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LESSON TEXT No. 37

DESIGN AND INSTALLATION OF SHORT WAVE TUBE TRANSMITTERS

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Radio-Trician's

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Complete Course in Practical Radio

NATIONAL RADIO INSTITUTE WASHINGTON, D. C.

DESIGN OF SHORT WAVE TRANSMITTERS

250 WATT TRANSMITTER: 20 TO 60 METERS

(15,000 Kcs. to 5,000 Kcs.)

Figure 1 shows the schematic wiring diagram of a short wave transmitting circuit that is capable of coverng the wave-length band between 20 and 60 meters. One UV-204-A is used in this circuit (250 watt tube).

This is a "Split Hartley" circuit, also called a "Series Hartley" circuit and differs from the similar type of circuit shown

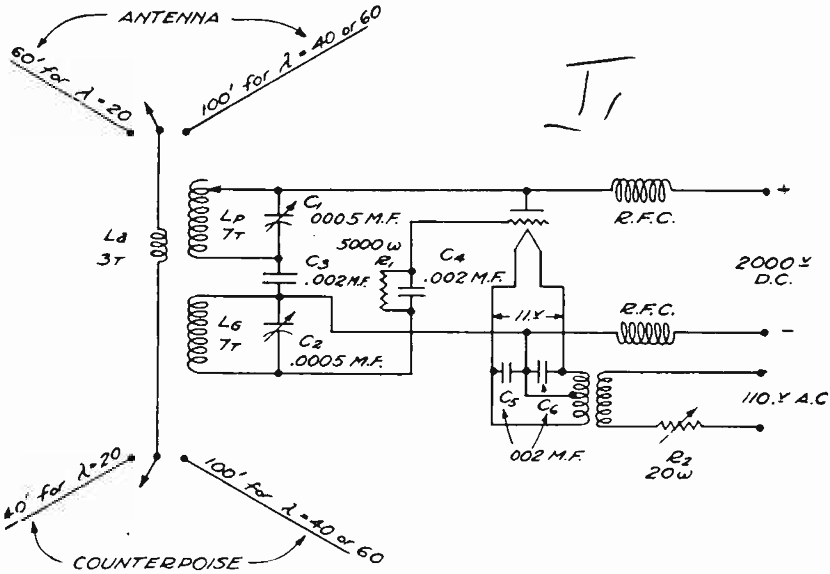

Fig. 1.—250 Watt Transmitter.

in a previous text-book in that it has tuning condensers, C_1 and C_2 across the plate and grid coils, respectively, to increase the flexibility of the transmitter. By increasing the "flexibility," we mean that the introduction of the tuning condensers increases the band of waves that it is possible to cover.

First of all, in this unit, we must have a power source, capable of supplying 2,000 volts D. C. and 110 volts A. C. One way of obtaining the 2,000 volts is by means of a motor-generator set and another is by means of a source of high potential A. C. and a suitable rectifier unit.

The positive lead from the high voltage D. C. source is connected to the plate of the UV-204-A through a radio-frequency choke coil. The plate is also connected to one end of the plate coil L_p which is shunted by the condenser C_1. C_3 is a radio-frequency by-pass condenser and also is a blocking condenser for the plate voltage.

The grid of the tube is connected to one end of the grid coil L_g through a grid biasing resistance R_1, the latter being shunted by a radio-frequency by-pass condenser C_4. The grid coil is shunted by the tuning condenser C_2.

The 110 volt A. C. supply for the filament of the tube is applied to the primary winding of a step-down transformer. The secondary winding should have a potential of 11 volts across its extremities. The mid-point of this secondary filament winding is common to the grid-return and the negative lead from the high voltage plate source. The negative lead from the 2,000 volt supply has a radio-frequency choke coil between the source and the mid-point of the filament secondary winding.

The antenna coupling coil consists of 3 turns which are wound around the plate coil of the closed oscillatory circuit. The antenna system has a 60 foot wire for an antenna and a 40 foot wire for a counterpoise when transmitting on 20 meters. For 40 and 60 meters, a 100 foot antenna and a 100 foot counterpoise are used.

There is a 0 to 5. thermo-coupled ammeter in series with the antenna lead to read the radio-frequency current and there is a 0 to 500 D. C. milliammeter in series with the negative plate supply lead to read the value of plate current.

It seems worth while to give you a list of the apparatus that was used in the construction of this transmitter because there may be some of you who will find it within your power to build this unit. Here are the parts that were used.

1—UV-204-A (250 watt tube).

1—Each, plate and grid sockets for above.

2—Radio-frequency choke coils; 100 turns of No. 22 double cotton covered wire, 3 inches in diameter.

1—7 turn plate coil (L_p); ½ inch copper ribbon self-supporting coil, 3 inches in diameter.

1—7 turn grid coil (L_g); same as the plate coil.

1—3 turn antenna coil (L_a); ½ inch copper ribbon self-supporting coil, 4½ inches in diameter.

2—.002 Mfd. fixed condensers (C_3 and C_4) rated at 6,000 volts.
1—Electrad 5,000 ohm resistor (R_1).
2—.0005 Mfd. variable transmitting condensers (C_1 and C_2).
1—General Radio type 214-A rheostat (20 ohms—.75 amp.) R_2.
2—Electrad .002 Mfd. fixed condensers (C_5 and C_6).
1—Weston Thermo-coupled Ammeter (Model 425) (0 to 5. amps.)
1—Weston Model 301 milliammeter (0 to 500.).

Figure 2 gives you an idea of the general appearance of the transmitter in question. The power tube is mounted in the foreground with the plate milliammeter at the left and the antenna ammeter at the right. The grid biasing resistance is shown at the right, shunted by the .002 Mfd. grid condenser

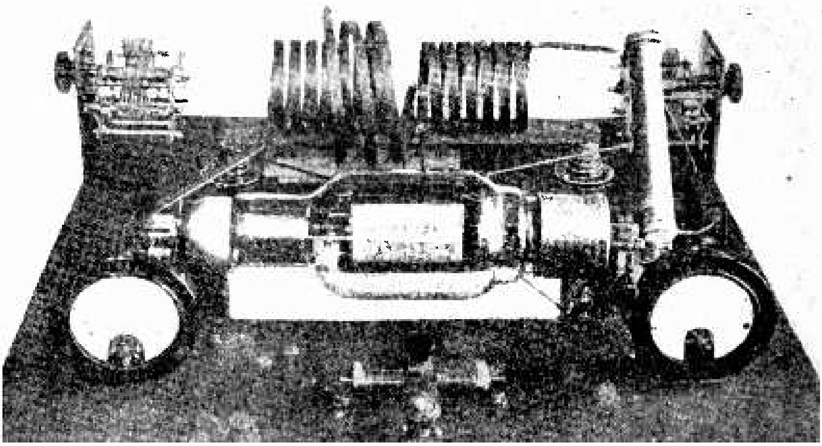

Fig. 2.—General Appearance of Transmitter.

C_4. The plate coil is shown in the coil assembly at the rear, left, with the antenna coil L_a wound around it. The grid coil L_g is just to the right of the antenna and plate coils. The plate tuning condenser C_1 is mounted at the rear of the baseboard to the left and the grid tuning condenser C_2 is on the extreme right.

HISTORIC SHORT WAVE TRANSMITTER, 15 to 85 METERS

Figure 3 is a view of one of the first short wave transmitters ever built for handling commercial radiotelegraph traffic. This ¼ Kw. transmitter was built by the Zenith Radio Corporation for the 1925 McMillan Arctic Expedition. It was capable of transmitting on either phone or C. W., on wavelengths ranging from 15 to 85 meters and was heard over extremely great distances.

First, we have the power supply panel at the extreme right. Then in the middle we have the modulator panel which includes a 50 watt speech amplifier and a 250 watt modulator. The 250 watt tube is shown mounted in a horizontal position. It is a type UV-204-A.

At the extreme left of the picture is the oscillator panel which includes a 250 watt oscillator tube with its associate circuit. The oscillator tube can also be seen, in a horizontal position, and this, too, is a UV-204-A.

Now, we have considered several different low power transmitters, which are by no means of commercial status, simply to help you grasp the fundamentals of short wave transmission and to get accustomed to the constants used on these short wavelengths. The foregoing transmitters described embody the fundamentals of short wave transmission and give the layman an opportunity to construct them and become accustomed to the intricacies in the operation of them. The discussion of the foregoing circuits gives you an insight into the field of short wave transmission and now we are going to tackle the real thing. We will go into the discussion of real commercial equipment and will show you the vast difference there is in the details of a high power short wave installation.

First of all, in commercial short wave transmitters, and by this we mean, transmitters that are used for the transmission of regular radiotelegraph traffic, a generator of high-frequency energy, other than the vacuum tube, is used, because of its inherent ability to maintain a very constant frequency. This unit is the "Crystal Oscillator" and the next part of this text will describe the fundamental principles underlying the operation of the "Oscillating Crystal."

