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By C. R. Runyon, Jr.

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Description of a Short-Wave Station

Details of the 500-Watt Crystal-Controlled Transmitter at 2 AG—The Four-Tube Short-Wave Receiver—A Radio Club of America Paper

By C. R. RUNYON, JR.

THE TRANSMITTER

THE short-wave crystal-controlled transmitter at radio station 2 AG employs seven transmitting tubes in the following combination: One UX-210 as a crystal oscillator tube; two UX-210's in the first intermediate push-pull amplifier; two UV-203-A's in the second intermediate push-pull amplifier; two UV-204-A's in the push-pull radio-frequency amplifier.

A schematic diagram of the crystal oscillator stage, together with its power supply, is shown in Fig. 1. The crystal is connected between the grid and filament terminals of the UX-210 crystal oscillator tube. The crystal used has a fundamental frequency of 3665 kc. (81.9 meters), so, in view of the fact that this station transmits on the 80-meter band, there are no frequency multiplier stages between the crystal oscillator and the antenna system, straight amplification being all that is required.

While we are discussing the grid circuit of the oscillator, it is logical that we consider the system of modulation that can be employed when it is desired, as modulation is effected in this circuit.

When the transmitter is in operation, the chopper disc (shown in Fig. 1) rotates at such a speed that it opens and closes the circuit through the primary winding of the modulation transformer (T_1) at an audio-frequency rate. The shunt across the chopper contacts is removed when the set is in operation, by virtue of the fact that relay No. 5 is energized at that time.

When the circuit is closed through the chopper contacts, a direct current flows through the primary winding of the modulation transformer (T_1), this current being supplied by a 6-volt storage battery, and being limited by the 50-ohm rheostat (R_4) and the resistance of the primary winding in question.

Every time the circuit through the chopper contacts is closed, we get a direct-current flow through the primary winding of (T_1), which sets up a field which cuts through the secondary winding of (T_1) and produces a potential "kick" across it. This voltage "kick" is passed on to the terminals of the crystal oscillator, and subsequently to the grid of the first amplifier tube. The effect of each one of these "kicks" is to change the frequency, right at the source; hence, the frequency of the transmitted signals is also changed.

The amount of this change, as near as the ear can tell, is between 500 and 1000 cycles. Thus, by this novel method of modulation, the frequency of the transmitted signals is changed through a band 500 to 1000 cycles wide, at an audio-frequency rate (the rate of make and break at the chopper contacts).

Plate voltage is supplied to the crystal oscillator tube from a full-wave rectifier system which employs two UX-216-B rectifier tubes. This plate supply lead is prevented from offering a radio-frequency shunt across the crystal oscillator tube output circuit by means of the radio-frequency choke coil RFC_2 which is inserted in series with it. A d.c. milliammeter (0-100 mils.) is connected in series with this plate lead to indicate the plate current drawn by this tube.

The blocking condenser C_7, which has a capacity of 0.002 mfd., bypasses radio-frequency energy, but prevents the coil L_1 from short-circuiting the d.c. plate supply.

The output circuit of the crystal oscillator tube is tuned to 80 meters by means of the 0.0005-mfd. variable condenser C_8 and the coil L_1. The "0 to 3" thermo-ammeter, A_2, indicates the radio-frequency current circulating in the output circuit of the crystal oscillator tube.

The filament of this tube is supplied with alternating current from one of the low-voltage windings on the Acme 200-watt power transformer, T_2. This filament current is controlled by means of the 2-ohm General Radio rheostat, R_2. C_4 and C_5 are 0.002-mfd. radio-frequency bypass condensers.

The filaments of the two UX-216-B rectifier tubes are heated by means of current from another low-voltage winding on transformer T_2. The plates of the rectifier tubes are supplied with high-voltage alternating current from a secondary winding of T_2 which has a potential of 550 volts (r. m. s.) between its extremities and its mid-tap. The filament current to the rectifier tubes is limited by the General Radio 2-ohm rheostat, R_3.

In the rectifier filter circuit there are two 2-mfd. condensers and one 10-mfd. condenser for smoothing, designated as C_1, C_2, and C_3 respectively. Two 30-henry chokes, X_1 and X_2, are also used in this filter circuit. The high-voltage direct-current output of this No. 1 rectifier can be switched either to the plate of the crystal amplifier tube, or the plates of the tubes in a receiver, by means of the switch S_1.

