FRANK C.

Jones

Radio Handbook

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World Radio History

Jones Radio Handbook

By

Frank C. Jones

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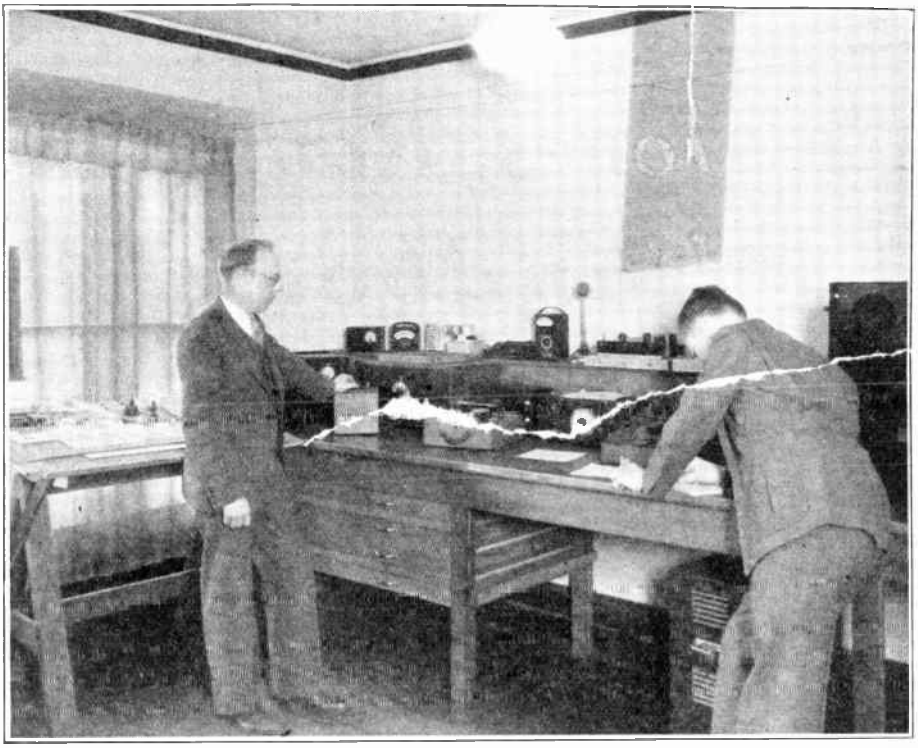


The Author - - - And the Laboratory

Equipment described in this Handbook is first conceived, then engineered, then designed, then constructed, if necessary then reconstructed again and again and, finally, when exhaustive tests under actual operating conditions both with local stations and with others in the far corners of the world have shown the worth of the conceptions they find their way into the pages of this Handbook.

The Third Edition of Your Handbook

TWO previous editions of this Handbook were produced in collaboration with a radio magazine publisher. Much of the data in these earlier issues was more or less a reprint of previously published technical magazine material. Many photographs and circuit diagrams were literally lifted from the pages of the magazine and transferred to the Handbook. Thus these earlier editions lacked the refreshing newness which is so evident in this the third edition. The author is no longer associated with a magazine publisher; he has written nothing for the pages of any magazine in recent months, for it was his desire to produce a book that would fill a long-felt want . . . a Handbook new and different.

Only the theoretical Chapters in this Handbook remain unchanged, for an Ohm is still an Ohm, the dots and dashes of the Continental Code are still memorized in the same tried-and-proven manner, and electrical and radio tests are not subject to drastic and sudden change. Yet, as you page through this edition of the Handbook, you will find many new thoughts even in those Chapters which previously left little to be desired from the average technical point of view. The Chapters that deal with Receivers, Exciters, Vacuum Tubes, Transmitters for Phone and C. W., Diathermy, Television, Ultra-High-Frequencies and Antennas are as new as tomorrow. Thousands of dollars were invested in new photographs and circuit diagrams alone.

Your particular attention is directed to the new Jones Multi-Band Crystal Oscillators which function at several frequencies from a single quartz crystal, and without buffer or doubler stages. The new Jones Receivers are far in advance of the times, some so simple in design and construction that even the inexperienced layman should have no difficulty in duplicating the performance of the engineer's model. Your listeners will enjoy a new thrill if you communicate with them by means of the new Jones crystal-controlled 5-meter transmitters. The author's 5-meter Exciter has already won wide acclaim among radio club members who were given a "preview" of the new device. The greatly enlarged Chapter on Antennas will help solve many of your difficult problems, particularly if you reside in congested areas.

The author has given all of his recent time to the engineering of equipment that will do a better job for you, at a lower cost. Only that which has withstood the rigid tests in the laboratory, followed by practical tests on the air under actual operating conditions, is found in the pages of this Handbook.

In the preparation of the text the author wishes to acknowledge gratefully the assistance he has received from Prof. F. E. Terman, Ralph R. Batcher, Arthur H. Halloran, Clayton F. Bane and D. B. McGown.

Chapter Contents

Chapter 1

Electrical Phenomena and Radio Theory

● A study of electrical or radio phenomena requires a knowledge of the electron theoretical conception of matter and energy. This theory assumes a scheme whereby very small particles of matter carrying electrical charges form the basic mechanism in electric conduction. These elemental units or electronic charges form the basis of the electron theory which has been universally accepted as the best means for coordinating present knowledge of electric phenomena.

In general, the smallest particle of matter which can exist alone is the atom. It consists of a heavy nucleus of one or more protons surrounded at planetary distances by an equal number of electrons. The outermost electrons revolve in elliptical paths around this inner nucleus. Every atom of matter has as many electrons as protons, and therefore the total number of positive and negative charges neutralize each other. This atomic system has been given the name of the *nuclear atom.* The charge retained in the nucleus of an atom is what designates its *weight,* while the attendant electrons revolving around the nucleus is that which determines the *atomic number.* Atomic numbers run from one to ninety-two, which are the ranges given to all the chemical elements.

To the electrons, or more properly to the negative electronic charges with corresponding positive charges on the protons, or positive nuclei, are ascribed properties of electric fields (the space surrounding magnets, electric charges and electric currents), considered as innate characteristics of each elemental unit. Electrons at rest produce electro-static phenomena, while electro-dynamic effects result from electrons in motion.

In all substances which are non-conductors of electricity, the electrons in the atoms are held permanently in place in fixed orbits about the nucleus, but in the atoms of all electrical conductors one or more of the electrons farthest out from the nucleus are attached rather loosely and may, by various means, be drawn away from the atom altogether. These are termed *free electrons.*

Electromotive Force

● Electricity consists of a movement of electrons through a conductor or conducting medium. To initiate the flow, a difference in electrical pressure (analogous to a hydrostatic head of water) or electromotive force must exist between the two ends of the conductor. To clarify these statements in an electronic exposition is without the scope of this text, but briefly the explanation is: The looseness with which the outer electrons are held in any atom is related to the electrical conductivity of the substance composed of this particular atom. The more loosely the free electrons are attached to their nuclei, the better the electrical conductivity. Thus, the flow of current in a conductor consists of a stream of electrons moving along the conductor, from atom to atom, in a definite direction under the influence of an outside applied force or pressure. In electrical circuits this outside force consists of an equalizing tendency on the part of the electrons which, like water, seek their level. Hence, there will be a flow of current in any conductor which possesses an excess of electrons at one point and a deficiency at another. This flow will continue until the number of electrons at all points along the conductor is equal. This equalizing force is called the *electromotive force,* abbreviated EMF, and is usually expressed in *volts.* This force is due to the non-uniform distribution of electrons in a circuit. For illustration, if a battery is placed in a closed circuit, a current of electricity will flow around the conducting medium because the battery pulls electrons into one terminal and pushes electrons out of the other. The source from which the electrons flow is called the *negative* terminal, and the point which the electrons travel to is called the *positive* terminal. The words POSITIVE and NEGATIVE have no meaning, but serve only to distinguish or differentiate between the two electrical charges. The terms were chosen many years before the electron-movement theory was established, and for a long time it was assumed, for reasons of conventionality, that current flowed from a positive terminal to a negative terminal. It is now known that the co-ordinated motion of electrons actually move in the opposite direction; that is, from the negative to positive terminals.

Electric Potential

● The value of an electromotive force existing between any two points is known as the potential difference, and is measured in units of volts.

The Electric Circuit

● The simplest electrical circuit consists of a source of electromotive force and a continuous path from the negative to the positive terminals through a resistance. The source voltage may be either a unidirectional (DC), or alternating (AC) force. If direct current, the voltage source maintains a constant positive and negative polarity. On the other hand, if the current be of an alternating nature the polarity of the two terminals is periodically reversed. In an alternating current circuit the direction of the electron movement reverses once each cycle. In the ordinary 60 cycle AC power line, the polarity of the AC generator reverses 120 times per second, which is proportional to the line FREQUENCY. Alternating and direct currents have quite different characteristics. Accordingly the study of electricity is divided into two parts: direct currents and alternating currents.

Electric Resistance

● Electrons moving through a conductor continually collide with atoms of the conducting material. This impedes or slows the electron flow to such an extent that the amount of current is limited which can flow through a circuit when a given voltage is applied. This limiting effect is termed the *resistance* of the conductor; it is expressed in *ohms.* Hence, a circuit has a resistance of 1 ohm when an EMF of 1 volt will force a current of 1 ampere through it. And, in an inverted sense, a source of EMF is said to have 1 volt electrical pressure when it will establish a current of 1 ampere in a resistance of 1 ohm.

The collisions between the free electrons and the atoms move the atoms around slightly, which takes a certain amount of energy away from the electron stream. This energy heats up the conductor and explains why resistors carrying current increase their temperature.

Electric Current

● Electric current describes the quantity of flow of electricity through a circuit, and the unit of current flow is the *ampere.* Electric currents are measured either by their heating effects on a conductor (thermoammeters, etc.) or by their magnetic effects (moving coil and moving iron instruments).

Sources of Electricity

● An electromotive force (and therefore a flow of current) can be produced either by chemical or mechanical means. All batteries produce electricity by converting energy from one form to another by means of a chemical reaction. All the common types of electrical generators transform mechanical energy into electrical energy, either by magnetic or electrostatic action.

Series and Parallel Circuits

● A simple circuit can contain any number of resistances. For example, Figure 1 shows a circuit having two resistances connected in series, while that in Figure 2 has resistances connected in parallel. The current in a parallel circuit will divide between the various resistance branches, and will not be equal in each branch unless the resistance in every branch is equal. In a series circuit the current flow is equal at every point in the circuit.

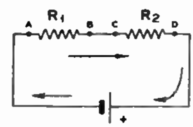


Fig. 1

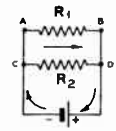


Fig. 2

Ohm's Law

● The resistance of any conductor depends on the structure of the material of which it is made, together with its cross-section and length. The relationship between the electromotive force (volts), the flow or current (amperes), and the resistance impeding the flow of current (ohms) is expressed in Ohm's Law, which states: *"For any circuit or part of any circuit the current in amperes is equal to the electromotive force in volts divided by the resistance in ohms."* This relationship is usually expressed by the following three formulas:

Where I is the current in amperes,
E is the electromotive force in volts,
R is the circuit resistance in ohms.

$$E = IR \qquad I = \frac{E}{R} \qquad R = \frac{E}{I}$$

Thus, resistance equals voltage divided by current,
current equals voltage divided by resistance,
voltage equals current times resistance.

In many commonly used circuits it is found that there are resistances connected in series, in parallel or in series-parallel, as shown in Figure 3. In order to calculate the total resistance of any network composed of two or more resistances connected in any of the above three ways, the formula shown in Figure 3 is used. Note that the total resistance of resistors connected in series is larger than that of the highest resistance in the circuit. Also, the total resistance of resistors connected in parallel is *less* than that of the *lowest* resistance in the circuit.

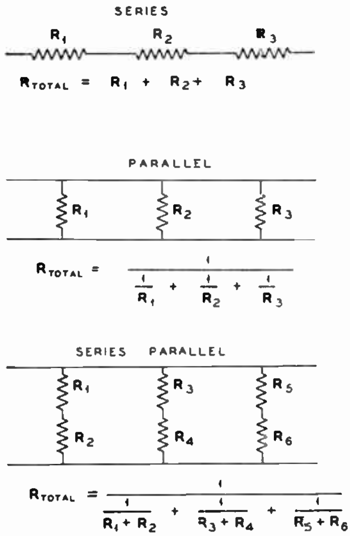


Fig. 3

Electric Power and Heating Effects

● The heat generated in a conductor by the flow of current varies directly with the resistance of the conductor and as the square of the amperes of current flow. The unit of power is the watt, and equals the product of the voltage across a resistor, times the current through it. This equals the amount of electrical power transformed into heat in the resistor. Using the symbols described above, plus *W = Watts of Power*, it is found that the following relationships hold true:

$$W = EI \qquad W = I^2R \qquad W = \frac{E^2}{R}$$

Electrical power can do other forms of work besides generating heat, such as driving a motor, radiating waves from an antenna or driving a loudspeaker. Electrical power takes many different forms and can be transduced from one form to another by means of a motor-generator, or vacuum tube.

Electromagnetic Phenomena

● A magnetic field envelops or surrounds a conductor when an electric current is flowing. How this field is developed is explained as follows: Electrons of like charge will repel each other due to the electrostatic field of force which surrounds each electron; this force is inversely proportional to the square of the distance. Thus, if the repulsion at any distance is a certain value, the repulsion at twice this distance is one-half squared, or one-quarter as much. The electrostatic field around any electron which is at rest, or moving with a constant velocity, can be visualized by a group of concentric equipotential circles surrounding the electron. See Figure below:

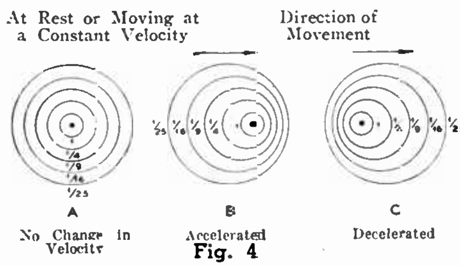
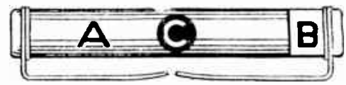


Fig. 4

When an electron moves, it must carry its field of force along with it. Hence, due to the relatively enormous volume of this field, each electron has considerable inertia. Thus, when a switch in a circuit is closed, the current does not jump instantly to the final value determined by the voltage divided by the resistance.

This gradual build-up of current in any circuit depends upon the circuit characteristics. It takes a greater length of time for current to build-up in a circuit containing a coiled wire than in one which consists of one long, straight wire. This is because the moving electro-static fields overlap surrounding electrons in adjacent turns of the coil. The energy stored at any point in space is proportional to the square of the electro-static intensity (or force) at that point. Thus, by coiling the wire, the energy concentration stored in the space around the coil has been materially increased, due

R M A STANDARD RESISTOR COLOR CODE



A BODY COLOR—1st figure of resistance value.
B COLORED END—2nd figure.
C CENTER DOT—number of ciphers following first two figures.

figure	color	figure	color
0	BLACK	5	GREEN
1	BROWN	6	BLUE
2	RED	7	VIOLET
3	ORANGE	8	GRAY
4	YELLOW	9	WHITE

to the increased overlap in the fields of the electrons. If the electro-static intensity at any point has been increased a hundred times over that of a point near a straight wire, the energy storage is 100 squared, or 10,000 times that of the energy stored in the space surrounding the long, straight wire. This stored energy comes from the source of power supplying the circuit, and any given current in a coil represents much more stored energy than the same current in a straight wire. Hence, for a given impressed voltage, it takes more time to start or stop the current flow in a coil than in a straight wire. Likewise, to start or stop the current flow in a coil *in a given time* requires the application of a larger voltage than would be necessary to start or stop the same current flow in a straight wire.

The inertia offered by a circuit to either an increase or a decrease in current is termed the *inductance* of the circuit. This inertia can be visualized in the following manner. When an electron is accelerated, or speeded up, its electro-static field does not instantly respond to the motion of the electron because the electro-static disturbances caused by the sudden acceleration of the electron travel outward from the electron with the speed of light. Hence, different parts of these fields are moving at different speeds, as shown in Figure 4 (B), and the concentration of energy ahead of the electron is greater than the concentration behind it. As soon as the electron attains constant velocity, its field again becomes systematically arranged. When the electron is decelerated the concentration of energy behind it becomes greater than that ahead of it, as shown in Figure 4 (C). These non-uniform concentrations of energy tend to oppose any change in the velocity of the electron, and it should be evident that the overlapping of the electron fields which occurs in the coil increases the non-uniform energy concentration which accompanies any change in the velocity of an electron, thus increasing the opposition to change, or inertia of the electron. This inertia, therefore, exerts a force opposing any change in the current through an inductance, and this opposing force is called the *back electro-motive force.*

Induction and Induced Voltages

● When an alternating current is passed through a coil of wire, energy is alternately stored in the field and returned to the wire. The greater the number of turns of wire on the coil, the greater is the *magneto-motive force.* This force varies with the number of turns, the diameter of the coil and the current. MMF corresponds to magnetic pressure.

Magnetic Flux

● Magnetic flux consists of the lines of magnetic force which surround any conductor. Magnetic flux might be termed magnetic current, just as magneto-motive force corresponds to magnetic voltage. The reluctance of a magnetic circuit could be described as the resistance of the magnetic path and the relationship between magnetic flux; magneto-motive force and reluctance is exactly similar to that between current, voltage and resistance, (Ohm's Law).

Magnetic flux depends on the material, cross-section and length of the magnetic circuit and varies directly as the current flowing in the circuit. Reluctance depends upon the length, cross-section, permeability and air-gap, if any, in the magnetic circuit.

Permeability

● Permeability describes the difference of the magnetic properties of any magnetic substance compared with the magnetic properties of air. Iron, for example, has a permeability of approximately 2,000 times that of air, which means that a given amount of magnetizing effect produced in an iron core by current flowing through a coil of wire will produce 2,000 times the flux density that the same magnetizing effect would produce in air. The permeability of different iron alloys varies quite widely and permeabilities up to 100,000 can be obtained, if required. Permeability is similar to electric conductivity. However, there is one important difference—the permeability of iron is not independent of the magnetic current (flux) flowing through it, although electrical conductivity is usually independent of electric current in a wire. After a certain point is reached in the flux density of a magnetic conductor, an increase in the magnetizing field will not produce any material increase in the flux density. This point is known as the *point of saturation.* The inductance of a choke coil whose core becomes saturated declines to a very low value. This characteristic is extremely valuable in the *swinging choke* and in the *saturable reactor* used in some controlled carrier modulation systems.

The magnetizing effect of a coil is often described in *ampere-turns.* Two amperes of current flowing through one turn equals two ampere-turns, or one ampere of current flowing through two turns also equals two ampere-turns.

Mutual Inductance

● When two parallel wires are placed in proximity to each other and a varying current flows through one of them, the non-uniform energy concentrations around the accelerating and decelerating electrons in the conductor carrying the varying current cause an induced electro-motive force to be applied to the free electrons in the neighboring conductor. The electro-motive force (voltage) produced in the adjacent wire is always in the same direction as the back-electro-motive force set up in the wire which is carrying the exciting current. This point helps to explain why the inductance of a circuit containing many turns of wire is greater than that of a circuit composed only of a straight wire. In a coil, each turn has a back-electro-motive force induced by the changing current within itself. In addition, it has an induced electro-motive force in the same direction, due to the changing current in the adjacent turns on each side of the portion of the coil under consideration. The self-inductance of a coil in henrys equals the induced voltage in volts across that coil when the current is varying at the rate of one ampere per second.

If a second coil is wound directly over the first coil, any change in current in the first coil will induce a voltage in the second coil, and the mutual inductance in henrys between the two coils equals the voltage induced in either coil when the current in the other is varying at the rate of one ampere per second. The unit of inductance is the *henry*.

Inductive Reactance

● The principal action of an inductance is to resist any change in current through it, and therefore any inductance in a circuit will impede the flow of alternating current. The higher the frequency of the alternating voltage impressed across the inductance the lower will be the current through the coil. The current flowing through the inductance is related to the inductance in henrys and to the frequency in cycles per second.

Formula:

Where X_1 is the inductive reactance in ohms,

f, the frequency in cycles per second,

L, the inductance in henrys,

$$X_1 = 2\pi fL$$

Thus, if the inductance of a coil and the frequency of the impressed alternating voltage is known, the current in any AC circuit in which there is an inductance can be determined by dividing the voltage by the inductive reactance.

Inductances can be connected in series or in parallel. The electrical effect of making such connections is quite similar to those obtained when connecting resistors in series or parallel. Inductances in series:

$$L\ \text{total} = L1 + L2 + L3, \text{ etc.,}$$

Inductances in parallel:

$$\frac{1}{L\ \text{total}} = \frac{1}{L_1} + \frac{1}{L_2} + \frac{1}{L_3} +, \text{ etc.,}$$

Transformers

● From the foregoing, it was seen that a variation of current flowing through an inductive- winding will induce a similar voltage in an adjacent winding if both are coupled within the proximity of the common magnetic circuit. This explains the operation of a *transformer*. The winding of a transformer carrying the exciting current is known as the *primary*, and the coupled coil in which is induced a voltage is known as the *secondary*. If both primary and secondary windings have an equal number of turns which are closely coupled, and if neither of the windings are tuned by means of a capacity to resonance at the frequency of operation, the voltage across the secondary will be equal to the voltage across the primary. If the secondary has twice as many turns as the primary, the induced voltage in the secondary will be twice the exciting voltage across the primary. For any other turns ratio between the primary and secondary windings, the ratio of the secondary voltage to the primary voltage will be equal to the ratio between the number of secondary turns to the number of primary turns. These relationships hold as long as no current flows in the secondary winding, which is the case in all low-level audio-frequency circuits. When a load is connected across the secondary, as in a power transformer, or audio-output transformer, the DC resistance and the leakage reactance of the transformer windings slightly modify the voltage relationships.

