. In general, everything that has been written in the foregoing paragraphs regarding fundamental requirements applies likewise to the vacuum-tube receiver. The same functions are to be performed except that in this case, we employ a vacuum tube for the purpose of detecting and rectifying the radio waves to such form that they will actuate the telephone receiver or sound reproducer.

By referring to Fig. 2, the designating numbers, 1, 2, 3, 4, 9 and 10, apply to the same kind of apparatus used in the simple crystal receiver shown in Fig. 1. It is, therefore, assumed that the prospective owner of this vacuum tube receiver will refer to these items when constructing or purchasing the necessary parts.

5. The Vacuum-Tube Detector. It is not practical to build your own vacuum tube detector. For this reason, it is necessary to purchase one at the nearest radio store. In asking for this tube you shouuld make the distinction between a *detector* vacuum tube and an *amplifier* vacuum tube. At the same time purchase a standard socket to fit the tube. There are four binding posts on the socket, each so arranged that when the tube is inserted in the socket, the proper connections will be made to *f,f*, the filament battery source; *g*, the grid connection and *p*, the plate connection.

6. Properly to control the burning of the filament, which, in turn, furnishes the electronic stream to the plate, it is necessary that we either make or purchase a filament rheostat. This is nothing more than a coiled resistance wire capable of holding a current of one or more amperes. It is hardly worth while to build the rheostat as this may be purchased almost as cheaply as it can be made. This filament rheostat is connected in series with the six-volt storage battery and the filament terminals of the vacuum tube. See Fig. 2 for the proper method of connection.

7. The Filament Battery. If the vacuum-tube receiver is to be employed for long periods (several hours) each evening, it will be better at the very start to purchase a 6-volt, 80-ampere hour storage battery, usually called and

referred to in radio terminology as the "A" battery. While this is a heavy initial expense of possibly $20.00 to $30.00, the storage battery will be much more satisfactory in the long run. The negative pole of this battery designated in Fig. 2 by a minus sign (—) and the positive pole designated by the plus sign (+) should be connected as shown. If the radio constructor does not wish to spend this sum at the beginning, he may employ three standard dry cells, such as those employed for bell ringing and for intermittent electrical work. Such cells, however, will quickly run down if the vacuum tube is burned for long periods. Assuming, however, that the radio receiver is used one hour each evening, these cells may last about a month before renewal is necessary.

In this connection there are certain types of complete vacuum tube receivers sold on the market which employ a special vacuum tube that requires but one dry cell to burn the filament.

8. The Plate Battery. This is usually referred to as the "B" battery and is necessary for proper vacuum tube operation. This battery consists of a number of dry cells similar to the flash light type, grouped together in one block form and furnishing 22½ volts. It is, however, frequently equipped with taps, so that it is possible to secure 18, 21 or 22 volts, *a necessary requirement for the operation of certain vacuum tubes which function best at 18 volts for the plate potential.* It is not considered practical to build your own "B" battery. For this reason, it should be purchased. It comes in two sizes; the small size costing about $1.50 and the large size costing about $3.00. The larger size, will of course, last more than twice as long as the smaller size.

11. The Grid Condenser. This is a small fixed condenser which should have a capacity of .0005 mfds. While this is easily made, it is hardly worth while for it may be purchased for 35 cents to 75 cents.

12. The Grid Leak. This is a very high resistance usually connected across the grid condenser in the manner shown in Fig. 2 and should have a resistance of 1 megohm (1,000,000 ohms). It may be purchased for about 50c. A grid leak, which will function quite well for practical purposes, may be made by the simple expedient of taking a small piece of card board and drawing a heavy line with a soft lead pencil for a stretch of about one inch. Binding posts are placed at the ends and in contact with the pencil line and the unit is connected across the grid condenser as previously explained. The most effective resistance can be secured by either increasing or decreasing the width of the lead pencil line.

The Simple Vacuum Tube Regenerative Receiver

This receiving circuit of Fig. 3 is practically the same as that described under Fig. 2, except that in this instance we are making use of the vacuum tube regeneration principle or "feed back." The principle of regeneration will be found fully explained in Professor Morecroft's volume of this course. Briefly, it consists in utilizing part of the energy which has been rectified by the vacuum tube and feeding it back into the secondary of the tuner 3. The secondary then takes this fed-back energy and strengthens the original antenna impulse to such an extent that it is once more sent on to the vacuum tube for further amplification and at much greater intensity than would otherwise be obtained were regeneration not employed.

Items 1, 2, 4, 5, 6, 7, 8, 9, 10, 11, and 12 are the same as those described under Fig. 2 except that in the case of 3, which is the tuner, an additional coil is wound next to the secondary coil, forming, therefore, a tertiary coil. This third coil, called the "feed back" coil, should consist in this instance of 15 turns of the same size wire used for the primary and secondary of the tuner. The third coil should be separated from the secondary by a space of ½ inch. It is assumed, of course, that this receiver will be used for broadcast reception, which means wave-lengths between 175 and 500 meters. Tuning to secure the required wave length is accomplished by means of the variable tuning condenser 4 shown in Fig. 3.

The Regenerative Receiver, Variometer Type

Fig. 4 shows another form of regenerative receiver employing a vario-coupler instead of the simple non-variable tuner described under Figs. 1, 2 and 3, and two variometers. This type of regenerative receiver has found great favor in amateur operation and is unusually sensitive and effective for short wave-lengths. It is more flexible, and in general, better results can be secured than with the arrangement shown in Fig. 3, but it requires more care in adjusting in order to secure these good results. Items 1, 2, 4, 5, 6, 7, 8, 9, 10, 11, 12, are the same as those mentioned under Figs. 2 and 3.

3. The Vario-Coupler. If the radio constructor does not wish to construct this piece of apparatus, it may be purchased at from $3.00 to $5.00 at the nearest radio

store. For those who wish to make their own, however, the directions given in Lesson 6 can be followed.

13. The Grid Variometer. This is for tuning the grid circuit. For best results, this variometer should be purchased at the nearest radio store as it is not very expensive. It may, however, be constructed by the beginner as described in Lesson 6 of this series.

14. The plate variometer tunes the plate circuit. This may also be purchased and is constructed exactly like the grid variometer. In broadcast and amateur reception, these two variometers are the controlling members of the entire receiver, No. 13 tuning the secondary system and No. 14 controlling the amount of regeneration to be obtained.

The Two-Step Vacuum Tube Amplifier

It is not possible to actuate a loud speaker unless the original signal received and rectified by the detector circuit has been greatly magnified in volume. In other words, a loud speaking device will not function in conjunction with a simple crystal detector circuit, nor will it function with a single vacuum tube detector.

To make the loud speaker respond it is necessary to amplify the original detector signal by means of either one or two steps of vacuum tube amplification at audio frequencies, depending upon the distance the signal is to be received. For instance, if the receiver is located in the same city as the broadcasting station, or within a few miles, it may be found that a detector and but one step of amplification will be sufficient to actuate the loud speaker.

If, however, and as is frequently the case, the receiver is located in the suburbs of the city served by a broadcasting station, say ten miles or more, it is usually necessary to employ two stages of amplification. In fact, most receiving sets of the amplifier class are equipped with first a tuner, then a vacuum tube detector, then two stages of vacuum tube amplification.

This method of amplification is quite satisfactory for general receiving work and especially when the customary 150 foot outdoor antenna is employed in conjunction with the "ground."

Since we have previously constructed a receiver employing a vacuum tube detector, it is comparatively easy to add the two-step amplifier to the former unit.

In setting up our two-step amplifier, we must consider two factors: the input and the output. Referring to Fig. 5, the two binding posts on the left hand of the diagram are connected with the point of the vacuum tube detector circuit (See Figs. 2, 3, 4) usually occupied by the head telephone receivers, while the two points of the jack at the extreme right hand of the diagram (8) termed the "output," from which may be plugged in either the pair of head telephone receivers or the loud speaker unit.

We now refer further to Fig. 5 and to the list of materials described below this circuit. As may be seen, it is comparatively simple to set up the two-stage amplifier unit. It is simply a matter of purchasing the component parts and connecting these according to the above diagram.

While the entire unit would probably look better if it were boxed in like the manufactured product, it is desirable for the radio student to set up the parts on an open base where he will have all sections of the circuit under observation and can make changes, tests and experiments in amplification.