CRYSTAL CONTROL

When certain crystals are subjected to stress or are heated or cooled, electrical charges are produced in certain sections. When these electrical charges are produced by stress, the effect is called "Piezo-electric." When these charges are produced by heat, the effect is called "Pyro-electric." It is with the piezo-electric effect that we are concerned at this time.

Many years ago, the discovery was made that a piece of Rochelle salt changes its shape when it is placed between two metal plates which are connected to a source of potential. The action that takes place is similar to that manifested when you squeeze a rubber sponge. For instance, say you have a square piece of rubber sponge and simultaneously apply a compressive force with your hands to the top and bottom surfaces. As you apply pressure to the sponge, the length of the surfaces which are perpendicular to your hands, becomes smaller, and the length of the surfaces which are parallel to your hands, becomes greater. This analogy gives you an idea as to how the crystal of Rochelle salt acts when it is placed between two charged plates.

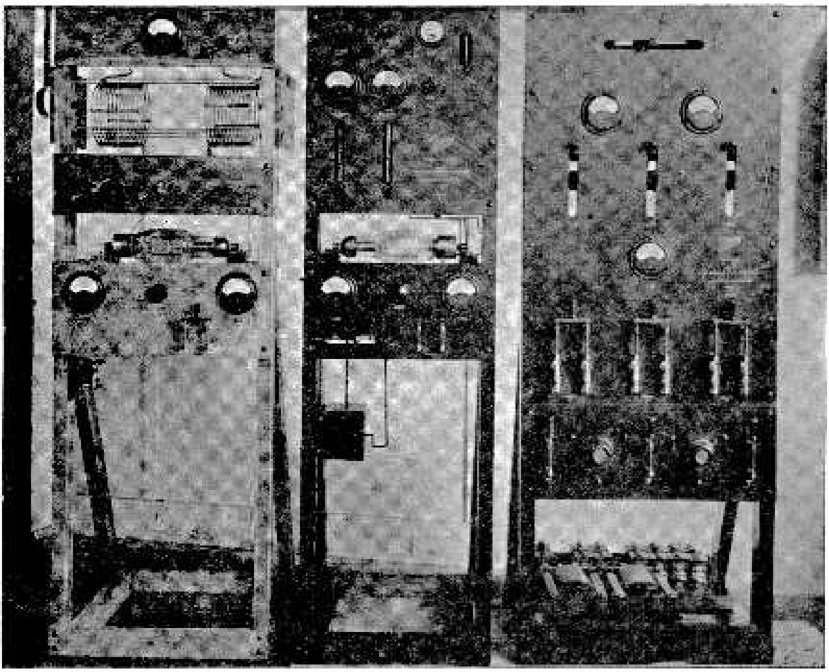

Fig. 3.—View of First Short Wave Transmitter.

It has also been found that this action can be reversed. For instance, if the crystal is subjected to a mechanical strain, its surfaces become charged electrically.

It follows, then, from the foregoing, that a crystal may be distorted by means of mechanical or electrical pressure. When this occurs, the crystal immediately tries to return to its original shape and in so doing it swings past the normal state and actually contracts. Then it tends to swing back the other way and, in so doing, it again passes the starting point and becomes larger along the particular dimension we are considering. In other words, the crystal oscillates, just the same as a metal disc oscillates when you hit it with a hammer.

In the case of the metal plate, hit with the hammer, the oscillations are of audio-frequency and you can hear them, but in the case of the crystal, the oscillations are of radio-frequency and you cannot hear them. Also, in the case of the metal plate, the magnitude of the vibrations becomes smaller and smaller and finally dies out, so with the crystal, the magnitude of the oscillations would diminish to zero if some means were not employed to maintain it in an oscillating condition.

Summarizing, to get at the fundamentals, we see that the crystal can be set into oscillation by either mechanical or electrical pressure, these oscillations being of radio-frequency. When the crystal is connected in the proper circuit the oscillations can be maintained.

Rochelle salt has the greatest piezo-electric effect and quartz has a comparatively small one, but due to the mechanical characteristics of the latter, it is much more suitable for use as a constant source of radio-frequency energy in a transmitting unit.

Thus, quartz crystals are the type that are used in commercial practice. These crystals are cut in a particular manner and they each have three fundamental frequencies, regardless of whether the cut is bounded by a rectangle, square, ellipse or circle, as long as the thickness is small in comparison with the other dimensions.

The following is a short list of the three fundamental frequencies of each of several crystals and the corresponding wavelengths in meters, to give you a general idea of the comparative values of these frequencies in kilo-cycles.

Crystal	f_1 K-C	f_2 K-C	f_3 K-C	λ_1	λ_2	λ_3
No. 1	74.95	105.5	452.5	4000.	2842.	663.
No. 2	75.05	105.91	454.2	3995.	2831.	659.8
No. 3	74.9	105.15	454.25	4003.	2853.	660.0
No. 4	75.4	106.0	457.0	3976.	2828.	656.0
No. 5	74.75	105.35	454.5	4011.	2847.	659.5

The thickness of the crystal is a function of the frequency. A thick plate is required for low-frequencies and a thin plate for high-frequencies. Of course, it is not logical to try and produce crystals with fundamental frequencies so high that the thinness of the quartz plate is such as to make it difficult to handle without fear of breaking. The logical limits at the present time are between 100,000 cycles and 7,500,000 cycles. Higher and lower frequencies are readily obtainable from these fundamentals, as the crystal oscillator output is rich in harmonics.

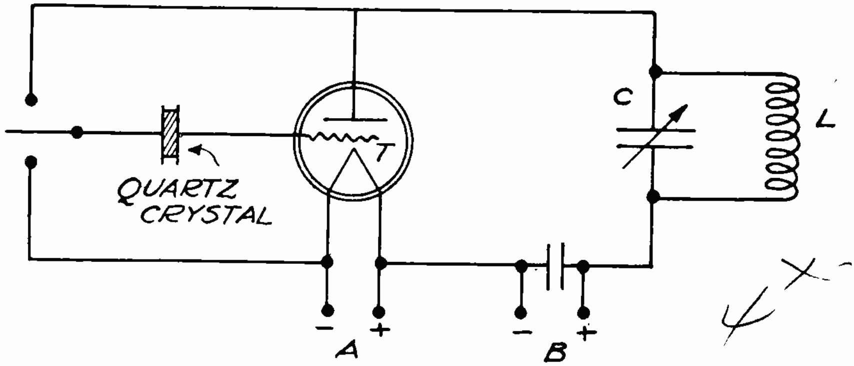

Fig. 4.—Circuit for Crystal Oscillator.

Figure 4 is a schematic diagram of the circuit connections for a Piezo-electric Oscillator. The crystal may be connected between the grid and the plate or the grid and the filament of the tube, in this particular circuit. The plate circuit is tuned to one of the fundamental frequencies of the crystal oscillator by means of the inductance (L) and the capacity (C).

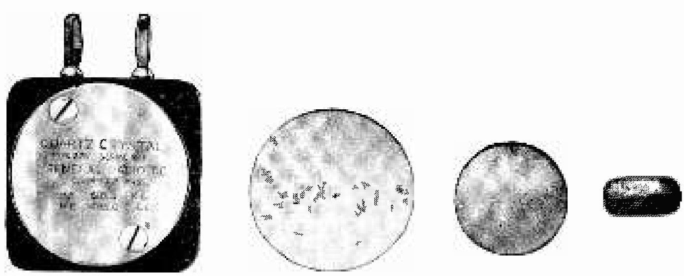

Fig. 5.—Quartz Plates.

The action that takes place is, in general, as follows: When the vacuum tube in the circuit in Figure 4 is put into operation by applying filament heating and plate potential, there is a difference of potential between the plates, between which the crystal is located. This distorts the crystal, which immediately tries to swing back to its normal state and in so doing, swings past normal, etc., thus a transient oscillation is produced which would die out before being noticed, if it weren't for the regeneration effected by means of the tuned plate and the capacity between the electrodes within the tube.

The oscillations that are set up in the grid circuit, appear in the plate circuit in magnified form due to the inherent characteristic of the vacuum tube to amplify voltages applied to its grid. These amplified variations are applied back to the grid of the tube, supplying the proper grid excitation, by virtue of the grid plate and grid filament capacity. If the crystal is connected between the grid and the filament of the tube, the grid

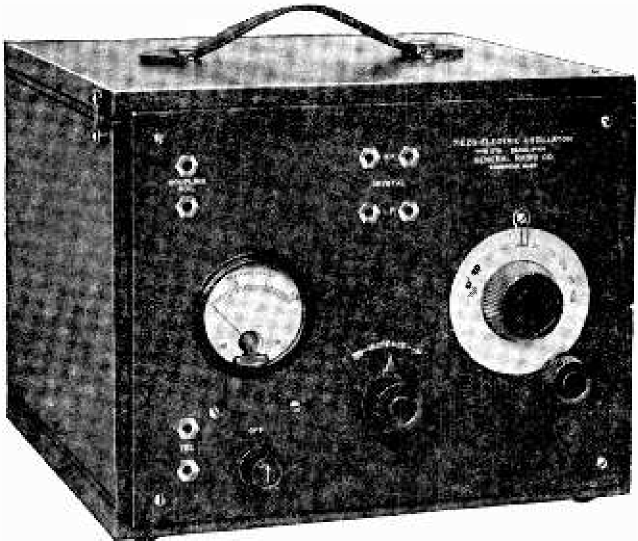

Fig. 6.—View of General Radio Company's Commercial Type of Piezo-electric Oscillator.

plate capacity functions to effect regeneration and if the crystal is connected between the grid and plate of the tube, the grid filament capacity functions to effect regeneration and maintain the crystal and the tube in the oscillatory state.

