NATIONAL RADIO INSTITUTE

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LESSON TEXT No. 36

(2nd Edition)

AMATEUR SHORT WAVE TRANSMITTERS AND RECEIVERS

Originators of Radio Home Study Courses
··· Established 1914 ···
Washington, D. C.

"Everybody likes and respects self-made men. It is a great deal better to be made in that way than not be made at all."—*Oliver Wendell Holmes.*

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AMATEUR SHORT WAVE TRANSMITTERS AND RECEIVERS

Prior to 1922, very little was known about the so-called "Short Wave-length"—that is, Radio waves of or below 100 meters. Since that time, a great deal has been found out and now the use of short waves is being developed by the commercial companies, and is supplanting some of the high powered long wave-length transmitting stations.

In 1912, the United States Government assigned to the amateurs the wave-length band between 150 and 200 meters, because at that time the amateurs were not considered very important and it was thought that the wave-lengths below 200 meters were of little value for commercial work, and were not satisfactory for long distance communication. About 1922, some of the more energetic amateurs, including Reinartz, decided to explore the short wave-length band below 100 meters, and if possible, determine just what could be accomplished on these short waves.

Experiments during 1922, 1923 and 1924 proved that these short waves were valuable, and that some peculiar conditions existed when transmitting on these waves. It was found possible to cover a much greater distance than when transmitting in the band between 150 and 200 meters, and using the same amount of power, also that on the waves around 20 meters, during the daytime, the signals could be heard several thousand miles, while at night, they could be heard only a very short distance. It was also noticed that these signals could not be heard very easily when the receiving station was located within a distance of 200 to 600 miles from the transmitting station. When transmitting on 40 meters, the signals were practically as strong during the day as they were at night, while on 80 meters, the signals were much stronger at night than they were in the daytime.

Reliable trans-continental communication was established during the daylight hours using only a small amount of power as compared to that used by the commercial stations. When commercial companies learned that reliable daylight transcontinental communication by means of short waves required less power than the longer wave-lengths they began to try out the possibilities of short wave transmitters during the past few years, these commercial companies have spent a great deal of money in developing short wave transmitters.

The result of this development is that there are today commercial stations which are operating on wave-lengths ranging between 15 and 100 meters, and in some cases, they are reliably covering the same distance as the long wave stations and using only a few kilowatts of power, perhaps, from 5 to 20 kilowatts, whereas, the long wave stations use from 100 to 200 kilowatts.

It must be remembered that most of the experiments of Maxwell and Hertz were conducted on very short waves. Therefore, we are today coming back to the short waves employed by Maxwell and Hertz, and we are finding out that we have heretofore overlooked a very valuable asset.

The apparatus used in a short wave transmitter or receiver is fundamentally the same as used in any other type of transmitter or receiver. Figure 1 illustrates the schematic wiring diagram of a Hartley short wave transmitting set including power supply, rectifier, and filter.

Several kits for short wave transmitting sets are now on the market—Fig. 2 illustrates one of these assembled kits. A list of parts necessary for the construction of this set is listed herewith. The numbers refer to the numbers in Figs. 1 and 3.

(1) Radio-frequency choke coil. (Type Radio Engineering Laboratories).

(2) A .001 mfd. receiving grid condenser and grid leak (Sangamo) including one 5,000 ohm Lavite transmitting grid leak.

(3) A .002 mfd. receiving plate condenser. (Sangamo).

(4) A primary inductance. (REL).

(5) A secondary inductance. (REL).

(6) Two brass angle supports for inductance. (Fig. 4).

(7) .0005 mfd. variable condenser. (Cardwell).

(8) .0005 mfd. variable condenser. (Cardwell).

(9) Filament switch.

(10) UX type socket.

Two dials.

One 3½ volt flashlight lamp with miniature base.
Eleven binding posts.
One baseboard of hardwood, ½x8x18 inches.
One panel, hardwood or hard rubber, ¼x7x18 inches.

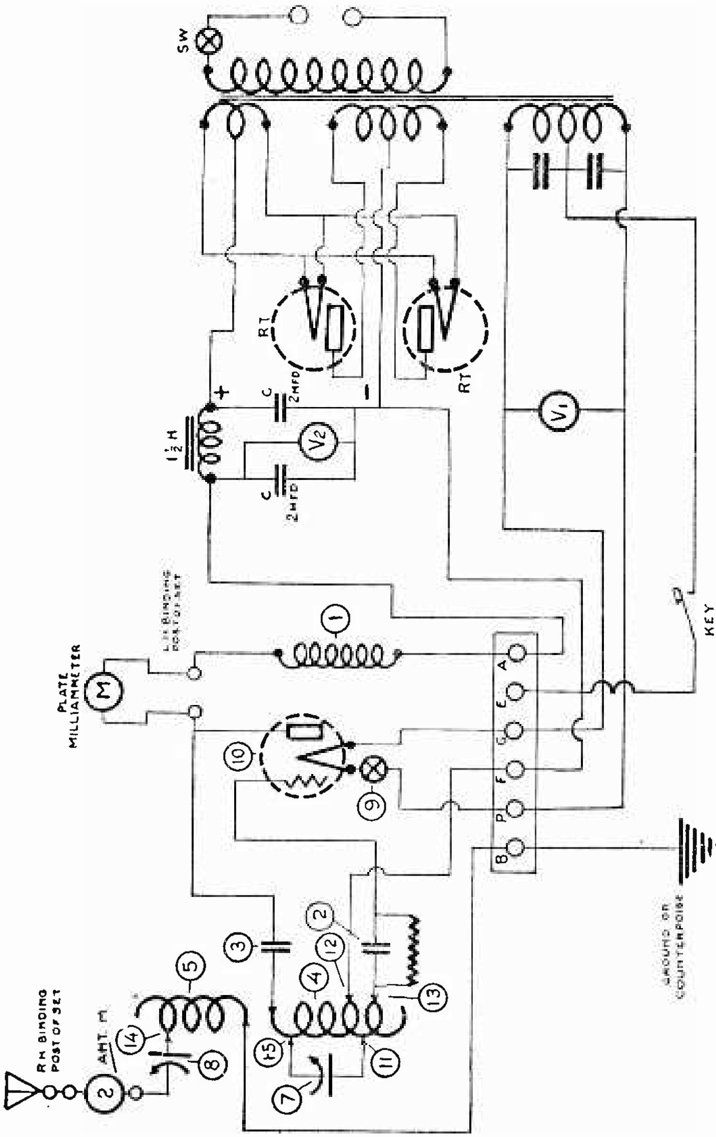

Fig. 1—Schematic wiring diagram of a Hartley Short Wave Transmitter and Power Supply, Rectifier and Filter.

One hard rubber or bakelite terminal strip, ¼x½x6 inches.
Bolts, nuts, screws, and the necessary wire.
Figure 4 is an end view of the transmitter and the right

hand portion of this figure illustrates the inductance clips. The inductances 4 and 5, Fig. 3, may be purchased outright, or they may be built as follows: The winding is 5 inches in diameter and approximately 6 inches long. The primary inductance (4) consists of 8 turns and the secondary inductance (5) consists of 3 2/3 turns. Flat copper strip ¼ inch wide and 1/16 inch thick is used, and this is wound on pyrex glass supports. These pyrex glass supports are approximately 1 inch square and 6 inches long. They are notched so as to space the wiring ¼ inch. Maple or other hardwood strips could be used if boiled in paraffine. Formica or hard-rubber tubing 3 inches in diameter and 1 inch long is used to support the ends of these pyrex glass rods.