It is common practice to employ the same "A" filament, and "B" plate batteries for both the detector and amplifier units. This saves the cost of additional batteries. While Fig. 5 shows the two-step amplifier as a separate unit, it is quite simple to incorporate it with such receiving circuits as shown under Figs. 2, 3, and 4. To do this connect the input side of the amplifier to the points otherwise occupied by the head telephone receivers of the vacuum tube detector circuit, then connect the two binding posts marked 11 to the "A" storage battery of the detector circuit, and the two binding posts marked 12 to the "B" dry cells. However, where but one block battery unit of 22½ volts is sufficient to operate the vacuum tube detector, two such units are required for vacuum tube amplifiers. We therefore add another 22½ volts. Fig. 7 illustrates this single source of "A" and "B" battery supply for all tubes.

Concerning the loud speaker, this device as most commonly used, is nothing more than a highly sensitive telephone receiver, the sound end of which is fitted to a horn, similar to a large size megaphone. If the receiver is supplied with a suitable amount of energy, as for instance, that supplied by a detector and two-stage amplifier, the diaphragm will *reproduce* the voice and music exactly as transmitted at the broadcasting station, and these reproduced sounds will be further magnified by the natural acoustics of the horn.

The Loop Receiver for Broadcast Reception

Fig. 6 illustrates the essentials of the Loop Receiver adapted for broadcast reception. This receiver employs a loop antenna, two stages of radio frequency amplification, one detector and one stage of audio frequency amplification. This type of receiver will function effectively up to distances of several hundred miles. It is especially useful to overcome interference from local stations as well as to reduce the effects of static disturbances.

The loop antenna as distinguished from the customary outdoor antenna possesses marked directional properties. That is to say, it can be pointed so as to receive signals from a given direction to the exclusion of signals advancing from other points. To do this, the loop is made movable upon an axis and the wire strung so that the turns will be parallel to the general direction of the advancing waves. The loop aerial is used extensively for direction finding work at sea.

A satisfactory loop for the purpose of receiving broadcasted voice and music can be made by using a wooden frame 3 feet square, wound with eight turns of No. 14 B. & S. lamp cord, each turn being spaced ½ inch apart. The ends of each wire are made long enough to enable the loop to be turned around freely; they are then led to the two binding posts of a variable condenser having a capacity ranging from .00004 to .0006 microfarad. This condenser permits tuning of the incoming waves. From this condenser, two additional wires lead the waves first to the radio amplifier unit, where they are highly magnified at their original frequency of oscillation, after which the vacuum tube detector unit rectifies to audio frequencies. It is then the task of the last unit, the audio frequency

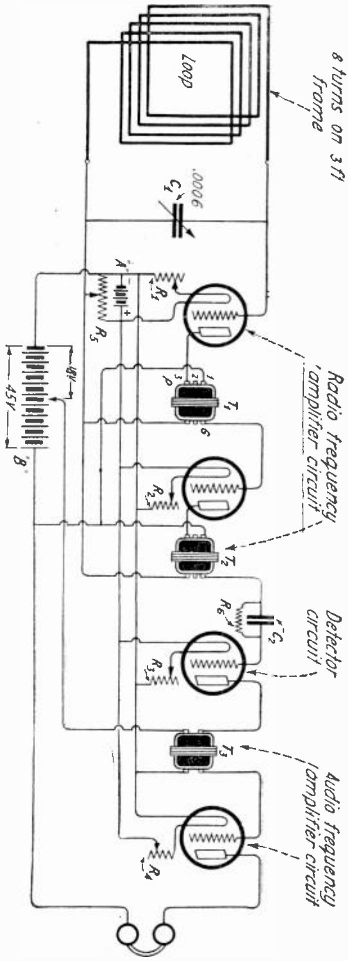


Fig. 7

A Loop Broadcast Receiver Circuit Diagram incorporating all necessary parts.

amplifier, to further magnify the signals to a volume great enough to operate a loud speaker, or if the distant station be too remote, to operate a pair of head telephone receivers.

Fig. 7 represents the same loop broadcast receiver but in accepted standard circuit form. Here we depart from the simple numerical designation of previous circuit diagrams in that we have marked the correct technical terms for each piece of apparatus employed. These are best described as follows:

Loop—Previously explained.

C1—A variable condenser having a maximum capacity of .0006 microfarad.

R1, R2, R3, R4—Rheostats for controlling vacuum tube filaments.

R5—"A" Battery Potentiometer (200 ohms).

R6—Grid Leak (2 megohms).

T1, T2—Radio frequency transformers designed for short wave work.

T3—Audio frequency transformer.

"A"—6-volt filament storage battery.

"B"—45-volt plate battery, 18 volts of which is tapped off for the detector vacuum tube and 40 volts for the amplifier vacuum tubes.

T—Head telephone receivers or loud speaker.

The first, second and fourth vacuum tubes are amplifiers, the third tube is a detector.

Note: For more detail description of the above parts study list of materials under Fig. 6.

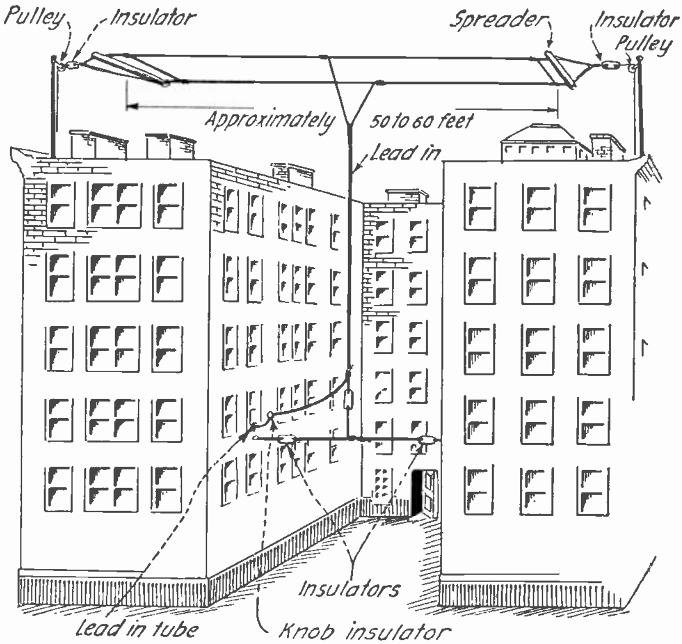
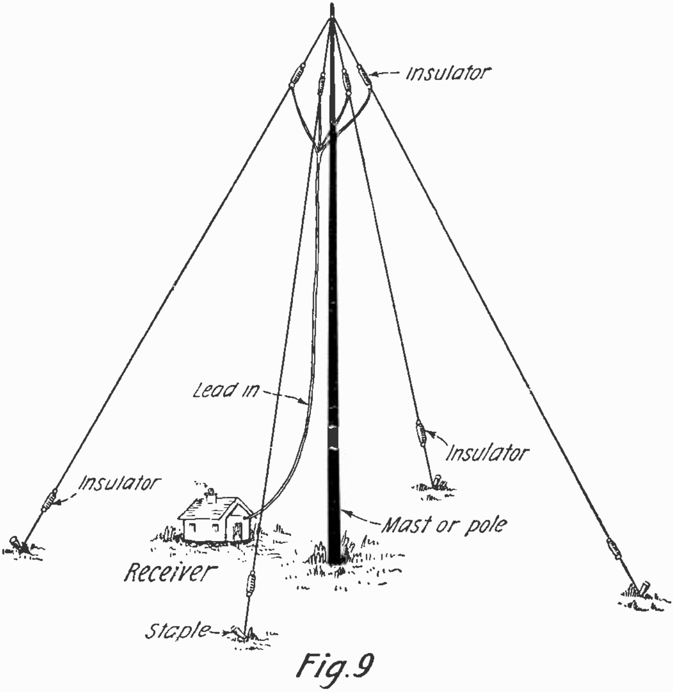


Fig. 8

Suggested Apartment House Antenna.

The Erection of Receiving Antennae

There are two general considerations to be taken into account by the broadcast enthusiast contemplating the erection of an antenna. One has to do with the city dweller and the other with the country or suburban resident. This is because the city offers difficulties not



The Umbrella-Type Antenna.

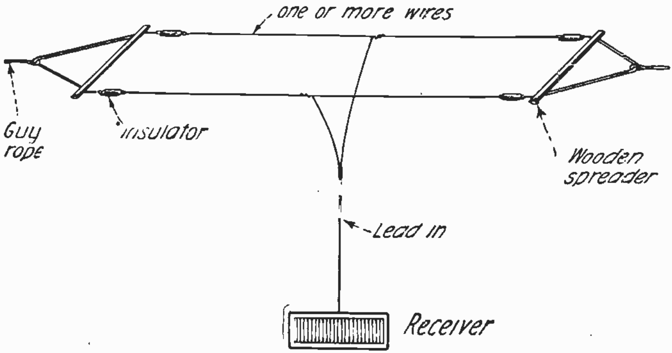


Fig. 10

The "T" Antenna.