Figure 5 is a picture of a commercial type of quartz crystal assembly that is put out by the General Radio Company. You notice on the left, the neat little case that is used to enclose the crystal. You will note that the two highest fundamental frequencies are marked on the outside of the case.

To the right of the case are several views of crystals of different shapes. These are the quartz plates that are enclosed in the case shown at the left. This assembly is known as the General Radio type 276 quartz plate.

Figure 6 is a view of the General Radio Company's commercial type of piezo-electric oscillator, type 275, which uses the type 276 quartz plate described above. Figure 7 shows the schematic wiring diagram for this particular oscillator and you can see that this diagram is fundamentally the same as that shown in Figure 4.

Crystals for frequencies above 500 kilocycles are plugged in the jacks marked "H. F." (between plate and grid), while crystals for frequencies below 500 kc. are plugged in the jacks marked "L. F." (between grid and filament). You may question this last statement due to the fact that there is no metallic circuit between one side of the crystal and the filament terminal when it is plugged in the "L. F." jacks, but on closer examination you will notice that there is a radio-frequency by-pass condenser between one side of the crystal and the positive "A" battery terminal which has the same effect, for radio-frequency, as tying the side of the crystal in question directly to the positive "A" battery lead.

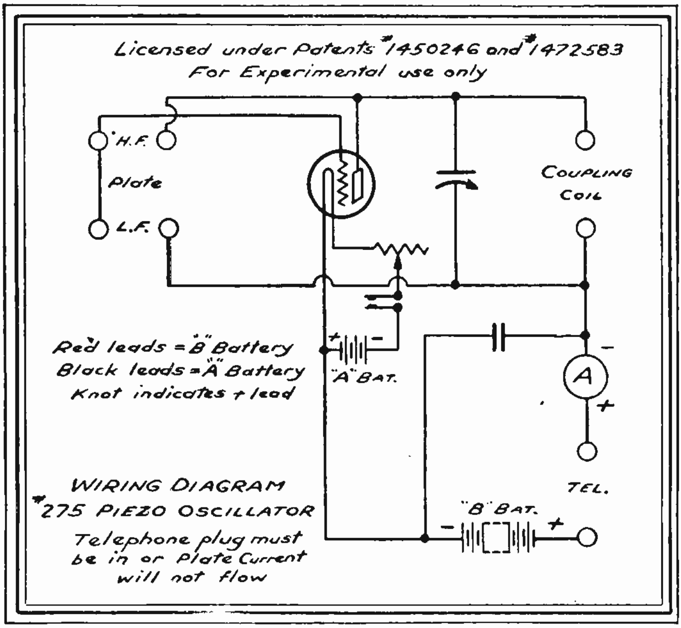

Fig. 7.

The coupling coil is applied externally and is a function of the frequency of the crystal, since the coil and the condenser C_1 are tuned to the crystal frequency. The milliammeter (A) and the telephones are used to indicate when the circuit is oscillating. This will be manifested by a decrease in the value of the current as shown by the milliammeter, and by a click in the phones.

COMMERCIAL 50. METER, 5. KW. TELEPHONE TRANSMITTER

We are now going to take up the description of a commercial radiotelephone transmitter that is operated on a wave-length of 50 meters with an antenna output around 5. kilowatts.

This transmitter is located at Belfast, Maine, and can be operated on either 70 or 50 meters. The fundamental details are similar in either case.

Figure 8 is a schematic wiring diagram of this transmitter. To start with we have a 100 meter crystal which is the constant source of our radio-frequency energy. As has been stated before, crystals that are thin enough to have a fundamental frequency of the order of 100 meters are quite delicate, mechanically, and must be handled with extreme care.

It is more difficult to make a crystal oscillate below 200 meters than it is above, and due to this fact as well as the fact that we have, to start with, a 100 meter crystal, it is necessary to use an auxiliary battery (E_1), about 8 volts, in the crystal circuit to insure dependable operation of the crystal oscillator. A radio-frequency choke (X_1) is used in series with the crystal battery to prevent any loss of energy in this circuit.

In this case, the crystal is applied between the grid and the filament of a 5. watt tube T_1, a UX-210. The plate circuit of this first tube is tuned to 100 meters and the thermo-ammeter (A_1) is connected in series with the tuning condenser C_{p1} so that radio-frequency current only passes through it, the D. C. plate current passing through the plate coil L_{p1}. The ammeter A_1 is a Weston thermo-ammeter having a range of from zero to 1.0 ampere.

The plate tuning coil in the crystal amplifier tube plate circuit is coupled to the grid coil (L_{g2}) which is in the input circuit of another 5. watt tube. This tube is a "frequency doubler" or "harmonic amplifier," either term being used to denote the function of the tube in question. What we want to do in this second tube circuit is to cut the wave-length in half, or, in other words, double the frequency.

We know that the output of the crystal amplifier tube T_1

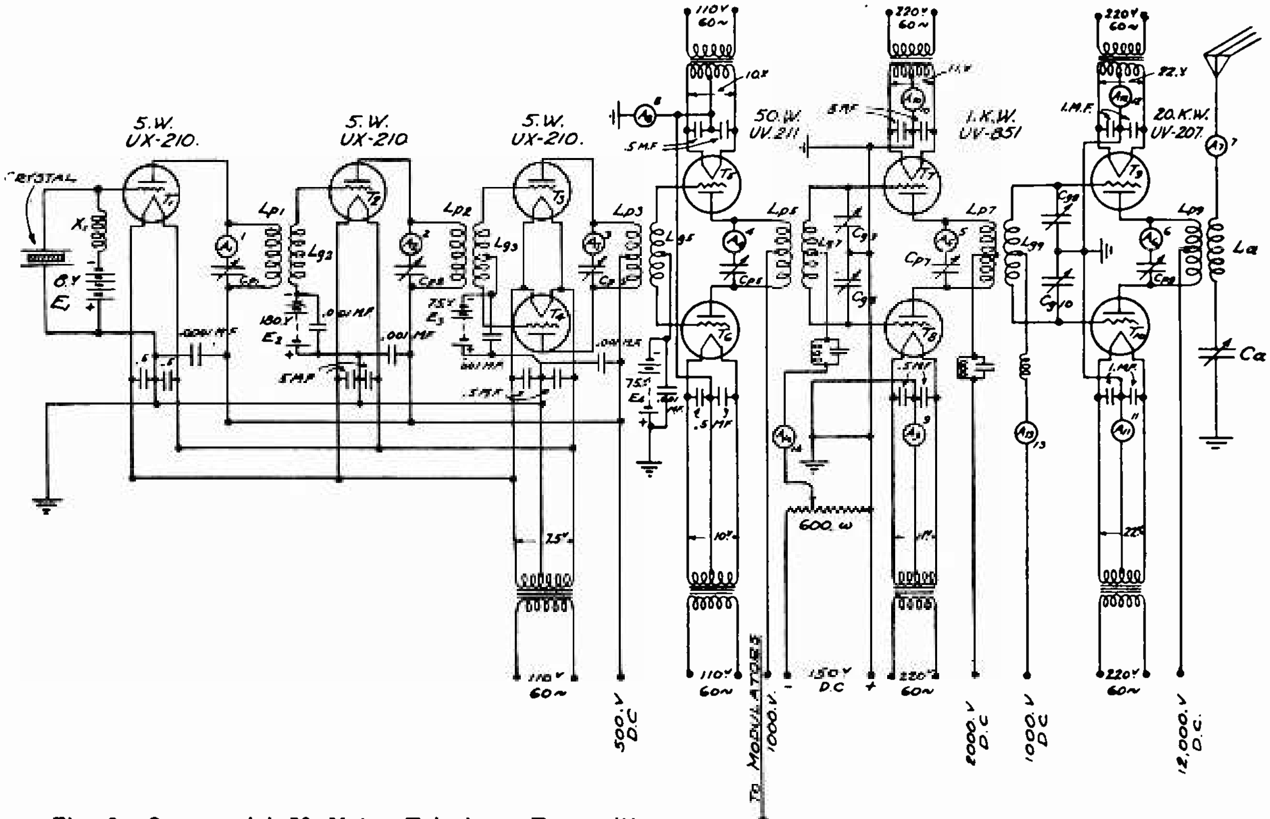

Fig. 8.—Commercial 50 Meter Telephone Transmitter.

is full of harmonics, from previous discussion in this text, and we apply a high bias to the grid of the harmonic amplifier tube T_2 to cause its output to be rich in harmonics. This bias, E_2, is 180 volts and is shunted by a radio-frequency by-pass condenser having a capacity of .001 Mfd.