Useful transformer formula:

$$\frac{Z_p}{Z_s} = \left(\frac{N_p}{N_s}\right)^2$$

Where Z_p = primary impedance
Z_s = secondary impedance
N_p = number of primary turns
N_s = number of secondary turns

Condensers and Capacitive Reactance

● A condenser is a device for storing electrical energy, and in its simplest form consists of two parallel metallic plates separated by an insulator, such as air. If the two plates are connected to a DC source, one will be positively and the other negatively charged. As soon as the potential difference between the two plates becomes equal to the voltage of the DC source, the current in the circuit will cease. If the condenser is connected to an AC voltage, the current will surge back and forth every cycle, because first one plate takes on a positive charge, then the other. During that part of the cycle when one plate becomes negative, the excess of electrons driven on to this plate repels an equal number of electrons off the other plate. These electrons then travel back toward the positive terminal of the voltage source. On the next half cycle this process is reversed. No electrons actually pass through the condenser from one plate to the other, because the electrons arriving at one plate drive an equal number away from the other plate. The effect on the circuit is the same as if the electrons actually passed right through the condenser — except for the phase relation between the impressed voltage and the resulting current.

The quantity of electricity stored in a condenser is proportional to the square of the impressed voltage. The quantity stored is measured in coulombs or ampere-seconds. One coulomb is the quantity of electricity carried by one ampere of current flowing for one second. Hence, if the voltage changes at the rate of one volt per second and the current produced (or absorbed) is one ampere, the capacity of the condenser has one *farad;* that is, the condenser has a capacity of one farad. The farad is too large a unit for practical use, so in radio work a very small fraction of this capacity is used, the more common unit being the *micro-farad,* which is one-millionth of a farad.

The capacity of a condenser depends on the area of the plates, their spacing, and the dielectric properties of the insulator which separates the plates. For mechanical reasons, it is desirable to construct condensers with two or more plates; hence, most radio condensers consist of two paralleled sets of plates, each connected together conductively. The dielectric property varies with the insulating material which affects the ability of a condenser to store electricity. The *dielectric constant,* therefore, describes the ability of a condenser to increase its capacity over that of an air condenser.

The capacity of a condenser can be computed from the following formula:

$$C\ (\text{microfarads}) = 0.8842\ \frac{kA}{d}\ (n-1)\ 10^{7}$$

Where k = the dielectric constant (air 1.00, mica 4.5 to 7.5)
A = area in cm² (one side of one plate)
d = separation in cm
n = number of plates

Condensers in Parallel and Series

● Condensers can be connected in series or in parallel, but the effect is just the opposite to that of connecting inductances or resistances in series or parallel. A simple rule covering parallel or series connections is: Capacities in parallel should be added to find the total capacity, and for capacities in series the reciprocal of the sum of reciprocals must be taken. Illustrating by formula:

$$C\ (\text{parallel}) = C_1 + C_2 + C_3 \text{ etc.,}$$

$$C\ (\text{series}):\ \frac{1}{C} = \frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_3} \text{ etc.,}$$

Capacitive Reactance

● Alternating current does not flow through a capacity without some impeding effect taking place, which is termed *capacitive reactance.* This retarding factor is inversely proportional to the frequency and the capacity of the condenser. To find the capacitive reactance, the following formula is given:

$$X_c = \frac{1{,}000{,}000}{2\pi f C}$$

Where X_c = the capacitive reactance in ohms
f = the frequency in cycles per second
C = the capacity in microfarads

Thus, if the capacity of a condenser and the frequency of the impressed alternating voltage is known, the current through any condenser can be determined by dividing the voltage by the capacitive reactance.

Impedance

● When an inductance, capacity and a resistance are connected in series, the combined effect is called the impedance of the circuit.

The capacitive reactance and inductive reactance are of opposite sign, because the current through a conductor leads the impressed voltage by 90 electrical degrees, while the current through an inductance lags the voltage by 90 degrees. Thus, the current is 180 degrees out of phase with that through the inductance. The reactance of the circuit becomes $X_L - X_c$. Since the current through an inductance or capacity lags or leads that through a resistance by 90 degrees, it is necessary to take the square root of the sum of the squares to solve for the total impedance of the circuit to the flow of current.

$Z \text{ (impedance)} = \sqrt{R^2 + (X_L - X_c)^2}$

With any two quantities known, the third can be solved from the following formulas:

$$E = IZ \qquad Z = \frac{E}{I} \qquad I = \frac{E}{Z}$$

From the equation of the impedance of a series circuit it can be seen that the impedance is equal to the resistance when the inductive reactance is equal to the capacitive reactance. This is known as *resonance.*

Alternating Current Considerations

● Alternating current produces a heating effect in a resistor in spite of the fact that the current flow periodically reverses at a uniform rate of speed. To explain the theory, principle, and applications of alternating current in its many ramifications, would be taking too much of the more valuable space in this book. The student, then, is referred to texts wherein this and other information on AC phenomena can be found. Briefly, a generator produces alternating current which starts at zero, reaches maximum, returns to zero, reverses direction, and repeats the performance. This variation follows a mathematical law called a *sine wave.* The actual heating effect of this alternating current depends on the effective value of each half-sine wave. This is called the RMS value and is equal to the peak value divided by 1.41. in case it is a pure sine wave. The RMS value of either voltage or current is the value read on most AC voltmeters or ammeters.

In considering alternating current the actual power is not the product of I^2Z, since the effect of either the inductance or capacity is to make the current lag or lead that through the resistance of the circuit. The lag or lead is known as the *phase angle,* and the power can be computed from the expression $P = E \times I \cos \theta$. The $\cos \theta$ represents the power factor which has a zero (unity) value in a pure (100%) resistive circuit. A perfect condenser having no resistance would have a zero power factor, which would provide a means for making comparative tests with other condensers.

One of the many interesting applications of "power factor" is in determining the effective shunt and series resistance of a condenser when the frequency of operation is known. Solutions for the determinants are:

$$\text{Series Resistance} = \frac{\text{power factor}}{2\pi f C}$$

$$R_s = \text{Shunt Resistance} = \frac{1}{2\pi f C \times \text{power factor}}$$

Eliminating the power factor term gives

$$\text{Series Resistance} = \frac{1}{R_s\,(2\pi f C)^2}$$

Fundamentals of Radio

● In power, telephone and telegraph lines, electricity energy is carried from the sending point to the receiving point through individual and isolated lines. All radio signals, however, utilize a common conducting medium, *the ether.* The mixing of thousands of radio signals in one conducting medium necessitates some method of selecting the desired signal and rejecting all others. This is accomplished by means of *resonant circuits* involving inductances and capacitances in series or parallel. Vacuum tubes are used to amplify the signals, while tuned circuits are used for *selecting* the desired signals.

Inductance Considerations

● Inductances are used in radio, audio-frequency and power circuits. An inductance used for the latter purpose can be designed from a rather simple formula:

$$L = 1.257\ N^2P \times 10^{-8}$$

Where N = the number of turns of wire
L = the inductance in henrys
P = the permeance of the complete magnetic circuit

In most inductances, the magnetic circuit is confined by means of an iron magnetic core to the close proximity of the coil itself. For radio-frequencies some form of air-core coil is most often used. Lately, pulverized iron has been successfully employed for low and medium frequency coils, such as in intermediate-frequency transformer assemblies.

The inductance of an air-core solenoid can be calculated from the formula:

$$L_1 = N^2dK$$

Where L_1 = the inductance in microhenrys
N = the number of turns
d = the average diameter of the coil
K = a constant depending on the ratio of the length to the coil diameter

This formula shows that the inductance of radio-frequency coils varies as the square of the number of turns and directly as the diameter of the coil.

An inductance has a certain amount of resistance due to the metallic conductor used in winding the coil. At radio-frequencies this resistance is a great many times more than the resistance would be for direct current. At radio-freqencies the current tends to concentrate at the surface of the conductor, which in effect gives an increase in the resistance. This crowding of the current density toward the surface of a conductor is known as the *"skin effect."*

The ratio between the inductive reactance of the coil and its effective resistance gives a measure of its efficiency, and is known as the "Q" of the coil. "Q," therefore, is the factor of merit of a reactance element; this factor can be determined by the following formula:

$$Q = \frac{1}{2\pi f C R} = \frac{2\pi f L}{R}$$

Series Resonance

● When an inductance, resistance and capacitance are connected in series, there will be a certain resonant frequency at which the inductive reactance is equal and opposite in effect to the capacitive reactance, and the flow of current will only be limited by effective resistance of the circuit. At higher frequencies than resonance, the capacitive reactance is less than the inductive reactance, with the result that the impedance is higher than at resonance. The same holds true at lower frequencies, except that the larger reactive term is capacitive. The reactive voltage drop across either the coil or condenser is very high at resonance, because the current is only limited by the resistance of the circuit. This reactive voltage may be several hundred times the value of the impressed voltage, as given by the expression:

$$Ex = \frac{E \times 2\pi f L}{R} = \frac{E}{2\pi f C R} = E \times Q$$

For example, if the impressed voltage is 10 volts, and if the "Q" of the coil is 100, the reactive voltage across the condenser or coil would be 1,000 volts. The sharpness of a resonance curve depends upon the "Q" of the coil, for example:

$\frac{1}{2Q}$ difference of frequency from resonance will only give 70% of the resonant current.

$\frac{1}{Q}$ difference of frequency from resonance will only give 45% of current at resonance.

Series resonance is applied to antennas, antenna feeders, and occasionally in audio-frequency and filter circuits.

Parallel Resonance

● Parallel resonant circuits are used in both transmitters and receivers for purposes of selectivity or coupling between vacuum tubes. At frequencies below resonance, the inductive branch draws high current while the capacitive branch draws low current, resulting in a lagging current known as *inductive reactance.* The opposite holds true for frequencies higher than resonance. At resonance the inductive reactance is equal to the capacitive reactance, and the parallel impedance is an effectively high resistance. The parallel impedance at resonance is equal to:

$$Z = \frac{(2\pi f L)^2}{R} = 2\pi f L Q$$

This shows that at resonance there is a resonant rise in impedance of "Q" times the reactance of either branch; meaning, for example, that a tuned radio-frequency amplifier would have more gain and also better selectivity with a high "Q" coil in the tuned coupling circuits. Since the plate impedance of an RF amplifier tube is often much greater than 100,000 ohms, it is important that inter-stage tuned circuits have a very high resonant impedance so that a good impedance match and maximum voltage step-up will be obtained.

When parallel circuits are placed across the grid or plate circuits of a transmitting amplifier tube, the impedance of the tank is greatly reduced, because of the low shunt resistance across the parallel tuned circuit. The effect of a shunt resistance is to increase the effective series resistance of the same circuit; the amount can be determined by the following formula:

$$r = \frac{1}{r_s (2\pi f C)^2}$$

Where r_s = the shunt resistance.

For example, a shunt resistance of 2,000 ohms would increase the effective series resistance of a representative tank circuit from 5 ohms to 100 ohms at a frequency of 7 megacycles. Assuming the circuit had a "Q" of 100 without any shunt load, the "Q" would be reduced to 5, due to the loading effect. The parallel impedance (from the above formulas) would be approximately 2500 ohms under load conditions, and 50,000 ohms with no load. The example brings out the effect of a resistance shunted across a parallel tuned circuit.

The resonant frequency of a parallel tuned high-Q circuit is given by the expression:

$$f = \frac{1}{2\pi\sqrt{LC}}$$

This expression is slightly in error for low-Q circuits, because the resonant frequency is affected by the effective series resistance. The sharpness of resonance is similar to that of a series resonant circuit and the same "Q" formulas can be used for determining currents at frequencies off resonance.

In many applications of a parallel tuned circuit, it is desirable to obtain a step-down ratio of impedance. A typical example is in matching a 500 ohm single wire antenna feedline to the tuned output circuit of a transmitter, as shown in Figure 6.

In this case, the load is only connected across part of the parallel tuned circuit impedance in order that optimum power transfer will be obtained.

Another case of parallel resonance occurs in radio-frequency choke coils which are

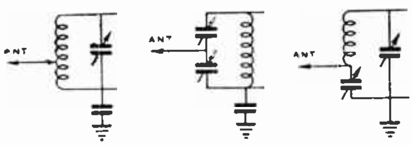


FIG. 6

used to prevent radio-frequency currents from flowing into undesired circuits. The self-capacitance of the coil resonates it with its inductance to a frequency usually much lower than the operating frequency. The RF choke functions as a very small condenser of not more than two or three microfarads which presents a high impedance to RF currents. At frequencies below resonance the choke performs like an inductance having an apparent value equal to:

$$\frac{L}{1 - m^2}$$

Where m is the ratio of applied frequency to the natural resonant frequency of the coil; and L the theoretical inductance. This apparent inductance can be very great near resonance.

Coupled Circuits

● As single reactive circuits are not always employed in radio transmitting and receiving circuits, it is therefore more common to use various combinations of coupled circuits; four simple electrical configurations are shown in Figure 7. In all of the diagrams the presence of a secondary circuit changes the impedance of the primary circuit by an amount equal to the expression:

$$\frac{(2\pi f M)^2}{Z_2}$$

The equivalent primary impedance becomes:

$$Z = Z_1 + \frac{(2\pi f M)^2}{Z_2}$$

Where Z_1 = the series impedance of the primary alone

Z_2 = the series impedance of the secondary alone

M = the mutual inductance of the coils L_1 and L_2

Note: When Z_2 is low, such as at resonance, and M is not small, the effect on the primary is large. The effect of the secondary upon the primary circuit may be determined from the above expression when applied to the schematic diagrams shown here. From these expressions it is possible to roughly analyze most any transmitter or receiving circuit.

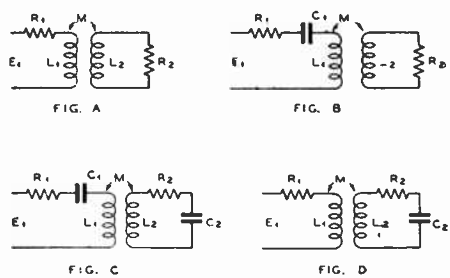


FIG. 7

Power transformers are a form of occupied circuits of the type shown in Figure 7-a. The difference between a power transformer and a similar RF coupled circuit is that the leakage reactance may only be about two per cent in the former case, and as high as 90 per cent in the latter case. The leakage reactance is much higher at radio-frequencies, because most high-frequency coupled circuits are resonant and require very loose coupling with a very small value of M to attain the desired result. In many cases the coupling between two or more circuits is obtained by other methods using some form of inductive or capacitive reactance, or even resistance coupling.

Band-pass circuits are special forms of parallel resonant coupled circuits. The coupling is increased until the secondary causes an extreme broadening of the resonance curve or it may even form a double resonant peak in the primary circuit. True band-pass circuits are seldom used in short-wave radio receivers or transmitters because selectivity and gain are more important to the amateur than a level frequency response over a range of frequencies.

Gauge No. B&S	Dia. in Mils	CROSS SECTIONAL AREA Cir. Mils	CROSS SECTIONAL AREA Sq. Inches	TURNS PER LINEAR INCH DCC.	SCC.	DSC.	SSC.	Enam.	Enam. and SCC.	Enam. and SSC.	TURNS PER SQUARE INCH DCC.	SCC.	DSC.	SSC.	Enam.	Enam. and SCC.	Enam. and SSC.	FT. PER POUND DCC	SCC.	Bare	RES PER 1000 FT. Copper	CARRYING CAPACITY Copper 1000 CM Per Amp.	1500 CM Per Amp.
0000	460.0	211600	.1662																	1.561	.0499	211.6	140.7
000	409.6	167800	.1318																	1.968	.0629	167.8	111.3
00	364.8	133100	.1045																	2.482	.0793	133.1	88.9
0	324.9	105500	.08289																	3.130	.1000	105.5	70.3
1	289.3	83690	.06573																	3.947	.1260	83.7	55.7
2	257.6	66370	.05213																	4.977	.1592	66.4	44.1
3	229.4	52640	.04134																	6.276	.2004	52.6	35.0
4	204.3	51740	.03278																	7.914	.2336	41.7	27.7
5	181.9	33100	.02600																	9.980	.3192	33.1	22.0
6	162.0	26250	.02062	5.44	5.60															12.58	.4028	26.3	17.5
7	144.3	20820	.01635	6.08	6.23															15.87	.5080	20.8	13.8
8	128.5	16510	.01297	6.80	6.94													19.6	19.9	20.01	.6405	16.5	11.0
9	114.4	13090	.01028	7.64	7.68													24.6	25.1	25.23	.8077	13.1	8.7
10	101.9	10380	.008155	8.51	8.55													30.9	31.6	31.82	1.018	10.4	6.9
11	90.74	8234	.006467	9.58	9.60													38.9	39.8	40.12	1.284	8.2	5.5
12	80.81	6530	.005129	10.62	10.80	11.8	12.1	12.1	11.4	11.8	121	136	139	146	146	130	139	48.9	50.2	50.59	1.619	6.5	4.4
13	71.96	5178	.004067	11.88	12.06	13.2	13.5	13.5	12.8	13.2	153	171	173	183	183	162	173	61.5	63.2	63.80	2.042	5.2	3.5
14	64.09	4107	.003225	13.10	13.45	14.7	15.1	15.2	14.2	14.7	187	213	216	229	239	201	216	77.3	79.6	80.44	2.575	4.1	2.7
15	57.07	3257	.002558	14.68	14.90	16.4	16.9	17.0	15.8	16.5	229	264	268	287	290	250	271	97.3	100	101.4	3.247	3.3	2.2
16	50.82	2583	.002028	16.40	17.20	18.2	18.9	18.7	17.6	18.4	280	327	333	358	350	309	338	119	126	127.9	4.094	2.6	1.7
17	45.26	2048	.001609	18.10	18.80	20.3	21.2	21.4	19.5	20.5	340	404	412	448	458	381	421	150	155	161.3	5.163	2.0	1.3
18	40.30	1624	.001276	20.00	21.00	22.6	23.6	24.0	21.7	22.9	412	498	510	559	575	469	524	188	196	203.4	6.510	1.6	1.1
19	35.89	1288	.001012	21.83	23.60	25.4	26.8	27.2	24.2	25.8	508	629	644	715	739	587	665	237	247	256.5	8.210	1.3	.86
20	31.96	1022	.0008023	23.91	26.40	27.8	29.5	30.1	26.5	28.4	596	752	773	867	904	701	805	298	311	323.4	10.35	1.0	.68
21	28.46	810.1	.0006363	26.20	29.70	30.8	32.8	33.6	29.6	31.5	752	919	949	1078	1129	878	991	370	389	407.8	13.05	.81	.54
22	25.35	642.4	.0005046	28.58	32.00	34.1	36.6	37.7	32.7	35.0	899	1161	1161	1337	1419	1071	1227	461	491	514.8	16.46	.64	.43
23	22.57	509.5	.0004002	31.12	34.30	37.6	40.7	42.3	36.1	39.0	1070	1416	1416	1656	1785	1306	1518	584	624	648.4	20.76	.51	.34
24	20.10	404.0	.0003173	33.60	37.70	41.5	45.3	47.2	39.7	43.1	1266	1722	1722	2018	2225	1575	1858	745	778	817.7	26.17	.41	.27
25	17.90	320.4	.0002517	36.20	41.50	45.7	50.3	52.9	43.7	47.9	1191	2085	2085	2525	2800	1907	2289	903	958	1031	33.00	.32	.21
26	15.94	254.1	.0001996	39.90	45.30	50.2	55.7	59.0	47.8	52.8	1745	2515	2515	3108	3484	2281	2788	1118	1188	1300	41.62	.25	.17
27	14.20	201.5	.0001583	42.60	49.40	55.0	61.7	65.8	52.1	58.1	2029	3019	3019	3811	4328	2713	3381	1422	1533	1639	52.48	.20	.13
28	12.64	159.8	.0001255	45.50	54.60	60.1	68.3	73.9	57.0	64.4	2317	3611	3611	4666	5456	3250	4141	1759	1903	2067	66.17	.16	.11
29	11.26	126.7	.00009953	48.00	58.80	65.5	75.4	82.2	61.9	70.6	2696	4294	4294	5688	6761	3830	4988	2207	2461	2607	83.44	.13	.084
30	10.03	100.5	.00007894	51.10	64.40	71.3	83.1	92.3	67.4	77.9	3076	5081	5081	6911	8527	4547	6075	2534	2893	3287	105.20	.10	.067
31	8.928	79.70	.00006260	56.80	69.00	77.3	91.6	103.0	72.8	85.3	3489	5981	5981	8389	10568	5305	7267	2768	3483	4145	132.70	.079	.053
32	7.950	63.21	.00004964	60.20	75.00	83.7	101.0	116.0	79.1	93.9	3931	7003	7003	10101	13363	6250	8818	3137	4414	5227	167.30	.063	.042
33	7.080	50.13	.00003937	61.30	81.00	90.3	110.0	130.0	85.6	103.0	4398	8143	8143	12130	16952	7326	10672	4697	5688	6591	211.00	.050	.033
34	6.305	39.75	.00003122	68.60	87.60	97.0	120.0	145.0	91.7	112.0	4883	9407	9407	14499	20967	8403	12610	6168	6400	8310	266.00	.039	.026
35	5.615	31.52	.00002476	73.00	94.20	104.0	131.0	164.0	98.8	123.0	5391	10817	10817	17217	26745	9766	15186	6737	8393	10480	335.00	.032	.021
36	5.000	25.00	.00001964	78.50	101.00	111.0	143.0	182.0	105.0	133.0	5917	12316	12316	20408	33051	11080	17777	7877	9846	13210	423.00	.025	.017
37	4.453	19.83	.00001557	84.00	108.00	118.0	155.0	206.0	113.0	146.0	6452	13996	13996	24015	40766	12758	21295	9309	11636	16660	533.40	.020	.013
38	3.965	15.72	.00001235	89.10	115.00	126.0	168.0	235.0	120.0	157.0	6978	15763	15763	28106	54990	14291	24685	10666	13848	21010	672.60	.016	.010
39	3.331	12.47	.000009793	95.00	122.50	133.0	181.0	261.0	128.0	172.0	7524	17630	17630	32690	68120	16308	29412	11907	18286	26500	848.10	.012	.008
40	3.134	9.888	.000007766	102.50	130.00	140.0	194.0	290.0	134.0	184.0	8045	19589	19589	37779	84246	18041	43727	14222	24381	33410	1069.00	.009	.006
41	2.800	7.841	.000006160	112.00	153.00													17920	30610	42130	1323.00	.008	.005
42	2.494	6.220	.000004885	124.00	168.00													22600	38700	53100	1667.00	.006	.004
43	2.221	4.933	.000003873	140.00	192.00													28410	48600	66970	2105.00	.005	.003
44	1.978	3.910	.000003073	153.00	210.00													35950	61400	84460	2655.00	.004	.0025

Copper Wire Table

Chapter 2

VACUUM TUBE THEORY

● In radio transmission and reception, vacuum tubes are employed for the generation, detection, and amplification of radio and radio-frequency currents; in addition, electron tubes serve as power rectifiers which convert alternating current into direct current, and in special cases for controlling and inverting electric power.

