group of medium-power tubes is rated at 35 to 50 watts output; a third group carries a nominal rating of 100 watts, and so on. Obviously, then, the first decision the amateur has to make in the choice of a transmitting tube is that of the power output he wants. The table of transmitting tubes gives the important characteristics and operating ratings of the tubes most suitable for use as radio-frequency oscillators and power amplifiers.

The design of almost every item in the transmitter will be influenced by the tube with which it is to be operated. The rating of the transformers, the current-carrying capacity of the filter, the rating of the fixed condensers, the type of variable condensers and the design of the inductances, all will depend upon the power and voltage rating of the tube. The amateur usually uses a low-power tube for his first transmitter. This practice is a good one. The use of low power enables the transmitter to be built cheaply and yet provides full opportunity for the amateur to gain a knowledge of the operation and handling of a transmitter. Many of the most experienced amateurs actually prefer a low-power transmitter of this type, knowing that they can readily communicate over many thousands of miles under good conditions. The distance that can be covered by a transmitter is, in fact, not very much dependent upon the power output. Even a receiving tube in the hands of an experienced amateur can send across the world when conditions are very good. The higher-powered transmitters can send no farther than this but they have the advantage of being able to put signals into far distant countries with greater reliability and readability.

Planning the Simple Transmitter

Before going on to the considerations involved in the construction of the more complicated oscillator-amplifier transmitters, we shall show some examples of the type of construction which has been found most satisfactory for low-power self-controlled oscillators. The use of oscillator transmitters is, in fact, confined almost entirely to low-power work (50 watts output or less) in present-day amateur radio; almost without exception the transmitters using the larger varieties of tubes are of the oscillator-amplifier type, generally with crystal control. Because the oscillator transmitter is the simplest and therefore the easiest to build and operate, most beginners build a transmitter of this type for their first attempt at radio transmission.

There is a splendid field for the exercise of thought and originality in the arrangement of the apparatus of the transmitter. The shortness of leads and the placement of the coils and condensers with respect to the other apparatus are matters of such importance that the amateur will always be rewarded for time spent in consideration of the problem. In the pages that follow some examples of satisfactory layouts will be given. These will serve to give a general idea of how the transmitter can be arranged. However, they are not the acme of perfection; neither are they applicable to all types of apparatus. The use of even a different variable condenser than that shown in any one of the examples — a condenser with its terminals in a different place — may make some entirely different lay-out preferable.

Most of the transmitters to be described are baseboard-mounted with all the apparatus exposed and readily accessible for adjustment or experiment. If desired, the apparatus can be mounted on a baseboard and a vertical panel in a manner somewhat similar to the receiver. Unless the apparatus is arranged with great care, however, this type of construction is likely to mean a sacrifice of convenience in making alterations and adjustments.

Building a Transmitter

The construction of a simple transmitter can be accomplished in the shortest time and with the least difficulty by mounting the apparatus on a baseboard in somewhat the manner shown in the illustrations. We will use this self-controlled self-excited transmitter as an example and describe it in detail. If the reader studies the circuit diagram, the photographs and the description carefully he will find that the transmitter is even simpler than it looks. If he understands just what it is all about he will find it easier to modify the arrangement to suit the particular apparatus at his disposal.

This transmitter is perhaps the simplest and most nearly fool-proof ever designed. It contains the very minimum of parts and is therefore extremely low in cost. The construction is in no way complex and the adjustment is easily accomplished by even the inexperienced operator. The circuit is a modification of the popular tuned-grid tuned-plate arrangement. Despite its simplicity, the set has excellent frequency stability and efficiency, comparing favorably with more complicated arrangements.

The frequency is determined by the tuning of the plate tank circuit and the excitation is dependent on the constants of the grid circuit. Since one excitation adjustment is satisfactory over a considerable range of plate-tank tuning, it is possible to use a fixed coil in the grid circuit for each amateur band. An antenna coupling coil is provided in the set but an external antenna tuning condenser (perhaps two of them) will usually be found necessary. The set is designed to use a Type 10 tube with a 500-volt d.c. plate supply and a 7.5-volt a.c. filament supply, a Type 45 tube with a 350-volt d.c. plate supply and a 2.5-volt a.c. filament supply, or a Type 01-A tube with a 135-volt d.c. plate supply and a 6-volt d.c. filament supply.