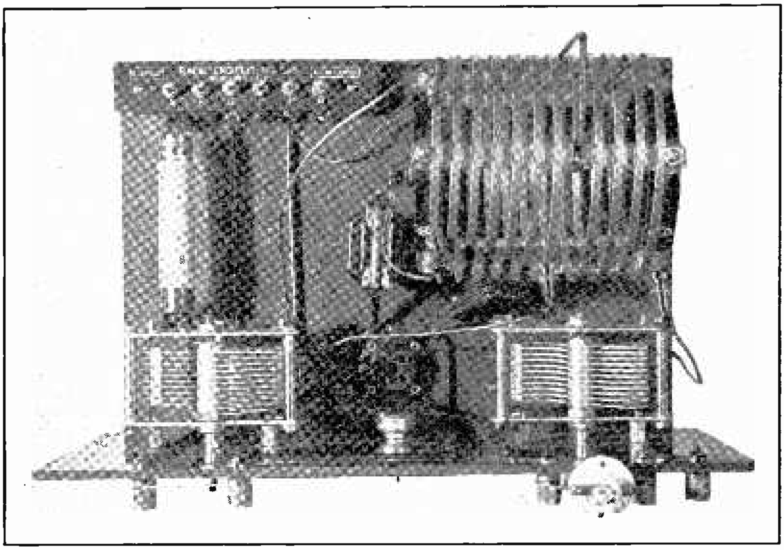

Fig. 2—Assembled Short Wave Transmitting Set.

The radio-frequency choke coil (1) can be constructed by winding 150 turns of No. 28 or No. 30 DCC wire on a cardboard or wooden tube ¾ inch in diameter, and 4 inches long. This choke is also shown in Fig. 5.

This set is so designed that any type of UX base tube may be used. That is a UX-199, UX-201A or a UX-210 may be used. It is necessary to apply the proper A and B voltages for the specific type of tube used. It can be readily seen that a beginner may start in with a UX-201A receiving tube using the conventional 6 volt battery for the filament circuit, and a "B" battery having a voltage from 90 to 180 for the plate circuit.

Thus, when the beginner is acquainted with the rudiments of transmission, he can, without incurring any great expense, insert a UX-210 tube and increase the "A" and "B" battery supply accordingly. However, all the parts furnished in the kit are of such dimensions that they can be used successfully with this larger type, UX-210 tube.

ASSEMBLY AND WIRING DATA

Figures 1, 2, 3 and 4 very plainly illustrate how the parts are mounted. Just a word may be given regarding a few of the pieces which may not show up very clearly. One terminal of the choke coil (1 in Fig. 3) is directly soldered to the soldering lug of binding post A on the binding post strip. This

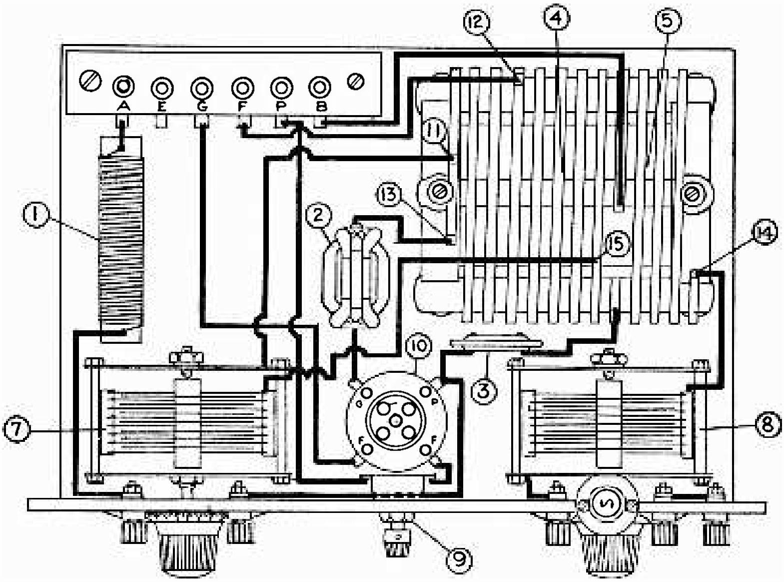

Fig. 3—Layout of Apparatus for Short Wave Transmitter.

will rigidly support this coil. The grid condenser (2) and the plate blocking condenser (3) are elevated from the baseboard by means of the short stiff wires to which they are connected. The inductance coils (4 and 5), are fastened to the baseboard by means of the brass brackets (6). It is necessary for the builder to realize that although the inductance coils are mounted in one piece, they are in reality, two separate coils. The one with the greater number of turns of wire (4) is mounted towards the left. This is shown as the primary or closed circuit coil. The other inductance coil (5) which has a smaller number of turns, is known as the secondary or antenna coil. Connections to these coils are made by means of the clips supplied. The clips are plainly illustrated in Fig. 4. Connections are made to the upper parts of the clips by means of flexible rubber covered wire.

The wire coming from the binding post (B) is permanently soldered to the inside end of the inductance coil (5). In likewise fashion, the wire coming from condenser (3) is soldered to the inside end turn of coil (4). All other connections to the inductance coils are made with flexible wire and clips. This is done so that they may be shifted from turn to turn to correspond to the wave-length required.

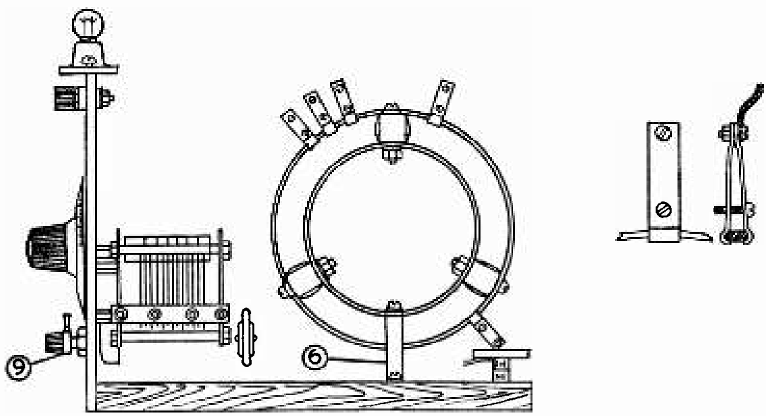

Fig. 4—End View of Short Wave Transmitter.

All other wiring except that going to the inductance clips should be made with bus bar wire of the usual type and covered with black cambric tubing or spaghetti. The builder can follow either the schematic wiring diagram in Fig. 1 or the wiring diagram shown in Fig. 3.

When a transmitter is oscillating we must have some indication as to whether we are putting any energy into the antenna. There are many ways that we can do this. The oldest system of doing this was to put a flashlight lamp or an automobile headlight lamp in series with the antenna circuit. This, however, has proved to be very inefficient and dissipates a great deal of power unnecessarily. We may use this method if a shorting switch is used or a switch connected directly across the bulb so that when a maximum output is obtained we may close the switch and the output will be much greater. The transmitter is first made to oscillate and the antenna tuning device is left in one position while the transmitting tuning condenser is rotated. When the right frequency is reached in the transmitter, to be determined by a wave-meter, the antenna condenser capacity is then varied until the flashlight lights its brightest. We know by this that the antenna coil is absorbing its maximum energy from the transmitting coil. However, meters prove to be much more efficient than any type of lamp even with the shorting switch.

There are radio-frequency ammeters made that have a very low internal resistance of the order of one-tenth of an ohm which indicate very clearly the exact amount of current which is being radiated. This type of meter may be placed directly in any part of the antenna circuit and a direct reading of the amount of current in the antenna circuit obtained. We do not need to short this meter because its resistance is so low that it does not reduce the power output but a very small

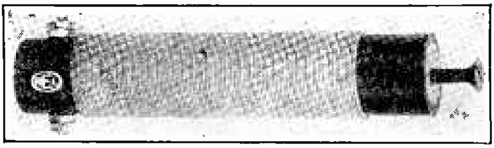

Fig. 5—Radio-frequency Choke Coil.

amount. With the flashlight type of antenna indicator, we cannot tell when the exact full brilliancy of the light has been reached, but with the meter, we can tell exactly when the needle reads highest on its range. Meters of this type, of course, must be radio-frequency ammeters. In some types of these meters thermocouples are used and the voltage produced by the AC causes the meters to read. The thermocouple, as you probably know, has an extremely low resistance and hence may be put directly in the antenna line.