The functions performed by a thermionic tube depend on the emission of electrons from a metallic surface and the flow of these electrons to other surfaces; the transition constituting an electric current.

An electron tube consists essentially of an evacuated glass or metal envelope in which are enclosed an electron emitting surface, called a *cathode*, and one or more additional electrodes. The connections from the various elements are carried through the tube envelope to special connectors.

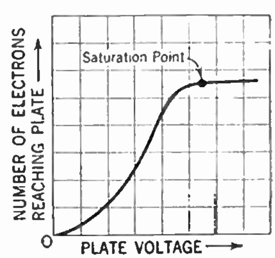
Electron Emission—Cathodes

● The rate of electronic motion in every atom increases if the molecular constituents of any material are subjected to thermal agitation. Hence, by heating certain metallic conductors the motion of electrons becomes so rapid that some of them break away from their parent atoms and are set free in space. In the absence of any external attraction, the electrons escaping from the emissive surface repel each other because they are all negatively charged. Therefore, the number of electrons leaving the emitter are limited on account of the free negatively charged electrons counteracting the escape function of new electrons. The point of electronic saturation is called the "space charge effect." When this condition is reached no further electrons will leave the emitter regardless of how much higher the temperature of the emitting surface is increased. The element from which electrons are detached in a radio vacuum tube is energized electrically by the passage of current through either a directly-heated filamentary cathode, or metallic sleeve indirectly-heated by an internal resistive element. In all modern vacuum tubes the surface of the cathode material is chemically treated to increase electronic emission. The two principal types of surface treatment include "thoriated tungsten filaments," as used in medium and high-powered transmitting tubes, and "oxide coated filaments," or cathode sleeves, such as used in most receiving tubes. Pure tungsten filaments are practically obsolete, and are only being manufactured for some types of high-power transmitting tubes where sufficient vacuum cannot be maintained for properly operating a thoriated tungsten type of filament.

Cathode Current

● When a heated cathode and separate metallic plate are placed in an evacuated envelope, it is found that a few of the electrons thrown off by the cathode leave with sufficient velocity so that they reach the plate. If the plate is electrically connected back to the cathode, the electrons will flow back to the cathode, due to the difference in electrical charges caused by the electrons leaving the cathode and reaching the plate. This small current that flows is the *plate current*. If a battery, or other source of DC voltage is placed in the external circuit between the plate and cathode, so that the battery voltage places a positive potential on the plate, the flow of current from the cathode to plate will be increased. This is due to the attraction offered by the positively charged plate for any negatively charged electrons. If the positive potential on the plate is increased, the flow of electrons between the cathode and plate will also increase up to the point of *saturation*. Saturation current flows when all of the electrons leaving the cathode are attracted over to the plate, and no increase in plate voltage can increase the number being attracted to the plate. Raising the temperature of the cathode will increase the plate current on account of the electronic

Fig. 9 — Curve showing emission from a cathode.



increment from the emitter. Operating a cathode at a temperature materially above its normal rating will shorten the life of the emitting surface. In the case of thoriated tungsten emitters, which are rather sensitive to changes in filament temperature, it is advisable to provide a close control over the filament voltage. If there is any doubt about the filament voltage, it is better to operate the filament slightly higher than normal, rather than below normal, especially if the tube is operating with high plate current.

Diode Rectification

● If a negative charge is applied to the plate, the electrons in the space charge are repelled back to the cathode and no current flows in the circuit between the cathode and plate. Thus, in a vacuum tube, current can flow from the cathode to plate, but not from plate to cathode. If an alternating current is applied to the plate, current will flow only when the plate is positive with respect to the cathode. This current will be pulsating, but uni-directional. If a suitable smoothing filter is placed in the circuit, the pulsations will be smoothed out and will simulate that of a direct current. This process is known as *rectification,* it is widely applied in all radio circuits. All amplifiers employing radio tubes usually require the application of rather high positive DC potential to the plate, which of course, necessitates the stepping-up of the AC current supplied by the power mains before it is rectified and filtered. Other applications of the principle of rectification occur in radio receivers and transmitters.

Vacuum Tubes as Amplifiers

● The addition of a mesh-like structure, called a *grid,* interposed between the cathode and plate in a vacuum tube allows a wide control over the electron flow from the cathode to plate. This control is made possible by applying small control voltages to the grid which either increase or decrease the plate current according to the direction of potential command. Vacuum tubes in which there are three electrodes are called triodes. Hence, when the grid is given a negative charge with respect to the cathode, it repels the electronic flow to the plate, resulting in a decreased plate current. On the other hand, if the voltage is made high enough, the plate current will be cut off. The point at which the flow ceases is called the "cut-off bias," and it depends on the grid-to-plate spacing, as well as the closeness of mesh of the grid structure. When the potential on the grid is made positive with respect to the cathode, electrons are attracted away from the space charge area surrounding the cathode and are speeded on through and past the grid structure on to the plate with increased velocity. This increases the plate current.

Some of the electrons are intercepted by the grid and flow back to the cathode through the external grid circuit, but this grid current is usually quite small in comparison to the plate current. The ideal grid structure would be one that would give high acceleration to the electron flow when positive, yet would not intercept any grid current. The interception of grid current requires that the source of controlling voltage applied to the grid will supply enough power to swing the grid voltage to the required positive point, in spite of the resisting effect of the grid current.

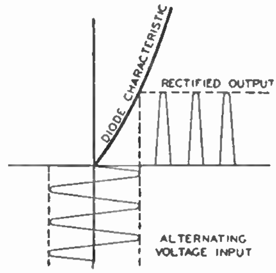


Fig. 10—Showing how a rectifier changes AC into DC.

A vacuum tube amplifies the voltage excursions of the grid by reason of the fact that the effected change in the plate current causes a similar amplified voltage drop to take place across an impedance in series with the plate circuit.

Tetrodes and Pentodes

● The term "tetrode" and "pentode" indicate the presence of four and five element tubes, respectively.

A tetrode consists of a triode to which has been added a second grid between the control grid and the plate. The grid is usually maintained at a positive potential, with respect to the cathode. The purpose of this grid is two-fold: first, it accelerates the electron flow from cathode to plate, thereby improving the tube's ability to amplify voltage. Second, it provides a grounded electro-static screen between the plate and control grid, so that energy will not be fed back to the control grid through the plate-to-grid capacitance of the tube. If the amplification through the tube is high enough, this feedback, or regeneration, of energy, might set the tube into self-oscillation, which would destroy its usefulness as an amplifier. This regeneration is put to work in certain detectors and in all oscillators, but its presence is undesirable in most amplifier applications. The tetrode has several disadvantages, the principal one being that the instantaneous AC plate voltage caused by the changing plate current cannot be allowed to swing to a value below the fixed positive potential on the outer, or screen grid. When the potential on the plate becomes less than the potential on the screen grid, the secondary electrons constantly being driven out of the plate by the impact of those arriving from the cathode fall into the more positive screen, instead of falling back into the plate, as they normally do. This increases the screen current, and under certain conditions, gives the tube negative resistance. This effect causes tremendous distortion in a voltage amplifier and limits the output of a power amplifier.

The pentode was developed to avoid this disadvantage of the tetrode. In this development, a third grid is added between the grid and the plate for the purpose of shielding the plate from the screen grid, so that the secondary electrons emitted from the plate will be forced to fall back into the plate and are prevented from going over to the screen. This outer grid in a pentode is called the *suppressing grid* because it suppresses the secondary electrons driven out of the plate.

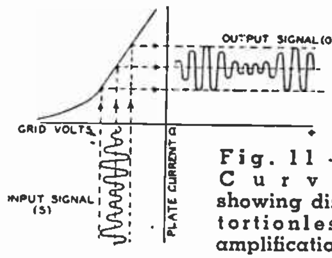


Fig. 11 — Curve showing distortionless amplification

Pentodes are highly useful for all class A voltage and power amplifiers, although they are not as desirable as triodes in high efficiency power amplifiers (above 40% overall efficiency). The main drawback to the use of tetrodes in high efficiency power amplifiers is the fact that the presence of the additional grids raises the plate resistance somewhat more than the amplification factor. Thus, the control-grid to plate transconductance cannot be as high in a similar triode. Transconductance, as will be explained in the next few paragraphs, is the best yardstick of a vacuum tube's ability to amplify power, particularly at high plate efficiencies required by economy considerations in the construction of radio transmitters.

Gaseous Conduction

● If a diode vacuum tube is evacuated and then filled with a gas, such as mercury vapor, its characteristics and performance will differ materially from an ordinary high vacuum type diode tube.

The principle on which depends the operation of a gas-filled rectifier is known as the *phenomenon of ionization.* Investigations have shown that electrons emitted by the hot-cathode in a mercury vapor tube are accelerated toward the anode (plate) with great velocity. These accelerated electrons move in the (electrical) force-free space between the hot-cathode and anode, in which space they collide with mercury vapor molecules. If the moving electrons attain a velocity equivalent to falling through a potential difference of 10.4 volts (for mercury), they are able to knock electrons out of the atoms with which they collide. When an electron is separated from its normal orbit it leaves not as an electron but as a *positive ion.* This freed positive ion will consequently be neutralized by the optional acquisition of a free electron. Finally the free electrons will be attracted to the anode or plate as will the positive ions that have been separated from the mercury atoms, which collectively constitute the flow of current in the tube. The passage of ions and electrons cause more of the atoms to be broken up by collision so that the vapor becomes heavily ionized and transmits a considerable amount of current. When the anode is positive, the ions are repelled and attracted to the cathode, tending to neutralize the negative space charge as long as saturation current is not being drawn. The mechanics of this electronic effect neutralize the negative space charge to such a degree that the voltage drop across the tube is reduced to a very low value and, in addition, reduces the heating of the diode plate as well as improving the voltage regulation of the circuit in which the tube is used. This greatly increases the efficiency of rectification because the voltage drop across any vacuum tube represents a waste of power.

Grid Controlled Rectifier

● A controlled rectifier is a gaseous type of diode employing either mercury, neon or argon gases, and a control grid. As the grid does not perform in the same manner as in the triode, it is necessary to give a description of the controlling action.

If a grid is placed between the cathode and the plate in a gaseous tube, the starting of the plate current can be controlled. A negative bias (or an absence of the required positive bias, in positive controlled tubes) prevents the flow of electrons from starting. However, once the flow begins, and the gas has become ionized, the grid loses all control over the electron stream. After starting, the grid neither modulates, limits, nor extinguishes the discharge. Herein lies the fundamental difference between high vacuum tubes and grid controlled rectifiers. The grid can regain control and prevent the passage of current if the potential on the plate is lowered to below the ionization voltage of the conducting vapor or gas. The time for de-ionization is very short; hence, interrupting the plate current for a few micro-seconds allows the grid to regain control.

If an AC voltage is applied to the plate, the grid is permitted to regain control after every positive half-cycle when the plate goes negative. In addition, the grid can delay the start of ionization for as long a period during the positive half cycle, as long as the grid bias voltage is sufficiently negative. In this manner, the grid can control the average current flowing through the tube if both plate and grid are supplied with AC, and the phase relation between the grid and plate voltage are adjusted to either increase or decrease the frequency or time of ionization.

Grid controlled rectifiers are more commonly known by their trade names—"Thyraton" (General Electric Co.) and "Grid Glow Tubes" (Westinghouse Company). For the amateur, the tubes are quite useful in varying the output of DC power supplies. Grid controlled rectifiers are also used in keying CW transmitters, or in applying carrier control to the plate power supply of a modulated amplifier.

The use of gaseous conduction tubes are limited to very low frequencies, such as 500 cycles and lower. The tubes are unstable at high-frequencies due to the finite time required for the internal gas to deionize after each cycle of conduction.

Vacuum Tube Characteristics

● The characteristics of a vacuum tube are the electrical properties which describe its ability to perform various functions. These characteristics are obtained by operating a vacuum tube under certain known electrode voltages, and then measuring the electrode currents. By plotting the change in any electrode current as any one of the electrodes voltages are likewise varied, a *characteristic curve* is obtained. When a negligible amount of impedance is inserted in the plate circuit of a tube and different DC potentials are applied to the tube electrodes, and should the variations in electrode current be graphically plotted on cross-section paper, the results are known as the tubes' *static characteristic curve.* On the other hand, if there is an impedance in the plate circuit, the plate voltage will vary with the plate current; hence, if a pure resistive impedance is placed in the plate circuit, and an AC voltage is impressed on the control-grid under various conditions of DC potentials on the electrodes, and if the variations in current are plotted on graph paper, the result will be the *dynamic characteristic curve.* This characteristic indicates the performance of a vacuum tube under actual operating conditions.

From three sets of static curves, it is possible to calculate in advance the actual performance of practically any type of vacuum tube amplifier or detector. Investigators have done a great deal of work in developing means by which the optimum operating conditions for the operation of class B and C power amplifiers can be accurately determined in advance. This information, in the form of curves or tables, will probably be made available soon by the tube manufacturers, so that proper values of bias, plate voltage, grid current and plate current can be chosen in order to obtain optimum power output and plate efficiency from any power amplifier.

Dynamic Characteristics
Amplification Factor

● The amplification factor, cryptically written as either μ, mu, or k, is **the ratio** of the change in plate voltage, plate current constant, to a change in grid voltage in the opposite direction. For example, if the plate voltage is changed 20 volts, and if it requires a change of 2 volts (opposite polarity) in the control grid voltage to hold the plate current constant, the amplification factor is 20/2 or 10. Expressed as an equation, it is:

$$\mu = \frac{dE_p}{dE_g}$$

Where d = any small change increment
E_p = variable component of plate voltage
Where E_g = variable component of grid voltage

Plate Resistance

● The plate resistance of a vacuum tube is defined as the ratio of a small change in plate voltage to the resulting change in plate current, when the grid voltage is assumed to remain constant. For example, if a change in plate voltage of 20 volts causes a change in plate current of 10 milliamperes (ma.), the plate current resistance equals 20 divided by .01 ampere (10 ma.), or 2000 ohms. Expressed as an equation:

$$R_p = \frac{dE_p}{dI_p}$$

It is desirable to make the plate resistance of a tube as low as possible, especially in power amplifiers where the load circuit is coupled to the plate in order to make a more effective impedance match. This allows the use of a lower plate voltage than would otherwise be obtained.

Transconductance

● The control grid-plate transconductance (S_m), formerly called mutual conductance, combines in one term the μ and **the plate** resistance of a vacuum tube, and is the ratio of the first to the second. By introducing the equations given above for μ and R_p in the ratio defined for transconductance, it can be seen that the S_m can also be expressed as the ratio of the change in plate current to the small change in grid voltage producing it (plate voltage constant, load resistance zero). Combining the above expressions, the formula for transconductance can be written:

$$S_m = \frac{\mu}{R_p} = \frac{\frac{dE_p}{dE_g}}{\frac{dE_p}{dI_p}} = \frac{dI_p}{dE_g}$$

S_m is expressed in MHOs, the unit of conductance.

Note that it is ohm spelled backwards; this is logical, since conductance is the reciprocal of resistance.

To illustrate an example of transconductance, take the case where ratio of the dI_p to dE_g equals S_m; hence, if a grid voltage change of 5 volts causes a plate current change of 10 ma., the transconductance is .04 divided by 5, or 0.002 mho.

A convenient means of determining transconductance without any calculations is to read the plate current change caused by a change of exactly one volt on the control grid. By multiplying the resulting I_p change in ma. by 1000, the S_m obtained is directly in micromhos.

Vacuum Tube Amplification

● A tube amplifies by reason of the fact that a small change in grid voltage produces a larger change in plate current than would be produced by the same change in plate voltage. See Figure 11, page 17. This function can be applied in many ways, depending upon the result desired.

Vacuum tubes can be classified into two general categories, according to *application* and *operating characteristics*.

In general, vacuum tubes may be classified into four groups, according to their principal application. These are:

Voltage amplifiers
Power amplifiers
Current amplifiers
General purpose amplifiers

A voltage amplifier tube usually has a very high mu and finds its greatest use where tremendous voltage amplification is desired. This type of tube, like the type 57, must feed into a high impedance device like the grid of another vacuum tube for maximum voltage amplification. High mu tubes are used mostly as radio and intermediate-frequency amplifiers.

A power amplifier tube has a relatively low amplification factor and is used where the primary consideration requires a maximum amount of undistorted output. For maximum power transfer the load impedances must be properly matched to the plate resistance, which is generally of a low value. In power tubes, the output increases with great rapidity as the plate voltage is increased; hence, for maximum transfer, power tubes are operated with high plate voltages.

A current amplifier tube is one that gives large changes in plate current for very small changes in grid voltage; in other words, a tube having a high S_m will pass high plate currents; hence, the term "current amplifier." The use of these tubes is mostly confined to electronic industrial applications and therefore will not be discussed here.

General purpose amplifier tubes have characteristics between voltage and power amplifier tubes. The usefulness of this type of amplifier tube, in radio, is practically without end; for instance, in voltage amplification where a smaller power output is desired, and where the connecting link is a voltage step-up transformer, a general purpose triode will supply the circuit requirements. These tubes are now used extensively in class B or C power amplifiers.

From the foregoing it can be seen that vacuum tubes may be employed in a wide variety of ways, depending on the result desired. In addition to the above classification there are three principal types of tube amplifiers and two secondary types. These types differ largely in the choice of bias axis, angle of plate current flow and whether the average DC plate input is constant or variable.

Class A Amplifier

● The class A amplifier is biased usually in the middle of the linear portion of the dynamic characteristic curve. This is the usual condition of operating vacuum tubes, since the input impedance is then very high and very little energy is required to control the tube. In this type of amplifier, plate current flows the whole AC cycle, or 360 degrees. The average plate current waveform is independent of the signal or exciting voltage.

Class A amplifiers are used in all RF, IF and low level audio amplifiers in receivers. It is characterized by low plate efficiency and power output, but almost infinite power gain, because the control grid never goes positive and thus requires no grid driving power.

Class B Amplifier

● The class B amplifier is always biased to the point known as the "theoretical cut-off." The plate current is not zero at this point, but is quite low (no signal present on the grid). Theoretical cut-off bias equals the plate voltage divided by the μ, or amplification factor (not applicable to pentodes). It can also be determined by extending the linear portion of the dynamic characteristic down to the zero plate current line and reading the negative bias intercepted at that point. In class B amplifiers, the useful plate-current flow should last for exactly 180 electrical degrees, or one-half cycle.

The class B amplifier is used as an audio power amplifier where it is too expensive to provide the required audio power output from a class A amplifier. It will also give distortionless amplification of a radio-frequency wave that has been modulated in some preceding stage of a transmitter. Class B is characterized by maximum plate efficiencies from 40 to 70 per cent, depending upon application. This type amplifier is practically a compromise between power gain and power output, when functioning as an amplifier of unmodulated radio-frequency power. For audio-frequencies, it is necessary to use two tubes in push-pull in order to eliminate high distortion. As an audio-amplifier, the plate input varies widely with the signal, but the input remains constant when amplifying a modulated radio-frequency wave. At audio-frequencies the power output is proportional to the square of the grid excitation voltage.

Class C Amplifier

● The class C amplifier is biased considerably beyond the cut-off, and requires the application of a high amplitude signal voltage to carry the grid positive. Plate current flows for less than 180 degrees and the pulsating power pulses are usually quite peaked, which renders this type of amplifier unfit for distortionless amplification. However, for radio-frequency amplifiers and vacuum tube oscillators it is customary to use some type of class C amplifier. The characteristics of the amplifier render it capable of very high plate efficiency and power output, although the power gain drops as the plate efficiency and power output go up. In general, the output varies as the square of the plate voltage within limits. A common use for a class C amplifier is that of functioning as a plate modulated RF power amplifier, in which case the grid must be biased to at least twice the cut-off.

Class AB Amplifier

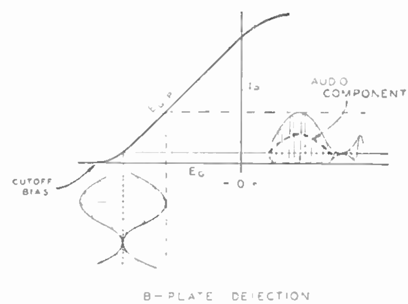
● The class AB amplifier is biased somewhere between the class A and the class B points. Plate current flows for more than 180 degrees, but less than 360 degrees. The plate efficiency and power output are intermediate between class A and B, and tubes with low μ are often adaptable to this class of service. Amplifiers of this class are almost exclusively used for audio-frequencies which are generally operated in push-pull to avoid distortion. The class AB amplifier was formerly called the class A Prime Amplifier.

Class BC Amplifier

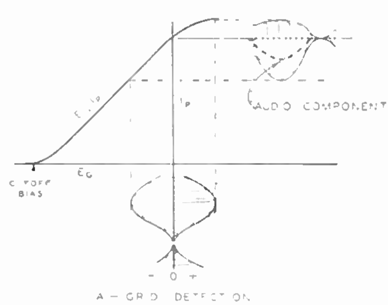
● The Class BC amplifier is biased somewhat beyond the cut-off, and thus plate current flows for less than 180 degrees. The only applications of the class BC amplifier at the present time are the RF linear amplifier and the grid bias modulated RF amplifier. In both these amplifiers, fixed low resistance bias equal to "theoretical cut-off" is supplemented by approximately an equal amount of cathode resistor bias. This arrangement permits the angle of plate current flow to be constant and independent of the audio modulation signal, even though the actual plate current flow is less than 180 degrees. The power output, plate efficiency and power gain are intermediate between class B and C.

Detection

● Detection is a process by which the audio modulation is separated from the radio-frequency signal carrier at the receiver.