The output voltage of the rectifier can be controlled to a certain extent by means of the 30-ohm rheostat R_1. When the master control switch at the operator's desk is thrown to the "send" position, relay No. 3 closes, closing the circuit through the primary winding of the power transformer, T_2, and thus lighting the filament of the crystal oscillator tube and applying plate potential to the crystal oscillator tube. Relay No. 5 also closes when the master control switch is thrown to the "send" position, and the resultant action of this relay is to remove the shunt across the chopper contacts.

When the master control switch is returned to the "receive" position, the circuit to the chopper motor is opened and it starts to slow down. The main function of relay No. 5 is to place a shunt across the chopper contacts when the master control switch is in the "receive" position, so that the make and break of the contacts will not cause Q R M (interference) when the chopper motor is slowing down.

Energy is transferred from the crystal oscillator tube output circuit to the input circuit of the first intermediate amplifier (the latter being push-pull, using two UX-210's), by means of the inductive coupling between the two coils, L_1 and L_2, the former being in the output circuit of the crystal oscillator, and the latter being in the input circuit of the first intermediate push-pull amplifier.

The mid-tap on the coil L_2 is connected to ground through a 45-volt bias battery, which applies a negative bias to the grids of both of the UX-210 tubes in the first intermediate amplifier. There is a 0.002-mfd. radio-frequency bypass condenser across this bias battery.

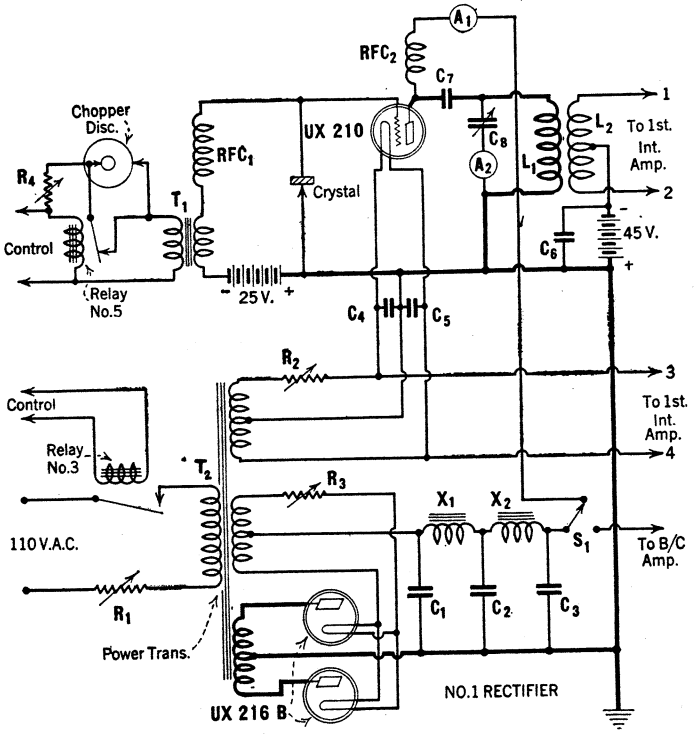


FIG. 1

FIRST INTERMEDIATE AMPLIFIER AND ITS POWER SUPPLY

A SCHEMATIC diagram of the first intermediate amplifier is shown in Fig. 2. The attendant rectifier system is also shown in Fig. 2.

Midget, five-plate, neutralizing condensers are connected from the grid of one tube to the plate of the other in this stage of amplification, to neutralize the feed-back effect due to the inter-electrode capacity of the amplifier tubes used. This is an application of the "bridge" method of neutralization. For instance, when C_1 is adjusted to a value of capacity equal to the plate-grid capacity of the UX-210 whose grid is connected to No. 1 terminal in Fig. 2, the grid of the tube in question is at ground potential as far as the radio-frequency energy in the output cir-