POWER SUPPLY

If the builder contemplates using the UX-210 type of tube, it would be best to use a step-up transformer and some scheme of rectification instead of trying to employ "B" batteries. The UX-210 tube draws approximately 60 milliamperes at 350 volts on the plate and hence, it would be much better to use rectified alternating current for the plate supply instead of "B" batteries, as the "B" batteries will not stand up under this heavy drain for a considerable length of time.

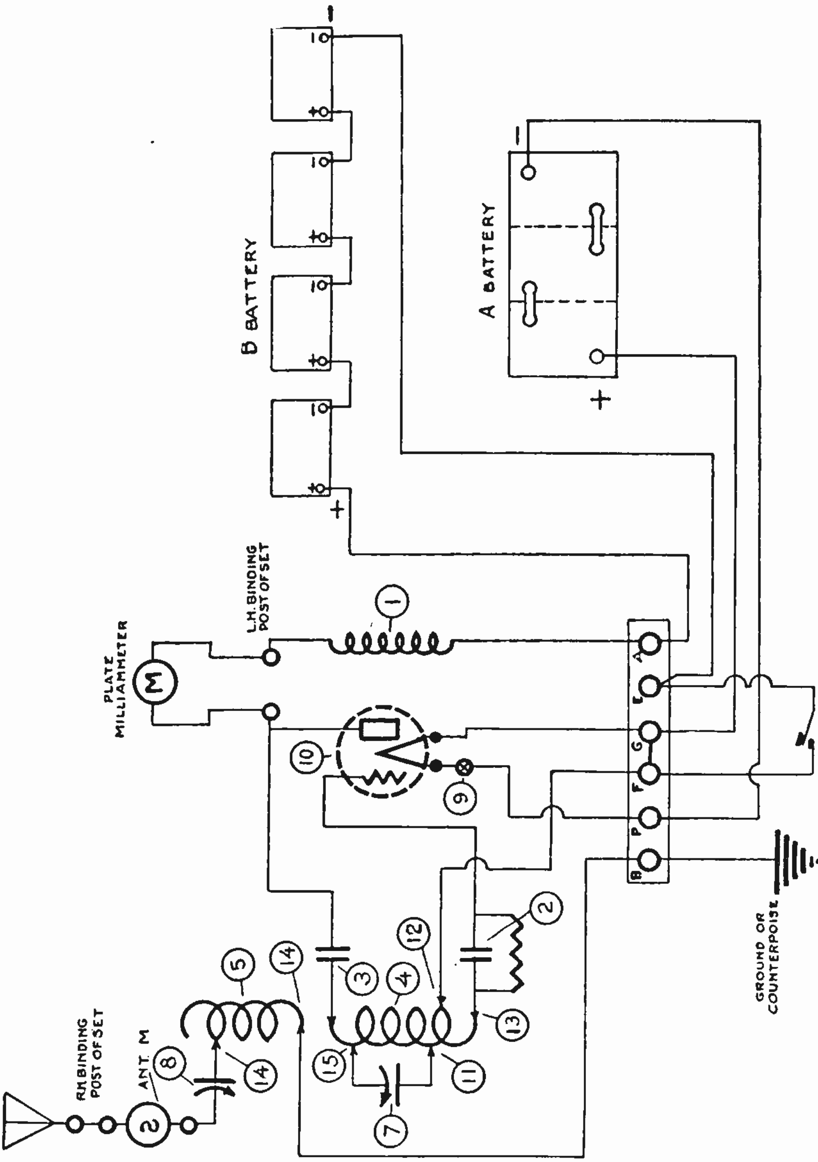

Fig. 6—Schematic wiring diagram of a Hartley Short Wave Transmitter, showing power supply when using batteries.

If it is desired to work the UX-210 tube at full capacity, it will be necessary to have a power transformer with a center tap on the secondary so that 500 volts are supplied on each half of the secondary. The rectifier tubes can be the UX-216B type, or any other type of tubes which will satisfactorily handle this voltage and current. The filament secondary winding is used to supply the current for the filament of the rectifier tubes and the oscillator tube. This winding is tapped in the center as shown in Fig. 1. The voltmeters V1 and V2 are shown in their correct positions. These indicate the A.C. filament voltage and the D.C. plate voltage respectively. These may or may not be used; however, they are a valuable adjunct to the power supply set.

The audio-frequency choke coil shown in Fig. 1 should have an inductance of 1½ henries and be capable of carrying

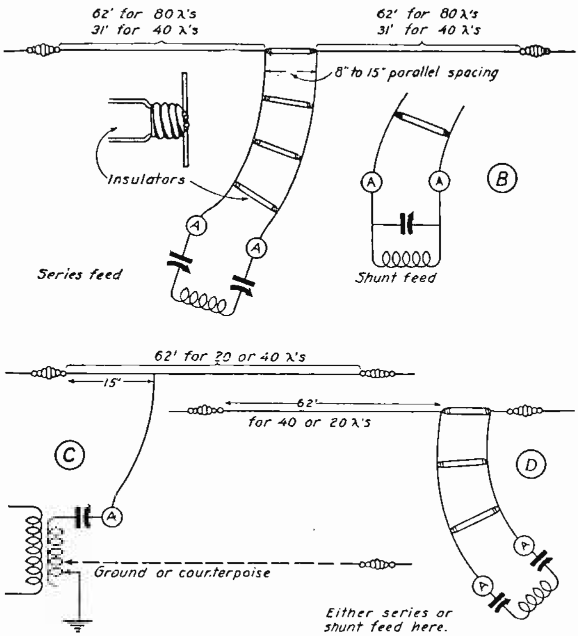

Fig. 7—Current and Voltage Feed Antennas.

150 Milliamperes. The filter condensers (C) may be either 2 or 4 mfd. capacity capable of operating above 500 volts. The whole power supply can be mounted as a separate unit, with the necessary connections to the other unit as shown.

Figure 6 illustrates the connections when using a storage battery for supplying the filament voltage and current and "B" batteries for supplying the plate voltage and current.

ANTENNA AND COUNTERPOISE SYSTEM

The Hertzian type of antenna has gained great favor in the armies of amateur operators, because of its great flexibility and efficiency. It is generally known that a good ground is extremely hard to obtain and the placing of the transmitter the correct distance from the ground is also hard to accomplish. The Hertzian antenna eliminates the necessity for either of these. It is entirely free from any type of ground. There are fundamentally two types of Hertzian antennas. The voltage feed type and the current feed type.

The **voltage feed** type—This type of antenna is fed by placing the lead-in nearest the highest voltage on the antenna, or placing it in any position such that the highest voltage will occur on the antenna at the lead-in, at any given instant. The same thing applies to the current feed antenna and the feeders or double leads from the transmitter are placed in the center of the antenna where the current is always highest. The high voltage on a Hertzian antenna is usually found in one end. So the feeder is attached at this end. This is not always the case, because sometimes the lead-in is placed ¼ of the length from the end. The point on the antenna which has the highest voltage at any given instant is called the voltage anode. And likewise, the point on the antenna which has the highest current is called the current anode. It would be useless to try to feed a current feed antenna at the point of highest voltage because at this point, the current would be zero. The places where the current or voltage are zero on the Hertzian type of antenna are known as the nodes. An antenna cannot be efficiently fed at these points. In Fig. 7-B is shown a current feed type of Hertzian antenna. Investigation of its characteristics would demonstrate that the current is highest right at the middle point between the two extremities and at this point there is no voltage. In Figure 7-C it is either a current or voltage feed antenna, depending on what frequency and the length of the antenna used. Figure 7-D is one of the most common types of voltage fed Hertizian antenna known to the amateur world as the 'Zepplin" type of antenna or "Zepp."