The plate circuit of T_2 is tuned to 50 meters, the first harmonic of the fundamental frequency of the crystal. It follows that the voltage on the grid T_2 at the first harmonic frequency will be of far smaller amplitude than that of the fundamental frequency and it also follows that we will have a correspondingly small amount of energy in the output circuit of T_2, so it is only necessary to have a zero to 250 mils. thermo-milliammeter (A_2) in the plate circuit of this tube to denote the point of maximum radio-frequency current in the tuned circuit.

If the plate circuit of T_2 were tuned to the fundamental frequency of the crystal, we would, of course, have a greater amount of radio-frequency current in the plate circuit of T_2 than in the plate circuit of T_1, but we must bear in mind the fact that we are amplifying the first harmonic of the crystal in the output circuit of T_2 and, therefore, do not expect as great a value of radio-frequency current as we had in the output circuit of T_1.

The inductance L_{p2} and the capacity C_{p2} in the plate circuit of T_2, then, tune to 50 meters. L_{p2} is coupled to the coil L_{g3}, the latter being the input coil to a push-pull amplifier consisting of two 5. watt tubes T_3 and T_4, with their associate circuits. From this point in the transmitter circuit, on, we want to have linear amplification. We want to amplify only one frequency, 6,000,000 cycles per second (50 meters), and we don't want any harmonics. Push-pull amplifiers are used because they are conducive to this effect; they eliminate the odd harmonics.

A 75. volt bias battery E_3 is used in the common grid-return circuit of the tubes T_3 and T_4. This battery is shunted by a radio-frequency by-pass condenser having a capacity of .001 Mfd. The inductance and capacity L_{p3} and C_{p3}, respectively, in the plate circuit of this 5. watt push-pull amplifier, tune to 50 meters and a Weston (0 to 1.5 amp.) thermo-ammeter (A_3) is used to denote the value of the radio-frequency current in the output circuit of this stage of amplification.

So far we have taken into account the functioning of the four 5. watt tubes, T_1, T_2, T_3 and T_4. The filaments of these tubes are all supplied with a potential of 7.5 volts, at their respective terminals, by means of a step-down transformer. The secondary winding of this transformer is tapped at its mid-point and this point is grounded. When alternating current is used for the filaments, instead of direct current, the grid-return lead is brought to the mid-point of the filament supply winding of the transformer used, rather than to one or the other of the filament terminals, as in the case of D. C. filament supply.

To keep all the radio-frequency leads as short as possible, an artificial neutral point between the two filament supply leads is effected right at the filament terminals of each of the four tubes in question, by means of two .5 Mfd. condensers, connected in series, and their mid-point grounded. The grid-return, in each case, is brought to the grounded point between the two condensers and the direct current in the grid circuit passes around through the tube, from grid to filament, through the winding of the filament supply transformer and back to the neutral point between the two series condensers right at the filament terminals. The radio-frequency current is by-passed by these series condensers.

There is also a .001 Mfd. radio-frequency by-pass condenser connected directly from the low side of the plate tuning coil, in each circuit, to the neutral point between the filament by-pass condensers. The plates of these four 5. watt tubes are supplied with a potential of 500 volts from a direct current source.

We now pass from the 5. watt push-pull amplifier to a 50. watt push-pull amplifier having two UV-211, 50. watt tubes, T_5 and T_6. The output coil (L_{p3}) in the 5. watt stage is coupled to the input coil (L_{g5}) in the 50. watt stage. There is a 75. volt bias battery E_4 in the common grid-return lead of these two 50. watt tubes. This bias battery is shunted by a radio-frequency by-pass condenser having a capacity of .001 Mfd.

The inductance and capacity L_{p5} and C_{p5}, respectively, are used to tune the output circuit in this stage of amplification to 50 meters. A closed oscillatory circuit of this type, functioning in this manner, is often called a "tank circuit." A Weston (0 to 10. amp.) thermo-ammeter, A_4, is used in the tank circuit of this amplifier to show the value of the radio-frequency current. The filaments of these two tubes require a potential of 10 volts which is supplied from two separate filament transformers. Two .5 Mfd. by-pass condensers are connected in series across the filament terminals of each tube and the two neutral points (one at each tube) thus formed, are brought to ground through a Weston (0-400 Mil.) D. C. milliammeter (A_8). This meter shows the value of the plate current flowing to these two tubes.

The radio-frequency output of this stage of amplification is modulated and the method of modulation will be taken up in detail later. It is sufficient to say here that the plates are supplied with potential from a 1,000 volt direct current source.

The output coil L_{p5} of the 50 watt amplifier is coupled to the input coil (L_{g7}) of the 1. kilowatt push-pull amplifier. The mid-point of the input coil (L_{g7}) is connected to a biasing resistance through a (0-300, m. a.) P. C. milliammeter (A_{14}) and a radio-frequency choke composed of an inductance and capacity, in parallel, tuned to 50 meters. 150 volts D. C. is applied across the biasing resistance which has a value of 600 ohms. By means of a movable contact on this resistance, it is possible to apply a negative potential anywhere between zero and 150 volts to the grids of the two UV-851, 1. kilowatt amplifier tubes. The positive terminal of the 150 volt D. C. supply for biasing the tubes in this stage of amplification is grounded. A_{14} shows the value of the grid current.

Two variable condensers C_{g7} and C_{g8} are connected in series across the input coil L_{g7} to effect tuning and thus increase the grid excitation for the two 1. kilowatt tubes T_7 and T_8. The mid-point between these two grid tuning condensers is grounded.

An inductance and a capacity, L_{p7} and C_{p7}, respectively, are used to tune the output of this stage of amplification to 50 meters. A Weston (0 to 20 amp.) thermo-ammeter, (A_5), is connected in the tank circuit to afford a visible indication of resonance and the value of the circulating radio-frequency current at this point in the transmitter circuit.

The mid-point of the tank coil (L_{p7}) is connected to the 2,000 volt D. C. supply through a radio-frequency choke. This choke consists of an inductance and a capacity in parallel, having the proper values to tune this parallel circuit to 50 meters.

Each one of the two 1. Kw. tubes in this amplifier has its separate filament heating transformer which maintains a potential of 11. volts at the filament terminals. The filament terminals, right at the tubes, are shunted, in each case, by two .5 Mfd. condensers connected in series and having their midpoint brought to ground through (0 to 1 amp.) D. C. ammeters (A_9) and (A_{10}). These ammeters show the value of the plate current flowing to each tube and they are placed at this particular point in the circuit because it is the low potential side of the plate circuit.

If it isn't exactly clear to you how the plate current can be shown by a meter in this part of the circuit, let us follow the plate circuit through from the source. Starting from the positive 2,000 volt terminal it passes through the radio-frequency choke to the mid-point of the output coil (L_{p7}). At this point the plate current divides, part of it flowing to one tube and part to the other. It is sufficient if we follow its course through one tube so we note that it passes to the plate of T_7, through the inside of the tube from plate to filament, then

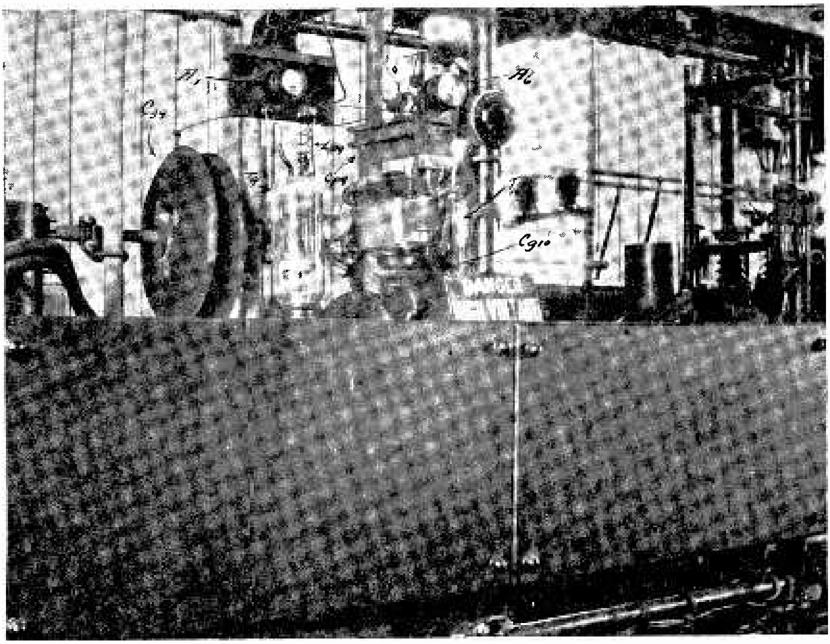

Fig. 9—20 Kw. Push-Pull Amplifier in 50 Meter Transmitter.

the filament supply winding to the mid-point, from whence it flows to ground through the plate current meter, and as the negative terminal of the plate supply is grounded, the circuit is complete.