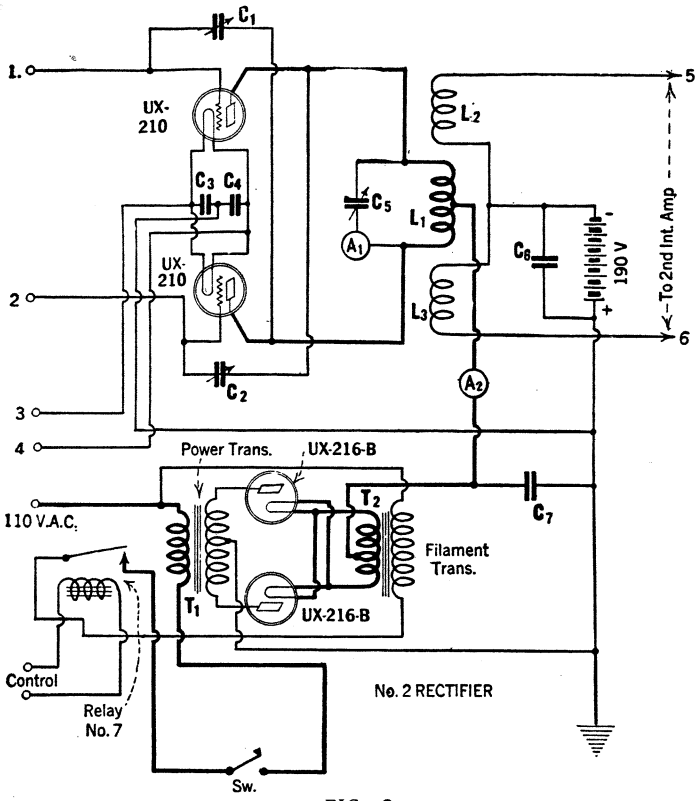


FIG. 2

cuit of this amplifier stage is concerned. Therefore, since the filament of this tube is metallically connected to ground, there can be no application of radio-frequency voltage to the grid of the tube in question, due to the radio-frequency energy in the output circuit of this amplifier stage.

The filaments of these two amplifier tubes are supplied with energy from the oscillator filament winding on the power transformer in the No. 1 rectifier assembly.

The output circuit of this stage of amplification is tuned by means of the coil L_1 and the 0.0005-mfd. variable condenser, C_5. The radio-frequency current flowing in this tuned circuit is indicated by the "0 to 5" thermo-ammeter, A_1.

The plate potential is supplied to the midpoint of the coil L_1, and the plate current is indicated by the 0 to 150 mil. meter (A_2). The source of this high-voltage d. c. supply is the No. 2 rectifier system. This rectifier employs two UX-216-B rectifier tubes which receive their plate supply from the high-voltage secondary winding of a step-up transformer, T_1.

A separate filament transformer is used to supply filament heating energy to the two rectifier tubes used, due to the fact that keying is effected by opening and closing the circuit through the primary winding of the power transformer, T_1, which removes and applies, respectively, high-voltage rectified a. c. to the plates of the two tubes in this amplifier stage.

If the filaments of the tubes in this No.2 rectifier were energized from a low-voltage winding on the transformer T_1, keying could not be satisfactorily effected, due to the time lag involved in bringing the rectifier tube filaments up to normal operating temperature, once the circuit through the primary winding of the transformer is closed.

When the master control switch is thrown to the "send" position, relay No. 7 closes, thus closing the circuit to the primary winding of the high-voltage transformer T_1, this circuit being under the control of the transmitting key.

Radio-frequency energy is induced into the input circuit of the second intermediate amplifier by means of the inductive coupling between L_1 in the output circuit of the first intermediate amplifier and L_2 and L_3 in the input circuit of the second intermediate amplifier.

The mid-point between the coils L_2 and L_3 is connected to ground through the 190-volt bias battery which maintains a negative bias on the grids of the two UV-203-A tubes in the second intermediate amplifier stage. This bias battery is bypassed by the radio-frequency bypass condenser, C_6

SECOND INTERMEDIATE AMPLIFIER

THE schematic diagram of this stage of amplification is shown in Fig. 3. The "bridge" method of neutralization is used in this amplifier stage and is effected by means of the two neutralizing condensers C_1 and C_2. The output circuit of this push-pull amplifier is tuned by means of the coil L_1 and the condenser C_5. The circulating current in this tuned circuit is indicated by the "0 to 10" thermo-ammeter, A_1.

The filaments of these two 50-watt tubes are supplied with filament heating energy from a separate transformer T_1, this current being controlled by means of the rheostat R_1. The plate supply for these two tubes is obtained from a 2000-volt d.c. generator, a plate resistor, R_2, functioning to drop the plate voltage from 2000, at the generator source, to 1000 volts at the plates of the 50-watt tubes in this stage of amplification. There is a 0.002-mfd. bypass condenser from the low side of R_2 to ground.