Construction of the Set

The schematic wiring diagram is given in Fig. 704, together with the constants, and the photographs show how the set looks when constructed. The layout chosen is one which allows short r.f. leads.

The baseboard is 12½ inches long by 10 inches wide. Two porcelain stand-off insulators are mounted at one end, as shown in the photographs, to support the plate coil, L_1. These insulators should be placed 4½ inches apart between centers. This mounting is very solid mechanically, and allows easy changing of coils. The tuning condenser C_5, in this case a 21-plate Cardwell, is mounted on small brass angles. Connections between the condenser and the coil are made by pieces of copper tubing, since the leads in the tank circuit must be as heavy as the inductance itself. The connection to the insulator at the rear of the baseboard should be from the rotary plates (the condenser frame); that to the front insulator goes to the stationary plates.

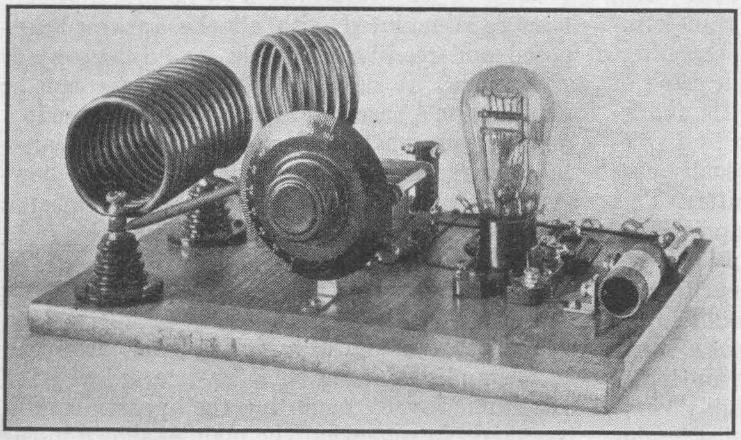

FIG. 703 — THE LOW-POWER SINGLE-TUBE TRANSMITTER

The plate tank circuit is at the left. The grid coil, leak and grid condenser are to the right of the Type 10 tube. The antenna coil is shown swung away from the plate coil to give loose antenna coupling.

The plate by-pass condenser, C_2, is mounted close to the tuning condenser on the baseboard. The radio-frequency choke, L_4, is just behind it. The filament by-pass condensers, C_3, are directly behind the tube socket. The purpose of these condensers is to provide an easy path for radio-frequency currents flowing to the filament of the tube, which would otherwise have to go through the resistor R_1. When the filament of the tube is heated from alternating current the "center-tap" resistor is necessary to avoid having the alternating voltages on the filament reach the grid, for this would cause modulation or "ripple" on the transmitted signal. The voltage at the leads to the filament is constantly changing at the 60-cycle supply frequency but the voltage at the center point of the resistor R_1 is constant. Another method of accomplishing the same result is to use a center tap in the filament-supply winding of the transformer. The center-tap resistor arrangement is sometimes preferable, however, since it permits the use of a filament rheostat in the secondary of the filament transformer instead of the primary. Rheostats for the secondary winding are more readily available than the other type.

The grid condenser, C_4, and leak, R_2, are to the right of the filament by-pass condensers. The condensers in this set are mounted flat by means of machine screws running up through the baseboard. The filament center-tap resistor, R_1, is mounted directly on top of the filament by-pass condensers.

All connections are run to the rear of the board where they terminate in Fahnestock clips. From right to left in the photograph, the first pair of clips is for antenna or feeder connections, the second for "plus" and "minus" high voltage, the third for filament supply and the fourth pair for the key. The wiring of the whole set is quite simple, and in case it is to be duplicated no difficulty should be experienced in following the diagram and photographs.