With regard to transmitting antennas, it is necessary to have their lengths very carefully estimated and very exact for good results. It is commonly known that the reception of any signal does not require a special length of antenna. Of course, one length may be better than another, but reasonable reception can be obtained from any antenna varying in length from 50 to 150 feet. On the contrary, transmitting antennas must be the correct length within at least 6 inches of that specified for best results. To obtain the correct lengths to be used for a Hertzian type antenna, multiply the wave-length in meters that you are going to use for transmission by 1.56 and you have the numbers of feet of antenna wire to use.

Its natural frequency will be equal to

$$\frac{300{,}000 \times 1.56}{\text{length of feet}}$$ the answer being in kilocycles

Thus, suppose we were to transmit on a wave-length of 40 meters and wanted to know how long to make our antenna. 40 times 1.56 equals 62.40 ft. This may be made 62 feet or 63

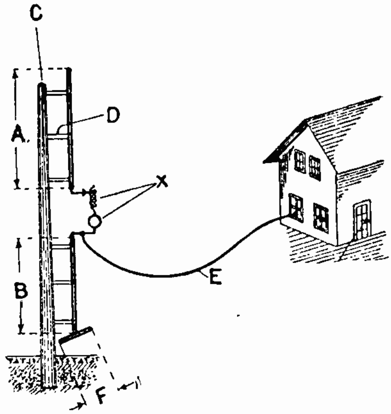

Fig. 8—Hertz Type of Antenna.

feet without serious results, but any greater deviation from this number might cause great loss of power output. Now it must be understood that this is the length in feet of only that part of the antenna which is doing the transmitting or which is radiating energy. With the Hertzian type of antenna the feeder systems are so designed that they do not radiate any energy, so that this number does not include the lead-in or the feeders. The lengths of the feeders which give best results on the current feed type of antenna should be ¼ of the length of the antenna or ¾ of its length. In fact, it is generally known that the length of the feeder system is not at all critical because any length which does not interfere with the natural period of the antenna may be used. In other words, if the feeders are both exactly 62 feet long for operation on 40 meters they would absorb too much energy and not enough would be left for the antenna. However, a half of the length, or 31 feet, would be very desirable for the feeder system. This includes the length of both the wires from the transmitter to the antenna making 62 feet of wire in all.

THE HERTZ ANTENNA SYSTEM

A simple Hertz antenna used for short wave apparatus is shown in Fig. 8. A and B are the antenna and counterpoise conductors. The antenna inductance and radiation ammeter are connected electrically to the inductance in the transmitter itself by the feeder wire E. C is a wooden pole and D the stand-off insulators.

No direct ground is made to the counterpoise B, but as shown in the drawing, the lowest point marked F is located several feet above ground, giving the effect of loading the circuit with additional capacity when necessary.

ADJUSTING AND TUNING THE TRANSMITTER

When all the parts have been assembled, properly wired and the antenna and counterpoise system installed, and all the connections made, the transmitter is then ready to be adjusted and tuned to a certain wave-length. At this point, it is advisable, if possible, to consult either a neighboring amateur or someone who has had experience in tuning a transmitting set. In this way, considerable time may be saved if the builder has not had any experience in adjusting and tuning a transmitting set. However, if no experienced person is available, the following procedure should be carried out. It would simplify matters to have a wave-meter on hand. First connect the power supplies to the plate and filament circuits. Then duplicate the setting of the inductance clips shown in Fig. 3. The connections from condenser (7) are made with clips 15 and 11. The center-tap connection is made with clip 12, and the grid connection with clip 13. The antenna connection is made with clip 14.

If a wave-meter is not available, it will be necessary to have a calibrated short wave receiving set so that it may be determined to what wave-length the transmitter is tuned. Tune the short wave receiver to some amateur station operating within the 80 meter band and leave the receiver oscillating. Disconnect the antenna and counterpoise leads from the transmitter and for the moment disregard the right hand condenser (8) in the transmitter. Then press down the transmitting key, listen in the headphones of the receiving set, at the same time, slowly vary the capacity of condenser (7). If the transmitting tube is oscillating when the variable condenser capacity is varied through the wave-length to which the receiver is tuned, a very loud buzzing noise will be heard in the head-phones. If this noise appears over a wide range of the condenser dial (7), move the receiver further away from the transmitter. If, on the other hand, you do not hear any buzzing at all, the tube in the transmitter is not oscillating. Move clip 12 a turn or two towards the right, again varying the capacity of the condenser (7) listening for the buzzing noise in the receiver. When it is heard, it should be at only one sharp definite point and should be very loud. After these adjustments have been made, connect the antenna and counterpoise to the proper terminals on the transmitter.

Now press down the key again and slowly vary the capacity of condenser (8), at the same time watch the lamp in the antenna circuit. When resonance between primary and secondary has been secured, the lamp will light and as soon as the lamp shows signs of becoming very bright and there is danger of it burning out, it is advisable to open the key circuit of the transmitter and short circuit the lamp or else use a larger lamp.

If, during any of these adjustments, the plate of the tube becomes more than a very dim cherry red, move clip 12 towards clip 13, then vary the capacity of condenser (7) and after the lamp has been made to burn as brightly as possible, it will then be necessary to vary the capacity of condenser (8). After this has been accomplished, it is advisable to slightly detune this condenser, otherwise the tube may stop oscillating when the set is keyed. Usually, it is not possible to key the set when the antenna condenser is so adjusted that the greatest amount of antenna current is present. It is necessary to vary slightly the capacity of this condenser (8) so that the keying may be accomplished without causing the tube to stop oscillating. After the set has been tuned, try varying clip 12 back and forth a turn at a time until the proper adjustment has been found when the lamp will burn brightest and the plate of the tube hardly shows any color at all. It will be necessary to retune the antenna every time the clip is changed.

For 40 meter operation, it is advisable to erect another antenna and counterpoise. These antenna systems should be at least 30 feet apart. When adjusting the transmitter to operate on 40 meters, the above procedure should be followed. First adjust the receiver to a station within the 40 meter band;

then using less turns in the plate and grid portion of the coil (4) of the transmitter, follow the previous instructions.

Bear in mind that all of the adjustments are more or less dependent upon each other. A change in any of the clip positions or the slightest variation of the condenser capacity will require readjustment of the other clips. One can always stop and start over from the beginning, and with a little time and patience, the transmitter can be adjusted so as to put more power into the antenna system.

METHOD OF KEYING

Keying may be accomplished in a variety of ways. With powers not exceeding 7½ watts or when using the UX-210 type of tube, the keying may be done directly in the plate circuit. Either the positive or the negative side will be equally as effective for this purpose. However, when higher powers than this are used, the keying must be accomplished in a different manner. It is more preferable to key even a low power transmitter such as shown in Fig. 1 by the center-tap method. You will notice that the high negative voltage of the power supply is applied constantly to the center-tap or the main coil and one part of the key and the entire filament circuit are isolated from the transmitter when the key is up. The key simply allows the current to pass into the filament when it is pressed. Much less arcing and key trouble will be encountered with this method. If the key does arc too much or if it continues to spark across when it is raised, a condenser of large capacity say .2 to .5 mfd. may be placed across the key contacts. This condenser should be constructed to stand the high plate voltage directly. Even better, this condenser and small series resistance on the order of 200 to 1,000 ohms may be placed in series and the combination shunted across the key contacts (as shown in Fig. 9). However, when using power up to 50 watts and above, an entirely different system must be used. In some cases, a relay is used which is operated by the key. With this method the key circuit is simply a very low potential circuit having a "C" battery or small battery, the key and an electromagnet in series. This system has many advantages. It prevents any damage to the operator due to high voltage, because the voltage at the key is not much greater than that of a dry cell. The relay may be made as large as necessary and the contacts open as much as ¼ or ½ an inch so that no arcing can take place. The relay has to be timed so that no dots are missed.