When the master control switch is closed, it operates relay No. 4, which closes the circuit through the primary winding of the filament transformer T_1 for the two 50-watt tubes in this second intermediate amplifier stage.

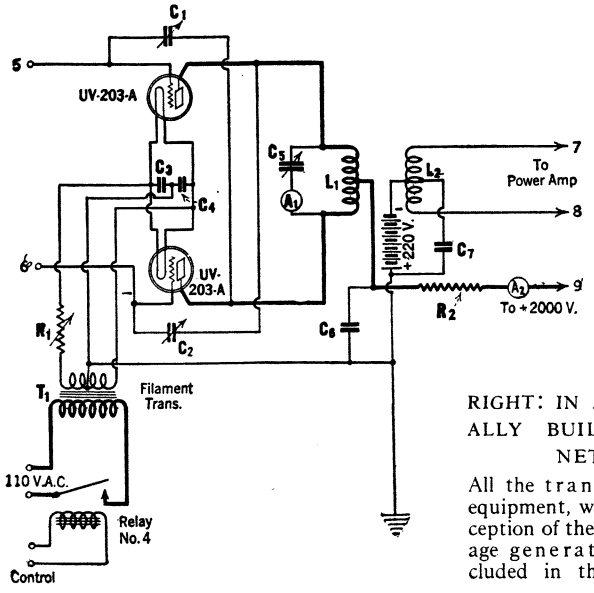
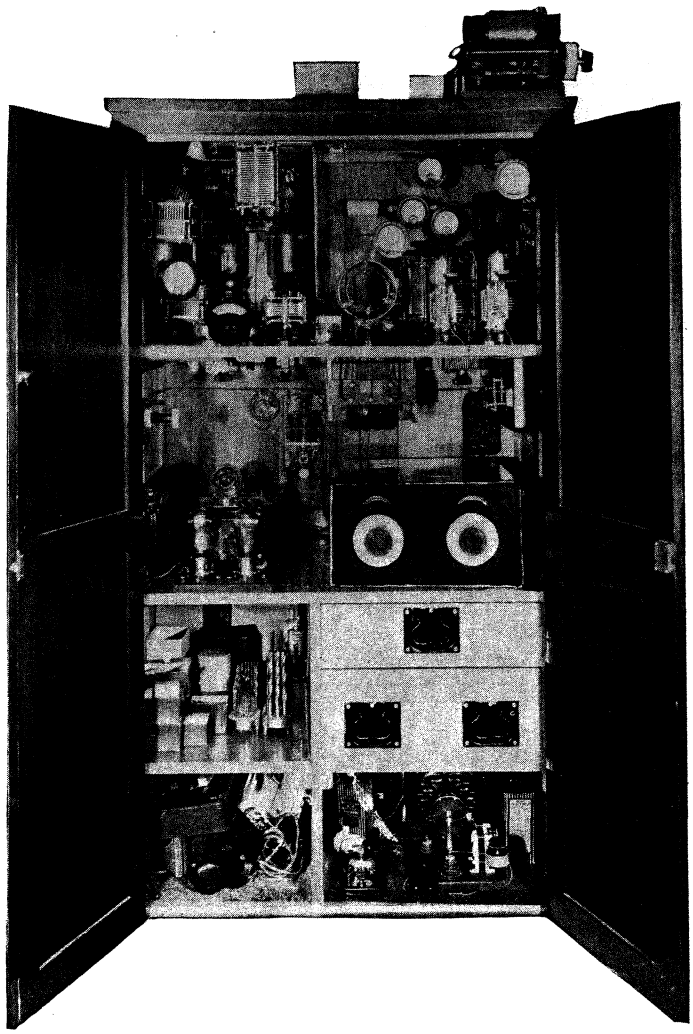


FIG. 3



RIGHT: IN A SPECIALLY BUILT CABINET

All the transmitting equipment, with the exception of the high-voltage generator, is included in the cabinet