The plate coils, L_1, are ¼-inch

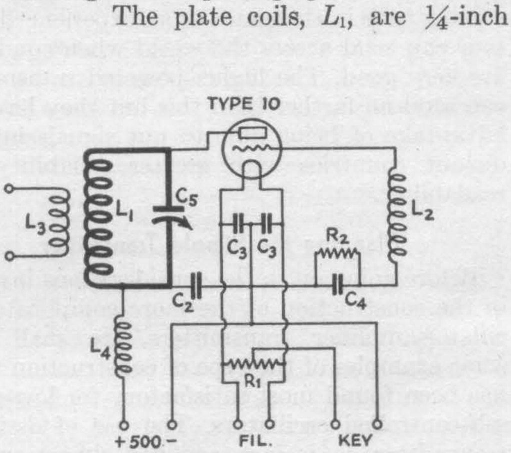

FIG. 704 — THE CIRCUIT OF THE TRANSMITTER

L_1, L_2 and L_3 — Plate, grid and antenna coils. The specifications are given under the illustration of the coils.
L_4 — A commercial "short-wave" receiving-type radio-frequency choke will do or one can be made by winding a two-inch length of half-inch tubing or wooden dowel with No. 38 d.s.c. or d.c.c. wire.
C_2 — 2000-μμfd. (.002 μfd.) mica fixed condenser, receiver type, if plate voltage does not exceed 500.
C_3 — 5000-μμfd. (.005 μfd.) mica fixed condenser, receiver type.
C_4 — 250-μμfd. (.00025 μfd.) mica fixed condenser, receiver type.
C_5 — 500-μμfd. (.0005 μfd.) variable condenser. Any good receiving condenser will be satisfactory.
R_1 — Center-tapped resistor, 75 to 100 ohms total resistance.
R_2 — Grid-leak resistor, 10,000 ohms. Any small resistor rated at 5 watts or more will do.

Three General Radio or similar stand-off insulators will be necessary, as well as 8 Fahnestock clips, some miscellaneous small machine screws and nuts, and a few feet of bus wire.

soft copper tubing, wound around a pipe 2⅜ inches outside diameter. The ends of the coils are flattened in a vise and drilled to fit over the machine screws in the mounting insulators. The 3500-kc. coil should have the turns so spaced that when finished it will just fit on the insulators without having the ends bent out, as is done on the coils for the higher-frequency bands. The spacing between turns on the 7000-kc. coil is about 3/16-inch, and on the 14,000-kc. coil about ⅞-inch.

The grid coils, L_2, are wound with No. 30 d.c.c. wire on 2½-inch lengths of 1-inch tubing, which may be of Bakelite, paper, wood or any other of the common insulating materials. The coils should be given a coat of collodion or clear Duco varnish to maintain their characteristics. Two small brass angles serve both as connections and supports for these coils, the ends of the winding being brought out to small machine screws inserted at the ends of the coil forms.

The antenna coil, made in similar fashion to the tank coils, is mounted on an insulator immediately behind the tank condenser. Connection to the far end of this coil is made by means of a clip and a small piece of flexible wire. The coil may thus be swung away from the plate tank coil in order to vary the antenna coupling.

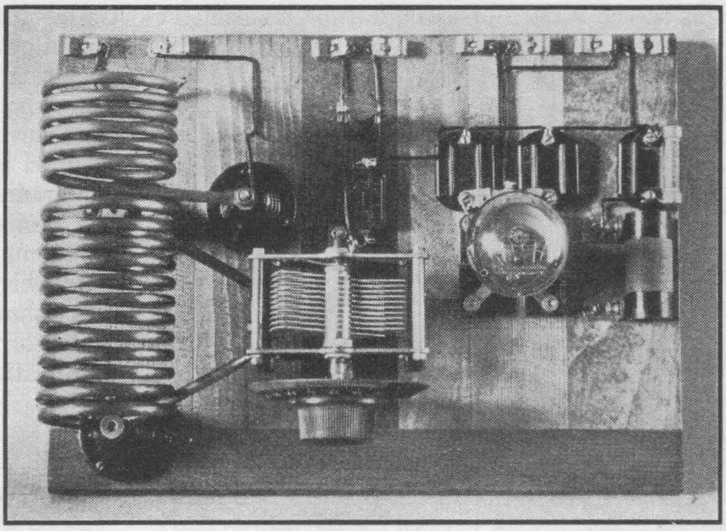

FIG. 705 — PLAN VIEW OF THE TRANSMITTER

The antenna coil, L_3, is to the rear of the plate inductance. The fixed condenser, C_2, and the radio-frequency choke are behind the tuning condenser, C_5. The two fixed condensers behind the socket are the filament by-pass condensers C_3. The filament center-tap resistor, R_1, is mounted on top of these condensers. The grid condenser, C_4, and grid-leak resistor, R_2, are to the right of the socket. The grid inductance, L_2, is in front of the grid condenser and leak. The connections to the Fahnestock terminals are explained in the text.