The output of the 1. Kw. amplifier is coupled to the input of the 20 Kw. amplifier by means of the two coils (L_{p7}) and (L_{g9}). Two UV-207, 20. Kw. tubes are used in this last stage of push-pull amplification. The mid-point of the input coil (L_{g9}) is connected to a bias voltage supply generator through a radio-frequency choke coil and a grid milliammeter (A_{13}).

This bias generator is capable of supplying a biasing potential as high as 1,000 volts and the operating bias is of this order.

The grid milliammeter used in this stage of amplification has 0 at the center of the scale, with a range of 300 milliamps. on either side. The direction in which the meter needle will travel depends upon the polarity of the grid current.

For normal operation, the grid meter needle should indicate that the grid current is flowing from grid to filament, but if the travel of the meter is in the opposite direction, indicating that the flow of current is from filament to grid, we have an unstable condition. This action of the grid current meter would indicate that secondary emission was taking place (electrons given off from the grid) and if it were allowed to continue there would be considerable damage done to the tube. This condition of reverse flow of grid current takes place with the higher power tubes but does not give any trouble with the lower power tubes, those under 1. Kw.

The two condensers (C_{g9}) and (C_{g10}) are used to tune the input circuit of the 20 Kw. push-pull amplifier and thus effect higher grid excitation than could be effected by the coupling bebetween (L_{p7}) and (L_{g9}), alone. The tank circuit of this stage of amplification is tuned by means of the condenser (C_{p9}) and the coil (L_{p9}). A Weston (0-40. amp.) thermo-ammeter (A_6) is used to indicate the value of the radio-frequency current in this last closed oscillatory circuit in the transmitter under discussion.

The mid-point of the output coil (L_{p9}) is connected to the 12,000 volt D. C. supply. The filaments of the two tubes in this stage are supplied with filament heating energy by means of a step-down transformer in each case which maintains 22 volts potential across the terminals of each filament. Two 1. Mfd. condensers are connected in series between the filament terminals at each tube. In each case, the mid-point of the filament supply winding is connected to the neutral point between the two series by-pass condensers through a (0 to 5 amp.) D. C. ammeter and thence to ground. These 5. amp. meters (A_{11}) and (A_{12}) show the value of the plate current to each of the 20 Kw. tubes and, the meters, of course, are connected in the low potential side of the plate circuit. See Fig. 9.

The output of the 20 Kw. tank is coupled to the antenna system by means of the coils (L_{p9}) and (L_a). The antenna system is tuned by means of the condenser (C_a) and the coupling coil (L_a). A Weston (0 to 10 amp.) thermo-ammeter (A_7)

is used in the antenna circuit to indicate resonance and also to give the value of the radio-frequency current flowing there.

Figure 10 shows the schematic wiring diagram of the modulator circuit. Four 50 watt tubes, T_1, T_2, T_3 and T_4 are used in this circuit. The filaments of these tubes are supplied with energy from the low potential winding of a step-down transformer. This transformer maintains a potential of 10 volts at the filament terminals of these tubes.

The audio-frequency input to the modulator system, which normally comes from a speech amplifier system, is applied to the primary winding of the input transformer. The high side of the secondary winding of the input transformer is connected to a lead which is brought out as a common audio-frequency supply to the grids of all the modulator tubes. Each grid is connected to this lead through a choke coil and a resistance.

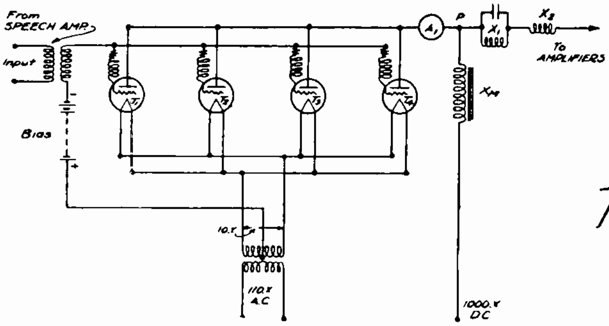

Fig. 10.—Bank of 50 Watt Modulators.

The low side of the secondary winding of the input transformer is connected to the negative terminal of the bias battery and the positive terminal of this battery is connected to the mid-point of the filament supply winding.

The plates of the four modulator tubes are all connected to the 1,000 volt D. C. source through a (0-400 mil.) D. C. milli-ammeter and an iron-core reactor X_m. The 1,000 volt supply for the two 50 watt push-pull amplifier tubes, T_5 and T_6 (Figure 8), also passes through the iron core reactor X_m, Figure 10, and the two radio-frequency choke coils X_1 and X_2. X_1 is a tuned choke and X_2 is untuned. They keep the radio-frequency from getting into the power supply or the modulator tubes.

The grid potential of the modulator tubes follows the audio-frequency variations of the input from the speech amplifier system and this causes a corresponding variation in the plate current to the modulator tubes. The iron-core reactor X_m is common to the modulator tubes and to the radio-frequency amplifier tubes in the 50. watt push-pull amplifier. Also, its position in the circuit causes it to function to maintain a constant current supply to the point (p), at which point the current divides, part of it flowing to the amplifiers and part to the modulators. If the current supply to the point (p) is constant, then, when the grids of the modulator tubes go positive and there is a greater flow of current to the modulator plates, there will be less current available for the amplifier plates. Therefore, the plate current supply to the amplifier tubes will vary in accordance with the audio-frequency variations that are applied to the grids of the modulator tubes and it is in this way that modulation is effected.

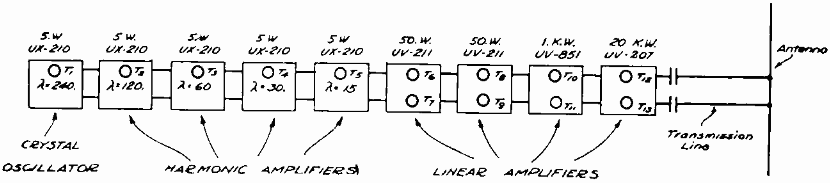

Fig. 11.—Commercial 15 Meter Transmitter.

COMMERCIAL 15 METER, 5 KW. TELEGRAPH TRANSMITTER

The preceding discussion has covered the fundamental details involved in a commercial type of short wave transmitter so, to avoid repetition and thus get as much information into a small space as is possible, we will consider this transmitter generally.

Figure 11 is a sketch of the tube arrangement for this transmitter which carries on commercial radiotelegraph traffic between the United States and South America, on 15 meters. This installation is at Rocky Point, Long Island.

To start with, we have a 240 meter crystal, the radio-frequency oscillations of which are amplified by means of a UX-210, 5 watt tube. The next four tubes are frequency doublers; they are all 5 watt tubes, UX-210's.

T_2 amplifies the first harmonic (120 meters) of the 240 meter crystal amplifier output. Now, we have 120 meters as the fundamental in the output circuit of T_2, since there is more energy at this frequency than at any other in this circuit.

T_3 amplifies the first harmonic of the output from T_2. Since the fundamental output from T_2 is 120 meters, the first harmonic is 60 meters. Hence, the fundamental wave-length in the output circuit of T_3 is 60 meters. T_4 amplifies the first harmonic of this 60 meter frequency which corresponds to 30 meters. This is applied to the input T_5 which again amplifies the first harmonic of the input and we have 15 meters in the output cir-

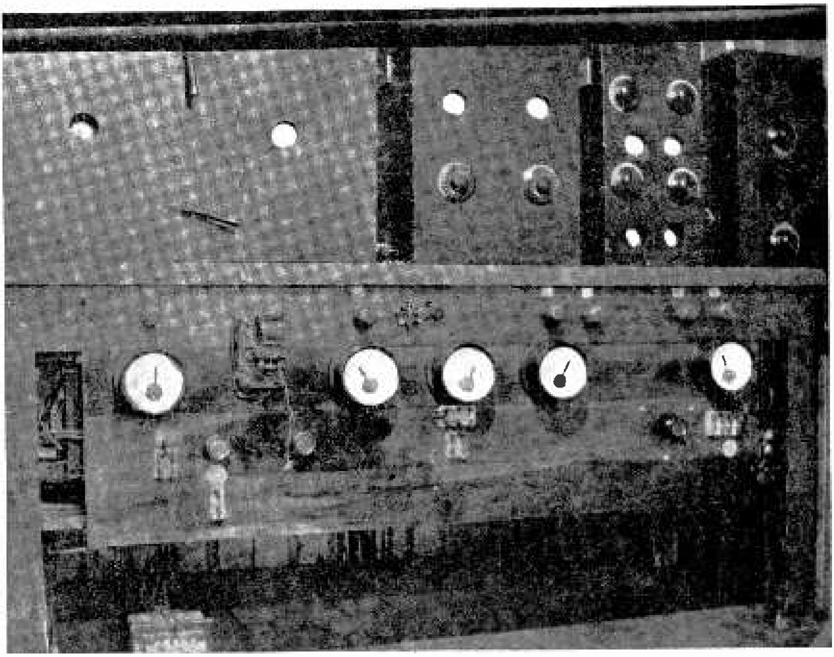

Fig. 12.—Front View of 15 Meter Transmitter Assembly Crystal Amplifier at Extreme Right. Four 5 Watt Frequency Doublers in Second Case From Right. Four 50 Watt Tubes in Third Case From Right, and Two 1 KW Tubes in the Fourth Case.

cuit of T_5. These four tubes, T_2, T_3, T_4 and T_5 can be called harmonic amplifiers, but the term "frequency doubler" seems to explain their function more fully.