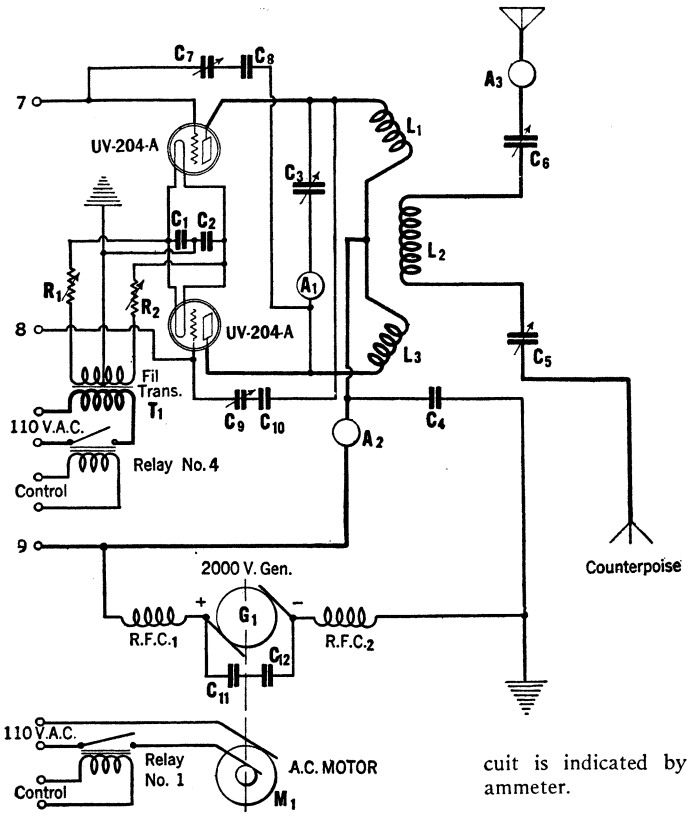


FIG. 4

The radio-frequency energy in the output circuit of this stage of amplification is induced into the input circuit of the succeeding stage, which is also push-pull, by means of the inductive coupling between the coil L_1 in the output circuit of the 50 watters, and the coil, L_2, in the input circuit of the power amplifier stage.

The mid point of the coil L_2 is connected to ground through a 220-volt bias battery, and, since the extremities of L_2 are connected to the grids of two UV-204-A 250-watt power tubes, the grids of the tubes in question are held 220 volts negative. There is a radio-frequency bypass condenser, C_7, across this bias battery.

POWER AMPLIFIER AND ITS POWER SUPPLY

THE schematic diagram of the power amplifier stage of amplification, its power supply, and the antenna system at station 2 AG, is shown in Fig. 4.

Filament heating energy for the two UV-204-A tubes in this stage of amplification is supplied from a separate step-down transformer, T_1. The filament current is controlled by means of two rheostats, R_1 and R_2.

Here again, the "bridge" method of neutralization is used, and is effected by neutralizing condensers, C_7 and C_9. The condensers C_8 and C_{10}, which are in series with the neutralizing condensers, are radio-frequency bypass condensers, and simply function to cut down the voltage drop across the neutralizing condensers and thus prevent the possibility of their arcing over.

The power amplifier output circuit is tuned by means of the coils L_1 and L_3 and the variable condenser C_3. The circulating current in this tuned circuit is indicated by the "0 to 20" thermo-ammeter. The mid-point between the two plate coils is connected to the positive 2000-volt terminal of the high-voltage d. c. generator through the "0 to 1000" milliammeter, A_2.

The high-voltage plate generator is driven by an a. c. motor which operates on 110 volts. When the master control switch is closed, relay No. 1 operates and closes the 110-volt circuit to the motor of the high-voltage motor generator set. Relay No. 4 also operates when the master control switch is closed, closing the circuit through the primary winding of the filament transformer T_1 which supplies filament heating energy to the two 250-watt tubes in this stage of amplification.

The energy in the output circuit of the power amplifier is fed into the antenna system by means of the inductive coupling between the power amplifier output coils, L_1 and L_3, and the antenna coil, L_2. A counterpoise is used in the antenna system at 2 AG and the whole arrangement is tuned by means of the variable condensers C_5 and C_6. The current in the antenna circuit is indicated by the "0 to 5" thermo-ammeter.

COMPLETE TRANSMITTER ASSEMBLY

A PHOTOGRAPH on page 172 shows the complete transmitter assembly at station 2 AG. The entire equipment is included in a cabinet built for the purpose, with the exception of the high-voltage generator which is located in the basement.

The chopper unit is located in the lower right-hand corner of the cabinet. The crystal oscillator and first intermediate amplifier are located on the middle shelf behind a shield painted black. No. 2 rectifier is just to the left of this black box, and rectifier No. 1 is located on the top of the cabinet.