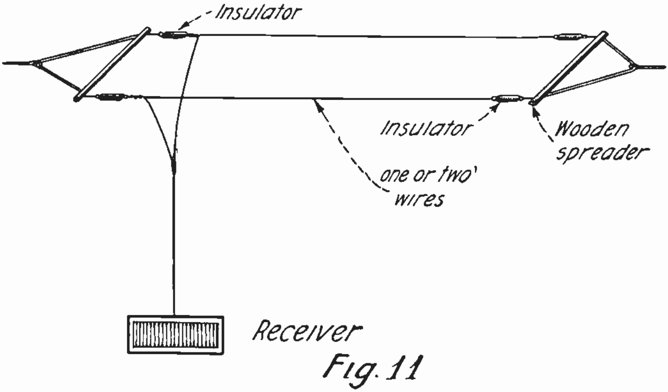
met with in the country. For instance, if you are living in a large apartment house, it is not always practicable to erect an efficient antenna. If no objections are raised by the landlord, however, an antenna suitable for broadcast reception may be erected according to the general set up of Fig. 8.

Outdoor Antennae

Before we proceed further, we will indulge in a brief discussion concerning the fundamental characteristics of various types of antennae. We shall, however, confine ourselves to three general kinds, namely:

The Umbrella Antenna.
The so-called "T" Antenna.
The inverted "L" Antenna.

The experimenter may choose the one particularly



The Inverted "L" Antenna.

adapted to his needs or limitations. For instance, if he has very little space in which to span it, the umbrella type probably will be the most effective, see Fig. 9. If, on the other hand, he has "elbow room" the T aerial may be adopted. See Fig. 10. If he is seeking general all around satisfaction or wishes to secure an exceedingly long span (300 feet or more) in order to receive long wave European stations, the inverted L is the proper type to resort to. See Fig. 11. In fact, the latter is the one most commonly employed (on shorter 150 foot spans), as it is effective, simple in construction and good in appearance. Incidently, it is also the one mostly used for shipboard.

Another factor to take into consideration is the directive effect of each type. If you have in mind the reception from a certain known station or of general directions such as those facing Europe, South America or Asia, you will probably wish to align your aerial so that it will pick up maximum energy from given directions. Fig. 12 shows the orientation curves of the three types mentioned. The curve at *A*, is for that of a vertical wire or an umbrella aerial where it will be seen that radiation or reception, will have an equal strength from all directions, and this type, therefore, may be said to be best suited for "all around" work.

It is, however, not always convenient or practical to obtain the great height of wire spread in order to secure the necessary wave lengths. That is why the flat top is mostly used. The curve at *B* is for that of a flat top

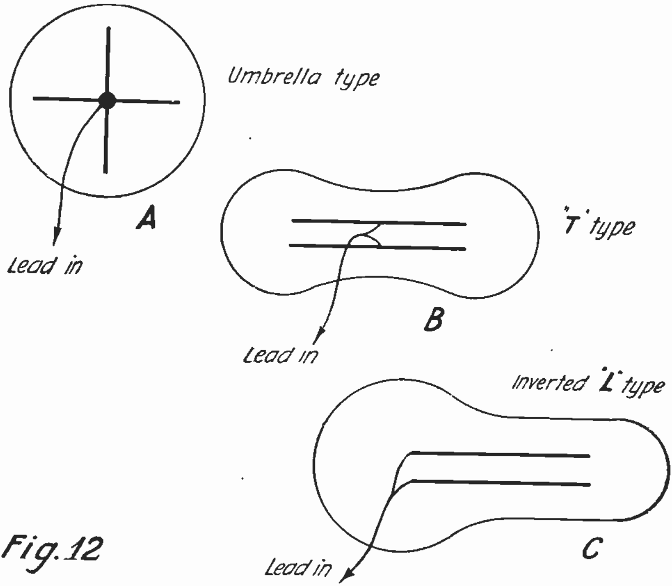


Fig. 12

Orientation Curves illustrating the directive qualities of three types of antennae.

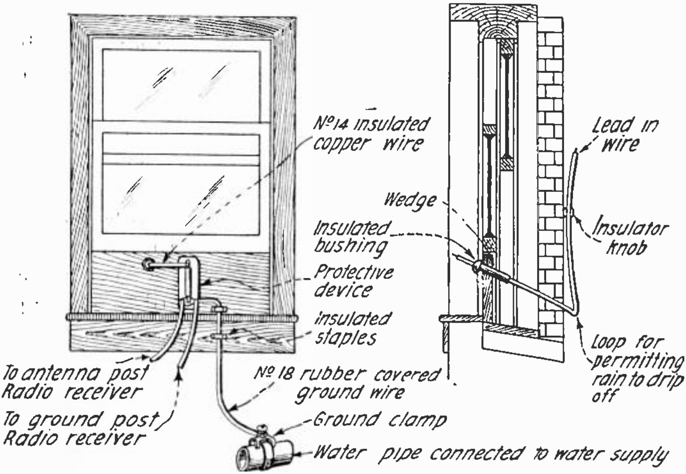
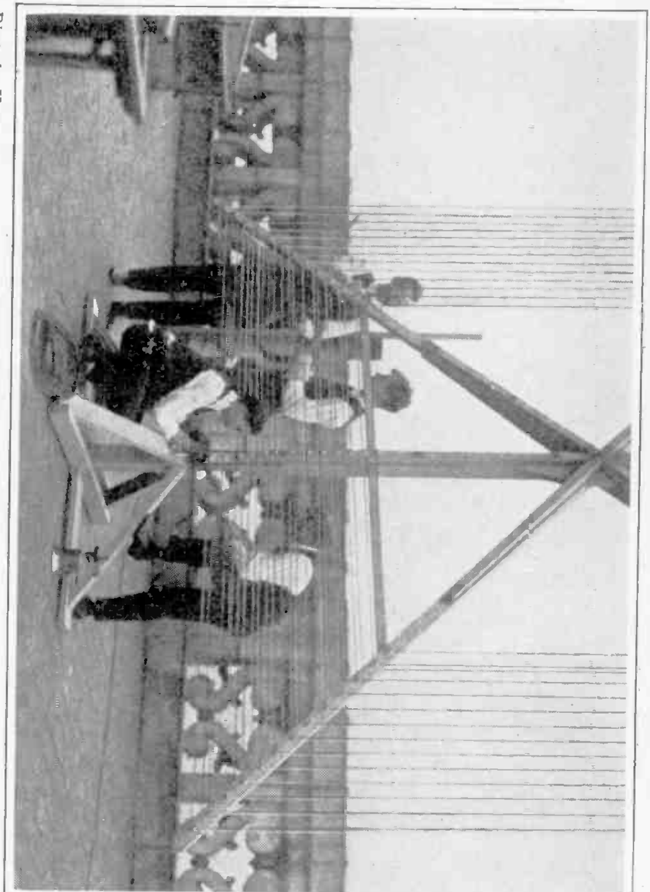


Fig. 13

Method of leading antenna into house and manner of installing protective device.

T-aerial in which case greater orientation lies in two general directions. This type is widely adopted by amateurs and broadcast enthusiasts for short wave work. The lead-in in this case should be connected exactly in the center; if connected slightly to one side, there will be theoretically a slight loss of received or transmitted energy due to unbalanced current-paths of the high frequency oscillations. This will become plain by referring to Fig. 13. The curve at *C* is for that of an inverted L-aerial, and, as may be seen, it is not unlike the shape of a shoe. Maximum orientation occurs in the direction pointing from or to the lead-in end and exactly *opposite*



Installing a large loop-antenna.

Photo by Keystone

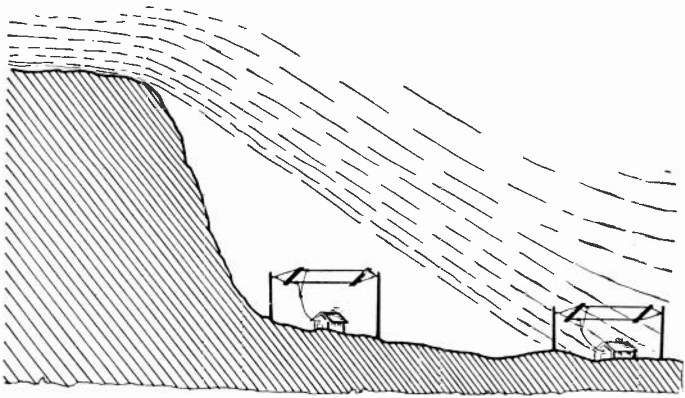


Fig. 14

Illustrating possible "dead zone" effect in mountainous country.

the free end. Therefore, if you wish to somewhat *direct* your reception in a certain line, the lead-in end should point that way. In other words, flat top aerials of the T and L variety are rather directive. By studying *B* and *C* of Fig. 12, it will thus be seen that the maxima lie in the *plane* of the aerial while the minima lie at right angles to the plane. These points should, therefore, be remembered if directive results are your aim.