From this point in the circuit, on, we simply have linear amplifiers to amplify the output of the last frequency doubler, T_5. This energy is first applied to the input circuit of a push-pull amplifier having two 50 watt tubes. The output of this first 50 watt stage is passed on to a second 50 watt push-pull amplifier which in turn passes the output energy on to a 1. Kw.

push-pull amplifier. The output of the 1 Kw. push-pull amplifier is passed on to a 20. Kw. stage of push-pull amplification.

In this particular transmitter, the keying is accomplished in the grid circuit of the 1 Kw. amplifier stage. The method of keying is quite simple. It simply consists of a scheme whereby the proper operating bias is applied to the grids of the two 1. Kw. push-pull amplifier tubes. When the key is up, there is a negative potential of 450 volts applied to the grids of the tubes from the bias generator through the resistance

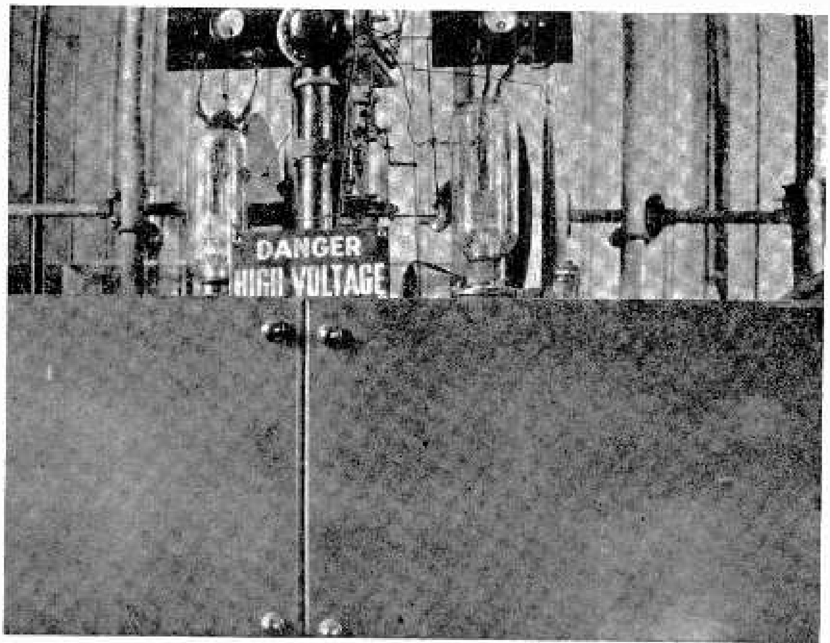

Fig. 13.—20 Kw. Push-Pull Amplifier Stage for 15 Meter Transmitter.

R1. With this amount of negative potential, the tubes will block (their plate current will become zero.)

When the key is pressed down, the negative bias from the generator is shorted through the resistance, R1, and the negative bias from the storage battery is applied, thus causing the tubes to amplify in normal manner, which produces a normal output from the antenna. See Fig. 15.

Another interesting point in the consideration of this particular transmitter is the method of coupling the output circuit of the last stage of amplification to the antenna system. This is done by means of a "transmission line" which carries the

10X

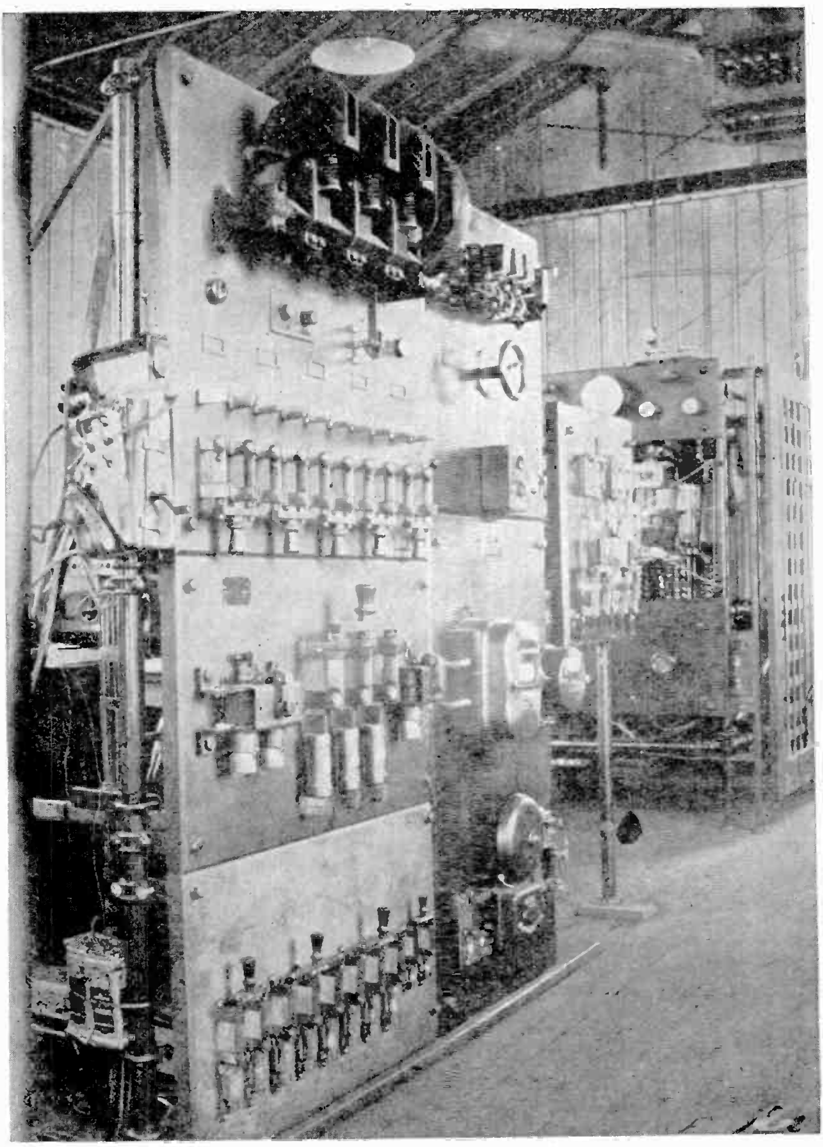

Fig. 14.—Power Panel for 15 Meter Transmitter.

energy from the transmitter to the antenna. Figure 16 is a schematic diagram illustrating this point. The transmission line is directly coupled to the inductance coil in the tank circuit of the last power amplifier. Two .0001 Mfd. blocking condensers are used to keep the high plate potential out of the transmission line and antenna but they, of course, pass the radio-frequency energy.

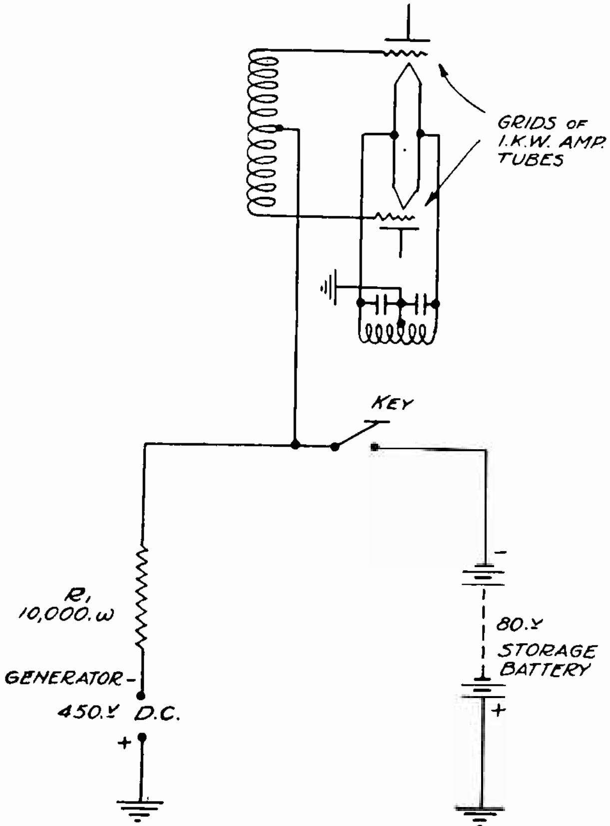

Fig. 15.—Keying Circuit for 5 Kw., 15 Meter Telegraph Transmitter.