When powers of the order of 50 watts are used, the high voltage transformers usually do not have the filament windings wound on them. In this case, the key may be placed in the primary of the high voltage transformer. You can readily appreciate the reason why the key could not be put in the primary if the filaments of the tubes were operated from the same transformer. Each time the key was lifted, the tubes would go out, and could not heat up quickly enough to start up oscillating instantly as

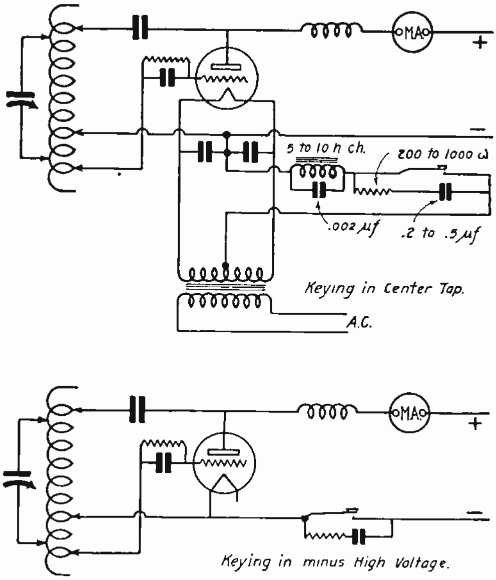

Fig. 9—Keying Circuits.

the key is pressed. In this case, the voltage is much lower then in the secondary and less trouble is encountered in keying.

In some cases, it is necessary to use a key filter of some type to prevent the peak voltage from changing the frequency of the transmitter at the instant it is pressed. In other words, a device for making the key current constant. Chokes for this purpose are of the order of 5 to 10 henries, wound with very large turns of wire on a heavy iron core. This system prevents what is known as chirping. If you have ever listened to short wave reception, sometimes a station will sound chirpy or in other words, its frequency will change slightly between the time the key contact is made and when the dash is ended. This is very undesirable as it is hard to copy and is very annoying.

When the filament leads are made rather long from the filament transformer to the transmitter, it is very desirable and often absolutely necessary to put two condensers across the outside of the filament and connect them together with the center-tap of the transformer. This provides a low resistance grid-return without having to go through the high inductance filament windings which in some cases, will ruin the transformer and in other cases prevent the transmitter from oscillating.

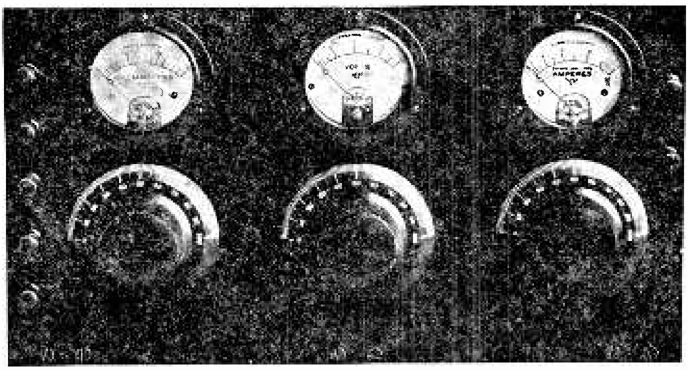

Fig. 10—Panel Arrangement of Tuned Plate Tuned Grid Transmitter.

RADIOTELEPHONE TRANSMISSION WITH THIS SET

If so desired, this set can be used for speech transmission. This can be accomplished by winding 1 turn of large, well insulated, copper wire around the left end of inductance (4). Across the two ends of this wire, connect any type of standard carbon microphone. This is known as the "absorption loop" method of modulation. Although it is not the most efficient, it is very satisfactory for low power and is capable of transmitting as far as 5 or 10 miles according to the type of tube being used in the transmitter.

TUNED PLATE-TUNED GRID TYPE OF TRANSMITTER

Another type of short wave transmitter which is very popular among the amateurs is known as the "Tuned Plate-Tuned Grid" circuit. Owing to the flexibility of this circuit and the ease with which it may be tuned and shifted from one waveband to another, it is very popular among amateurs. Since the short wave-length bands, 20, 40 and 80 meters vary in their effectiveness at different times of the day and different seasons of the year, it is highly desirable to be able to change the operating wave-length easily. In order to be able to change from one wave-band to another quickly, it is necessary to employ plug-in inductances which do not have taps, and make use of some circuits which can be tuned entirely by the use of variable condensers. Figure 10 shows a front panel view of a tuned plate-tuned grid circuit transmitter. Figure 11 shows the rear view of this set and Fig. 12, the schematic wiring diagram. A list of apparatus used in constructing this set is as follows:

List of Parts:

1—Aero interchangeable transmitter kit 2040 or 4080; including two mounting bases and two choke coils.

3—.0005 mfd. receiving variable condensers. (Karas or Cardwell).

3—Dials.

1—4,000, 5,000 or 10,000 ohm grid leak, wire wound. (Center-tapped.)

2—.0001 or .00025 mfd. fixed mica receiving condensers.

2—.001 mfd. or larger, fixed mica receiving condensers. (Paper dielectric cannot be used).

1—UX type tube socket.

7—Binding Posts.

1—Rubber, micarta, or bakelite panel, 10x18, or 7x18, depending upon whether meters are used.

1—Rubber, micarta, or bakelite sub-panel, 10x18.

2—Sub-panel brackets.

Hook-up wire, mounting screws, etc.

Optional Equipment:

1—0-100 D.C. milliameter.

1—0-10 A.C.-D.C. voltmeter.

1—0-1 thermocoupled radio-frequency antenna ammeter.

Other Equipment Needed:

One key.

Filament supply.

Plate supply.

Antenna and Counterpoise.

By carefully following these diagrams and photos, and the constructional data, the builder should be able to construct a very successful type of transmitter. As can be seen by the schematic wiring diagram, Fig. 12, the grid and plate circuits are tuned by their respective variable condensers, and the output or antenna circuit is coupled inductively to the plate circuit, in which most of the radio-frequency energy flows. This circuit is extremely flexible and is easy to adjust, therefore, it is suitable for both the experienced amateur and the novice. The antenna circuit is coupled through the variable coupling coil and is tuned by means of the variable condenser in series with the antenna and counterpoise.

The wave-length range of this transmitter complete with five coils is from 16.5 to 90 meters inclusive. The plate and grid coils are interchangeable and may be removed from their bases, as they are of the plug-in type. The two smaller coils have three turns each, and cover, when using the .0005 mfd. variable condenser, from 16.5 to 52 meters. The larger coils have 8 turns each. These cover, with the same condensers, 36 to 90 meters. Figure 12-A shows plug-in transmitter coils and bases.

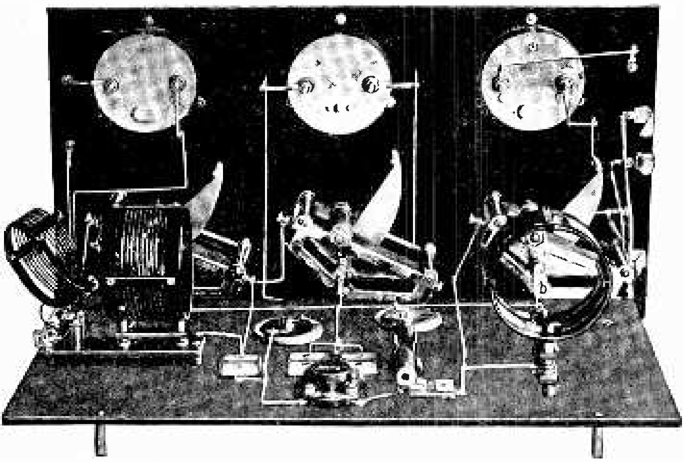

Fig. 11—Rear View of Transmitter.