The height of an antenna also decides to a certain extent its wave length. In other words, as you increase its height you also increase its natural or fundamental wave length. In general, the greater the height the better distance results are secured.

If you live in the country near a mountainous section consult Fig. 14 and try to avoid installing your antenna in what might be called the "dead zone." In ether wave propagation, the transmitted energy may be said to travel over the earth's surface in a straight line, except that upon reaching obstructions such as mountains, hills, etc., the waves are deflected in such a way that a considerable space on the other side of the hill is overlapped before the waves finally reach their normal level. For this reason, if your station happens to be in the hollow, very poor receiving will result. This is not a theory, but has been proved quite frequently in case of regular commercial installations where this dead zone effect had been overlooked. A broad rule is to erect the aerial at such a point that its distance from the mountain will be at least four times the height of the obstruction.

Insulation of Antennae

An antenna installed solely for the purpose of reception need not be as carefully insulated as that installed for the purpose of both transmission and reception. This, of course, is due to the fact that the intercepted energy in a received aerial is very small and does not need much insulation as compared to the high potential stress which takes place in an aerial used for transmission, particularly spark coil transmission where the voltage is sometimes very high. A good rule to follow, however, is to assume that the aerial will eventually be used for transmission, and therefore it should be insulated at the very start.

Insulators should be placed in the positions shown in Fig. 15. These insulators may consist of the regular manufactured kind, but if the beginner is pressed for time or short of money, ordinary electric light wire porcelain cleats which are about four inches long and have

Rigging the antenna.

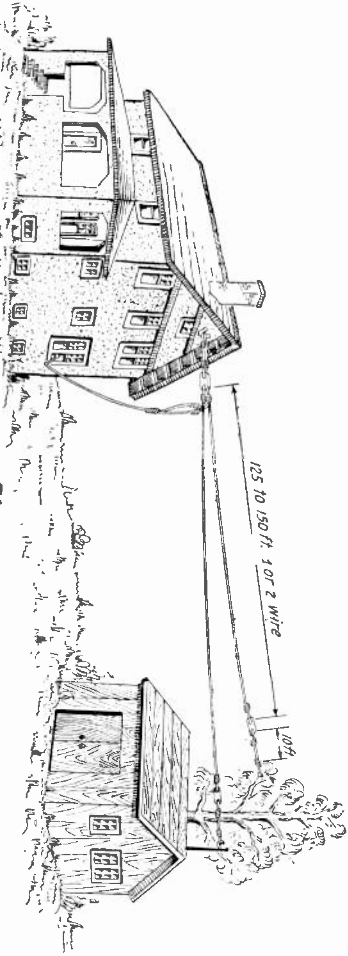


Fig. 15

Method of Installing Receiving Antenna.

holes at each end, may be used instead. As for the lead-in insulator, this may also be one of the regular kinds sold by any radio supply house, but if not procurable a porcelain electric light wire floor-tubing may be used. Great care must be taken in bringing a lead-in through a house to the instruments to clear all obstructions such as tree branches, metal roof, cornices, water-pipes, etc.

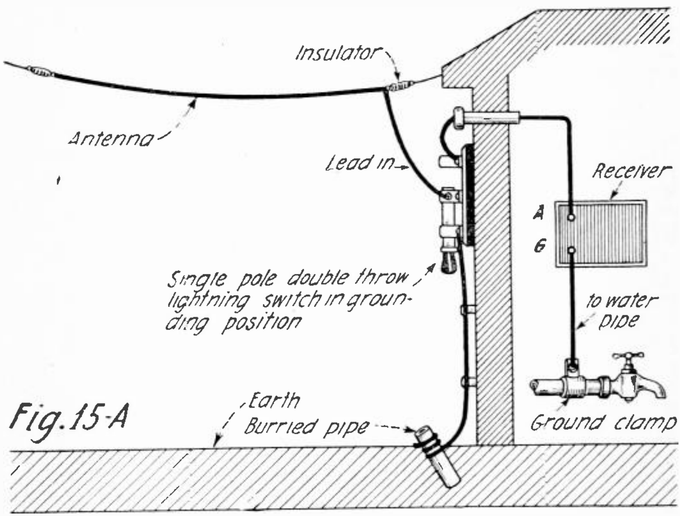
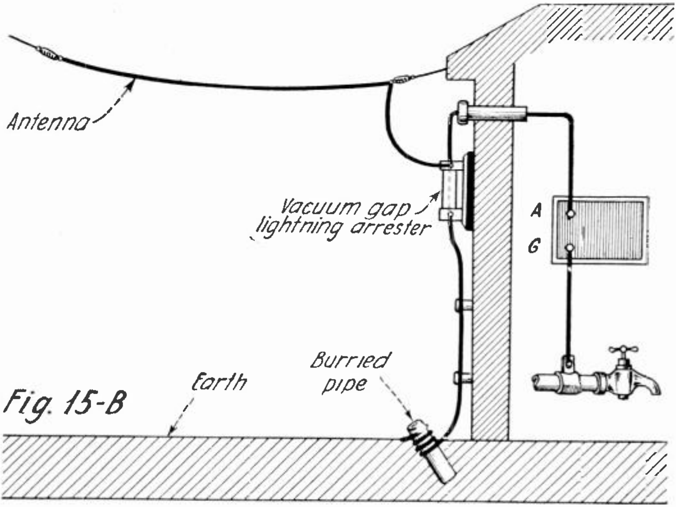


Fig. 15-A

Ground Switch.

Illustrating a grounded antenna. In this position there is no danger whatever from lightning even if it should actually strike the antenna. We employ two grounds here, one for the lightning switch and one for the receiver. The first is a piece of burried pipe, the second is the water main, or radiator system.

Leading the antenna wire into the house.

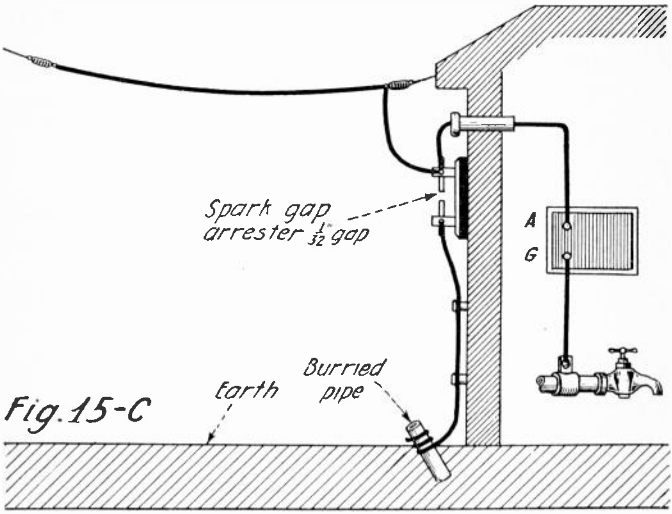


Lightning Arrester (Vacuum Gap Type).

Heavy electrical discharges resulting from lightning are automatically led off to the external ground.

Kind of Wire Used

Silicon bronze antenna wire is admittedly the best kind to use in any aerial; in fact it is used exclusively by government and commercial station on account of its great tensile strength combined with its good conductivity. It is usually stranded and comes in several sizes such as the seven strands of No. 19 wire and seven strands of No. 21. The experimenter may also use copper-clad steel or hard drawn copper wire. Aluminum wire is also successfully used on account of its lightness in weight and low price.



Lightning Arrester (Spark Gap Type).
Similar in action to the Vacuum Gap Type. The small air gap should be 1/32 inch wide.

An antenna suitable for broadcast reception may consist of one or two wires spaced about ten feet apart and possibly 150 feet long. For the amateur who wishes to transmit, however, it is advisable to use from four to eight wires, but since an amateur must not exceed two hundred meters in wave length, the length of such an aerial must not exceed one hundred twenty-five feet in length for the inverted L type, and one hundred and fifty feet for the T type; nor should the effective height of such antenna greatly exceed forty feet above the earth.