The 350-volt power supply described in Chapter Ten is an excellent one to use with this transmitter when the transmitter tube is a Type 45. This power supply may also be used to supply plate voltage for a Type 10 oscillator, in which case a separate 7.5-volt filament transformer for the 10 will be required. Alternatively, a 550-volt supply for a Type 10 tube may be built up from the information given in Chapter Ten. Most 550-volt power transformers intended for radio use have 7.5 volt filament-heating windings for the oscillator or amplifier and rectifier tubes, in addition to the plate windings. If a Type 01-A receiving tube is used, the plate supply can be a 135-volt "B" substitute or 135 volts of "B" batteries. Filament supply can be from a 6-volt battery, through a 6-ohm rheostat.

Tuning the Transmitter

The tuning of any transmitter is a matter of the greatest possible importance. The performance of even the best transmitter can be spoiled by the slightest misadjustment, and on the other hand almost any transmitter can be made to perform well by an amateur experienced in the work. Even the most experienced amateur, however, cannot tune the transmitter effectively unless he is able to listen to it as he adjusts the controls. The use of some sort of monitor to listen to the signal as the transmitter is tuned is essential. A detailed description of a simple monitor will be found in Chapter Six. It should be studied and a monitor built before any attempt is made to tune the transmitter.

In addition to the monitor, an extremely desirable aid to tuning is a "tuning lamp." This is nothing more than a flash-lamp bulb connected in series with a single turn of wire about two or three inches in diameter. In use, the turn of wire is coupled to the tank coil of the oscillator or amplifier and induced currents cause the lamp to glow. With practice, it soon becomes possible not only to detect the presence of r.f. current in the tank coil with such a lamp but also to gain a very useful idea of the amount of r.f. energy in the tank.

Before the transmitter can be tuned, it is obviously necessary to have available a suitable power supply, antenna and keying circuit. It will therefore be assumed that the reader will have studied the chapters on those matters and built the necessary equipment before attempting the all-important tuning process. It will be assumed, also, that the oscillator coils and leads have been made rigid; that the transmitter itself has been mounted in such a way as to escape vibration from keying and that the antenna and feeder wires have been made tight enough to avoid any swinging in the wind. We are ready to start tuning only after all these matters have been given attention.

Even then, we cannot expect to do a good job of tuning the set unless we have one or more meters. Of greatest importance is a plate current meter in the positive high voltage lead to the transmitter. Without such a meter, we have no idea of the power input and so are in danger of wrecking the tube and possibly other equipment right at the start. For a single tube transmitter like this one, the plate meter might well be a d.c. milliammeter reading to 100 ma. The other very desirable meter is a thermo-couple ammeter to be connected in the antenna or feeder circuit; its reading will give a good indication of *changes* of power in the antenna with changes in the transmitter adjustment. It is possible to dispense with the antenna meter and still tune the transmitter effectively if the operator is prepared to pay very careful attention to the plate meter and to make use of the tuning lamp.

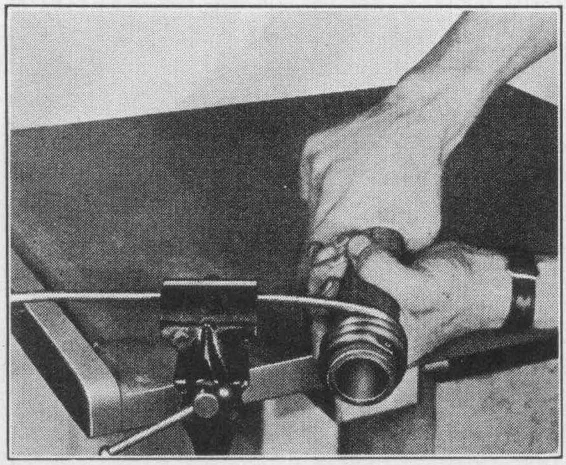

FIG. 706 — WINDING A COPPER-TUBING INDUCTANCE

One end of the tubing is held in the vise and the other is flattened out and bolted to the pipe used as a winding form. Pulling on the tubing and turning the pipe in the hands, the operator walks towards the vise. The turns should be wound as closely together as possible and spaced later.