The second intermediate amplifier is located in the upper right corner, and the power amplifier is to the left of the latter, in the upper left-hand corner of the cabinet. The operators' desk is just to the left of this cabinet.

A schematic diagram of the transmitter is shown in Fig. 5. Note that the diagrams of the various stages have given the complete details concerning each stage, whereas the diagram of the entire transmitter does not include the control relays or the power supply units.

CONTROL RELAY SYSTEM

WHEN the operator at station 2 AG closes the master control switch to the "send" position, there are a great many actions that take place. This can best be explained by a study of Fig. 6, which shows the control relay system alone.

When the single-pole single-throw switches, S_1 and S_2, are closed, the control relays are under the control of the master switch. The pilot lamps are lighted when S_1 and S_2 are closed. The former is in an 8-volt circuit and the latter is in a 6-volt circuit.

With the master control switch thrown to the "transmit" position ("T" in the diagram), the following actions take place:

(A). Relay No. 2 closes. Relay No. 1 is thrown on the 110-volt a. c. line and it closes. When relay No. 1 closes, 110 volts a. c. is applied directly across the terminals of the a. c. motor which drives the high-voltage d. c. generator for the plates of the two 50 watters, and the plates of the two 250 watters.

(B). Relay No. 3 closes. The 110-volt a. c. circuit is closed through the primary wind- of the power transformer in the No. 1 rectifier assembly.

(C). Relay No. 4 closes. An a. c. voltage of 110 is applied to the primary winding of the filament transformer for the two UX-216-B rectifier tubes in No. 2 rectifier.

A similar voltage is applied to the primary winding of the filament transformer for the two UV-203-A tubes in the second intermediate amplifier circuit.

A voltage of 110 is applied to the primary winding of the filament transformer for the two UV-204-A tubes in the power amplifier.

One hundred and ten volts a. c. is applied to the terminals of the motor that drives the chopper disc.

(D). Relay No. 5 opens. The shunt across the chopper contacts is removed.

(E). Relay No. 6 closes. The terminals of the headphones are connected to the output of the monitor receiver which allows the operator to hear the quality of his outgoing signals.

(F). Relay No. 7 closes. The circuit from the 110-volt a. c. supply, through the primary winding of the plate transformer for the No. 2 rectifier, is closed.

(G). Relay No. 8 closes. The A battery circuit to the filaments of the tubes in the monitor receiver is closed.

(H). The 8-volt control battery is connected in series with the modulation transformer and the chopper contacts.

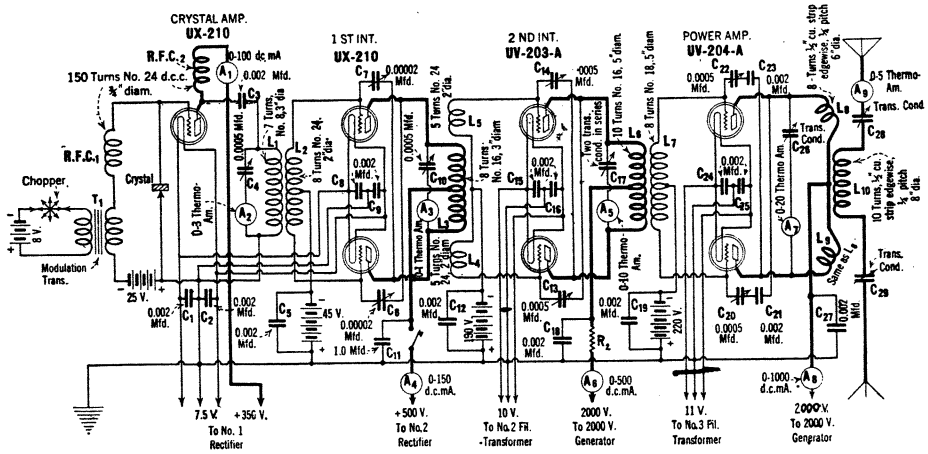


FIG. 5

A diagram of the complete 500-watt transmitter, 2 AG. The control relays and power supply equipment has been omitted in the diagram. This diagram combines Figs. 1, 2, 3, and 4, but the lettering of the parts is different