Showing how the average plate current increases.



Showing how the average plate current decreases.

Detection always involves rectification or non-linear amplification of an AC current. All other types of detectors or demodulators provide exactly the same rectification except the triode, tetrode and pentode detectors which, in addition, combine the function of amplification to such an advantage that more over-all amplification can be obtained with fewer tubes.

There are two types of detectors used in radio; these are the *plate* and *grid detectors.* How each of these function are briefly described below.

The plate detector (or bias detector), sometimes improperly called power detector, amplifies the radio-frequency wave and then rectifies it and passes the audio-signal component on to the succeeding audio amplifier. The detector works on the lower bend in the plate current characteristic, as it is biased out close to the cut-off point. It might be called a class B amplifier. Plate detectors can be either of the weak signal or power type. The plate current is quite low in the absence of a signal and the audio component is evidenced by an increase in the average unmodulated plate current. The grid detector differs from the plate detector, as will be evidenced in the subsequent explanation.

The grid detector rectifies in the grid circuit and then amplifies the resulting audio signal. The only source of grid bias is the grid leak, so that the plate current is maximum when no signal is present. This detector works on the upper, or saturated, bend of its curve at a high plate voltage, and the demodulated signal appears as an audio-frequency *decrease* in the average plate current. However, at low plate voltage most of the rectification usually takes place as a result of the curvature in the grid characteristic. As with plate detectors, grid detectors can be either of the weak signal, or power type. By proper choice of grid leak and plate voltage, distortion can be held to a small value. The grid detector absorbs some power from the preceding stage, because of drawing grid current. The higher gain through the grid detector does *not* indicate that it is more sensitive. Detector sensitivity is a matter of rectification efficiency, not amplification alone.

The grid detector has an advantage when used as a regenerative detector because the grid leak usually allows a somewhat smoother control of regeneration than is possible with any form of plate or bias detection.

Oscillation

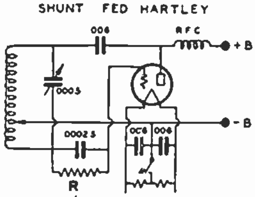
● The ability of an amplifier tube to control power enables it to function as an oscillator in a suitable circuit. By coupling part of the amplified output back into the input circuit, sustained oscillations will be generated; that is, if the input voltage to the grid is of the proper magnitude and phase with respect to the plate. In general, the voltage fed back and applied to the grid must be approximately 180 degrees out of phase with the voltage across the load impedance in the plate circuit and, in addition, have sufficient magnitude to develop the necessary grid voltage. The voltage swings are limited by the circuit losses and are of a frequency depending upon circuit conditions.

When a parallel resonant circuit consisting of an inductance and a capacitance (LC) is inserted in series with the plate circuit of an amplifier tube and connected so that the potential drop across its terminals is impressed on the grid in the same tube 180 degrees out of phase, amplification of the potential across the LC circuit will result. The potential would increase to an unrestricted value were it not for the limited range of linearity of the tube characteristic and the limited voltage available on the plate. Therefore, a value will eventually be reached limiting the amplitude of oscillation. When this value is attained, the process of amplification reverses, reducing the voltage across the LC circuit as quickly as it had been raised a moment before. When the voltage across the resonant circuit reaches zero, it reverses, and is developed to another value having the same amplitude but of opposite polarity; at the point of the greatest voltage swing, amplification again reverses, and the process continues indefinitely.

The frequency range of an oscillator can be made very great; thus, by varying the circuit constants, oscillations from a few cycles per second up to many millions can be generated. One of the unique properties of an oscillator is that it can oscillate at more than one frequency at the same time; these frequencies are called *harmonics.*

One of the most common types of oscillator circuits known is called the "Hartley Oscillator," a diagram of which is shown.

SHUNT FED HARTLEY



In this circuit the *plate* and *grid inductances* together with the *tank condenser* form an oscillatory circuit known as the *tank circuit.* If the condenser in this circuit be charged, then allowed to discharge through the plate and grid inductances as shown, the current flow would be alternating and of decreasing magnitude. The frequency is determined by the size of the condenser and inductances and is equal to:

$$f = \frac{1}{2\pi\sqrt{LC}}$$

Where f, the cycles per second; L, in henrys; and C, in farads.

The decrease in amplitude is due to losses in the tank circuit and to the energy delivered to the output. If sufficient energy be supplied to this circuit, during each cycle, to supply the losses and power output per cycle, the amplitude of the current would remain unchanged. The function of the vacuum tube is to deliver the required energy to the tank circuit.

As the energy stored in the tank circuit alternates, there will be a time when the grid will be charged positively with respect to the filament. A large direct-current plate current will flow under the influence of this positive grid potential, building up the field and storing energy in the plate choke (inductance). At a time of one-half cycle later the grid will be negative, thereby greatly decreasing the flow of plate current and causing the plate choke to discharge its energy into the tank circuit. This discharge occurs once each cycle and thereby the necessary energy is delivered to the tank circuit to maintain oscillations of constant magnitude.

When the grid is positive with respect to the filament, electrons leak back to the cathode via the grid leak and condenser. If the value of this RC path is high, a high effective grid bias results, making the tube function as a class C amplifier. This results in maximum output and high efficiency.

The best way to classify regenerative vacuum tube oscillators is by the feedback coupling method. All such oscillators use either capacitive or inductive coupling from the plate circuit back into the grid circuit. Usually very low-frequency oscillators (below 100 KC) use some form of inductive coupling, while high-frequency oscillators (100 to 100,000 KC) are capacitively or inductively coupled; however, for frequencies higher than 100,000 KC, only capacitive feedback is required.

At frequencies above 100,000 KC (3 meters) the effectiveness of the regenerative oscillator drops off rapidly because the time of flight from the electrons between the grid and plate becomes a large fraction of one cycle of oscillation. The losses in regenerative oscillators also become so large at these frequencies that the plate circuit is incapable of supplying the grid losses let alone supplying power for driving an amplifier or antenna.

Thus, at frequencies above 100 MC (100,000 KC), the newer *electron orbit* oscillator is becoming more widely used. This type of oscillator can be of several forms, the more important being the Magnetron and the Barkhausen-Kurz oscillators.

Color Code for Mica Condenser Marking

● The following color code is useful for the capacity marking of mica condensers for manufacturers' use. The colors are those adopted as standard in the R. M. A. Resistance Code, as follows:

Numeral	Color	Numeral	Color
0	Black	5	Green
1	Brown	6	Blue
2	Red	7	Violet
3	Orange	8	Gray
4	Yellow	9	White

A prerequisite to the use of this code is that capacity first be expressed in terms of micro-microfarads, as .00025 mfd. = 250 mmf.

The three color rings on the face carrying the name are used as follows, reading from left to right:

1. The first dot indicates the first digit.
2. The second dot indicates the second digit.
3. The third dot indicates the number of zeros which appear after the first two digits.

The above covers practically all requirements, but if three numbers exclusive of zero appear in the capacity, such as 1250 mmf., then the marking is as follows:

.00125 mfd. = 1250 mmf. =	Brown	Red		o
	Green	Brown		
.000375 mfd. = 375 mmf. =	Orange	Violet		o
	Green	Black		

Examples:

.000025 mfd. = 25 mmf. =	Red	Green	Black
.00005 mfd. = 50 mmf. =	Green	Black	Black
.0001 mfd. = 100 mmf. =	Brown	Black	Brown
.00025 mfd. = 250 mmf. =	Red	Green	Brown
.0005 mfd. = 500 mmf. =	Green	Black	Brown
.00075 mfd. = 750 mmf. =	Violet	Green	Brown
.001 mfd. = 1000 mmf. =	Brown	Black	Red
.01 mfd. = 10000 mmf. =	Brown	Black	Orange

1. The first two digits are indicated in first and second lots, as usual.

2. The third dot is left blank, which indicates the remaining code is on the reverse side of condenser.

3. Use is then made of the two code rings on the reverse side of the condenser from the trademark, the dot on the left indicating the third digit, and the dot on the right indicating the number of zeros which appear after the first three digits, as

(Courtesy Solar Mfg. Co.)

Chapter 3

DECIBELS AND LOGARITHMS

Decibels—Technique and Practical Application

● The decibel unit used in radio engineering and virtually universal in all power and energy measurements is actually a unit of amplification expressed as a common logarithm of a power or energy ratio. One decibel is 1/10th of a bel. One bel or 10 decibels indicates an amplification by 10, the common logarithm of 10 being 1. Similarly, 2 bels or 20DB means amplification by 100; 30DB means amplification by 1,000 and so on. The power ratio for one decibel is expressed as

$$\frac{P_1}{P_2} = 10^{.1} \quad \ldots\ldots\ldots\ldots (1)$$

where P_1 is the power input; P_2, the power output. The number of decibels represents a power gain or loss depending upon whether the relation P_1/P_2 is greater or less than 1.

Expressions for various power ratios are now commonly employed in communication engineering at audio and at radio frequencies. To express a ratio between any two amounts of power, it is convenient to use a logarithmic scale. A table of logarithms facilitates making conversions in positive or negative directions between the number of decibels and the corresponding power, voltage and current ratios.

The Logarithmic Table

● A table of logarithms is here presented. This table does not differ essentially from any other similar table except that here no proportional parts are given and the figures are stated to only three decimal places; this arrangement has been found to be satisfactory for all practical purposes. A complete exposition on logarithms is without the scope of this HANDBOOK, however, the very essentials together with the practical use of the tables and their application to decibels is given herewith. Thus, a person need not be concerned with the study of logarithms other than their direct employment to decibels.

The logarithm of a number usually consists of two parts; a whole number called the characteristic, and a decimal called the mantissa. The characteristic is the integral portion to the *left* of the decimal point (see examples below), and the mantissa is the value placed to the right. The mantissa is all that appears in any table of logarithms. In the logarithm the mantissa is independent of the position of the decimal point, while on the contrary, the characteristic is dependent only on the position of the number with the relation to the decimal point. Thus in the following examples:

	NUMBER		LOGARITHM
(a)	4021.	=	3.604
(b)	402.1	=	2.604
(c)	40.21	=	1.604
(d)	4.021	=	0.604
(e)	.4021	=	—1.604
(f)	.04021	=	—2.604

It will be seen that the characteristic is equal, algebraically, to the number of places minus one, which is the first significant figure occupied to the left of the decimal point. In (a) the characteristic is 3; in (b) 2; in (d) 0; in (e) —1; and in (f) —2. The following should be remembered: (1) that for a number greater than 1, the characteristic is *one less* than the number of significant figures in the number; and (2), that a number wholly a decimal, and the characteristic is negative and is numerically *one greater* than the number of ciphers immediately following the decimal point. Notice (e) and (f) in the above examples.

Finding a Logarithm

● To find a common logarithm of any number simply proceed as directed herewith: Suppose the number to be 5576. First, determine the characteristic. An inspection will show that this number will be three. This figure is placed to the *left* of a decimal point. The mantissa is now found by referring to the logarithm table. Proceed selecting the first two numbers which are 55, then glance down the N column until coming to these figures, advance to the right until coming in line with the column headed 7, the number will be 746. (Note that the column headed 7 corresponds to the *third* figure in the number 5576). Place the mantissa 746 to the *right* of the decimal point making the number now read 3.746. This is the logarithm of 5576. *Important:* do not consider the last figure, 6, in the number 5576 when looking for the mantissa; in fact, disregard all figures beyond the first three when determining the mantissa, however, be doubly sure to include *all* figures when ascertaining the magnitude of the characteristic.

Practical applications applying the logarithm to decibels will follow. Other methods using the logarithm will be discussed as the subject develops. See Logarithm Table.

Three Place Logarithms

N	0	1	2	3	4	5	6	7	8	9
00	000	000	000	000	000	000	000	000	000	000
10	000	004	008	012	017	021	025	029	033	037
11	041	045	049	053	056	060	064	068	071	075
12	079	082	086	089	093	096	100	103	107	110
13	113	117	120	123	127	130	133	136	139	143
14	146	149	152	155	158	161	164	167	170	173
15	176	179	181	184	187	190	193	195	198	201
16	204	206	209	212	214	217	220	222	225	227
17	230	233	235	238	240	243	245	248	250	252
18	255	257	260	262	264	267	269	271	274	276
19	278	281	283	285	287	290	292	294	296	298
20	301	303	305	307	309	311	313	316	318	320
21	322	324	326	328	330	332	334	336	338	340
22	342	344	346	348	350	352	354	356	358	359
23	361	363	365	367	368	371	372	374	376	378
24	380	382	383	385	387	389	390	392	394	396
25	397	399	401	403	404	406	408	409	411	413
26	415	416	418	420	421	423	424	426	428	429
27	431	433	434	436	437	439	440	442	444	445
28	447	448	450	451	453	454	456	457	459	460
29	462	463	465	466	468	469	471	472	474	475
30	477	478	480	481	482	484	485	487	488	490
31	491	492	494	495	496	498	499	501	502	503
32	505	506	507	509	510	511	513	514	515	517
33	518	519	521	522	523	525	526	527	528	530
34	531	532	534	535	536	537	539	540	541	542
35	544	545	546	547	549	550	551	552	553	555
36	556	557	558	559	561	562	563	564	565	567
37	568	569	570	571	572	574	575	576	577	578
38	579	580	582	583	584	585	586	587	588	599
39	591	592	593	594	595	596	597	598	599	601
40	602	603	604	605	606	607	608	609	610	611
41	612	613	614	616	617	618	619	620	621	622
42	623	624	625	626	627	628	629	630	631	632
43	633	634	635	636	637	638	639	640	641	642
44	643	644	645	646	647	648	649	650	651	652
45	653	654	655	656	657	658	659	659	660	661
46	662	663	664	665	666	667	668	669	670	671
47	672	673	673	674	675	676	677	678	679	680
48	681	682	683	683	684	685	686	687	688	689
49	690	691	692	692	693	694	695	696	697	698
50	699	699	700	701	702	703	704	705	705	706
51	707	708	709	710	711	712	713	713	715	715
52	716	716	717	718	719	720	721	722	722	723
53	724	725	725	726	727	728	729	730	730	731
54	732	733	734	734	735	736	737	738	738	739
N	0	1	2	3	4	5	6	7	8	9

Power Levels

● In the design of radio devices and amplifying equipment the power level is taken at six milliwatts (.006w). This corresponds to the arbitrary reference level of zero decibels. All power levels above the reference level are designated as "plus" quantities, and below as "minus." The figure is always prefixed by a plus (+) or minus (—) sign commanding the direction in which the quantity is to be read.

Power to Decibels

● The power output (watts) of any amplifier may be easily converted into decibels by the following formula, assuming that the input and output impedances are equal:

$$N_{db} = 10 \text{ Log}_{10} \frac{P_1}{P_2} \qquad (2)$$

where N_{db} is the desired power level in decibels; P_1, the output of the amplifier; and P_2, the reference level of 6 milliwatts. The subnumeral, 10, affixed to the logarithm indicates that the Log is to be extracted from a table to which 10 must be raised in order to produce a number.

By substituting values for the letters shown in the above formula, take the following illustration:

An amplifier using a 2A5 tube is said to deliver an undistorted output of three watts. How much is this in decibels?

Solution by formula (2):

$$\frac{P_1}{P_2} = \frac{3}{.006} = 500$$

and Log 500 = 2.69

therefore $10 \times 2.69 = 26.9$ DECIBELS.

By placing other values for those shown in the solution any output power may be converted into decibels *provided* that the decibel equivalent is *above* the zero reference level or the power is *not less* than 6 milliwatts.

To solve most all problems to which the solution will be given in minus DBs, a simple understanding of algebraic adding is required. To add algebraically, it is necessary to observe the plus and minus signs of expressions. (Do not confuse these signs with decibels.) In the succeeding illustrations notice that the result was caused sometimes by addition and at other times by subtraction.

(a)	(b)	(c)	(d)
+2	—4	—4	+4
—4	—2	+2	+2
—2	—6	—2	+6

The terms used in (c) are those that apply to decibel calculations.

Three Place Logarithms

N	0	1	2	3	4	5	6	7	8	9
55	740	741	741	742	743	744	745	746	747	747
56	748	749	749	750	751	752	752	753	754	755
57	755	756	757	758	758	759	760	761	761	762
58	763	764	764	765	766	767	767	768	769	770
59	770	771	772	773	773	774	775	776	776	777
60	778	778	779	780	781	781	782	783	783	784
61	785	786	786	787	788	788	789	790	791	791
62	792	793	793	794	795	795	796	797	798	798
63	799	800	800	801	802	802	803	804	804	805
64	806	806	807	808	809	810	810	811	811	812
65	813	813	814	814	815	816	816	817	818	818
66	819	820	820	821	822	822	823	824	824	825
67	826	826	827	828	828	829	829	830	831	831
68	832	833	833	834	835	835	836	837	837	838
69	838	839	840	840	841	842	842	843	843	844
70	845	845	846	847	848	848	849	849	850	850
71	851	851	852	853	853	854	854	855	856	856
72	857	857	858	859	859	860	860	861	861	862
73	863	863	864	865	865	866	866	867	868	868
74	869	869	870	871	871	872	872	873	873	874
75	875	875	876	876	877	877	878	879	879	880
76	880	881	882	882	883	883	884	884	885	885
77	886	887	887	888	888	889	889	890	891	891
78	892	892	893	893	894	894	895	896	896	897
79	897	898	898	899	899	900	900	901	902	902
80	903	903	904	904	905	905	906	906	907	907
81	908	909	909	910	910	911	911	912	912	913
82	913	914	914	915	915	916	917	917	918	918
83	919	919	920	920	921	921	922	922	923	923
84	924	924	925	925	926	926	927	927	928	928
85	929	929	930	930	931	932	932	933	933	934
86	934	935	935	936	936	937	937	938	938	939
87	939	940	940	941	941	942	942	943	943	944
88	944	945	945	946	946	946	947	947	948	948
89	949	949	950	950	951	951	952	952	953	953
90	954	954	955	955	956	956	957	957	958	958
91	959	959	960	960	960	961	961	962	962	963
92	963	964	964	965	965	966	966	967	967	968
93	968	968	969	969	970	970	971	971	972	972
94	973	973	974	974	975	975	975	976	976	977
95	977	978	978	979	979	980	980	980	981	981
96	982	982	983	983	984	984	985	985	985	986
97	986	978	987	988	988	989	989	989	990	990
98	991	991	992	992	993	993	993	994	994	995
99	995	996	996	996	997	997	998	998	999	999
00	000	004	008	012	017	021	025	029	033	037
N	0	1	2	3	4	5	6	7	8	9

When a solution to a problem involving logarithms will be in minus DBs, note particularly that the characteristics of the logarithm will be prefixed by a minus sign (—). This sign only effects the characteristic while mantissa remains positive. The mantissa always remains thus, no matter the direction the solution brings the decibel. A prefix —1 to a logarithm means that the first figure of the number will be the *first place* to the *right* of the decimal; —2, will occupy the second place to the right, while a cipher fills the first place; —3, the third place with two ciphers filling the first and second places, and so on.

To multiply a *minus* characteristic and a *positive* mantissa by 10, each part must be considered separately, multiplied by 10, and then the products added algebraically; thus, in the following illustration:

An amplifier using a 199 tube has an output of 5 milliwatts. How much is this in decibels?

Solution by formula (2):

$$\frac{P_1}{P_2} = \frac{.005}{.006} = .83$$

Log .83 = —1.9 (actually —1.920)

Therefore 10 × —1.9 = **—1 DECIBEL** (10 × —1 = —10; and 10 × .9 = +9, hence, adding the products algebraically = —1).

By substituting other values for those in the above solution, any output power *below* 6 milliwatts or the zero reference level may be converted into decibels.

Determining DB Gain or Loss

● In using amplifiers it is a prime requisite to know the decibel gain or loss when the input and output powers are known. To determine the gain or loss in DB employ the following formula:

$$\text{(gain) } N_{db} = 10 \text{ Log } \frac{P_o}{P_i} \quad (3)$$

$$\text{(loss) } N_{db} = 10 \text{ Log } \frac{P_i}{P_o} \quad (4)$$

where N_{db} is the number of DB gained or lost; P_i, the input power; and P_o, the output power.

Applying, for example, formula (3): Suppose that an intermediate amplifier is being driven by an input power of .2 watts. and after amplification, the output is found to be 6 watts.

$$\frac{P_o}{P_i} = \frac{6}{.2} = 30$$

Log 30 = 1.48

Therefore 10 × 1.48 = **14.8 DB POWER GAIN.**

Amplifier Ratings

● The technical specifications or rating on power amplifiers must contain the following information: the overall gain in decibels; the power output in watts; the value of the input and output impedances; the input signal level in DB; the input signal voltage; and the power output level in decibels.

If the specifications on any one particular amplifier had included only the input and output signal levels in DB, it then would be necessary to know how much these values represented in power. The methods employed to determine power levels are not similar to those used in previous calculations. Caution should therefore be taken in reading the following explanations with particular care and attention being paid to the minor arithmetical operations.

The Anti-logarithm

● To determine a power level from some given decibel value, it is necessary to invest the logarithmic process formerly employed in converting power to decibels. Here, instead of looking for the log of a number it is now necessary to find the anti-logarithm or number corresponding to a given logarithm.

In deriving a number corresponding to a logarithm it is important that these simple rules be committed to memory: (1) that the figures that form the original number from a corresponding logarithm depend entirely upon the mantissa or decimal part of the log; (2), that the characteristic serves only to indicate where to place the decimal point of the original number; and (3), that if the original number was a whole number the decimal point would be placed to the extreme right.

The procedure of finding the number corresponding to a logarithm is explained as follows: Suppose the logarithm to be 3.574. First, search in the table under any column from 0 to 9 for the numbers of the mantissa 574. If the exact number cannot be found, look for the next *lowest* figure, which is nearest to, but less than, the given mantissa. After the mantissa has been located simply glance immediately to the left to the N column and there will be read the number, 37. This number comprises the first two figures of the number corresponding to the antilog. The third figure of the number will appear at the head of the column in which the mantissa was found. In this instance the number heading the column will be 5. If the figures have been arranged as they have been found, the number will now be 375. Now since the characteristic is 3, there must be four figures to the *left* of the decimal point; therefore, by annexing a cipher the number becomes 3750; this is the number that corresponds to the logarithm 3.574. If the characteristic was 2 instead of 3, the number would be 375. If the logarithm was —3.574 or—1.274 the antilogs or corresponding numbers would be .00375 and .375 respectively. After a little experience a person can obtain the number corresponding to a logarithm in a very few seconds.