The coils and condensers are primarily adapted for low power transmitters using up to about 100 watts input. This means that anything from a 199 type of tube up to a 50 watt tube, working at the rated input, can be used. Operation is possible with one UX-210 type tube or two in parallel. While ordinary amplifier tubes, such as the UX-171, 112, or 201-A may be used with good results; greater range, of course, will be obtained with higher power. When using any of these receiving tubes, "B" batteries may be used for the plate supply. However, it is best to use rectified alternating current for the plate supply when using a UX-210 type of tube.

The tuning condensers used are the ordinary single spaced receiving condensers, as the power is low and no flash-over troubles will be encountered. When using high power, double spaced condensers will be necessary. The plate and grid blocking condensers are .0001 mfd. fixed mica receiving condensers. Better operation might be secured by using .00025 mfd. fixed condensers instead. The filament by-pass condensers are also mica fixed receiving condensers, .001 mfd. or larger may be used. The grid leak is a small size 4,000 ohm wire wound resistance, known by the trade name of Crescent Lavite. A 10,000 ohm resistance, center-tapped, so that either 10,000, 5,000 or 2,500 ohms may be used to an advantage, gives better output under certain circumstances. The choke coils are small honeycomb inductances of at least 200 turns which serve to keep the radio-frequency component out of the direct current leads. In some cases it may be necessary to use slightly larger honeycomb coils.

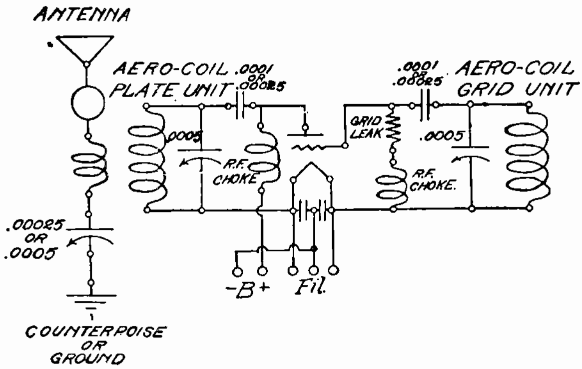

Fig. 12—Circuit Diagram of a Tuned Plate Tuned Grid Transmitter.

The meters shown are optional, but are of great assistance in tuning the set. A plate milliammeter having a scale reading of 0-100 D.C. milliamperes should be used with one 210 type tube. When using any of the receiving tubes mentioned, a smaller reading meter may be used, and when using a 50 watt tube, a higher reading meter will be required. The filament voltmeter is merely used to indicate the filament voltage, and when using the 210 type of tube, it should read 7½ volts. It will be found that in some cases, the filament voltage can be reduced without lowering the antenna current, and this is, of course, advisable, as it will prolong the life of the filament. The antenna ammeter is used to indicate the antenna current and when using a 210 type of tube should be a 0 to 1 ampere thermocoupled radio-frequency meter. When using a 201A or 199 type of tube, the antenna ammeter can be a 0-500 or even a 0-250 milliampere meter, while for a 50 watt tube, a 3 ampere meter should be used.

By referring to Fig. 11, it will be noted that the grid and plate coils are placed at right angles to one another and some distance apart. This reduces coupling between them and makes for better control. In assembling the set, the coils should not be placed too near metallic bodies, such as the condensers, frame, etc. The lay-out as shown in the sketch should be followed for best results.

OPERATION

Unless the operator is experienced in tuning a transmitter, extreme care should be used. If inexperienced methods of tuning are used, the tube may be injured.

Let us presume that the set is completed, power supply connected to the transmitter, but not turned on, and the antenna coil is connected to the antenna and counterpoise. The antenna tuning condenser is the one shown to the right in Fig. 10, the plate tuning condenser is the center one; and the grid tuning

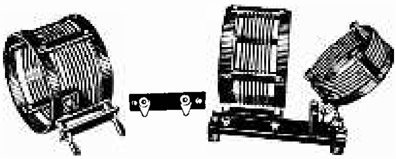

Fig. 12-A—Transmitting Plug-in-Coils.

condenser is the one on the left hand side of the panel. Set the plate tuning condenser at some convenient point such as 20 on the dial. Set the grid condenser at the same point. Turn on the filament current. Then turn on the plate current and quickly vary the grid tuning condenser until the plate milliammeter shows a minimum reading. When this is obtained, the grid and plate circuits are in resonance and the set will oscillate, but if the two circuits are not tuned to resonance, a large plate current will be indicated with the key open. If the current is not turned off quickly, the tube may be ruined. **Be sure to switch off the plate supply immediately if the plate of the tube begins to heat with key open.** When this has been done, the antenna and counterpoise may be brought to resonance by varying the position of the antenna series condenser while the key is closed. Resonance will be indicated by a maximum reading both in the plate milliammeter and the antenna ammeter. This adjustment of the antenna may tend to throw the plate and grid circuits out of resonance, and a slight readjustment of the grid tuning condenser capacity may be necessary. At first, the antenna coupling coil should be tightly coupled to the plate coil. By listening in on a short wave receiving set located near-by, the tone of the note may be determined. If it is found that the wave is unsteady when in this condition, the antenna circuit should be slightly detuned or the coupling loosened.

Now press down on the key of the transmitter, and by means of a wave-meter or calibrated receiving set determine on what frequency the transmitter is operating. Then vary the capacity of the tuning condensers until you attain the desired wave-length as indicated by the wave-meter or calibrated

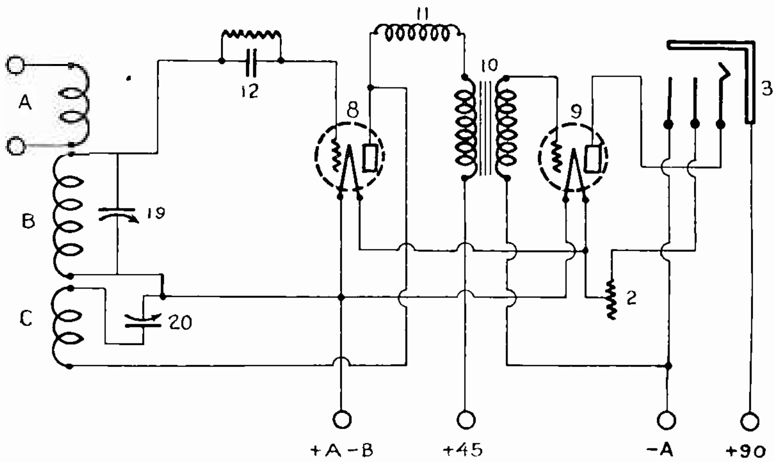

Fig. 13—Schematic Diagram of Short Wave Receiver.

receiver. **Be sure to vary both grid and plate tuning condensers together.** Otherwise, the set may get out of resonance and you will damage the tube. Be sure to switch off the plate voltage every time you see the plate beginning to get too hot, or when the plate milliammeter reads too high when the key is open. The secret of successful operation of this set is to keep the plate and grid circuits in resonance.

The matter of coupling between the antenna and plate coils is one which can be worked out to best advantage by the operator. Too tight a coupling will produce a bad note and unstable operation; too loose a coupling will not put the maximum amount of energy into the antenna.

While any type of antenna system may be used with this circuit, however, better results may be expected with the Hertz type of antenna described in the early part of this lesson. For best results on any particular wave-band, it is found that the antenna should really be constructed to operate on that particular wave-band, although a single wire, from 40 to 100 feet long, and a single wire counterpoise of the same length may give good results on any wave to which the set can be tuned. It is very important that the antenna system be as high and as free from obstructions as possible.

THE SHORT WAVE RECEIVER

There are various types of short wave receiving sets now in use and their owners have reasons for their preferences "or selections." However, to successfully receive signals on the short wave-length (high frequencies), certain principles of design must be more closely followed than for reception on the higher or broadcast wave-band. In general, when receiving short wave signals, the strength of the signal is far less than when receiving broadcast signals. This is especially true when the signals come from a great distance.