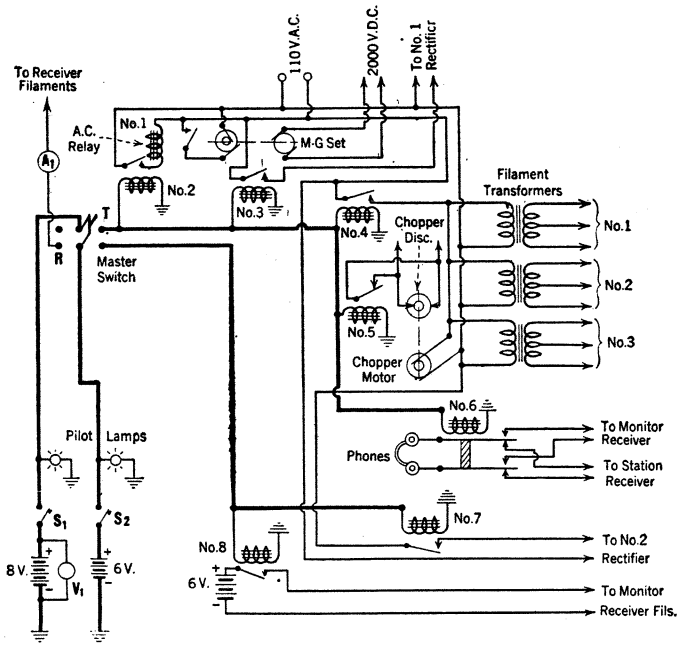


FIG. 6

The control relay system at 2 AG. Filament Transformers: No. 1 supplies filaments of rectifier tubes in No. 2 rectifier for the first intermediate amplifier; No. 2 for filaments of the second intermediate amplifiers (UV-203-A's); No. 3 for filaments of power amplifier tubes (UV-204-A's). The functioning of this control relay system is explained in the text on page 173

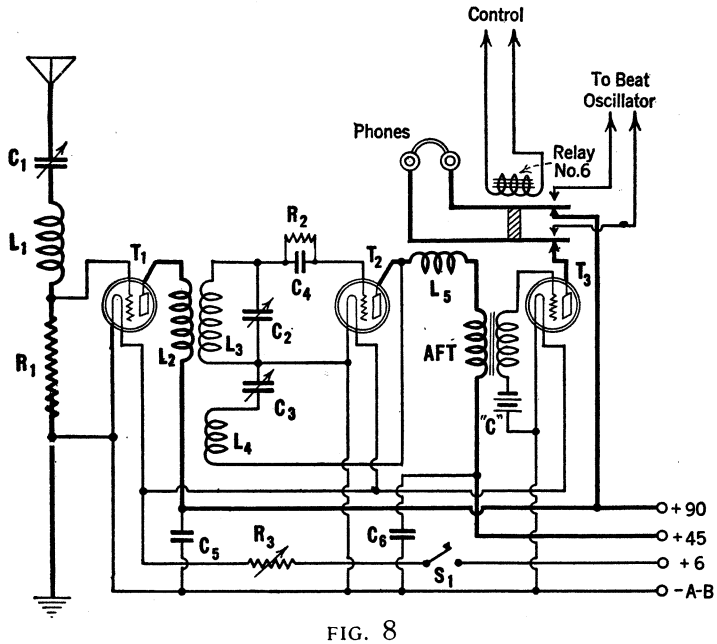


FIG. 8

The short-wave receiver. The following are the constants of the circuit: AFT, audio-frequency transformer (ratio 6-1); L_1, 50 turns No. 16 d. c. c. 3 inches diameter; L_2, 6 turns No. 16 bare wire, spaced wire width, 3 inches diameter; L_3, 23 turns No. 16 bare wire, spaced wire width, 3 inches diameter; L_4, 4 turns No. 16 bare wire, spaced wire width, 3 inches diameter; L_5, 175 turns No. 34 d. s. c. 1 inch diameter; C_1, 0.0005-mfd. variable condenser; C_2, 0.000075-mfd. variable condenser; C_3, 0.00025-mfd. variable condenser; C_4, 0.00025-mfd. fixed condenser; C_5, 0.1 mfd. fixed condenser; C_6, 0.1-mfd. fixed condenser; R_1, 50-ohm fixed resistance; R_2, 3-megohm grid leak; R_3, 6-ohm rheostat; S_1, Filament control switch (on master control switch); relay No. 6, 6-volt, d. p. d. t. The coils given above are for the 80-meter band. Those used for the 40-meter band are as follows: L_3, 10 turns No. 16 bare wire, spaced wire width, 3 inches diameter; L_4, 3 turns No. 6 bare wire, spaced wire width 3 inches diameter.