Converting Decibels to Power

● It is always convenient to be able to convert a decibel value to a power equivalent in order to determine the ratio difference. The formula used for converting decibels into watts is similar in many respects to equation (2), the only difference being that the factor P_1 corresponding to the power level is not known. Usually the formula for converting decibels into power is written as

$$N_{db} = 10 \text{ Log } \frac{P_1}{.006} \quad (5)$$

In practice it has been found that it is too difficult to explain the solution to the above equation on account of the expression being written in the reverse. However, by re-arranging the various factors, the expression can be simplified to permit easy visualization, thus

$$P = .006 \times \text{antilog} \frac{N_{db}}{10} \quad (6)$$

where P is the desired power level; .006, the reference level in milliwatts; N_{db}, the decibels to be converted; and 10, the divisor. To determine the power level, P, from a decibel equivalent simply divide the decibel value by 10, then take the number comprising the antilog and multiply it by .006, the product gives the power level of the decibel value.

NOTE: In all problems dealing with the conversion of *minus* decibels to power it often happens that the decibel value $—N_{db}$, is not always equally divisible by 10. When this is the case, the numerator in the factor $—N_{db}/10$ must be made evenly divisible by the denominator in order to derive the proper power ratio. Note that the value $—N_{db}$ is negative, hence, when dividing by 10, the negative signs must be observed and the quotient labeled accordingly.

To make the numerator in the value $—N_{db}$ equally divisible by 10, proceed as follows: Assume $—N_{db}$ to be the logarithm —38 with a zero mantissa, hence, in order to make —38 divisible by 10 simply annex as many units as is necessary from the zero mantissa and add them to the —38 until the figure can be equally divided. An examination will show it was only necessary to add two units to bring —38 up to —40. CAREFULLY NOTE that every unit borrowed from the zero mantissa must be returned to it as a positive quantity multiplied by 10. Thus, the two units borrowed to bring —38 up to —40 is returned as 20, making what was a zero mantissa now have a value of 20. The numerator $—N_{db}$, now becomes —40.20; this figure can now be equally divided by 10.

While the above discussion applied strictly to negative values the following examples will clearly show the technique to be followed for most all practical problems.

(a) The output level of a popular velocity ribbon microphone is rated at —74DB. What is this equivalent in milliwatts?

Solution by equation (6)

$$\frac{-N_{db}}{10} = \frac{-74}{10} \text{ (not equally divisible by 10)}$$

Routine:

```
   —74      mantissa
   +6 60  (6×10)
   ------
   —80 60
```

$$\frac{-N_{db}}{10} = \frac{-80.60}{10} = -8.6$$

Antilog —8.6 = .00000004
.006×.00000004 =.000000000240 or
240 MICROMICRO-WATTS

(b) This example differs somewhat from that of the above in that the mantissas are added differently.—A low powered amplifier has an input signal level of —17.3DB. How many milliwatts does this value represent?

Solution by equation (6)

$$-N_{db} = \frac{-17.3}{10} = -2.33$$

```
 —17 .  3
 + 3 . 30
 --------
 —20 . 33
```

(The mantissas were added as 30 plus 3, and NOT .3 plus .30)

Antilog —2.33 = .0214
.006 × .0214 = .000128 or
.13 MILLIWATTS.

Voltage Amplifiers

● When plans are being drafted contemplating the design of power amplifiers it is essential that the following data be determined: First, the input and output signal levels to be used; second, the size of the power tubes that would adequately deliver an undistorted output; and third, the input signal voltage that must be applied to the amplifier to deliver the desired output. This last requirement is the most important in the design of voltage amplifiers as it is the ratio of the input signal voltage to the output signal voltage that governs the amount of amplification.

The voltage step-up in a transformer coupled amplifier depends chiefly upon the mu of the tubes and the turns ratio of the inter-stage coupling transformers. The step-up value in any amplifier is calculated by multiplying the step-up factor of each voltage amplifying or step-up device. Thus for example, if an amplifier were designed having an output transformer with a ratio of 3:1 coupled to a tube having a mu of 7, the voltage step-up would be approximately 3 times 7, or 21. It is seldom that the total product will be exactly the figure derived because it is not quite possible to obtain the full mu of the tube.

From the voltage gain in an amplifier it is possible to calculate the input and output signal levels and at the same time be able to determine at what level the input signal must be in order to obtain the desired output. By converting voltage ratios into decibels, power levels can be determined. Hence, to find the gain in DB when the input and output voltages are known, the following expression is used:

$$\text{(gain) } N_{db} = 20 \text{ Log } \frac{E_1}{E_2} \qquad (7)$$

where E_1 is the output voltage: and E_2 the input voltage.

Employing the above equation to a practical problem, note that the logarithm is multiplied by 20 instead of by 10 as in previous examples.

A certain one-stage amplifier consisted of the following parts: 1 input transformer, ratio 2:1; and 1 output tube having a mu of 95. Determine the gain in decibels with an input voltage of 1 volt.

Solution by equation (7)

$2 \times 95 = 190$ voltage gain

therefore, $\frac{E_1}{E_2} = \frac{190}{1} = 190$

Log 190 = 2.278

20 × 2.278 = 45.56 **DECIBEL GAIN**

To reverse the above and convert decibels to voltage ratios, use the following expression:

$$\text{E (gain)} = \text{antilog } \frac{N_{db}}{20} \qquad (8)$$

where E is the voltage gain (power ratio); N_{db}, the decibels; and 20, the divisor.

To find the gain, simply divide the decibels by 20, then extract the antilog from the quotient, the result gives the voltage ratio.

Input Voltages

● In designing power amplifiers, it is paramount to have *exact* knowledge of the magnitude of the input signal voltage necessary to drive the output power tubes to maximum undistorted output. Without this information it would largely be a matter of guesswork in determining whether or not the power stages were being worked overloaded or underloaded.

To determine the input voltage take the *Peak voltage* necessary to drive the grid of the output tube to maximum and divide this figure by the total overall gain *preceding the last stage.*

Microphone Levels

● Practically all acoustic-electric apparatus energizing amplifiers have output levels rated in decibels. The output signal levels of these devices vary considerably from each other as may be noted from the table above:

	Decibels	Average
Phonograph pickup	0 to —30	—15
Carbon microphones	—30 to —60	—45
Piezo-elec. microphones	—70 to —80	—75
Dynamic microphones	—75 to —95	—85
Condenser microphones	—95 to —100	—97
Velocity microphones	—100 to —110	—105

In general, the lower the output signal level, the higher will be the acoustic fidelity over the entire audio spectrum. On the other hand, the higher the input signal level, the lower will be the overall fidelity.

The output levels of microphones and phonograph pickups have the same power values ascribed to them as those derived from calculating power output levels of amplifiers. Therefore, the same equations employed in connection with power ratios are similarly applied when converting output signal levels to power levels.

Computing Specifications

● From the preceding explanations the following data can be computed with a very high degree of accuracy:

(1) Voltage amplification
(2) Overall gain in DB
(3) Output signal level in DB
(4) Input signal level in DB
(5) Input signal level in watts
(6) Input signal voltage

Push-Pull Amplifiers

● To double the output of any cascade amplifier it is only necessary to push-pull the last amplifying stage and replace the interstage and output transformers with push-pull types.

To determine the voltage step (voltage ratio) of a push-pull amplifier take the ratio of one *half* of the secondary winding of the push-pull transformer and multiply it by the mu of one of the output tubes in the push-pull stage; the product, *when doubled*, will be the voltage amplification or step-up.

NOTE: Doubling the output power of any amplifier will not double the output signal level. In general, doubling the power adds about only 3 DB.

Acoustically, that is from the loudspeaker standpoint, it takes approximately one DB to note any appreciable change in the volume of sound. This is because the intensity of sound as heard by the ear varies logarithmically with the acoustic power. For practical purposes it is only necessary to remember that if two sounds differ in physical intensity by less than one DB they usually sound alike. If they are much more than one decibel apart one sounds slightly louder than the other. This quantitative data is also applicable to amplifiers in that the output signal levels must differ by at least 1.5 DB in order to note any change in volume.

Pre-amplifiers

● Pre-amplifiers are employed to raise low input signal levels up to some required input level of another intermediate or succeeding amplifier. For example: If an amplifier was designed to operate at an input level of —30DB, and instead, a considerably lower input level was used, a pre-amplifier would then have to be designed to bring the low input signal up to the rated input signal level of —30DB to obtain the full undistorted output from the power tubes in the main amplifier. The amount of gain necessary to raise a low input signal level up to another level may be determined by the following equation:

$$E(\text{gain}) = \text{antilog}\,\frac{N_{db_1} - N_{db_2}}{20} \quad (9)$$

where E is the voltage step-up or gain; N_{db_1}, the input signal level of the pre-amplifier or the new input signal level; N_{db_2}, the input signal level to the intermediate amplifier; and 20, the divisor.

To apply the equation, take the following example: If a 7-watt amplifier had an input signal level of —32.8DB and a microphone had an output signal level of —60DB which was exciting the amplifier, how much voltage amplification will be necessary to raise the gain up to —32.8DB so that the amplifier will work at full output?

$$\frac{N_{db_1} - N_{db_2}}{20} = \frac{60 - 32.8}{20} = 1.355$$

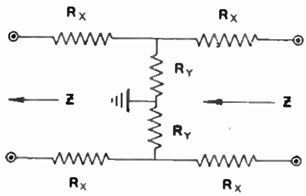
Antilog 1.355 = **22.6 VOLTAGE GAIN**

The additional gain can be obtained by designing a pre-amplifier having an input transformer with a ratio of 2.5:1 coupled to a tube having a mu of 9.

Design of Fixed Networks

(T&H Pads)

● The "T" section, which is an unsymmetrical network (unbalanced) is most frequently used where small unbalances in the line or to ground are of little importance. Fixed type networks are chiefly employed in circuits where it is desired to limit the



"H" Pad.

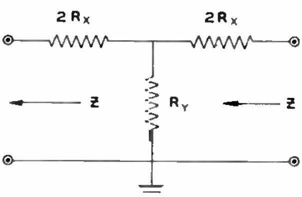


FIG. 1—"T" Pad.

amount of input voltage available to excite amplifiers, thus precluding the possibilities of overloading certain components in the amplifying system. A resistive network which functions as an absorption device loses its identity as a "pad" and is most often referred to as an "insertion loss," because the section has been inserted to attenuate a known and definite quantity.

To design a fixed "T" or "H" type section for some predetermined loss in DB, the following equations are given. These equations only hold good when the line impedances terminating each end of the network are equal; therefore from Figure 1 where R_x

$$R_x = \frac{Z}{2}\,\frac{(K-1)}{(K+1)}$$

$$R_y = 2Z\,\frac{K}{(K^2-1)}$$

$$K = \text{antilog}\,\frac{N_{db}}{20}$$

equals the series resistor (this value must be multiplied by 2 for "T" sections); R_y, the shunt resistor; Z, the line impedance; and K, a constant derived by taking the inserted attenuation in DB and dividing by 20, then extracting the antilog.

Impedance Matching Networks

● At audio frequencies an impedance matching network comprised of resistive impedances can be substituted for an impedance matching transformer or like device. Unfortunately, this type of network introduces a small loss: however, this loss is of little consequence because it can be counteracted by simply working the input or output circuits at a higher level.

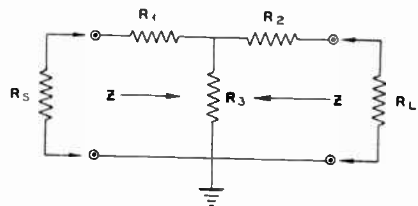


FIG. 2—Impedance Matching Network.

In Figure 2 it is very important that the resistors R-1 and R-2 be placed correctly in the configuration otherwise impedances will be mismatched and reflections will oc-

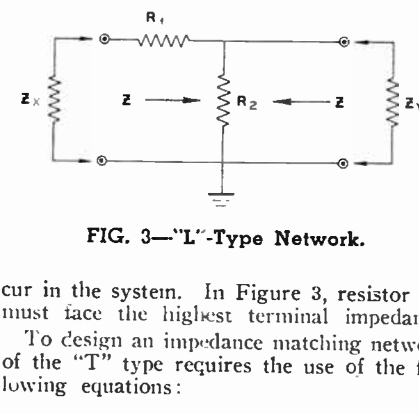


FIG. 3—"L"-Type Network.

cur in the system. In Figure 3, resistor R1 must face the highest terminal impedance.

To design an impedance matching network of the "T" type requires the use of the following equations:

$$R\text{-}1 = \frac{(R_S + R_L)\,K_1 + (R_S - R_L)}{2}$$

$$R\text{-}2 = \frac{(R_S + R_L)\,K_1 - (R_S - R_L)}{2}$$

$$R\text{-}3 = \frac{(R_S + R_L)}{2K_2}$$

Where R_s is the input impedance; R_L, the output impedance: and K_1 and K_2 are constants taken from the table shown on page 30. These constants appear directly opposite the amount of attenuation in the N_{db} column:

N_{db}	K_1	K_2
1	.057	0.115
2	.114	0.232
3	.171	0.352
4	.226	0.477
5	.280	0.609
6	.331	0.747
7	.382	0.897
8	.430	1.055
9	.476	1.233
10	.519	1.422
11	.560	1.634
12	.598	1.863
13	.634	2.122
14	.667	2.404
15	.697	2.720
16	.726	3.075
17	.752	3.468
18	.776	3.907
19	.798	4.398
20	.818	4.952
21	.835	5.555
22	.852	6.262
23	.867	7.013
24	.880	7.868
25	.893	8.870
26	.904	9.977
27	.914	11.188
28	.923	12.484
29	.931	14.091
30	.938	15.734
31	.945	17.744
32	.950	19.810
33	.956	22.339
34	.960	24.939
35	.965	27.121
36	.968	31.393
37	.972	35.397
38	.975	39.515
39	.978	44.555
40	.980	50.237
41	.982	56.079
42	.984	63.230
43	.985	70.583
44	.987	78.792
45	.988	88.836
46	.990	100.165
47	.991	111.813
48	.992	126.070
49	.993	140.729
50	.994	158.672

To design an impedance matching network of the "L" type requires this set of equations:

$$R_1 = Z_x(Z_x - Z_y)$$

$$R_2 = \frac{Z_x Z_y}{\sqrt{Z_x(Z_x - Z_y)}}$$

Since the insertion loss is a function of the impedances terminating the network it can be calculated as follows:

$$K = \sqrt{\frac{Z_x}{Z_y}} + \sqrt{\frac{Z_x}{Z_y} - 1}$$

Where loss in DB = 20 Log_{10}K.

Radio Data Charts

● Radio data charts provide designers of amateur radio equipment with a ready and convenient means of solving problems without having recourse to complicated formula and mathematics.

To properly use the chart and to prevent disfiguring the page, simply place a piece of tracing paper, celluloid, or waxed paper over the scales, then, the index line which intercepts the scales may be drawn with a hard pencil and a straight edge.

The first chart which is a *logarithmic alignment nomogram* will solve many problems encountered in ordinary practice.

Voltage Drop Calculation in Resistors

● To find the voltage drop for a certain bias for a self-biased tube, add three ciphers to the value desired, seek this value on scale A; next, search for the value which corresponds to the plate current (cathode current) on the B scale, now, drawing a line between these two points will intersect a point on C, this corresponds to the ohmage. Hence, a resistance required to produce 9 volts bias for a triode which operates at 3 MA plate current is: on the A scale, 9 plus three ciphers equals 9000; on the B scale 3MA; and the ohmage 3000. is found on C.

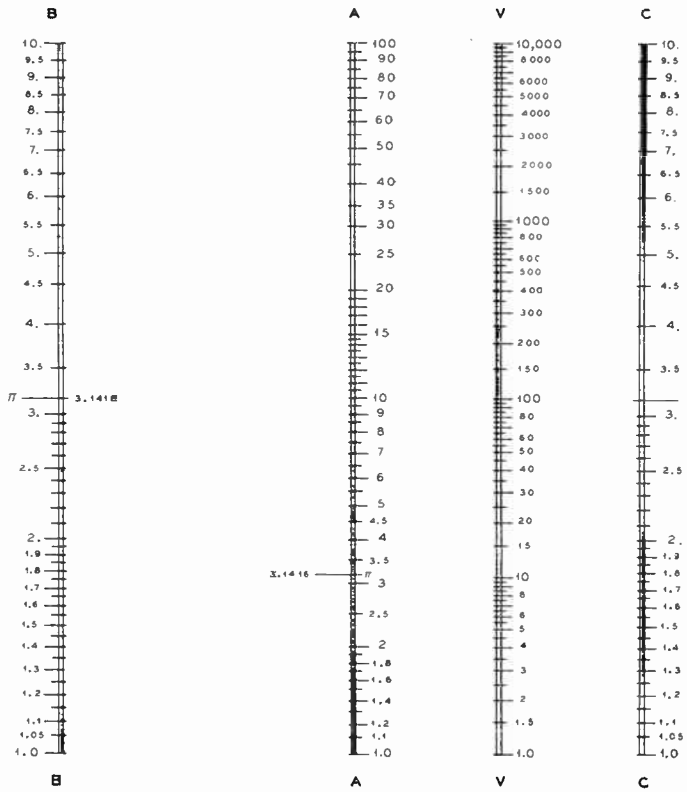
Wattage or Heat Capacity in Resistors

● To find the power liberated in watts by a certain resistor when ohmage and voltage is known, proceed as follows: On C find the voltage, on A, the resistance; draw a line connecting these two points over to the B scale, next, find the voltage (for the second time) on the A scale and draw a line from point B through A, the wattage will be given on C. See the auxiliary Figure for an example.

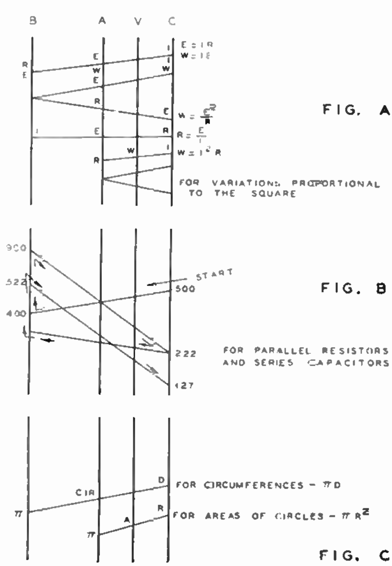
If the current instead of the voltage is known in the above procedure, the technique is as follows: On C find the value of current, on A, the resistance, a line drawn connecting these points will intercept the wattage rating on V.

Series Capacity Calculations

● To determine the value of any *two* series-capacities, find one of the values on C and the other on B, draw a line to connect these



Jones Radio Handbook Logarithmic Alignment Nomogram.



Auxiliary Chart.

two points; next, *add* the values of the capacities on B, then from this new point, draw a line to intersect A, and the series value will be read on C.

If three series capacities are to be employed, the value of any two of them is found as above, and then this is treated as a single capacity and its value combined with the third can be found by repeating the process which can be carried on indefinitely.

An example illustrating the method is shown in auxiliary Figure (b).

NOTE: Raise the A scale the distance from 1 to 10 when the reading is beyond the bottom, or by taking a piece of tracing paper and tracing the A scale so as to extend it another length of 1 to 10.

Parallel Resistor Calculations

● These are treated exactly as series capacities, and the above explanation will solve all values.

Coil Winding Considerations

● It is often necessary to know, in coil winding procedure, the resistance of coils when re-wound to the same volume with a wire larger or smaller than the coil was originally wound with; hence, by knowing the size of the wires, the circular-mil areas, and the ohmage of the original winding, the ohmic value of the new winding can be found as follows: select the value corresponding to the circular-mil area of the new winding on the C scale, select the value corresponding to the ohmage of the original winding on the V scale, draw a line to A intersecting these points; next, on C find the value corresponding to the circular-mil area of the old winding, a line drawn from A to C will intercept the ohmage of the new winding on V.

These calculations are based on the principle that resistances are inversely proportional to the squares of the wire sizes. This is sensibly true for a change of a few sizes, but the error increases with the range of sizes which should not be over five.

Sound and Light Calculations

● The intensity of sound and light, on a surface varies inversely as the square of the distance from the source. Variations proportional to the square is of importance in the sound, light, magnetic and gravitational fields. By employing the considerations given in the preceding paragraph all problems enunciated in this topic can be solved. By using the example shown in auxiliary Figure (a) it will be found that if a surface 12.7 feet distant from a light source receives an intensity of 100 foot-candles when moved 20.2 feet from the light, it will receive 39.5 foot-candles. (After C.P. Nachod, N&US Sig. Co.)

Areas of Circles

● The area of any circle can be found by placing the Pi constant (3.1416) on A and the radius on C, the area will be found on V when a line intersects V drawn through A and C.

Another method for finding the area is to place the constant 0.785 on A, the diameter on C and the area will be found on V when a line is drawn through A, C.

Circumference of Circles

● The circumference of any circle can be found by placing the Pi constant (3.1416) on B and the diameter on C, a line connecting B. C will intercept the circumference on A.

Multiplication

● The multiplication table is represented on scales A, B, and C. A line drawn through values on scales B, C will intersect the product on A.

Division

● To divide the process of multiplication is reversed, the values for the divisor will appear on the C scale, and the dividend on A and a line drawn through these points will intersect the quotient on B.

Square Root

● To extract the square root of any number, seek the number on the A scale and the root will appear horizontally on either the B or C scales.

Powers of Numbers

● To raise the number to the fourth power ($3 \times 3 \times 3 \times 3 = 81$), select the number in both the B and C columns, a horizontal line drawn through these points intersects the fourth power on the V scale.

Chapter 4

Radio Code Instruction

● Every person who desires to operate an amateur transmitting station must obtain a "station" and "operating" license from the district offices of the Federal Communication Commission. The locale of these district offices is given in the Appendix. A license is not required to operate a receiver. To secure the necessary licenses, the applicant must pass an examination in order to prove his technical knowledge of the theory and practice of amateur radio communication, as well as being able to copy the Continental Code at a speed of thirteen words per minute.