A Few Instructions in Erecting

In laying out a permanent antenna try to avoid spanning it parallel to nearby high or low voltage power lines or telephone and telegraph wires. Otherwise you will be bothered by undesirable induction while receiving. For this reason, it is a good rule to erect an antenna at right angles to such circuits when they are close to your station. For proper lightning precautions study Figures 15-*A*, 15-*B*, 15-*C* and 15-*D*.

In the erection of aerials in rural or suburban districts spanning is seldom a difficult matter. In large cities, however, complications are introduced, for then there are streets, car and elevated lines, lofty buildings and what not which must be considered. This is particularly the case when the amateur desires to erect a long aerial suitable for long wave reception, for it is then that he finds that the average city building roof has its limitations. If a stretch has been decided upon which involves crossing streets or lofty heights and provided permission has been secured from the owner of the distant building to which the free end of the aerial is to be attached, the amateur may use the following method of spanning.

A favorable opportunity is awaited at such times as a fair wind is blowing toward the general direction of the distant building. An ordinary kite is then raised to which has been attached a good grade of string or cord. When the kite is directly above the desired spot the tension on the string is suddenly let go whereby the kite will drop on the roof below. It is then the job of a friend to go to the next building and pull in the cord to which has previously been fastened the aerial wire. Ordinarily, the cord will be strong enough to accomplish this and in this

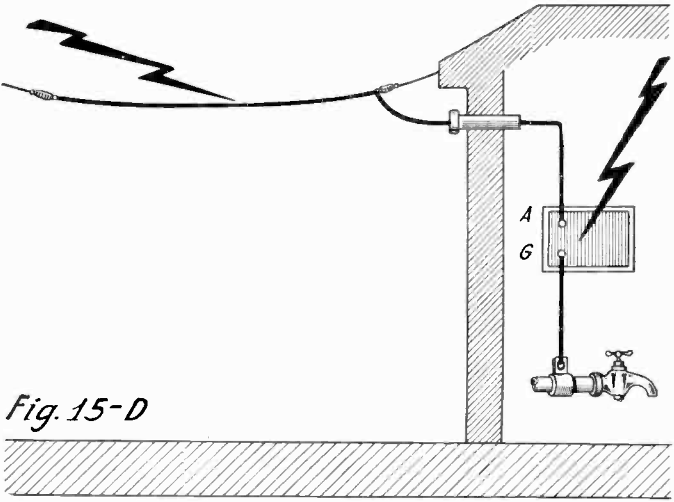


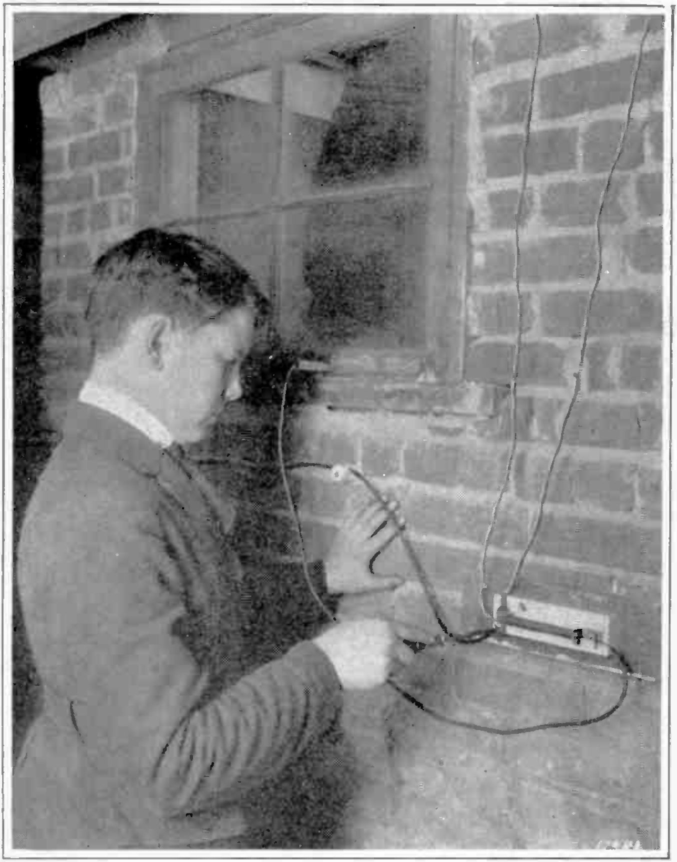
Fig. 15-D

Dangerous Practice.

If you do not protect your antenna by one of the methods illustrated in previous figures, lightning may burn out the inductance of your receiver, or the very fine windings of your head telephone receivers or ruin your vacuum tubes.

way the person on the station roof can slowly uncoil the wires so that kinking or entangling can be avoided.

A word or two may be said concerning the spreader, when two or more strands are used. This should preferably be of some hard, well-seasoned wood, either round or square and well painted to preserve it. If procurable, bamboo rods of two inch diameter are quite suitable, owing to their lightness and strength. If properly guyed by means of a stout tarred rope as shown in Fig. 16 the



Antenna should have protective devices to protect the set from lightning.

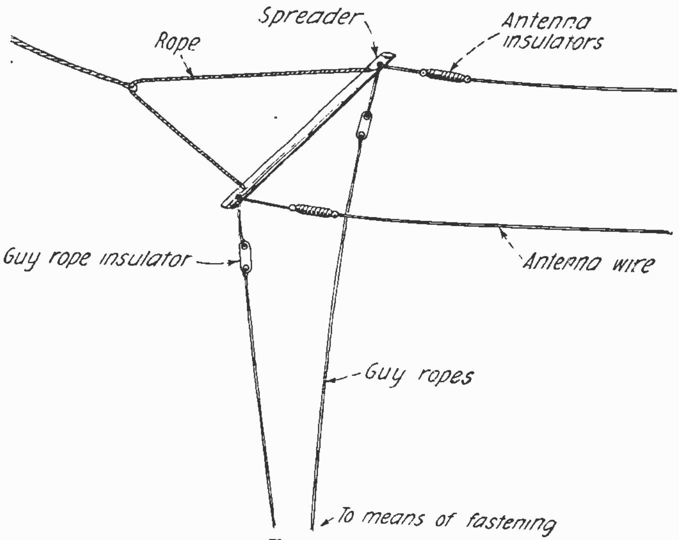


Fig. 16

Manner of guying spreader when two or more antenna wires are employed for reception.

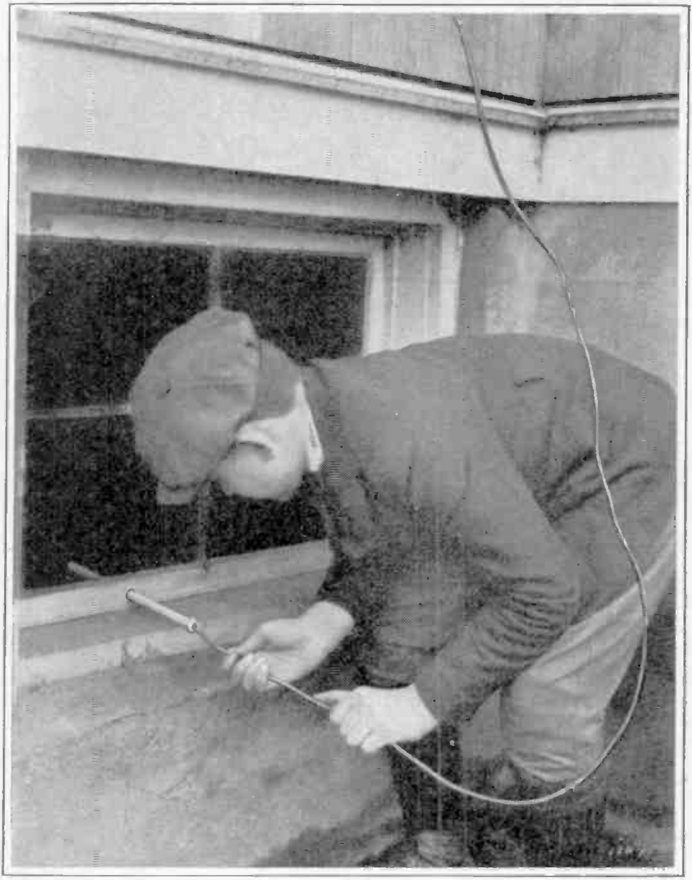
aerial will be prevented from undesirable swinging or entangling of the wires even during severe wind storms. The use of a spreader and its proper guying, however, is not necessary when but one antenna wire is employed. For general broadcast reception, one wire answers the purpose quite satisfactorily. Two or more wires prove advantageous when the broadcasting station is located more than 50 miles away.