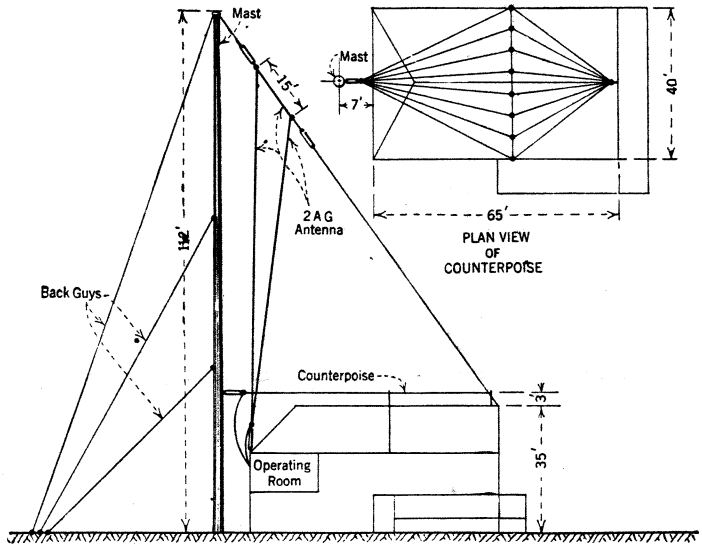


FIG. 7

The antenna system at 2 AG.

When the master control switch is thrown to the "receive" position, which is indicated by "R" in Fig. 6, all the control relays, with the exception of relay No. 5, open, and the contacts of this latter relay close, thus shunting the chopper contacts during the period that the chopper motor is coming to a stop. It is well to note that the filaments of the short-wave receiver are turned on by putting the master control switch in the "receive" position, and the headphones are disconnected from the output of the monitor receiver, and connected to the output of the short-wave receiver, this latter action being taken care of by relay No. 6.

THE ANTENNA SYSTEM

A DIAGRAM of the antenna system is shown in Fig. 7. The antenna consists of two verticals which are connected to the extremities of a very short flat-top, the latter being an active part of the antenna system, which is insulated from a guy wire which extends from the top of a 112-foot mast to the top of the roof at the front of the house. The mast itself has three sets of back guys, this mast being about 18″ in diameter at the base and 6″ in diameter at the top.

The counterpoise is arranged on the top of the roof of the house, as shown in the plan view in the upper right corner of Fig. 7.

SHORT-WAVE RECEIVER

THE schematic diagram of the short-wave receiver used at 2 AG is shown in Fig. 8.

The first tube in this receiver, T_1, is simply a coupling tube. The antenna is connected to the grid of the receiver through the variable 0.0005-mfd. condenser C_1 and the coil L_1. There is a 50-ohm resistor, R_1, between the grid and filament of the coupling tube, and the filament is grounded.

The radio-frequency energy in the output circuit of the coupling tube is passed on to the input circuit of the detector tube through the medium of the inductive coupling between the coils L_2 and L_3, the latter being tuned to the incoming signals by means of the 0.000075-mfd. variable tuning condenser C_2

Regeneration is accomplished by means of the inductive coupling between the feed-back coil L_4 and L_3, and the tuning is effected by the variable condenser C_3. The function of C_3 is to limit the amount of radio-frequency current flowing in the feed-back circuit, hence also limiting the amount of regeneration.

L_5 is a radio-frequency choke and AFT is the first audio-frequency interstage transformer. Only one stage of audio-frequency amplification is shown on the diagram, although in the actual receiver there are two stages.

C_5 is both a radio- and an audio-frequency-bypass condenser, and C_6 is an audio-frequency bypass condenser.

MONITOR RECEIVER

THE monitor receiver is just an ordinary receiver which is tuned so that one of its harmonics beats with the fundamental frequency of the transmitter. In this way it is possible to monitor the outgoing signals by picking up a small amount of signal energy without danger of blocking the tubes in the receiver.

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The last meeting of the Radio Club of America for the season was held on June 8th when Mr. Lloyd Espenscheid, Research Engineer of the American Telephone and Telegraph Company read his paper on "Factors Governing the Service Area of the Broadcast Transmitting Station." The next meeting will be called in September.

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