Those who desire to learn the code without the aid from others may do so by means of a CODE PRACTICE SET. Several kinds of these sets can be constructed, of which the simplest is not always the best. Any amateur will gladly assist the beginner to properly build a practice instrument. Of importance, the instrument must be so designed that a sharp, clear tone will be produced in the receivers, simulating that of a continuous-wave signal (c.w.) as commonly heard on short-wave receivers. Only a few moments are required to assemble a code practice set, of which the parts may be purchased at a modest cost from most any radio store. Should difficulty be encountered in making the instrument properly function, it should be taken to an amateur or radio service man who will make the necessary adjustments.

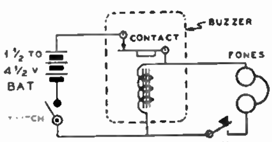


Fig. 1

The simplest code practice set is shown in Figure 1. Here, an oscillator consisting of a high-frequency buzzer, one or two dry-cells, a pair of headphones, and a telegraph key complete the instrument ensemble. The advantages of this oscillator are that the buzzer operates continuously to produce a stable audio-frequency tone. The headphones and telegraph key are connected in series across the buzzer coil. The buzzer contacts should be adjusted for the least change in the note when the key is depressed. Although the buzzer operates continuously as long as current is being supplied from the batteries, the tone is only heard in the headphones when the key is manipulated.

Another code practice set is shown in Figure 2. Here a cathode-heater type vacuum tube functions as an oscillator in what is known as a "Hartley" oscillating circuit. The 2.5 volt or 6.3 volt tubes may be substituted in the circuit with equal success. The type 76 tube is the 6.3 volt equivalent of the type 56 which draws only 0.3 ampere heating current; hence, on account of such low current consumption the tube

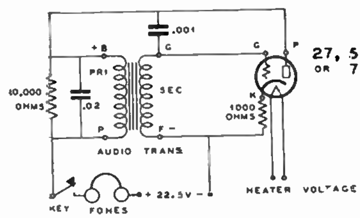
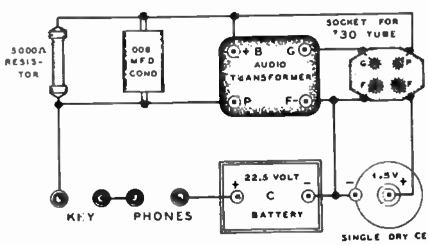


Fig. 2

Code Practice Oscillator Using Heater Tube

can be operated from a series of four No. 6 dry-cells. The coupling transformer is of the audio-frequency type, any turns ratio.



Pictorial and schematic diagrams showing how to wire a simple code practice oscillator for use with dry batteries.

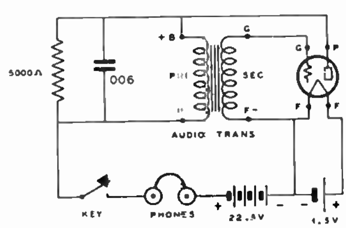
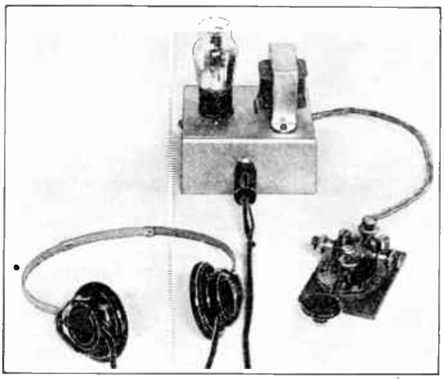


Fig. 3

A type '30 tube, a single dry-cell and a 22½ volt B battery gives good results in the code practice set shown in Fig. 3.

The telegraph key is in series with the headphones and the plate ("p") terminal of the audio transformer. The pitch of the note may be varied by merely increasing or decreasing the "B" voltage. It will be found that the most pleasing note will be obtained at about 22½ volts.

The capacity of the fixed condensers will also affect the pitch of the note, as well as the volume. The vacuum tube code practice oscillator is far more satisfactory than the buzzer type shown in Fig. 1. It gives a more stable tone, which can be varied in intensity and pitch to suit the individual requirements of the operator.



Code Practice Oscillator as shown in Fig. 2.

How to Master the Radio Code

● There is nothing complicated about learning the code. Many young boys and girls have succeeded in attaining a code speed of ten words per minute with but few months of practice. When learning the code it is important to distinguish dots and dashes: that is, a dot or a dash must always be properly characterized, no matter how fast or slow one transmits. A dash, however, should be three times as long as a dot. Beginners commonly make the mistake of "holding the dots"—not making dots at all but a series of long and short dashes. A dot is made by one quick, sharp touch of the key, irrespective of the sending speed. A dash should never be made longer than the time required to make three quick dots. The difference between slow and fast sending is the time interval between letters which comprise words, and not between the characters which make a letter. *The space between letters and words may be lengthened when slow speed sending is used.* All dots and dashes should have the same "time form" no matter whether an attempt is being made to send 5 or 50 words per minute. The

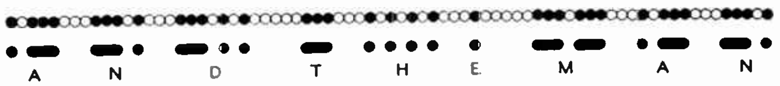
THE RADIO TELEGRAPH CODE

A	• —
B	— • • •
C	— • — •
D	— • •
E	•
F	• • — •
G	— — •
H	• • • •
I	• •
J	• — — —
K	— • —
L	• — • •
M	— —
N	— •
O	— — —
P	• — — •
Q	— — • —
R	• — •
S	• • •
T	—
U	• • —
V	• • • —
W	• — —
X	— • • —
Y	— • — —
Z	— — • •

Numerals, Punctuation Marks, Etc.

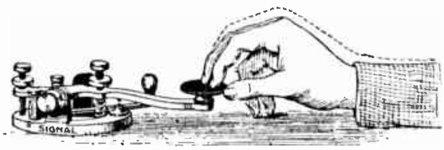
• — — — —	1
• • — — —	2
• • • — —	3
• • • • —	4
• • • • •	5
— • • • •	6
— — • • •	7
— — — • •	8
— — — — •	9
— — — — —	Ø

• • • — — — • • •	INTERNATIONAL DISTRESS SIGNAL
• • • • • •	PERIOD
• — • — • —	COMMA
• • — — • •	INTERROGATION
• — • • — •	QUOTATION MARKS
— — • • — —	EXCLAMATION
— — — • • •	COLON
— • — • — •	SEMICOLON
— • — — • —	PARENTHESIS
— • • — •	FRACTION BAR
• — • • •	WAIT SIGN
— • • • —	DOUBLE DASH (BREAK)
• • • • • • • •	ERROR (ERASE) SIGN
• — • — •	END OF MESSAGE
• • • — • —	END OF TRANSMISSION



DASH EQUAL TO THREE DOTS—SPACING BETWEEN CHARACTERS EQUAL TO ONE DOT
SPACING BETWEEN LETTERS EQUAL TO ONE DASH
SPACING BETWEEN WORDS EQUAL TO FIVE DOTS

secret of success of good operating is in the *spacing* between letters and words, but there should be no spacing between dots and dashes which make up an individual letter. For example: take the letter A; it consists of a dot and a dash, but in code it should not be considered graphically except as a dot and a dash. Phonetically, pronounce it as "did-daw," "did" for the dot, "daw" for the dash. Thus, the letter A becomes "did-daw," *not* dot-dash. By repeating the phonetic sounds, the letter soon becomes firmly

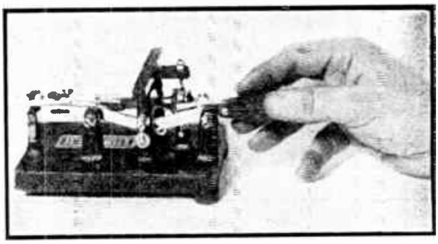


Proper grip for manipulating the key.

fixed in the mind. During mental repetition, no pauses should be made between the "did" and the "daw"; the two must roll smoothly into each other; thus, "diddaw." One of the greatest mistakes made by operators is in permitting a pause to come between the "did" and the "daw." To further illustrate code learning examples, take the letter B, which consists of a dash and three dots. Again, there must be no spacing between the dash and the three dots. B is "dawdiddiddid." Now, if a space is permitted to come between the daw and the three dids, the code character will have the form of the letters T S, and not B.

Send cautiously, slowly and surely! Haste makes waste. One often hears of the operator "who falls all over himself." He becomes confused, sends faster than he can receive. Nothing is more painful than to listen to a fast, erratic operator who cannot read his own sending. How, then, can he expect others to copy his signals?

The SOUND system of learning the code has been universally proven as the best method for beginners to use. This system teaches the operator to think in terms of SOUND, instead of the more common letter formations. By thinking in such terms a letter is recognized by its characteristic sound and cadence. When the sound "did-



Correct "grip" and position of wrist for operating automatic key ("bug").

daw" is heard, it is immediately recognized as the letter A, and not in any other form.

With the code practice set connected, grasp the key *gently* with the thumb, fore and index fingers being placed on the knob of the key. The illustration shows how to properly manipulate the key. Avoid cramping the hand—relax—forget entirely that the thumb and forefingers are on the key. Be interested in correctly making the telegraph signals "dids" and "daws." Send slowly, until becoming adept to the knack of sending. Do not open the key too wide, else the sending will become "choppy." On the other hand, if the key does not have sufficient play, the sending will sound "sloppy." Do not make the key too "stiff" by exerting too great a pressure on the adjusting spring. If in doubt about the correct tension, ask a more experienced operator to assist you in making the proper adjustment.

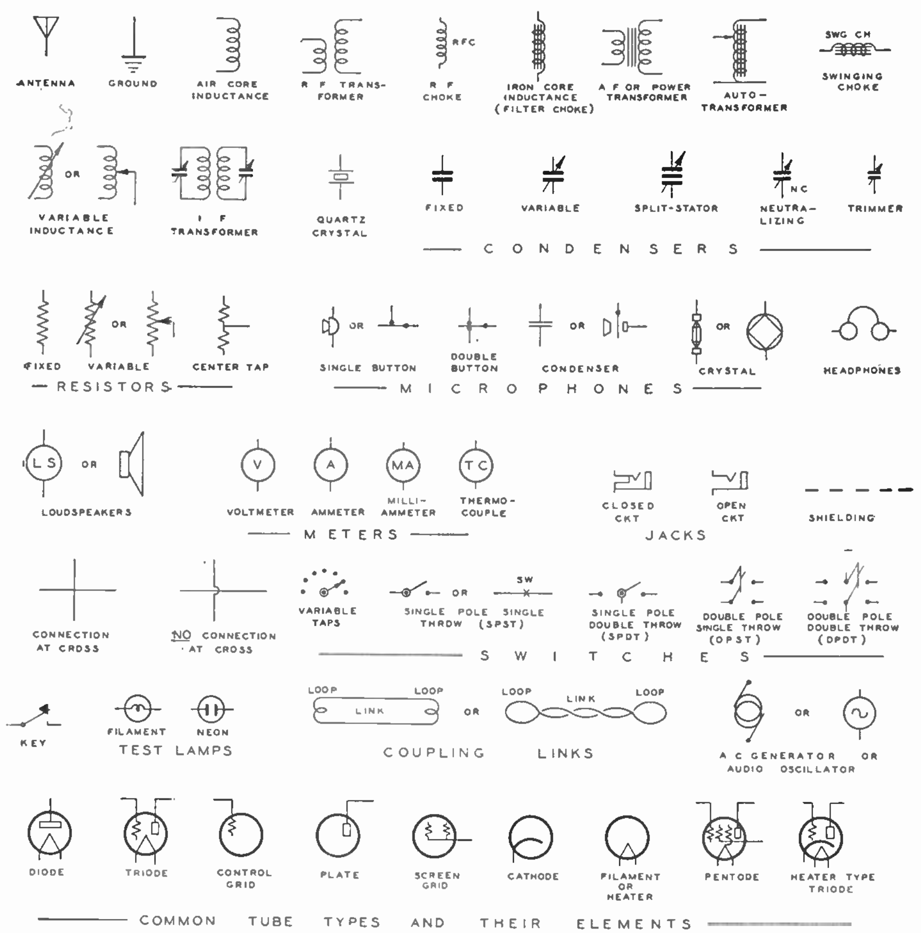
Easily Memorized Practice Letters.

Begin learning the code without assistance from others. First memorize a few letters of the alphabet, starting with the letter A. Proceed by the methods outlined in the above text until finally practicing with the telegraph key. To augment the mind's retentive powers, use a short-wave receiving set and pick out as many diddaws as can be recognized from a slow sending station. At each recognition the letter should be written down on a small pad. After becoming thoroughly acquainted with the letter A, proceed until the complete alphabet can be *instantly* recognized by sound code-formations. Later, connective words like AND, TO, OF and others should be learned. Words composed entirely of dots and dashes are excellent for practice. For example: (all dots) is, his, sis, and she; (all dashes) to, Tom, Otto and etc. In exercising, it is important that the letters be properly spaced lest the word structure be ruined.

The next step is to make short sentences consisting of words, some of which are all comprised of dots, others all dashes, such as "she sees Otto." The student operator will find that by learning all code characters comprised of dots or dashes before others, that his telegraphic technique will be developed at much faster rate than it otherwise would be. Every effort should be made to copy signals heard on short-wave sets until proficiency is attained.

Throughout the day, it would be advisable to make silent repetitions of the diddaw sounds, including words, short sentences, figures, calls and other miscellany. Always think in terms of SOUND . . . in dids and daws. Soon it will be amazing to learn how simple it is to gain speed and accuracy in a relatively short period of time.

Radio Symbols Used in Schematic Circuit Diagrams



Chapter 5

ANTENNAS

Antenna Theory

● An antenna is an electrical conductor, suspended in air and insulated from ground, which either radiates or receives radio-frequency energy. Sometimes the ground is used in conjunction with the antenna conductors, as will be defined later. The effectiveness of an antenna depends upon numerous electrical and mechanical factors of design, all of which are discussed under *antenna types.*

An antenna can be compared to any tuned circuit, except that its capacity and inductance are distributed along the wire instead of being lumped, as in a coil and variable condenser. Every antenna system has a fundamental wavelength or resonant frequency of its own. It should always be operated at its resonant frequency, because the efficiency is many times greater in this condition.

The physical dimensions of the antenna at resonance bear a certain relation to the wavelength. In order to simplify the explanation of *radiation* in space, it can be compared with waves in water produced by throwing a stone into a still body of water; there will be waves which have peaks and troughs, similar to those produced in space by radio waves. The radio waves, in effect, require a physical amount of space between the peaks and troughs (*condensations* and *rarefactions*) and therefore the antenna is made of such a length that it is equal to one peak or one trough of a wave in physical length.

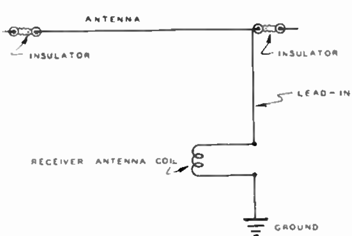


FIG. 1
Conventional Antenna for Receiving.

A complete wave consists of one peak and one trough, defined as *one wavelength.* Any resonant circuit is the electrical equivalent of one-half wavelength; in the case of a tuned circuit the constants are lumped and the space required is very small. For an antenna, the wire may be stretched out into a straight line so that it is nearly a full half wavelength long. For an antenna consisting of a straight wire one-half wavelength long electrically, the *physical* length will be approximately 5% shorter than the *electrical* length, because it is impossible to secure a wire having zero diameter supported in space without end insulators.

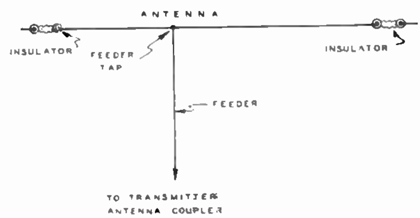


FIG. 2
Single Wire Antenna for Transmitting.

Radio waves travel with approximately the speed of light, which is 300 million meters per second. This provides a convenient method for expressing the resonant frequency in terms of wavelength, or vice-versa.

$$F = \frac{300{,}000{,}000}{\lambda}$$

where F is the frequency in cycles per second λ is the wavelength in meters.

Radiation Field

● A wire connected to any source of oscillating electrical energy will radiate radio waves due to the varying intensity of the electrical field surrounding the wire. The field closest to the wire is called the *induction field,* which oscillates to-and-fro; that part of the field which escapes forms the energy in the radiated field which is urged outward and diffused in all directions through space. Any wire supported in space and within range of the radiated field will intercept the energy and will have induced in it a radio-frequency voltage, which is detectable as an incoming signal by receiving apparatus.

Radio waves are transmitted from an antenna through space in two general types of waves. One is called the *ground wave,* which follows along the surface of the ground, and is rapidly attenuated for very short waves. The ground wave is useful in long-wave radio communication, also for very short distance work on ultra-short wavelengths. Best broadcast reception is always had when the receiver picks up only the ground wave, which means that normally it must be within a 100 mile radius of even a high power transmitter. *Fading effects* take place at greater distances, due to the interference between the ground wave and the sky waves.

That portion radiated upward from the antenna is known as the *sky wave,* since it is reflected back to earth by ionized layers in the upper atmosphere known as *The Kennelly-Heaviside Layers,* as shown in Fig. 3.

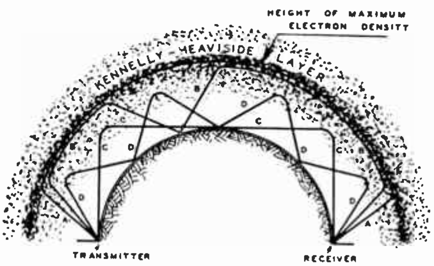


Fig. 3

Reflection of Radio Waves from the Heaviside Layer Around the Earth.

At very low angles of radiation, the waves start out practically tangent to the earth's surface, penetrate into the ionized layers and are bent back to the earth at a very distant point. Higher angles of radiation are bent back to earth at shorter distances until a certain high angle is reached for any particular frequency which will not be bent back to earth. This angle varies with the season of the year, frequency and time of day. At angles slightly less than this value at which the layers are penetrated, the radio waves can be carried around one of the upper layers to extremely great distances before being bent back to earth, no matter what the angle of propagation.

The Kennelly-Heaviside Layer is a strata of ionized air molecules, of which the ionization is due to the ultra-violet radiations from the sun. This stratospheric layer lies above the earth at distances of less than one hundred up to several hundred miles elevation. The relative density of the layers is not constant, but varies from year to year and seems to depend upon sun-spot activity.

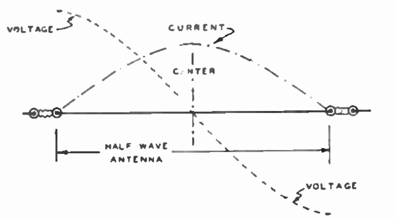
The time required for the sky waves to reach the receiver varies in accordance with the number of reflections to and from earth and the changes of ionization in the Kennelly-Heaviside Layers. Obviously the time required for a ground wave to reach the receiver will be less than that of a high angle sky wave, resulting in variations of signal strength at the receiver. When two or more waves from these different paths arrive at the same instant (*in phase*) the signal strength will be greatest. If the time lag is great enough so that one wave tends to neutralize another (*out of phase*), the signal intensity will decrease, resulting in the phenomena known as *fading.*

The rate of fading varies with frequency, and even small changes of frequency sometimes have entirely different rates of fading. A modulated wave from a radiophone station consists of a band of frequencies being transmitted, and this variation of fading within this narrow band results in distortion in the received signal. This effect is known as *selective fading,* because the side-band frequencies may be stronger at a given instant than the carrier signal at the receiving point, resulting in bad distortion of audio quality in the output of the receiver.

Electrical Properties

● A wire stretched out into space has *inductance* of the same type as that produced by wire wound into a coil. This antenna wire also has a *distributed capacity* to nearby objects, such as the ground. As in any electrical circuit, inductive reactance and capacitive reactance impede the flow of current in either a transmitting or receiving antenna. At resonance, the inductive reactance is equal and opposite to the capacitive reactance, with the result that the electrical current is only limited by the resistance. The resistance consists of several components, such as wire resistance, dielectric losses from nearby objects, ground resistance, insulator losses and *radiation resistance.* The latter is a fictitious term which is useful in expressing the power radiated by the antenna. It is that resistance which would consume the same amount of power that is radiated into space by the antenna; the power lost in other forms of resistance is wasted. Short-wave antennas generally have a very high ratio of radiation resistance to loss resistance and are therefore very efficient.

In a resonant antenna, *standing waves* of current and voltage exist. In a typical half wave antenna the current is maximum at the center, and zero at the ends. The radio-frequency voltage is maximum at the ends and minimum at the center. These standing waves exist because an impressed radio wave will travel out to the end of the antenna and be reflected back toward the center, since the end is an open circuit corresponding to a large mismatch of impedance. The resonant antenna is of such length that the reflected wave will be in phase with each succeeding impressed wave, or oscillation, resulting in a standing wave along the antenna wire. Standing waves produce more actual radiated power into space from an antenna than when the values of voltage and current are uniform and of lower value all along the antenna wire. Radio-frequency feeders to an antenna are generally designed for uniform distribution of current and voltage along their entire length (no standing wave). In other words, the feeders should *not* radiate because the antenna proper alone should be the radiating medium.



SHOWING HOW STANDING WAVES EXIST ON A RESONANT ANTENNA
CURRENT IS MAXIMUM AT CENTER — VOLTAGE IS MAXIMUM AT ENDS

FIG. 4

The *impedance* along a half wave antenna varies from a minimum at the center to a maximum at the ends. The impedance is that property which determines the antenna current at any point along the wire for the value of radio-frequency voltage at that point. The main component of this impedance is the radiation resistance; normally the latter is referred to the center of the half wave antenna where the current is a maximum. The square of the current multiplied by the radiation resistance is equal to the power radiated by the antenna, and for convenience these values are usually referred to the center of a half wave section of antenna.