Practical Measurements

Since these instructions are intended for the beginner who is not familiar with the mathematics of radio measurements we will confine ourselves to a few simple general rules which may be followed. The natural period or wave length of an antenna before it is connected to a tuner may be roughly determined from its physical dimensions. For instance, the wave length of an umbrella aerial as well as a horizontal L or T type may be calculated by multiplying the total length from the free end straight through to the ground connection by the approximate constant 4.2. This gives a result in feet so that in order to bring it to meters it is necessary to divide the result by 3.28. This manner of calculation, however, does not consider the many and various conditions which apply to individual installations, and as previously mentioned, is rather a crude method.

The Ground Connection

To the city dweller a suitable ground may be obtained by soldering or otherwise permanently connecting a lead wire to either a water-pipe or steam radiator system. In fact it is a good rule to secure connections on both. So-called "ground-clamps" may be obtained specially for this purpose from any radio supply house. In the country or isolated districts the permanent ground may be established by burying a metal pipe 6 feet in length in a preferably moist section and at a ground depth of about 5 feet. To this must, of course, be soldered or firmly attached a heavy copper wire preferably No. 14 B. & S. gauge which



How the antenna wire is passed through a cylinder of porcelain before it is grounded.

is lead to the instruments. A more certain ground may be obtained by immersing a long pipe or other piece of metal in a small lake or swamp, providing this body of water is close to the station. This practice is an excellent one for the summer camper or vacationist who wishes to enjoy broadcast reception with a portable receiver. Reference should again be made to Figs. 15, 15-*A*, 15-*B*, 15-*C*, 15-*D*.

Indoor Antennae

Occasionally, it is not possible for the city dweller to erect an outdoor antenna. In this instance, and provided the receiver is located within very close proximity of the broadcasting station (1 or 2 miles) a small indoor aerial may be used with success, stretched from one wall to another. The most effective method of indoor reception, however, is by employing the loop receiver with suitable steps of amplification and as described under Figs. 6 and 7.

SUPER-REGENERATION*

By Edwin H. Armstrong

(Marcellus Hartley Research Laboratory, Columbia University, New York)

It is the purpose of this paper to describe a method of amplification which is based fundamentally on regeneration, but which involves the application of a principle and the attainment of a result which it is believed is new. This new result is obtained by the extension of regeneration into a field which lies beyond that hitherto considered its theoretical limit, and the process of amplification is therefore termed *super-regeneration.*

Before proceeding with a description of this method it is in order to consider a few fundamental facts about regenerative circuits. It is well known that the effect of regeneration (that is, the supplying of energy to a circuit to reinforce the oscillations existing therein) is equivalent to introducing a negative resistance reaction in the circuit, which neutralizes positive resistance reaction and thereby

* As this "Easy Course in Home Radio" was about to go to press, Mr. Edwin H. Armstrong announced before the Institute of Radio Engineers the discovery of what he called "super-regeneration"—a discovery of such vast importance in the development of radio that it was felt it should be considered in this series of pamphlets. With "super-regeneration" it becomes possible with two vacuum tubes to obtain amplification effects which are out of the question with the standard Armstrong "feed back." Indeed, the whole art of building both transmitting and receiving sets will probably be modified in order to apply Armstrong's discovery of super-regeneration.

It seems best to permit Mr. Armstrong to explain his new system himself. Accordingly, we present here an abstract of the memorable paper that he read on June 7, 1922, before the Institute of Radio Engineers.

reduces the effective resistance of the circuit. There are three conceivable relations between the negative and positive resistances: namely—the negative resistance introduced may be less than the positive resistance, it may be equal to the positive resistance, or it may be greater than the positive resistance of the circuit.

We will consider what occurs in a regenerative circuit containing inductance and capacity when an alternating electromotive force of the resonant frequency is suddenly impressed for each of the three cases. In the first case (when the negative resistance is less than the positive), the free and forced oscillations have a maximum amplitude equal to the impressed emf. over the effective resistance, and the free oscillation has a damping determined by this effective resistance. The steady state is attained after the initial free oscillation dies out and continues until the impressed emf. is removed, when the current dies out in accordance with a second free oscillation. The maximum amplitude of current in this case is always finite; it reaches this maximum amplitude in a finite time, and when the impressed emf. is removed the current dies away to zero. This is the action of the circuits which are now in every-day practical use.

In the second case the negative resistance is equal to the positive resistance, and the resultant effective resistance of the circuit is therefore zero. When an emf. is suddenly impressed in this case, the current in the circuit starts to increase at a rate which is directly proportional to the impressed emf. and to the square root of the ratio of the capacity to the inductance of the circuit (for a given impressed frequency). If the emf. is impressed for an infinite time, then the current in the circuit reaches infinity.

If the emf. is impressed for a finite time, then the current reaches some finite value. When the impressed emf. is removed, the current in the circuit at that instant continues indefinitely with unchanged amplitude as a free oscillation. Theoretically, this is the limiting case for regeneration; practically, it is always necessary to operate at some point slightly below this state at which the circuits have a definite resistance.

It is important to note here that although the circuit of this case has zero resistance, oscillations will not start unless an emf. is impressed upon the circuit; furthermore, that oscillations once started continue with undiminished amplitude indefinitely. This state cannot be attained in practice, because the negative resistance furnished by the tube is dependent on the amplitude of the current and for stable operation decreases with increasing amplitude.[1]

In the third case the negative resistance introduced into the circuit is greater than the positive resistance, and the effective resistance of the circuit is therefore negative. When an emf. is impressed upon a circuit in this condition, a free and a forced oscillation are set up which have some interesting properties. The amplitude of the forced oscillation is determined by the value of the impressed emf. divided by the resultant resistance of the circuit. The free oscillation starts with an amplitude equal to the

[1] It is very important at this point to distinguish between this purely theoretical state and the state which exists in oscillating tube circuits. In the various forms of self-heterodyne circuits a free oscillation of constant amplitude is maintained in the system and the circuit may be considered as having zero resistance, *but only for that particular amplitude of current.* An external emf. impressed on the circuit always encounters a positive resultant resistance, assuming, of course, that the existing oscillation is stable. This is due to the non-linear characteristic of the tube.

forced oscillation, and builds up to infinity regardless of whether or not the external emf. is removed. This free oscillation starts with an amplitude which is proportional to the impressed emf., and this proportionality is maintained throughout any finite time interval, with constant impressed electromotive force.

It is important to note that although the negative resistance of the circuit exceeds the positive, and the effective resistance of the circuit is negative, oscillations will not occur until some emf. is impressed. *Once an emf. is impressed, however, no matter how small it may be, the current in the circuit builds up to infinity regardless of whether or not the external emf. is removed.*

The fundamental difference between the case in which the resistance of the circuit is positive and the case in which the resistance of the circuit is negative may be summed up as follows: in the first, the forced oscillation contains the greatest amount of energy and the free oscillation is of very minor importance[2] (after a short interval of time), in the second, it is the free oscillation which contains the greatest amount of energy and the forced oscillation which is of negligible importance.

It is, of course, impossible with present-day instrumentalities to set up a system in which the negative resistance exceeds the positive without the production of oscillations in the system, since any irregularity in filament emission or impulse produced by atmospheric disturbances is sufficient to initiate an oscillation which builds

[2] This is strictly true when dealing with continuous waves which we have been considering. It is not true in the regenerative reception of spark signals, particularly of short wave length, large damping and low spark frequency. In this case the energy in the free oscillation exceeds the energy in the forced oscillation.

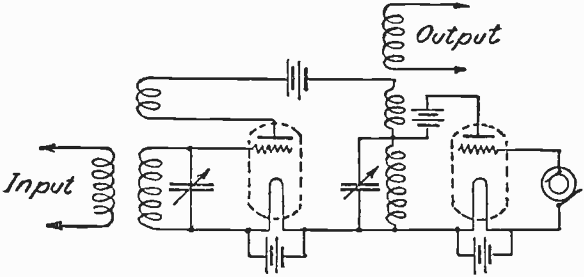


Figure 1

up to the carrying capacity of the tube. It is, however, possible, by means of various expedients, to set up systems which avoid the production of such a paralyzing oscillation and which approximate the theoretical case in the use of a free oscillation to produce amplification.