Tests by the U. S. Bureau of Standards on various forms of inductances used in receiving sets have proved that the loose basket-weave wound coil is superior to other types for short wave receivers. The advantage is that the loose basket-weave coil is slightly more efficient; has a lower distributed capacity due to its form of winding; low dielectric loss, because no forms of any kind are used to support the coils; they are mechanically rugged because of the heavy gauge wire used; and in general, are more easily constructed than the space wound solenoid type of coils.

Short wave receivers must have interchangeable coils in order to cover all the amateur wave-bands. It is desirable that each coil cover only a small wave-band (for example, 30 to 50 meters). Reception on short waves being very critical, a number of coils must, therefore, be used to cover and spread out all wave-lengths between 10 and 200 meters, also the tuning variable condensers must be of low maximum capacity so as to efficiently operate in conjunction with these coils.

The type of circuit shown in Fig. 13 is very well adapted to the reception of short wave signals. Figure 14 shows a picture diagram of how the apparatus is mounted and wired. A list of parts required for building this receiver is as follows:

1—Tuning or wave-length control condenser 19. (Radio Engineering Laboratories).
1—Oscillation control variable condenser 20, .0001 to .00025 mfd. (Type REL).
1—Grid condenser 12, .00025 mfd.
1—Grid leak, 1 to 10 megohms.
1—Filament rheostat 2, 10 to 20 ohms, according to type of tubes used.
1—Radio-frequency choke coil 11. (Type REL., No. 132).
2—UX tube sockets.
1—Audio-frequency amplifying transformer 10, ratio 10 to 1.

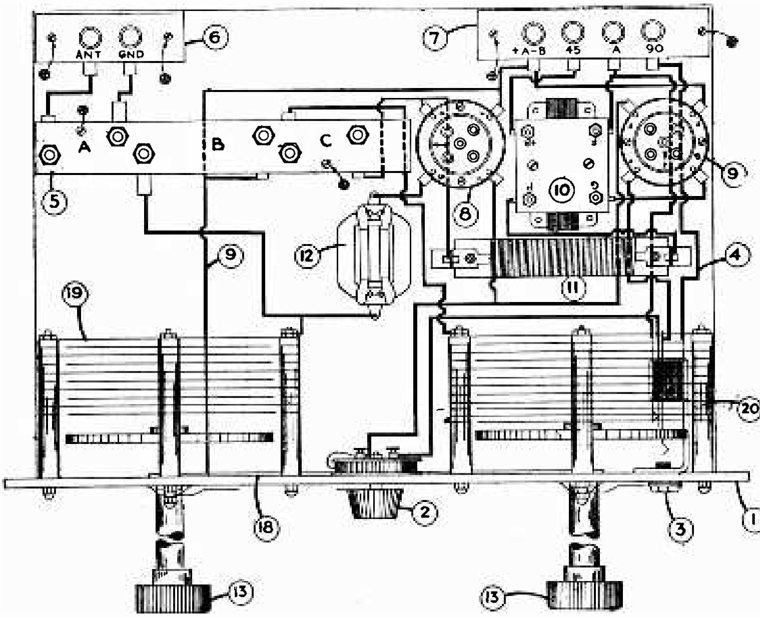

Fig. 14—Picture Diagram Showing Apparatus Mounted and Wired.

1—Filament control jack 3.
6—Binding posts.
1—Set of REL short wave coils with plug-in arrangement and bases.
1—Panel 14x7, rubber, micarta, or bakelite.
1—Baseboard, 13x8¾ inches.
Necessary wire, bolts, screws, nuts, etc.

Figure 15 shows a view of the unassembled parts. The circuit employed is the well-known capacity control feed-back with separate coils for antenna, secondary and tickler circuits. The variable condensers are expressly designed for short waves. Double spacing eliminates any chance of leakage due to dirt and moisture. These condensers are so constructed that a few stationary and a few rotor plates may be removed so that the capacity may be reduced. Vernier control is obtained by means of soft and hard rubber discs mounted behind the panel. This eliminates any metallic friction noises as well as all back lash. The vernier control knobs of these condensers are mounted on half-inch round rubber shafts extending 4 inches from the front of the panel. This arrangement eliminates body capacity without sacrificing efficiency on short wave reception.

ASSEMBLY

The panel (number 1 referring to Fig. 14) is supplied separately and is partially assembled with the variable condensers and the vernier controls. To complete the panel assembly, it is necessary to mount the rheostat (2) and the jack (3). The panel is then fastened to the baseboard (4) by means of the three small wood screws. A blue-print is supplied with the kit; it is of actual size, and may be used as a template for mounting the other parts on the baseboard.

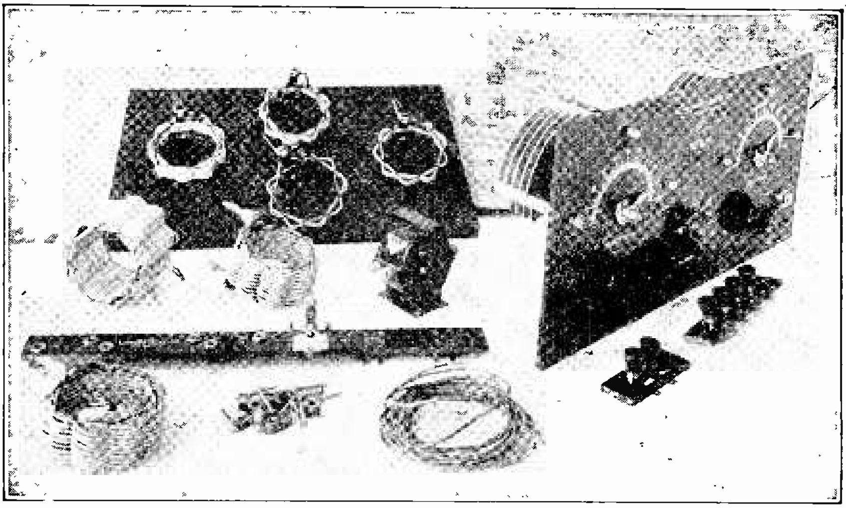

Fig. 15—View of Unassembled Parts for Short Wave Receiver.

By closely following the blue-print, the coil base (5), antenna binding post strip (6), battery binding post strip (7), detector tube and audio amplifier sockets (8 and 9), audio transformer (10), radio-frequency choke coil (11), and the grid condenser and grid leak (12), should all be located and mounted on the baseboard. The vernier knobs (13) are fastened to the shafts by means of small set screws. The shafts have the holes drilled to take these set screws. Proper friction must be maintained at all times between the soft rubber ring and the hard rubber disc. Should the soft rubber ring become worn, it can easily be replaced. The bakelite strips (5, 6, and 7) are raised from the baseboard by means of the small bushings underneath. The antenna coil (A), the secondary coil (B), and the tickler coil (C) plug in at their respective positions marked A, B and C on strip (5).

WIRING

It will be noted that the rotor plates of both variable condensers are connected by a strip of brass (18). All positive "A" and minus "B" connections should be made to this strip by means of the wire (9).

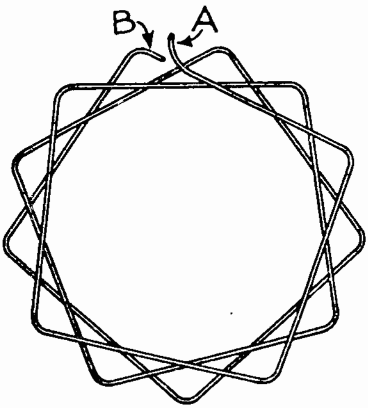

Fig. 16—Illustration Showing How Inductance Coils are Wound.

It is advisable to fasten the two wires to the rheostat before the choke coil is mounted, otherwise, it will be hard to get at this device. By carefully following the above instructions and the schematic wiring diagram as shown in Fig. 13, it will be found a simple matter to build this receiver. If a soldering paste is used for flux in soldering the joints, it will be necessary to wipe all joints with alcohol afterwards, otherwise, corrosion will occur. The best policy is to use rosin core solder and thus eliminate this kind of trouble.