The length of the antenna used in this 15 meter transmitting system is just ½ a wave-length, or 7½ meters, or approximately 26½ feet. This 26 foot antenna is suspended between two masts and the transmission line is connected to it at its mid point. (See Figure 16.) The points (a) and (b) where the two leads from the transmission line fasten to the antenna are quite critical and have to be determined very accurately. The impedance of the wire between points (a) and (b) should be such that it would give the effect of a line of infinite length, to the current flowing in the line. This would mean that there would be no reflection at the end of the line, hence the line would not radiate and the antenna would be the only portion of the system that would radiate energy.

Figure 17 is a view of the 15 meter antenna, showing the transmission line and the method of connecting it to the antenna. The system of wires behind the antenna constitutes a reflector which works on the same principle as the reflectors in Marconi's "Beam System" which cause the radiated energy to be most effective in one particular direction. This particular reflector is so constructed with reference to the antenna that it is directive towards South America.

Looking at Fig. 17, it is interesting to compare this little short wave antenna with the large antenna system shown in

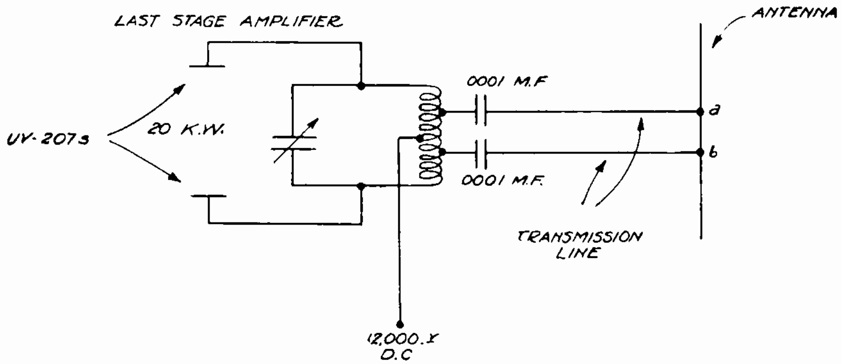

Fig. 16.—Transmission Line Circuit.

the background. The antenna in the background is also for trans-Atlantic radiotelegraphic communication, but it is supplied with 200 Kw. of radio-frequency energy on a wave-length of approximately 12,000 meters. Alexanderson alternators are the source of this radio-frequency energy. The question is, when will these massive antenna systems give way to the miniature systems such as the 15 meter antenna system shown in the foreground, which is supplied with 5 Kw. of radio-frequency energy and which is capable of working with Europe or South America.

Figure 18 is a view of a 15 meter antenna system, without a reflector, and here again the transmission line and method of application is shown quite clearly.

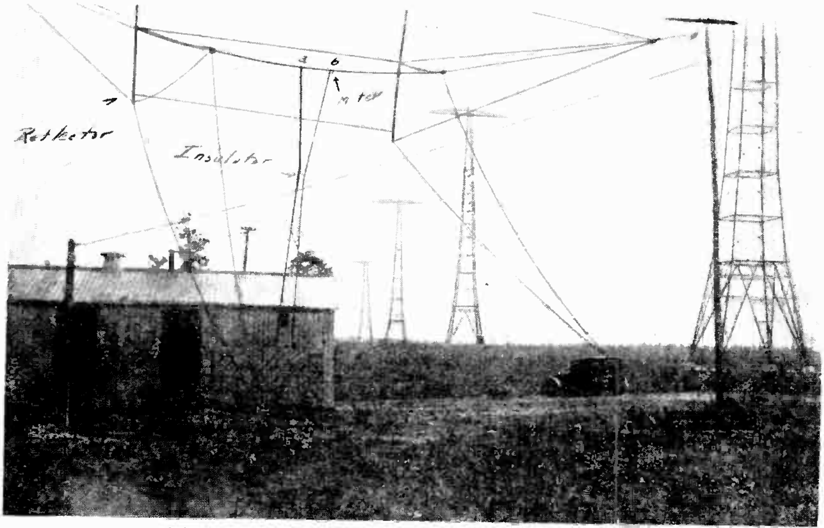

Fig. 17.—View of the 15 Meter Antenna.

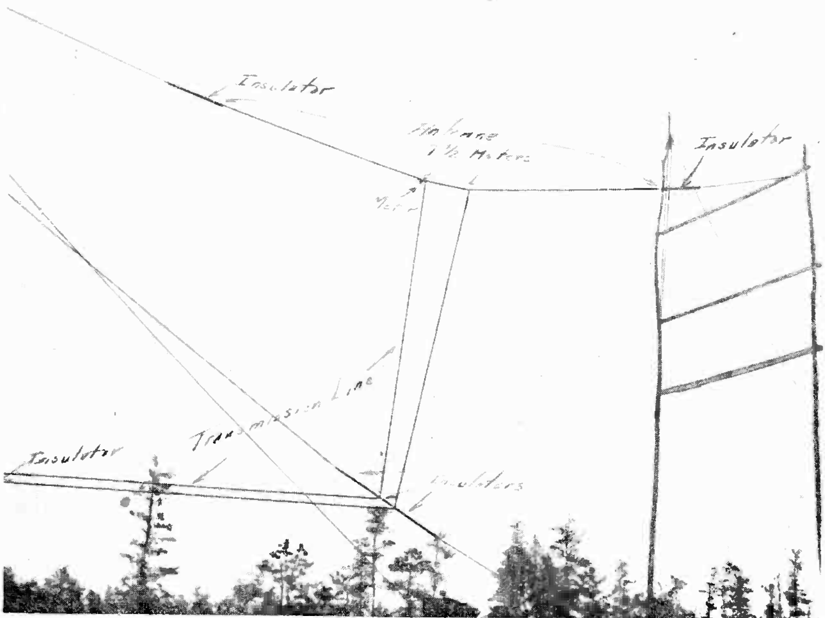

Fig. 18.—15 Meter Antenna System Without Reflector.

AMATEUR'S 150-175 METER C. W. VACUUM TUBE TRANSMITTER

THE MEISSNER TRANSMITTING CIRCUITS

This type of transmitter is used by a number of amateurs. The Meissner circuit employs inductive coupling between the plate and grid circuits and the antenna circuit.

In the circuit shown in Figure 19, the antenna circuit consists of an inductance from which one connection is made to the ground, the other to the antenna. A variable condenser is usually employed in series with the antenna to effect close variation of the wave-length.

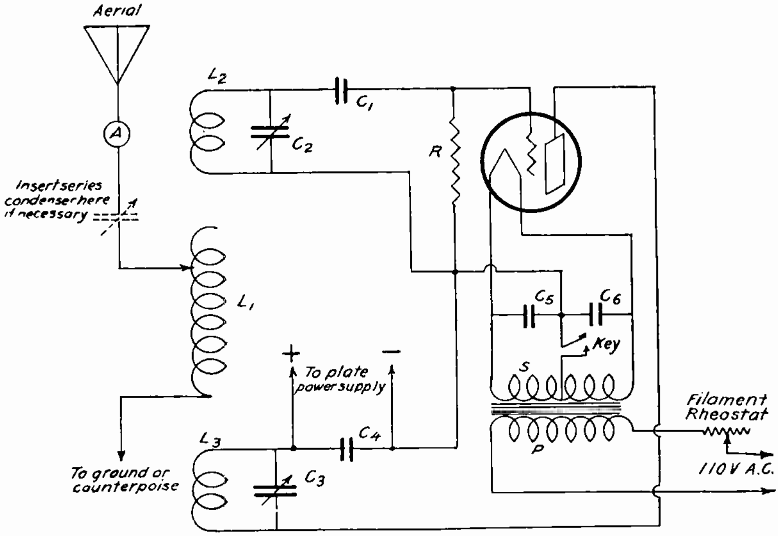

Fig. 19.—Three Coil Meissner Circuit.

The Meissner circuit will work with a ground almost as well as with a counterpoise. The most pleasing thing about the Meissner circuit is that one can change the wave-length from 150 meters to 160, or 175, by simply moving one antenna clip or tuning the antenna series condenser. In addition, the Meissner circuit has the advantage of the inductively coupled circuit in general. Naming the parts in Fig. 19, L_1 is the antenna coil, L_2, the grid coil, L_3, the plate coil. The constructional details of these coils are as follows: L_1, 14 turns heavy wire (such as No. 10 Bare Copper) on 6 inch form; L_2, 15 turns of wire (No. 20 to 30 DCC) on 6 inch tube when using condensers; 18 to 25 turns when working without condensers. L_3, 18 turns of wire (No. 20 DCC) on 6 inch tube when using condensers; 18 to 25 turns when working without condensers. C_1, .00025 to .002

mfd.; C_2 and C_3, good low-loss variable condensers, maximum .0005 mfd., C_4, .002 mfd., C_5 and C_6 1 mfd.; R, 1,250 to 10,000 ohms depending on the tube used.