The curve in Fig. 5 indicates the theoretical center point radiation resistance of a half wave horizontal antenna for various heights above ground. These values are of some importance in matching radio frequency feeders to the antenna in order to obtain both a good impedance match and an absence of standing waves on the feeders.

A transmitting antenna usually consists of a wire of definite length which may be grounded, ungrounded or connected to a counterpoise. A ground made by either a direct or capacitive connection acts as a reflector to the aerial wire, therefore completing the circuit. With a direct ground connection, the antenna may be either an electrical quarter wavelength or odd multiples of quarter wavelengths; the ground

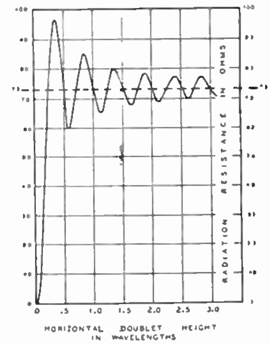


Fig. 5

Radiation Resistance of Half Wave Horizontal Antenna for Various Heights Above Ground.

acts as a subterranean reflector, furnishing quarter waves to the antenna to give half waves or multiples of half waves for the desired resonant effect. A very short wire can be loaded to an electrical quarter wave by means of a loading coil to ground; a wire over a quarter wave long can be reduced to an electrical quarter wave by means of a series condenser to ground.

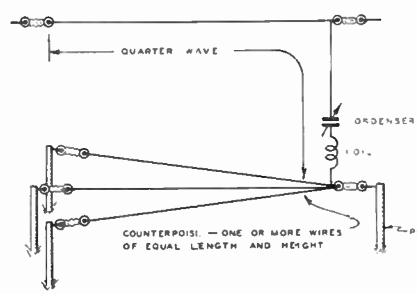


Fig. 6

A counterpoise which consists of one or more wires in a network insulated from ground will often reduce loss resistances which might occur when the quarter wave antenna is connected to poorly conducting earth. The counterpoise in the case of a network of several wires acts as a condenser plate with high capacity to earth, with the result of lower loss in the antenna system; for this reason the counterpoise should be fairly close to the ground.

Fig. 7 shows a vertical antenna with an elaborate ground wire system buried under the surface of the earth for the purpose of obtaining low loss resistance connection to ground. This system is more generally used than the counterpoise.

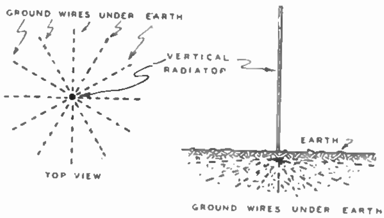


Fig. 7

Directional Properties

● The radiation field of an antenna is more intense in certain directions, depending upon its height above ground, as well as the length of the antenna and the tilt or angle of the antenna wire with respect to ground. A short antenna (up to a half wavelength long) radiates most of its energy in a circular pattern at right-angles to the wire, something in the shape of a doughnut.

As the length of a horizontal antenna is increased in multiples of half waves, the radiation pattern changes into cone-shaped loops, one at each end of the antenna. Smaller intermediate loops occur as shown in Fig. 8. A short horizontal antenna, therefore, may be considered as a *broadside radiator* and a long antenna as an *end-fire radiator.* A vertical half wave or quarter wave antenna radiates equally well in all directions, horizontally.

Angle Radiation

● All but the ultra-short-waves are reflected back to earth from the Heaviside Layer. By directing the greater portion of the transmitted wave at certain angles above the horizon, the signal at the receiving station will be increased; the angle above the horizon depends upon the distance and condition of the Heaviside Layer. For extremely long distances a low angle radiation is preferable, or an extremely high critical angle above the earth horizon. Intermediate angles tend to shorten the skip distance, and in case of long distances the total number of reflections may be so great as to attenuate the signal to such an extent that it cannot be received. Each time the signal is reflected from the earth's surface back to the Heaviside Layer the signal strength is reduced, due to losses which become evident because the earth is not a perfect reflector.

Vertical antennas provide low angle radiation as indicated in Fig. 9. The earth acts as a mirror and prevents the radiated wave from going out exactly in a plane to the horizon, unless the vertical antenna is several wave lengths above the earth.

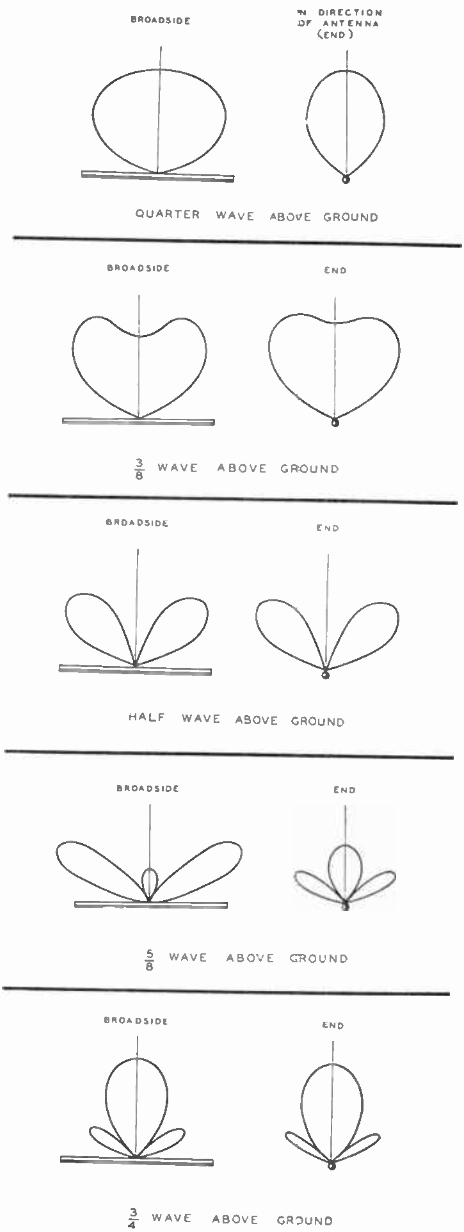


Fig. 8

Horizontal Half Wave Antenna Radiation Patterns.

The effect of the earth on the angle of radiation is more noticeable in the case of horizontal antennas, as can be seen in Fig. 10, showing that the horizontal antenna should be approximately a half wave above ground in order to avoid excessive radiation straight up, which would penetrate the Heaviside Layer and not be reflected back to earth at distant points.

Heights above ground of one quarter wave and three quarter waves provide excessive radiation straight upward, which represents a loss of power. The radiation pattern shown in *C* of Fig. 10 indicates that nearly all of the radiation is at right angles to the antenna wire. This is not actually true, because the doughnut-shaped radiated field actually produces high angle radiation outwardly over the ends of even a half wave horizontal antenna.

Long antennas operated at a harmonic tend to give low angle radiation. An analogy can be made to an ordinary garden hose and nozzle when considering the radiation from one end of the antenna. As the nozzle is turned from the fine spray position, the cone of water has a more narrow angle and is more concentrated. A second or third harmonic antenna (two or three half waves) is like the fine spray condition, whereas a long antenna of six or eight wavelengths projects most of the signals outward in the form of a very narrow cone, having a radiation much greater at its maximum as compared with a half wave antenna.

Careful antenna design will enable a low power transmitter to deliver a powerful signal at certain distant points.

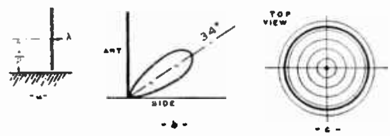
Antenna Tilt

● The presence of ground near any horizontal antenna has a very decided effect upon its directivity pattern. A half wave antenna normally produces high angle radiation from its ends, and both high and low angle radiation from its sides, as can be seen by referring back to Fig. 8.

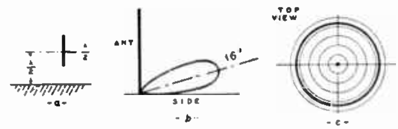
The difference becomes more pronounced with a full wave antenna; in either case, tilting the antenna will lower the angle of radiation to some extent in line with the antenna wire. Since low angle radiation is generally desirable for long distance communication, a slight tilt from the horizontal angle with respect to earth in the desired direction will often produce a very noticeable increase in signal strength. An antenna which has one end higher above the earth than the other does not transmit or receive well in the direction toward the higher end.

Antennas for Transmitting

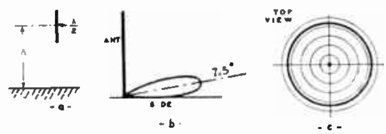
● Antennas for transmitting differ from those used for receiving only in that the former require better insulation. A good



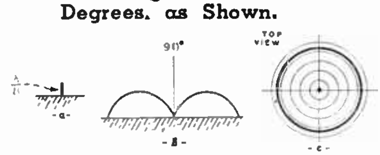
Full Wave Antenna Gives Maximum Radiation Upward at an Angle of 34 Degrees from the Horizon.



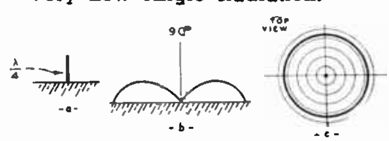
Half Wave Antenna, Same Height as Full Wave Antenna Above. Here the Radiation Is Known as 16-Degree "Low Angle" Radiation.



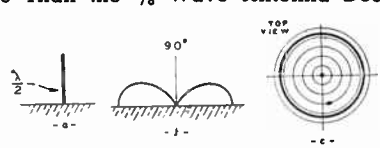
Increasing Height of Antenna Above Ground Lowers Angle of Radiation to 7.5 Degrees, as Shown.



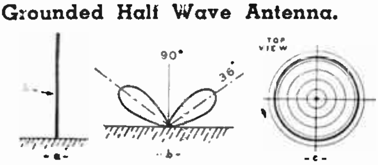
Short Vertical Antenna, Grounded, Gives Very Low Angle Radiation.



Quarter Wave Grounded Antenna Concentrates More of the Radiation at a Low Angle Than the 1/8 Wave Antenna Does.



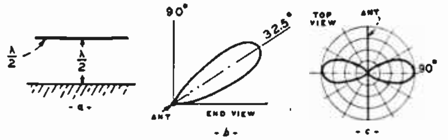
Grounded Half Wave Antenna.



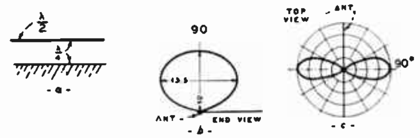
Full Wave Grounded Antenna.

Fig. 9

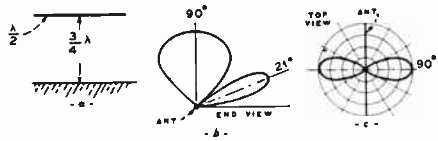
Angle of Radiation of Half Wave Vertical Antennas.



Horizontal Antenna Half Wave Above Ground. This is the best height for horizontal antenna for general use.



Horizontal Antenna, Quarter Wave Above Ground.



Horizontal Antenna, ¾ Wave High, Radiates Mainly Upward.

Fig. 10

Showing How the Earth Affects the Angle of Radiation from a Horizontal Antenna.

antenna for transmitting likewise makes a good antenna for receiving. All antennas for transmitting fall into two general classifications: (1) A half wave, or multiple of half waves, known as a *Hertz Antenna,* (2) A quarter wave, or odd multiples of quarter waves, known as a *Marconi Antenna,* because it must be used in conjunction with either a ground or counterpoise connection. For frequencies above 3,000 KC (100 meters), Hertz Antennas are more efficient because losses caused by ground connections are eliminated. The *Hertz* designation covers such types as *Single Wire Fed, Zepp, Two Wire Fed, End Fed, Doublets,* and *Directional Arrays,* because these systems use half wave sections of antennas for the radiating portion.

Marconi Antennas are generally used for frequencies *below* 3000 KC because space requirements are less than when Hertz Antennas are used. Marconi Antennas are generally a quarter wave long, measured between ground and the far end of the antenna. The electrical length can be adjusted by a tuning condenser, either in shunt or in series with the coupling coil. A shunt condenser increases, and a series condenser decreases, the electrical length of the antenna system. The Marconi Antenna is cut so that the electrical length is exactly a quarter wave long; the coupling coil and tuning condensers can be eliminated and some form of single wire feed line can be used to supply power from the transmitter to the antenna. The effectiveness of a Marconi Antenna depends on its height above ground, also upon a very low resistance ground connection. Where a sufficiently low resistance ground is not available, a counterpoise is used. If the physical length does not exceed a quarter wave by more than ⅓rd, the use of a series tuning condenser will reduce it to an electrical quarter wavelength. For wires less than a quarter wave long, an inductance (loading coil) will lengthen the antenna to a quarter wave electrically. The effective electrical length of the antenna can be increased slightly by the use of a large capacity at the end of the wire, such as insulator caps, balls, or cages.

Choice of Antenna

● There are so many suitable types of antennas for accomplishing a similar result that a brief explanation of some of the features of each is here disclosed. For 160 meter operation, some form of Marconi Antenna is desirable because most Amateurs have only a limited amount of space in which to erect an antenna. Most Marconi Antennas radiate a fairly strong ground wave, which is desirable for short and moderate distance communication. For 80 meter operation, the choice lies in some form of half wave antenna, such as a Zepp, End Fed, or Single Wire Fed. The difference lies in the method of coupling the radiating portion of the antenna to the final amplifier of the transmitter. Any one of the three aforementioned antennas can be operated on several bands by utilizing harmonics of the antenna. For example, a 130 foot half wave antenna operating on 80 meters becomes a full wave second harmonic antenna on 40 meters, and a two wave fourth harmonic antenna on 20 meters. Other forms of 80 meter half wave antennas are often desirable under certain conditions.

The Johnson "Q," Collins All-Wave Antenna, Two Wire Matched Impedance Antenna, and the Twisted Pair Feeder Antenna are all suitable for 80 meter operation. The advantages and disadvantages of each are discussed elsewhere in these pages.

Figure 11 shows the directivity patterns of a horizontal antenna operated at its fundamental and on its various harmonics.

For 40 meter operation, any of the types listed for 80 meter operation are suitable, yet an antenna for 80 meter operation is twice as long as one required for 40 meter operation. Directional effects should be taken into consideration if space permits the choice of antenna placement. For 20 meter operation, the same types of antennas are suitable, but on this band the physical size of the antenna is so small that highly-direc-

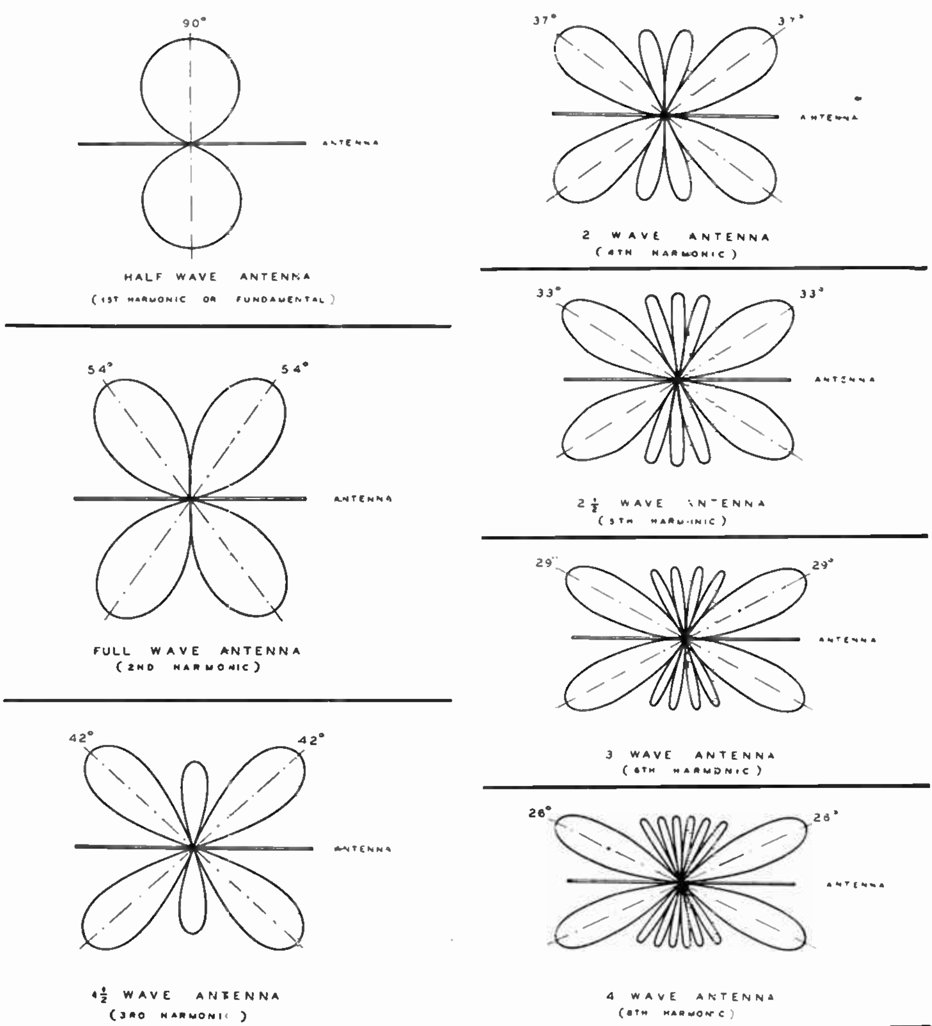


Fig. 11
Radiation Patterns of Horizontal Antennas, Half Wave to 4 Waves Long.

tional types can be used to greater advantage. Directional antennas increase the power radiated in some certain desired directions, but at the expense of lower radiation in the other directions.

For 10 meter operation any harmonic antenna can be used, although a half wave vertical antenna is most popular because it transmits a very low angle of radiation and is non-directional. Directional arrays are easily constructed for operation on this band, and they are equivalent to greatly increasing the power in the transmitter proper.

The ground wave alone is useful for 5 and 2½ meter operation, and thus the vertical types of antennas are more suitable. For short distance communication (a few miles), a single vertical half wave antenna, mounted as high as possible, gives satisfactory results. Directional arrays are recommended for point-to-point communication. Various forms of directional arrays should be used for micro-wave operation because these arrays can be easily rotated, due to their small physical size. Half wave or quarter wave antennas are only occasionally used for micro-wave communication.

Single Wire Fed Antenna

● When a single wire feeder is connected to the proper impedance matching point of a half wave (or multiple of half waves) in the radiating portion of an antenna, it is called a *Single Wire Fed Hertz Antenna*. The center impedance is somewhere between 50 and 100 ohms in a half wave antenna, increasing outwardly toward the ends. A feeder wire can be attached at a point of about 500 to 600 ohms impedance either side of center for the purpose of supplying RF energy from the transmitter. In this case, the ground acts as a phantom return circuit and the characteristic impedance of the single wire to ground is in the neighborhood of 600 ohms. The exact value of impedance varies with the frequency of operation and the diameter of the conductor.

Antenna Impedance

● The impedance of any circuit is a function of the reactance and resistance which impedes the flow of current. In a resonant antenna the reactive terms cancel each other, as in any resonant circuit, and the impedance is equal to the resistance which in this case is largely radiation resistance. The radiation resistance at the center of a half wave antenna is about 73 ohms, and 2400 ohms at the ends if it is very high above earth. It can thus be seen that at either side of center, values of from approximately 73 ohms to 2400 ohms can be obtained for impedance matching to non-resonant RF feeders. The single wire feeder is one type of non-resonant line.

A non-resonant RF feeder system of infinite length has a characteristic surge impedance which is a function of the diameter of the wires, the spacing and the dielectric between the wires. Short lines, such as used in radio practice, can be terminated by using the characteristic impedance as a load, which makes the line equivalent to one of infinite length without reflections and standing waves of RF voltage. If the line is not terminated by the proper impedance the impressed radio wave will be reflected and standing waves will exist to cause radiation from the feeder or feeders. To simplify the foregoing explanation, the single wire feeder gives best results when it is connected across approximate 600 ohms of antenna impedance. This value of impedance (600 ohms) normally occurs at a point about one-seventh of the total length either side of center. The same applies to any half wave antenna which is not too close to nearby objects or ground. Under conditions of perfect impedance match there will be no standing waves on the RF feeder and maximum efficiency will result. Unfortunately, this point is not correct for harmonic operation and if the single wire fed antenna is to be used on several bands a compromise should be made which will not materially lower the efficiency on any band. The feeder should be connected to the antenna at a point one-sixth, instead of one-seventh, of the total length of the antenna either side of center. Another simple way to find this point is to divide the antenna into three equal lengths and attach the feeder at a point one-third of the total length from either end. See Fig. 12.

Typical example: A 134 foot 80 meter antenna (for operation on 80, 40, 20 and 10 meters) should be tapped 45 feet from one end, or 22 feet from the center of the antenna. See Fig. 12. This automatically places the tap 12 feet from center of one of the half wave sections when the antenna is operated on 40 meters, and 5 feet from the center of a half wave section when the antenna is operated on 20 meters. These values are such that good impedance match will be had, resulting in satisfactory all-band operation. For a 67 foot (40 meter) antenna, the tap should be a little over 22 feet from one end, which places it at about 11 feet from center. This automatically provides a point which is 6 feet off-center on 20 meters and 2½ feet off-center on 10 meters. The value of 9-feet-4-inches-off-center for a 40 meter antenna, widely recommended in the past, gives a distance of only 0.8-foot off-center for 10 meter operation, which explains why such poor results are obtained when such a 40 meter antenna is used for 10 meter operation. The same holds true for 80 meter antennas operating on 20 meters. Connection of the feeder at a point of such low impedance for harmonic operation will not provide much actual radiation from the flat top portion of the antenna.

There will be a small standing wave on the single wire feeder when it is terminated one-third the distance from the end of the antenna. The reactive effect can be practically eliminated by making the feeder some multiple of quarter waves long. At the station end, the impedance would then be purely resistive, and no detuning effect will be in evidence in the final amplifier tuning circuit when connecting or disconnecting the feeder. The formula for calculating the feeder length in feet is:

$$l = \frac{234,000}{f_1}$$

Where f_1 is the lowest frequency of operation in Kilocycles, l is the feeder length in feet.

SINGLE WIRE FED ANTENNA FOR ALL BAND OPERATION

ANTENNA FOR 80, 40, 20 & 10 METERS IS 134 FEET LONG, WITH SINGLE WIRE FEEDER TAPPED 22 FT. OFF CENTER. THE FEEDER CAN BE EITHER 66 OR 132 FEET LONG.