If so desired, all filament and high voltage "B" leads may be cabled together. Make sure that the plate and grid leads are short, direct and free from other objects.

TUNING

Any type of tubes may be used with this receiver. It will, however, be necessary to apply the correct plate and filament voltages as required for the tubes used. If every connection is properly made, the filament will light when the phone plug is inserted in the filament control jack (3). The rheostat knob should then be turned until the tubes indicate proper brilliancy.

By setting the tuning condenser (19) at some arbitrary position and rotating the oscillation control condenser (20), a point on the dial will be reached where the detector tube oscillates; this will be indicated by a click in the head-phones. Keeping this condenser (20) so that the detector is in an oscillating condition and varying the capacity of the wave-length condenser (19), signals should be heard. If it is desired to receive modulated signals, it will be necessary to tune condenser (20)

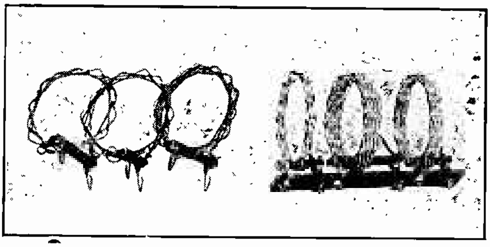

Fig. 17—R. E. L. Short Wave Coils.

to a point just below oscillation. Oscillation may be more easily controlled by using less filament current and keeping the oscillation control condenser (20) nearer maximum capacity.

There may be a possibility that "dead" spots or points will be noticed on the condenser dial (19) where oscillation does not take place. In such cases, a very small variable condenser with a maximum capacity of .00001 to .0001 mfd. should be inserted in series with the antenna.

The following table shows the correct coils to be used to cover various wave-lengths:

Wave-length Range in Meters	Primary Coil A	Secondary Coil B	Tickler Coil C
12 to 29	7 turns	3 turns	5 turns
29 to 58	5 turns	7 turns	7 turns
52 to 107	7 turns	14 turns	12 turns
100 to 212	12 turns	32 turns	18 turns

The primary and tickler coils are interchangeable and have the same number of turns and same width of base mounting.

For those who desire to construct their own coils, Fig. 16 will give them a clearer idea of how these coils should be constructed. Thirteen wooden or metal pegs ¼ inch in diameter are equally spaced on the circumference of a circle 3 inches in diameter. As noted in this figure, the consecutive turns are not parallel to each other, the winding starts at point "A" and makes three complete revolutions before coming back to the point "B". This gives practically a space-wound, air dielectric coil of exceedingly low distributed capacity. Figure 17 shows the plug-in coils and mounting.

ANOTHER TYPE OF SHORT WAVE RECEIVER KIT

The short wave, interchangeable coil system was invented primarily for amateur and experimental use, but it is suitable also for reception of broadcast programs on the short wave-

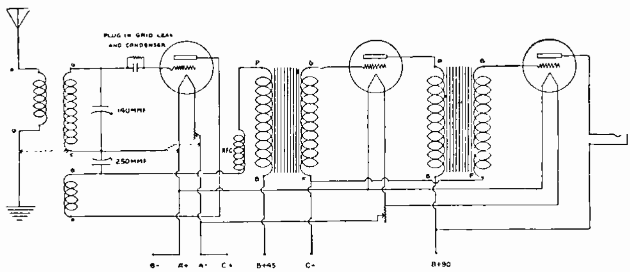

Fig. 18—Short Wave Circuit with Two Stages of Audio-frequency Amplification.

lengths. This receiver consists briefly of three interchangeable coils, each unit comprising a grid and plate inductance. A suitable base is provided, on which is mounted an adjustable primary coil, whose coupling may be set for best results with a long or short antenna. The circuit of this receiver is shown in Fig. 18. It uses the familiar fixed tickler, capacity control circuit, which has been found suitable for short wave receivers. It is recommended that if you use this circuit in a low wave set, make it so you can use interchangeable coils. This receiver uses two controls, tuning and feed-back, and since the feed-back is quite constant over a fairly wide band, operation is very simple. Two variable condensers are used. To obtain satisfactory results, the grid tuning condenser must be a 7 plate 140 mmf. (.00014 mfd.) straight line frequency condenser, while the feed-back control may be any 250 mmf. (.00025 mfd., usually 11 to 13 plates) condenser of good construction. The shape of the plates of this condenser does not matter very much, as it only controls regeneration. One stage of audio-frequency amplification is usually ample for ordinary head-phone reception, although two stages are used for broadcast music, or code signals from foreign countries.

The following is a list of apparatus to be used in building this receiver:

These parts or their equivalent will give satisfactory results.

1—7x18x3/16 inch drilled and Engraved Formica Panel.
1—5/8x2½x3/16 inch Formica Terminal Strip.
1—5/8x5x3/16 inch Formica Terminal Strip.
1—8½x17x½ inch Wooden Baseboard.
2—Karas Harmonik Audio Transformers.
1—Karas .00014 mfd. SLF Variable Condenser.
1—Karas .00025 mfd. SLF Variable Condenser.
3—Benjamin Type 9040 Cleartone Sockets.
2—Yaxley 4 ohm Fixed Resistances.
1—Yaxley Type 2-A Jack.
1—Yaxley Type 3 Jack.
1—Yaxley Filament Switch.
1—Daven No. 51 Mounting.
1—Daven 8 Megohm Grid Leak.
1—Dubilier .0001 mfd. Fixed Condenser.
1—25 Ohm E.E.E. Rheostat.
1—Set of Aero Interchangeable Coils—Range from 15 to 133 Meters.
1—Piece Bakelite Tubing ¾ inch, 3½ inches long.
1—Foot Insulated Flexible Wire. (For finding grid-return, grounding filaments, etc.)
Miscellaneous Screws, Wire, Lugs, etc.
1—Package Kester Rosin Core Solder.
1—Blackburn Ground Clamp.
40 feet or more of No. 28 DCC Copper Wire.
25 feet No. 12 Belden Copper Tinned Wire.

The detector tube socket should be either of some cushion or spring construction or be supplied with a sponge rubber base. The four leads going to the socket should be very light flexible leads, so as to allow the socket to vibrate. This eliminates microphonic noises which are so troublesome on the shorter waves.

The grid condenser and leak should be mounted in a removable fashion, so that various values of either may be tried in combination. Change the grid-return from positive to negative filament and vice versa until the best point is found. If a choke coil is needed, it may be home-made or purchased, and any very small coil, wound with fine wire (No. 28 or smaller, insulated) and having 200 turns or more, may be used, 200 turns on a ¾ inch tube or wound lorenz (basket-weave) fashion will be ample. In some cases, this coil may not be necessary, as the primary of the audio transformer may have sufficient impedance to act as a radio-frequency choke, but this effect varies and it is always best to include the choke coil.

Various broadcasting stations are now transmitting on short wave-lengths. These stations furnish considerable entertainment for those who are interested in receiving broadcast programs, and for those interested in code reception.

TEST QUESTIONS

Number your Answer Sheet 36—2 and add your Student Number

Never hold up one set of lesson answers until you have another set ready to send in. Send each lesson in by itself before you start on the next lesson.

In that way we will be able to work together much more closely, you'll get more out of your course, and better lesson service.

1. What wave-lengths are included in the short wave-length band?
2. Draw a diagram of a Hartley short wave transmitter showing power supply, rectifier and filter.
3. Describe the construction of the inductances used in the transmitter illustrated on page 3.
4. What kind of tubes may be used with this transmitter?
5. When using a UX-210 tube, what kind of power supply should be used?
6. How is it possible to eliminate arcing at the key points?
7. What change is necessary to make the set illustrated in Fig. 3 into a transmitter suitable for speech transmission?
8. Draw a diagram of a tuned plate—tuned grid transmitter.
9. What is the best form of inductance for use in a short wave receiver?
10. Draw a wiring diagram of a two tube short wave receiver.

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