The plate coil should be coupled closely to the antenna coil. The grid coil should be loosely coupled. Since grid coupling must be adjusted exactly, it is suggested that the grid coil be mounted so as to rotate. A pan-cake grid coil can be used.

To tune the set, put the antenna clip on some convenient point on the antenna coil and then adjust the grid and plate coils, either by means of clips to regulate the number of turns, or by condensers, so that the antenna current reaches its maximum. Then by means of a wave-meter, measure the wave-length radiated. If it is too high, cut out some of the turns of the antenna coil, and adjust the set as before, until the desired wave-length is reached. After the set is once adjusted, the plate and grid circuits need not be varied again, even if the wave-length is changed a great deal, for the antenna current will vary but little over the whole wave-length band between 150 and 175 meters. (The antenna current may be maintained steady by changing the adjustments of the plate and grid condensers. This change is very slight, and for ordinary work, it need not be done.)

The Two Kinds of Meissner Circuits.

There are two main forms of Meissner circuits in use among amateurs today; one form is the 3 coil Meissner as shown in Fig. 19; the second form is the 4 coil Meissner, shown in Fig. 20. In the 4 coil Meissner, two antenna coils are used. They are placed at right angles to each other and as far apart as convenient. With the grid and plate coils placed as they are in the 3 coil circuit, the full benefits of the Meissner arrangement cannot be had. There should be no coupling between the grid and plate coils, excepting through the antenna, but the 3 coil system places the grid and plate coils on the opposite ends of the same antenna coil, which means that there will be coupling between the grid and plate coils. Where the plate and grid coils are coupled directly to each other, oscillations of a different wave-length will be set up which are not the same as those radiated by the antenna. The energy required to do this is lost as far as the working wave-length is concerned. Also, these separate waves may cause correspondence with the Radio Supervisor's office.

The 4 coil Meissner circuit is the best of the two by far, because in the 4 coil set, the coils can easily be placed so that there is little coupling between the plate and grid coils. This is as it should be because it does away with extra waves and puts all the power into the main wave. The result is more miles per watt. The coils L_1 and L_4, in Figure 20, contain 7 turns on a 6 inch form or tube. The rest of the coils and condensers are the same as in Figure 19.

Mount the plate coil next to the lower antenna coil, L_4. The coupling between these two coils must be close, and the number of turns in the antenna coil, L_4, should not be changed.

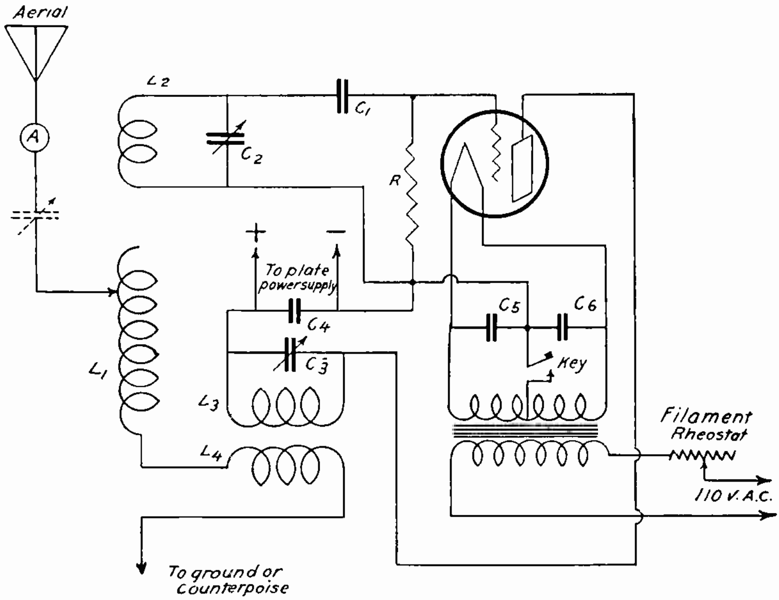

Fig. 20.—Four Coil Meissner Circuit.

Couple the grid coil to the variable antenna coil; place the two sets of coils at right angles so as to prevent setting up local oscillations of an undesired wave-length.

When the coils of the 4 coil set are properly arranged, the set will not oscillate if the antenna is disconnected, and the plate current will drop to almost zero. When adjusting the set, first find a place where the highest antenna current is produced for the least input to the tube. After getting an adjustment where a fair antenna current is produced with a small input, open the antenna switch. Now adjust the grid clip or grid variable condenser until the plate current is lowest. Then close the antenna switch. This grid adjustment should be made with care, but the adjustment of the plate clip (or plate coil condenser) is not critical.

LIST OF A FEW U. S. SHORT WAVE STATIONS

Wavelength	K. C.	Call	Location
14.93	20082	2XS	Rocky Point, New York
16	18738	NKF	Anacostia, D. C.
17.7	16940	KFD	Denver, Colorado
18.3	16380	WBQ	Schenectady, N. Y.
18.62	16100	KEB	Los Angeles, Calif.
19.56	15340	W2XAD	Schenectady, N. Y.
20	14991	NAL	Washington, D. C.
20.8	14414	NKF	Anacostia, D. C.
21.8	13750	KEB	Los Angeles, Calif.
22	13628	WIK	New Brunswick, N. J.
24.3	12340	KFD	Denver, Colorado
25.4	11814	W8XK	East Pittsburgh, Pa.
29.3	10230	KEL	Bolinas, Calif.
30	9994	2XI	Schenectady, N. Y.
30.6	9798	NAL	Washington, D. C.
31.48	9530	W2XAF	Schenectady, N. Y.
35.03	8560	WQO	Rocky Point, N. Y.
37	8130	6XI	Bolinas, Calif.
37.43	8010	WLC	Rogers, Michigan.
40	7496	NAS	Pensacola, Fla.
40	7496	NAJ	Great Lakes, Ill.
40	7496	NPG	San Francisco, Calif.
41.3	7260	NKF	Anacostia, D C.
42	7139	5XH	New Orleans, La.
43.02	6970	WIZ	New Brunswick, N. J.
44	6814	WQO	Rocky Point, New York
44	6814	KZA	Los Angeles, Calif.
44	6814	KZB	Los Angeles, Calif.
49	6119	WHD	Sharon, Penna.
49.02	6120	WABC-W2XE	Cross Hassock Bay, L. I.
49.83	6020	W9XF	Chicago, Ill.
49.9	6040	W2XAL	Coytesville, N. J.
50	5996	WBZ	Springfield, Mass.
51.5	5822	WQN	Rocky Point, New York
54.4	5511	NKF	Anacostia, D. C.
54.5	5501	WQN	Rocky Point, New York
56	5354	KFKX	Hastings, Nebr.
56	5354	1XAO	Belfast, Maine
57	5260	WGN	Rocky Point, New York
58.79	5100	KDKA	East Pittsburgh, Pa.
59	5082	KDC	Casper, Wyo.
62.5	4800	W8XK	East Pittsburgh, Pa.
63	4759	KDKA	East Pittsburgh, Pa.
67	4475	8XS	East Pittsburgh, Pa.
68.4	4383	WRB	Miami, Fla.
68.4	4383	WRP	Miami, Fla.
68.4	4383	WFV	Põinciana. Fla.
70	4283	2XAO	Belfast, Maine
70	4283	KFZP	San Francisco, Calif.
70.5	4253	NQG	San Diego, Calif.
71.3	4205	NKF	Anacostia, D. C.
71.7	4182	NPL	San Diego, Calif.
74	4052	WIR	New Brunswick, N. J.
74.77	4010	WLC	Rogers, Michigan
76	3945	NAJ	Great Lakes, Ill.
77.4	3874	NFV	Quantico, Va.
80	3748	NEL	Lakehurst, N. J.
81	3701	NPQ	San Francisco, Calif.
81.5	3679	NKF	Anacostia, D. C.
84	3569	NKF	Anacostia, D. C.

TEST QUESTIONS

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.

Number your answers 37 and add your **Student Number.**

1. Draw a circuit of a 250 watt transmitter for short wave communication, naming each piece of apparatus.

2. Why are crystal oscillators used in transmitters?

3. What type of oscillating crystal is used for commercial practice?

4. Draw a diagram showing how a crystal oscillator is connected in a circuit.

5. Explain why a grid milliammeter is used in the last stage of the push-pull amplifier, Figure 8.

6. How is the antenna system tuned in Figure 8?

7. Draw a circuit showing a bank of four 50 watt modulators.

8. What is the purpose of using the two choke coils X_1 and X_2 in Figure 10?

9. Draw a diagram of a typical keying system in a 5 Kw. 15 meter transmitter.

10. Explain what happens when the key is pressed down in this circuit.

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