Assuming that at least a plate meter is in the circuit, the first move is to switch on the filament supply, make certain that the tube lights, and then check the voltage at the filament terminals. Excessive filament voltage will soon ruin any tube. Then the antenna leads should be disconnected, the key opened and the plate tank tuning condenser set to approximately the correct position. If the constructional specifications have been followed closely, this setting will be with the rotor plates about four-fifths meshed for the 3500-kc. band; about three-quarters meshed for the 7000-kc. band; and about half meshed for the 14,000-kc. band. The antenna system should have been constructed to specifications for a frequency in one of the bands, preferably for about 3575 kc. in the 3500-kc. band.

Tuning for operation on the 3500-kc. band (with the 12-turn plate coil), set the condenser with the rotor plates four-fifths in, turn on the power supply and close the key. If the tuning lamp is now held near the front end of the plate coil the bulb should glow, indicating that the set is oscillating. The loop should not be held too close to the coil, however, because the bulb is likely to burn out. The frequency should now be checked with the frequency meter following the method described in the preceding chapter. If the frequency is outside the band, the transmitter should be retuned to a frequency inside the band.

During this process the plate current milliammeter should be watched to make certain that the plate current falls to a minimum as the plate tank is tuned to the desired setting. Should this minimum point occur at a frequency much lower than that desired, it is an indication that the grid coil has too many turns. If the minimum point occurs at too high a frequency, it shows that the grid turns should be increased. This trouble is not likely to happen, however, if the constructional specifications are followed carefully.

Coupling the Antenna

With the oscillator operating on the desired frequency, the feeder or antenna may be con-

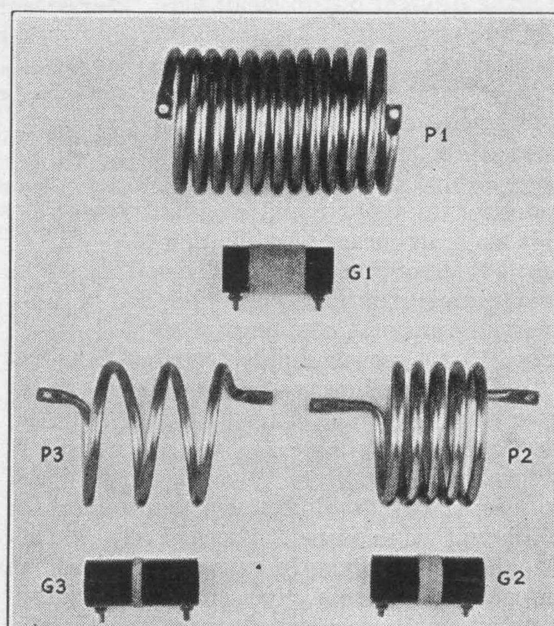

FIG. 707 — THE PLATE AND GRID COILS

A description of these coils is contained in the text, while the number of turns on each is given below.

Coil	Band	Turns
P-1	3500	12
P-2	7000	5
P-3	14,000	3
G-1	3500	60
G-2	7000	25
G-3	14,000	9

For the 1750-kc. band, a plate coil of 25 turns of No. 14 d.c.c. on a 3" diameter form with spacing between turns equal to the diameter of the wire; a grid coil of 150 turns on the same size form as the other grid coils. The number of turns on the grid coils may require some modification. Turns should be added or removed until the set operates stably and efficiently over the required frequency band.

The antenna coil is of 6 turns exactly similar to those used in coil P-1. A clip on this coil enables the best number of turns to be selected.

nected and the antenna coil swung at an angle of about 45 degrees to the plate coil. As the antenna or feeder condensers are tuned it will now be found that the plate current rises as the antenna comes into tune with the oscillator. Also it will be seen that while the tuning lamp bulb may glow brightly (when the loop is placed near the tank coil) with the antenna detuned, it will become dim as the antenna comes into tune and takes power from the tank. These effects of the rising plate current and the dimming tuning lamp are of the greatest assistance in tuning the antenna circuit when no antenna meter is available. With an antenna ammeter, of course, it is merely necessary to tune the antenna or feeder circuit for maximum meter reading in order to locate the point of resonance.