It is the purpose of this paper to describe a principle of operation based on the free oscillation which is quantitative and without a lower limit. This new method is based on the discovery that if a periodic variation be introduced in the relation between the negative and positive resistance of a circuit containing inductance and capacity, in such manner that the negative resistance is alternately greater and less than the positive resistance, but that the average value of resistance is positive, then the circuit will not of itself produce oscillations, but during those intervals when the negative resistance is greater than the positive will produce great amplification of an impressed emf. The free oscillations which are set up during the periods of negative resistance are directly proportional in amplitude to the amplitude of the impressed emf. The variation in the relation between the negative and positive re-

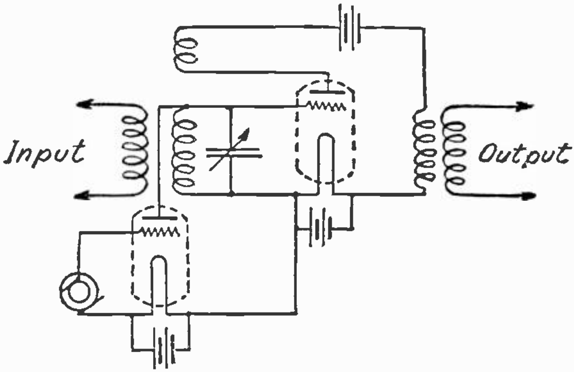


Figure 2

sistance may be carried out by varying the negative resistance with respect to the positive, by varying the positive resistance with respect to the negative, or by varying both simultaneously at some frequency which is generally relatively low compared to the frequency of the current to be amplified.

These three methods of producing the super-regenerative state are illustrated respectively by Figures 1, 2, and 3, which figures indicate the general scheme of the system and the methods varying the relation between the negative and positive resistance. Figure 1 shows a method of varying the negative resistance produced by the regenerative system by varying the voltage of the plate of the tube by means of a second tube, the grid of the second tube being excited by an emf. of suitable frequency.

Figure 2 illustrates a method of varying the positive resistance of the circuit with respect to the negative. This is accomplished by connecting the plate circuit of a vacuum tube in parallel to the tuned circuit of the regenerative system and exciting the grid by an emf. of suitable frequency. Figure 3 illustrates a combination of these two systems in which simultaneous variations are produced in both the negative and positive resistances and provision made for adjusting the relative phases of these two variations.

A general idea of the phenomena occurring in these systems when an emf. is applied to the imput circuit will be obtained from the diagram of Figure 4 which applies specifically to the circuit of Figure 1. This figure illustrates the principal relations existing in the system in which the positive resistance is constant and the variation

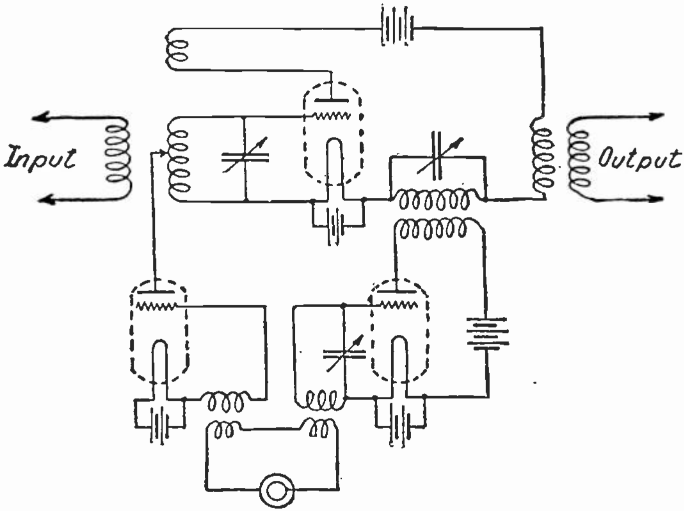


Figure 3

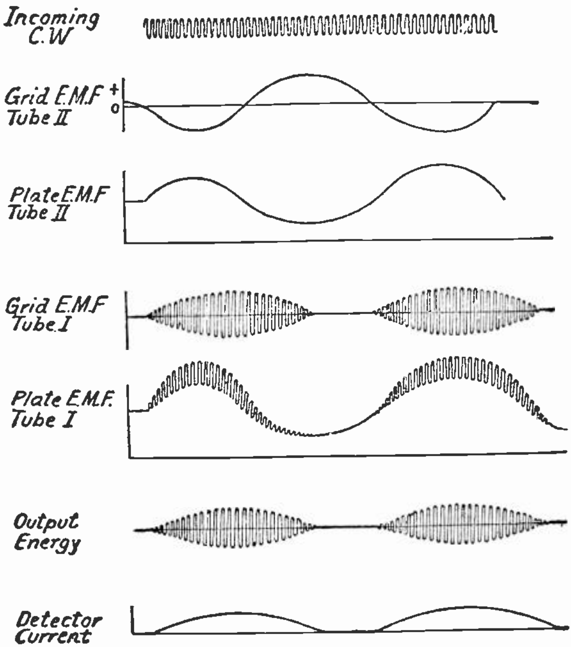


Figure 4

is introduced into the negative resistance. It will be observed that the frequency of variation appears as a modulation of the amplified current so that the output circuit contains currents of the impressed frequency plus two side frequencies differing from the fundamental by the frequency of the variation.

Oscillograms show that a free oscillation starts every time the resistance of the circuit becomes negative. This free oscillation is small compared to that produced by the signal, and therein lies the complete explanation of the operation of the system. The free oscillations produced in the system when no signaling emf. is impressed, must be initiated by some irregularity of operation of the vacuum tubes, and must start at an amplitude equal to the amplitude of this disturbance. This initial value is of infinitesimal order, and hence, in the limited time interval in which it can build up the locally excited oscillation, never reaches an amplitude comparable to the oscillation set up by a signal of any ordinary working strength.

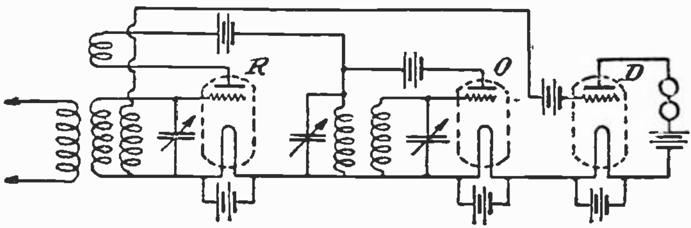


Figure 5

The rate of variation in the relation between the negative and positive resistance is a matter of great importance. It may be at sub-audible, audible, or super-audible frequencies. In radio signaling, for the reception of telephony, the variation should be at a super-audible frequency. For modulated continuous wave telegraphy and spark telegraphy, to retain the tone characteristics of the signals, it must be well above audibility; for maximum amplification a lower and audible rate of variation should be used. In continuous wave telegraphy, where an audible tone is required, the variation is at an audible rate; where

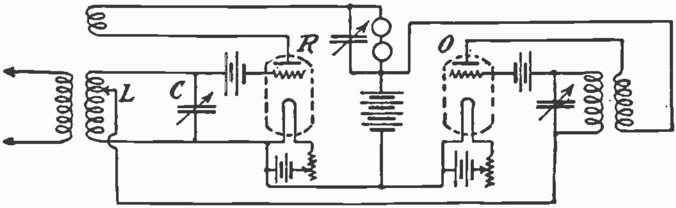


Figure 6

the operation of an indicating device is required, a sub-audible frequency may be best. The choice of frequency is a compromise, particularly in telephony, since obviously the lower the frequency the greater the amplification, and the higher the frequency the better the quality.

Some practical forms of circuits are illustrated by Figures 5, 6, and 7, which illustrate respectively the three types of variation. Figure 5 shows a method of varying the plate voltage coupled into the plate circuit. In this arrangement a third tube acts as a detector. This is essential when an audible frequency is employed; when a super-audible frequency is used the telephones can be placed directly in the plate circuit of the amplifying tube.

Figure 6 shows the second case in which the variation is introduced into the positive resistance of the tuned circuit. This is done by means of an oscillating tube *O*, the grid circuit of which is connected through the tuned circuit *LC* of the amplifying tube *R*. The variation in the resistance of the circuit is effected through the variation in potential of the grid of the oscillating tube. During that half of the cycle, when the grid of the oscillating tube is positive, energy is withdrawn from the tuned circuit in the form of a conduction current from the grid to the filament of the oscillating tube, thereby increasing the effective resistance of the circuit. During the other half of the cycle, when the grid of the oscillating tube is negative, no conduction current can flow through the grid circuit of the oscillating tube, and hence no resistance is introduced into the tuned circuit of the amplifying tube. In this case the amplifying tube serves also as the detector for any frequency of variation, as the tuned circuit forms a sufficiently good filter even for an audible frequency to prevent a disturbing audible tone in the telephones.