The next adjustment to be made is that of antenna coupling. It must be kept closely in mind that there is an optimum value of coupling which allows the greatest transfer of power from the tank circuit to the antenna. Closer coupling than this results in lowered efficiency and, in the case of the self-controlled self-excited transmitter, invariably destroys the quality of the transmitted signal. Excessive coupling usually can be detected by the existence of two settings of the feeder or antenna condensers at which the feeder or antenna current rises to a peak. In a transmitter of this type, the antenna coupling must always be less than the optimum value just mentioned. Experience has shown that it is a good plan first to get the optimum coupling for greatest output and then to reduce the coupling until the feeder or antenna current reads about 85 per cent of the first value. Then, the antenna or feeder circuit should be detuned until the current drops a further 10 or 15 per cent. These adjustments should only be made while listening to the signal on the monitor since the most unexpected things may happen to the quality of the signal and its frequency. The signal quality is usually better with the antenna circuit detuned on one side of resonance than on the other.

It is futile to give definite instructions with respect to the proper plate current since this depends so much on the plate voltage and on the manner in which the transmitter is adjusted. When the oscillator is operated at high efficiency, the input can be carried above the 350 volts and 60 ma. at which the Type 10 tube is rated. About the only practical procedure is to keep a careful watch for heating of the tube plate. Even a dull red plate is indication of excessive plate dissipation. The remedy is either decreased plate current or improved efficiency.

Using Two Tubes

If one wants more power output from the transmitter than one tube can give and yet does not wish to go to the expense of installing the next larger size of power tube, it is possible to use two tubes in parallel or push-pull to double the power output. Tubes connected in parallel have their plates, grids and filaments respectively connected together; the oscillatory circuits used with them are otherwise exactly the same as for one tube. The push-pull oscillator circuits correspond to the push-pull amplifier circuits so common in present-day broadcast receivers; that is, the tubes are in effect connected in series in both input and output circuits. Although the total power output is the same with either method of connection, in actual practice the push-pull arrangement is preferable for oscillator circuits at the high frequencies used by amateurs.

A Push-Pull Transmitter

Although two tubes are used, the design and layout of a push-pull transmitter is little more difficult or intricate than that of a single-tube set, as the accompanying photograph shows. This transmitter is intended to be used with either Type 45 or Type 10 tubes.

The circuit of the two-tube transmitter is the push-pull Colpitts, which has been found to be particularly effective for high-frequency work. This circuit is in fact "double-barrelled" — not only is it a good high-frequency oscillator circuit, but it can, with minor modifications, readily be converted into a push-pull amplifier should it be considered desirable later on to change the transmitter to the oscillator-amplifier type. Since every serious amateur sooner or later graduates to the more complicated — but equally more satisfactory — oscillator-amplifier transmitter, the construction of a transmitter using this circuit is actually economical of time and apparatus.

The chief distinguishing features of the circuit are the use of a split-stator tuning condenser, variable grid condensers, and a split tank coil, to which the antenna coil is coupled at a point of low r.f. potential. These features result in good oscillator efficiency and frequency stability, and reduce the possibility of radiation of harmonics. (A later section in this chapter discusses harmonic radiation in detail.)

Front and below-baseboard views of the transmitter are shown in Figs. 708 and 710. The circuit diagram is given in Fig. 709. All parts are mounted on a 11½-inch by 14-inch baseboard, on the bottom of which are 1½-inch-high cross pieces which make room for parts fastened beneath the base. The tube sockets are placed at each side of the tuning condenser with the grid and plate terminals facing the condenser terminals; this permits short leads and at the same time crosses the filament wiring, a device which is helpful in preventing modulation from the filament supply.

The two variable grid condensers, C_1, are mounted immediately in front of each tube. The grid leads are crossed, to give the push-pull connection, right at the terminals of the tuning condenser (terminals are available on both sides