Figure 7 illustrates the case of a simultaneous variation in both positive and negative resistances. This is accomplished by providing the amplifying tube *R* with a second feed-back circuit L_1C_1 and L_2C_2 adjusted to oscillate at some lower frequency, thereby introducing a variation in the negative resistance through the variation of the plate potential of the amplifier and a variation in the positive resistance by means of the variation of the grid of the amplifier. The proper phase relations between the nega-

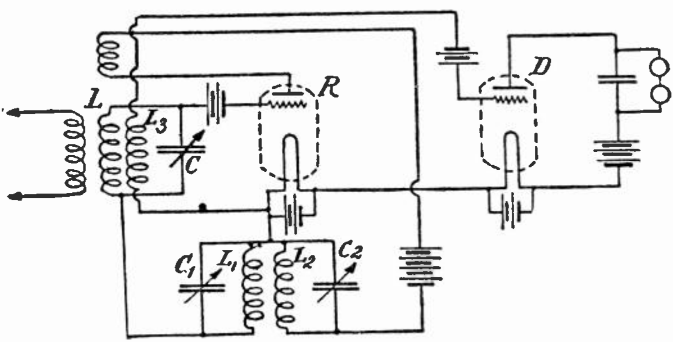


Figure 7

tive and positive resistance are obtained by adjustment of the capacity of condensers C_1 and C_2 and the coupling between L_1 and L_2. In operation this system is very critical and extreme care is necessary in order to obtain the super-regenerative state.

In each of the preceding cases the detecting function has been carried out either by a separate tube or by means of the amplifying tube. When a super-audible frequency of variation is employed, it is sometimes of advantage to perform the detecting function in the oscillating tube, and a system for carrying this out is illustrated in Figure 8. The operation of this system is as follows: incoming signals are amplified by means of the regenerative action of the amplifier tube *R* and the variations of potentials across the tuned wave frequency circuit *LC* impressed upon the grid of the oscillating tube *O*. These oscillations are then rectified, and two frequencies are produced in the circuits of the amplifier tube. One of these frequencies corresponds to the frequency of modulation of the signaling wave. The other corresponds to the frequency of the variation and contains a modulation in am-

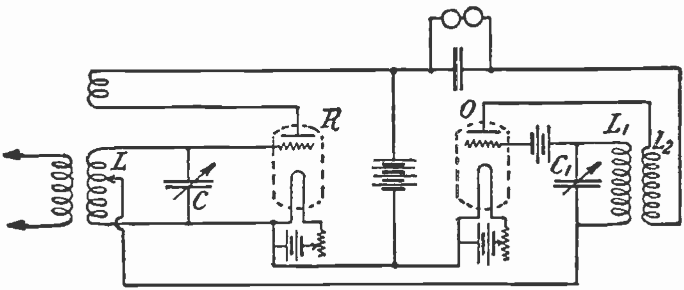


Figure 8

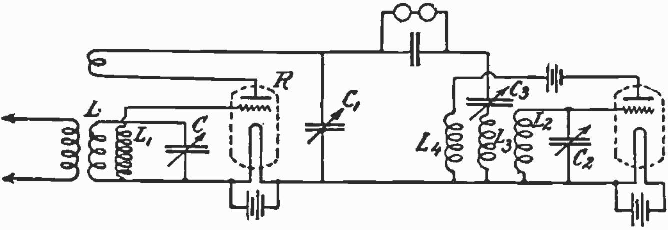


Figure 9

plitude corresponding to the modulation of the transmitted wave. This second frequency is then impressed upon the circuits of the oscillating tube with which it is in tune, amplified by the regenerative action of the system L_1 C_1 L_2 O and then rectified. The amplification obtainable with this form of system is considerably greater than that of the single amplification circuits, but is naturally more complicated to operate.

When a super-audible variation is employed in a system such as illustrated in Figure 1, it is generally necessary to introduce a certain amount of resistance in the tuned circuit to insure the dying out of the free oscillation during the interval when the resistance of the circuit is positive. This is most effectively illustrated by Figure 11. This may be adapted to work on either the sum or difference frequencies, but when the higher frequency is used, care should be taken that it is not near the second harmonic of the local heterodyning current. In the particular arrangement illustrated, *LCD* represents, together with the heterodyne, the usual agency for changing the incoming frequency, and *A* represents the super-regenerative amplifier which may be of any suitable type.

One of the curious phenomena encountered with the super-regenerative system is found when it is attempted to secure sharp tuning by the use of tuned circuits placed between the antenna and the amplifying system. The free oscillations set up in these circuits by the reaction of the amplifying system continue in these circuits during the interval when the resistance of the amplifier circuit is positive, re-excite the amplifier when the resistance becomes negative, and hence the entire system is kept in a continuous state of oscillation. The effect is most critical, and may be produced with most extremely weak couplings between the amplifier circuit and the second tuned circuit. The simplest solution of the difficulty is to perform the function of tuning at one frequency and amplification at another, and this is best accomplished by means of the super-heterodyne method carried out by means of the arrangement illustrated in Figure 9, in which a secondary coil L_1 of large inductance and high resistance is coupled to the tuned circuit LC and the energy withdrawn thereby

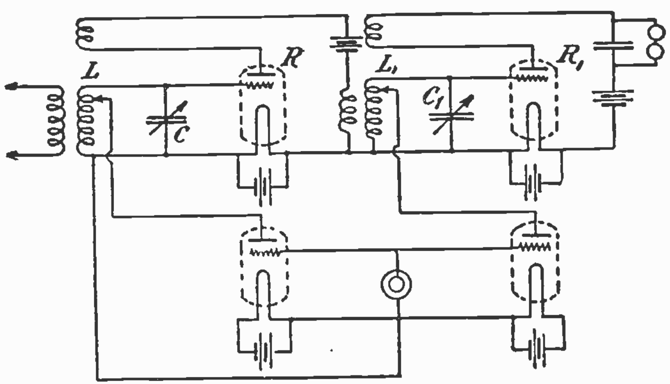


Figure 10

from the oscillating circuit stepped up and applied to the grid of the tube. In the operation of this system a curious phenomena is encountered. This is the manifestation of an inductive reaction by the plate circuit of the amplifying tube to the auxiliary frequency emf. supplied the plate circuit by the oscillating tube. This comes about in the following way: When the auxiliary emf. is impressed upon the plate of the amplifying tube, a current is produced in this tube in phase with the emf. across the tube. Now suppose the plate voltage is at its maximum positive value. This means that the negative resistance of the circuit is a maximum in amplitude. This in turn means that the average value of the grid is becoming more positive and the current in the plate circuit is likewise increasing. Since the free oscillation in the system will increase in amplitude as long as the resistance of the circuit is negative, it will reach its maximum amplitude after the maximum positive voltage is applied to the plate. Hence the component of current corresponding to the frequency of the variation set up in the plate circuit by the rectification of the radio frequency oscillations lags in phase behind the auxiliary

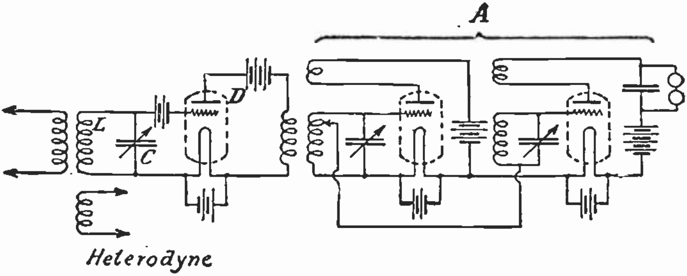


Figure 11

emf. impressed on the plate. Hence the plate circuit of the tube manifests an inductive reaction to the auxiliary emf. It was found that this inductive reaction could be tuned out by means of the parallel condenser C_1 with the great improvement in the stability of the operation of the system and increase in the signal strength. The resonance point is pronounced, and once the other adjustments of the system have been correctly made is as readily found as any ordinary tuning adjustment.

The problem of cascade amplification with these systems is a rather involved one on account of a great number of effects which are not encountered in ordinary methods of cascade amplification. The principal trouble is the reaction of the second amplifying system on the first, and the difficulty of preventing it in any simple way on account of the high amplification per stage. While this difficulty is not insuperable, a simple expedient may be employed which avoids it. On account of the large values of radio frequency energy in these amplifying systems, the second harmonic is very strong in the plate circuit of the amplifying tube and is of the same order of magnitude as the fundamental if the tube is operated with a large negative voltage on the grid. Hence by arranging the second stage of a cascade system to operate at double the frequency and to amplify this harmonic, the difficulty is avoided. The general arrangement of such a system is illustrated by Figure 10, in which the positive resistance of the circuits LC and L_1 C_1 of a two-stage amplifier are varied synchronously by a single oscillator. The circuit L_1 C_1 in this case is tuned to the second harmonic of the circuit LC, but the combinations of circuits which may be arranged on this principle are very numerous.