ANTENNA FOR 40, 20 & 10 METERS IS 67 FT. LONG, WITH FEEDER TAPPED 11 FT. OFF CENTER. THE FEEDER CAN BE 33 66 OR 99 FEET LONG.

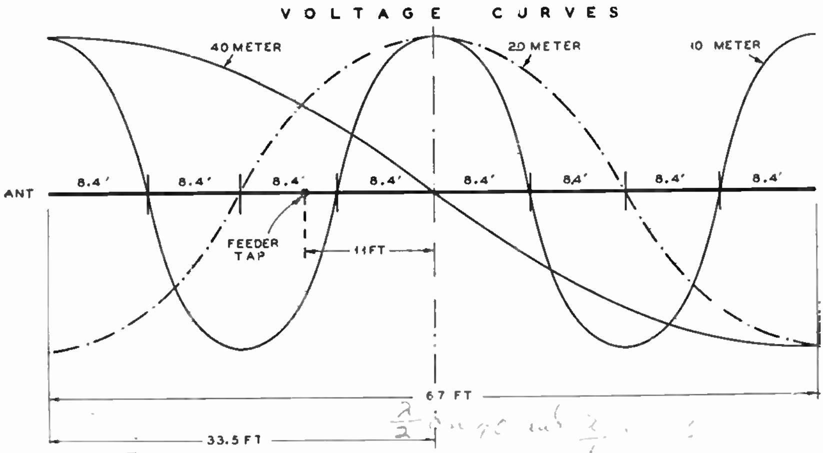


Fig. 12

The antenna length should be cut so that it will resonate at the middle frequency band desired. The formula:

$$L = \frac{(K - .05)\,492{,}000}{f_2}$$

where L is the antenna length in feet,
f_2 is the frequency in kilocycles,
k is the number of half wavelengths at that frequency.

The slight error in length for the lower and higher frequencies must be tolerated because the actual length is a compromise. The end effects shorten a half wave antenna approximately 5%, which is equivalent to 2½% per end. In a long antenna, such as two full waves, the two end half wave sections are each shortened 2½%. The middle sections are not shortened. This means that a wire cut for 3,600 KC operation as a half wave antenna will be a little short for operation as a full wave antenna on 7200 KC, which is the second harmonic. In spite of these minor defects, this antenna has become highly popular and is being widely used because of its simplicity and all-around usefulness.

Non-resonant feeders of any type can be of any length and sometimes they are made as long as 4000 feet. No sharp bends should be tolerated, otherwise the RF wave will be reflected and standing wave effects will result. *The feeder wire should run at a right-angle to the flat top portion for at least a quarter wavelength from the point where it attaches to the antenna.* A single wire feeder should always be used in conjunction with a good ground connection at any wavelength because the single wire feeder uses the ground as part of its return system in feeding power to the antenna.

One of the disadvantages of the single wire fed antenna is a tendency for the RF to feed back into electric wiring circuits near the transmitter. In radiophone operation this feedback can find its way into the microphone circuits, resulting in distortion and audio howls.

Coupling the Single-Wire Feeder to the Final Amplifier

● A single-wire antenna with off-center feeder should preferably be coupled to the final amplifier by means of system *A*, shown in Fig. 13. *B* and *C* are alternate methods for increasing or decreasing the electrical length of the feeder, yet these methods are seldom required.

The method shown in *A* consists of link coupling the final amplifier plate coil to an antenna tuning system. L1 is the final amplifier plate coil. L2 is a coupling loop of from one to four turns of insulated wire around the center of L1. L3 is a similar coupling loop around the center of the antenna coil L4.

L4 should have approximately 10% fewer turns than L1, but both coils should be of the same diameter. The coupling loops L2 and L3 are connected together with a twisted pair feed line so as to isolate the

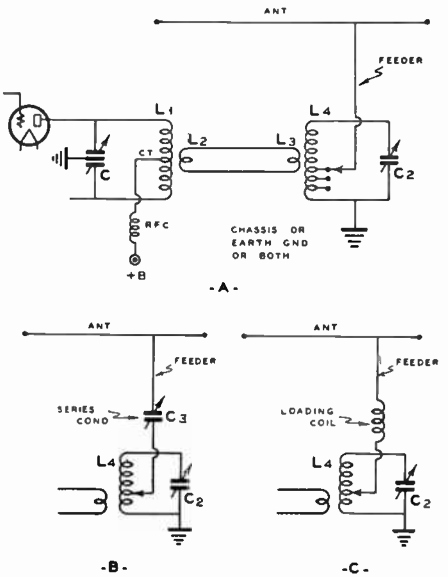


Fig. 13
"A" Is the Best Coupling System for a Single Wire Feeder; "B" and "C" Are Seldom Used in Amateur Practice.

final amplifier plate coil from the antenna coil by several feet. L4 is tuned with a 100 mmfd. variable condenser which has sufficient plate spacing to prevent flash-over. Taps are soldered to L4 at points beginning approximately one-third the way up from the grounded end of the coil, and continuing up the coil to a point near the center. One end of L4 schould be grounded to the transmitter chassis, or to an earth ground, or both.

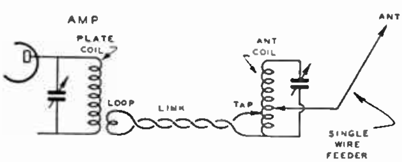


Fig. 14
Alternate Method of Coupling Single Wire Antenna by Tapping the Link Line Directly to the Antenna Coil. The Lower End of the Antenna Coil Should be Grounded, Unless the Antenna Is of the End-Fed Type.

A small flashlight globe, or a 0-to-1 RF antenna ammeter should be connected in series with the feeder and the tap on coil L4 in order to provide a means of comparative indication of antenna power. See Fig. 15. The indicating device should be removed, or short-circuited, at the completion of the tests.

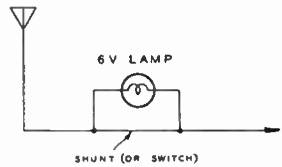


Fig. 15
Lamp Indicator or R-F Meter for Denoting Comparative Output.

Tuning Procedure

(1) With the antenna feeder *disconnected* from coil L4, tune the final amplifier plate circuit to resonance, then tune the antenna coil to resonance. The final amplifier plate current should take the customary pronounced resonance dip when *either* the plate or antenna circuit is tuned to resonance. If resonance in the final amplifier cannot be secured when the antenna coil is tuned, turns should be removed from, or added to, coil L4. When resonance is secured by tuning *either* circuit, the antenna feeder should be connected to L4.

(2) Connect the feeder to a tap on L4 at a point about one-third the way up from the grounded end of the coil. Observe the indication of the RF antenna meter or flashlight globe. Hold one hand on the final plate tuning condenser dial, the other hand on the antenna tuning condenser dial. Vary both condensers at the same time and tune for maximum indication of the RF meter or flashlight globe. Then connect the antenna feeder to a different tap on coil L4 and repeat the tuning process. A tap position will soon be found which gives greatest indication of antenna power, at normal plate current. Once the system is correctly tuned, the resonance dip indicated by the final amplifier plate milliammeter will be very small when the final plate condenser is tuned through the resonance point. If the dip is pronounced, make slight readjustments of both circuits until maximum indication is shown by the RF meter or flashlight globe. The point to remember is that both condensers should be tuned and retuned simultaneously for maximum output.

(3) If the final amplifier draws more than normal plate current after the system is tuned to resonance, remove a turn or more of wire from both L2 and L3; conversely, add a turn or more to both L2 and L3 if the plate current is too low.

Relative Radiation Patterns

● Fig. 16 shows other methods for coupling the single wire feeder here described, as well as a sketch showing the directivity of an 80 meter antenna of this type. For all-around

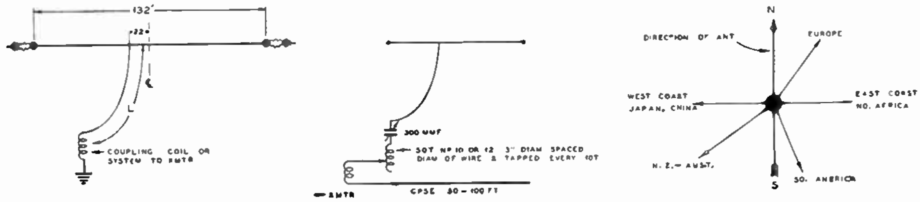


FIG. 16.
Left: 80-Meter Antenna, 132 to 134 Feet Long, Suitable for Operation on 80, 40, 20 and 10 Meters. Center: Antenna Feeder Loading System for 160 Meter Operation. Right: Approximate Direction of Other Countries.

operation in as many directions as possible, from any point in the United States, this 80 meter antenna should preferably be run in a North and South direction, as shown. On the other hand, when this same antenna is operated on its harmonics, the antenna directivity changes to four main lobes in the approximate directions as shown.

the figures. The radiation is in the form of a doughnut for a half wave antenna and consequently high angle radiation *does* take place in the end directions, assuming that the antenna points North and South. The main low angle radiation on 80 meters would be East and West. When this 80 meter antenna operates on harmonics, the radiation

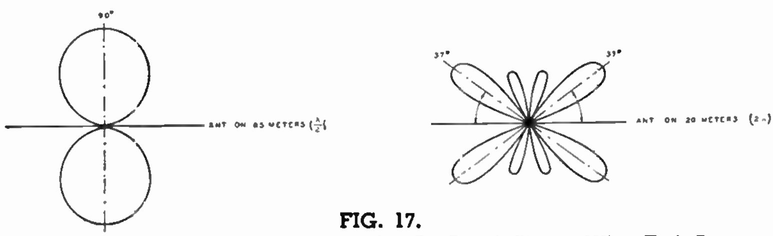


FIG. 17.
80- and 20-Meter Radiation Patterns for All-Band Single-Wire Fed Antenna.

All of the lobes in Figs. 17 and 18 apply to an 80 meter antenna, operating on harmonics. Long-distance operation is more easily accomplished on the shorter wavelengths, such as 10, 20 and 40 meters, thus making it a very effective all-band radiator. The directivity patterns do not hold good for *all* locations, and neither is it necessary to point the antenna in the prescribed direction in order to communicate with other countries or localities. However, if an approximate North and South placement can be arranged, better results will be secured.

appears to be in four separate directions, or lobes, as shown in Fig. 18. The radiation goes out in two main cones and therefore it is not as directional as would appear at a casual glance.

Impedance Matching Stubs

● In a great many directive antenna arrays, and often in the more simple forms of antennas, an impedance matching *"stub"* is desirable. This stub permits the use of a non-resonant feeder system, which results

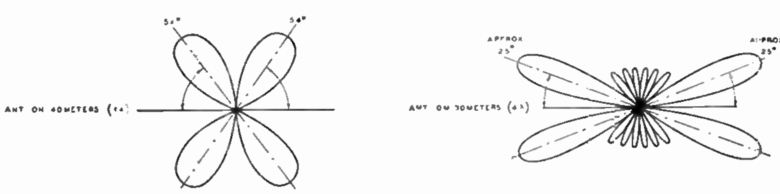


FIG 18.
40- and 10-Meter Radiation Patterns for Same Antenna.

Fig. 18 shows the radiation patterns of an 80 meter antenna of this type when operated on 40 and 10 meters. These diagrams show the cross-section only, therefore the directivity, in effect, is not the same as indicated in

in better efficiency than could otherwise be obtained with long Zepp feeders. The *stub* consists of a quarter or half wave section of feeder, either open at the lower end, or with a sliding link for tuning the stub. Fig.

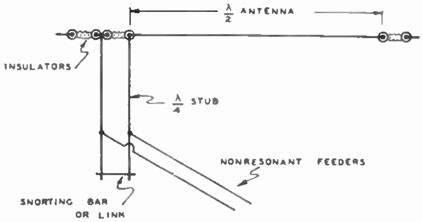


Fig. 19
Half Wave Antenna with Quarter Wave Matching Stub.

19 shows a quarter wave stub, which is similar to a quarter wave Zepp feeder.

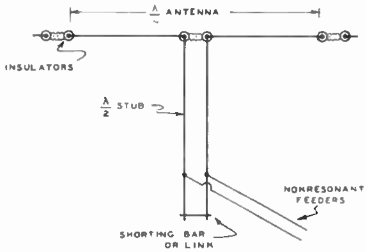


Fig. 20
Center Fed Half Wave Antenna with Half Wave Matching Stub.

Fig. 20 shows a half wave stub for feeding into the center of a half wave antenna.

The impedance at the short-circuited end of this stub is only a few ohms, and this impedance increases toward the antenna end. A non-resonant feeder can be tapped across this stub at a point corresponding to its characteristic impedance, which usually lies between 400 and 600 ohms.

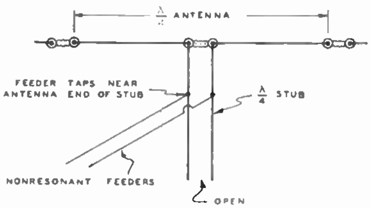


Fig. 21
Center Fed Half Wave Antenna with Stub Line Cut to Exact Length Without Shorting Bar.

The antenna length and stub length must be such that exact resonance is obtained. In the case where the stub has a shorting link near one end, the link may be moved up or down to tune the system to resonance with the transmitter frequency. In the case of a center fed antenna with a quarter wave stub without shorting link, Fig. 21, the wires must be cut to correct length by trial in order to obtain resonance. The non-resonant feeders tap across the matching stub at a point which eliminates standing waves on this line. The antenna and stub lengths should be correct for the particular installation in order to eliminate standing waves on the non-resonant feeders. The crystal detector-milliammeter measuring device described in Fig. 95 is suitable for tuning up this type of antenna system.

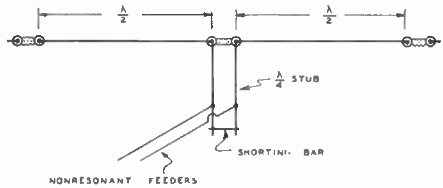


Fig. 22
Two Half Wave Sections in Phase, with Quarter Wave Stub.

In Fig. 22 two half wave sections are used in phase in order to obtain greater radiation at right angles to the direction of the antenna.

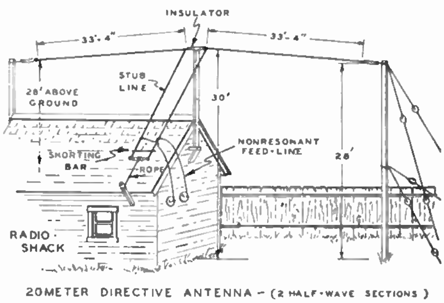
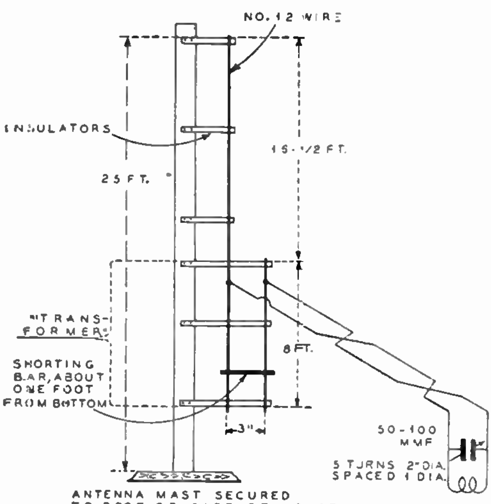


Fig. 23
Pictorial of Fig. 22, Showing Simplicity of 20 Meter Antenna Installation.

In one particular installation (Fig. 23) it was found that the standing waves on the non-resonant feed line could not be eliminated until one of the half wave antennas was shortened nearly 10%. The apparent reason was the proximity of a small metal chimney to one end of this antenna.

10 Meter Vertical Antenna With Matching Stub

● A very effective antenna system for non-directional 10 meter operation is shown in Fig. 24. It consists of a 25 foot pole, supported on the roof or to one side of a building or other structure, a 16½ foot vertical antenna wire run up along the pole and insulated from it with small insulating strips or rods. At the bottom of the 16½ foot section is another section of two wires, called the matching stub. These wires are 8 feet long, one of them being a portion of the antenna proper. A shorting bar, connected across the bottom of the two wires, is moved upward or downward for antenna tuning; likewise, the feed line tapped across the two wires at a point about ⅓rd the way down from where the two wire portion begins, is also later adjusted and readjusted in tuning up the system.



10-METER VERTICAL ANTENNA WITH QUARTER WAVE MATCHING TRANS.

Fig. 24

Tuning Procedure

(1) Place transmission line ⅓rd the way down from the point where the two wires begin, that is, ⅓rd the way down from the top of the "matching transformer."

(2) Adjust the shorting bar by placing it approximately 1 foot or 18 inches from the bottom of the "matching transformer."

(3) Turn "on" transmitter, and loosely couple the antenna coil to the final amplifier plate coil.

(4) Place a "field strength meter" somewhere where it can be seen from the roof, or let someone else watch the reading of the meter.

(5) Never re-adjust the field strength meter once it is set, while the antenna is being tuned.

(6) Take readings on the field strength meter and adjust the antenna coupling to the instrument so that half scale readings are obtained.

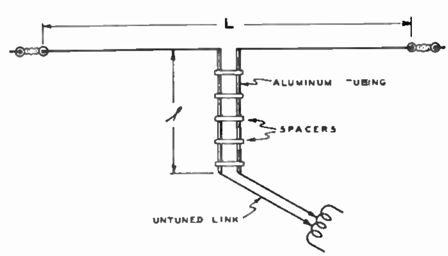
(7) Return to the roof, put on a pair of gloves, and adjust the shorting-bar until the field strength meter denotes maximum reading.

(8) Next, adjust the position of the feed-line to a point, where maximum indication is again had on the field strength meter.

(9) Lastly, re-adjust the shorting-bar so that a more accurate position can be found, as again denoted by still greater reading of the field strength milliammeter.

The Johnson "Q" Antenna

● Another type of single band half wave antenna is the Johnson "Q," which uses a special quarter wave matching transformer to couple a more or less conventional 400 to 600 ohm two-wire line to the 73 ohm impedance which exists at the center of a half wave antenna. This matching transformer consists of two parallel aluminum tubes, each a quarter wave in length, suspended from the center of the antenna. See Figs. 25 and 26.



JOHNSON "Q" ANTENNA

Fig. 25

The surge impedance is made fairly low by using half-inch diameter tubing, spaced 1.6 inches apart. This spacing results in an impedance of slightly over 200 ohms, which is the geometric mean between the antenna center impedance of 73 ohms and the impedance of a two-wire line of 600 ohms. The matching section should be approximately a quarter wave in length for the particular frequency used.

Fig. 26
Pictorial Sketch of Johnson "Q."

The design formulas are as follows:

$$L \text{ (in feet)} = \frac{468{,}000}{f}$$

$$l \text{ (in feet)} = \frac{246{,}000}{f}$$

where L is the antenna length in feet.
l is the matching section length in feet.
f is the frequency in kilocycles.

This antenna is quite widely used on 20 meters because of its relatively high efficiency. The 600 ohm untuned or non-resonant line can be of any length and should be connected across the equivalent of 600 ohms of impedance at the transmitter.

The Collins Multi-Band Antenna

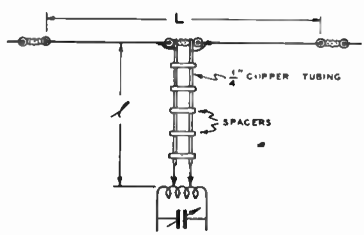
● This antenna system is a special form of Zepp antenna suitable for operation on several bands. The losses are less in dry weather, and even in wet weather it should be a comparable system to the Zepp antenna. It consists of a half wave antenna at the lowest frequency of operation, with parallel copper tubing quarter wave feeders connected in the center of the antenna. See Figs 27 and 28. The system can be used on harmonics because of the special form of RF feeders which are used.

The center impedance of a half wave antenna is approximately 75 ohms; the center impedance of a full wave antenna is about 1200 ohms. Consequently the RF feeder is designed to have an impedance which is the geometric mean of these two values, or 300 ohms. This value of 300 ohms is obtained by using quarter-inch copper tubing with 1½-inch spacing, held in position with small ceramic separators. The impedance mismatch between 300 ohms and 75 or 1200 ohms is 4-to-1, which is not great enough to cause excessive values of standing waves on the feeders. The line is made a multiple of quarter waves in length and thus the reactance at the station end is negligible; it will provide a resistive impedance of 75 or 1200 ohms. A simple untuned pickup coil (variable turns) is suitable for coupling to the transmitter or receiver tuned circuits. The design formulas are as follows:

$$\text{Antenna length in ft.} = L = \frac{(k-.05)\,492{,}000}{f}$$

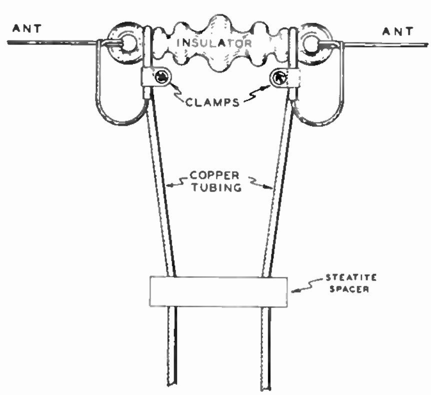
$$\text{Feeder length in feet} = l = \frac{234{,}000\ m}{f}$$

Where k = number of half wavelengths.
f = frequency in kilocycles.
m = number of quarter wavelengths.



COLLINS MULTI-BAND ANTENNA

Fig. 27



COLLINS MULTI-BAND ANTENNA

Fig. 28
Close-Up of Center of Antenna, Showing Feeder Connections.

CHART FOR COLLINS MULTI-BAND ANTENNA							
Antenna	A	B	C	D	E	F	G
Antenna Length in Feet	136	136	275½	250	67	67	103
Feeder Length in Feet	66	115	99	122	65	98	82½
Frequency Range in Megacycles	3.7— 4.0 7.0— 7.3 14.0—14.4	3.7— 4.0 14.0—14.4	1.7— 2.0 3.7— 4.0 7.0— 7.3 14.0—14.4	1.7—2.0 3.7—4.0	7.0— 7.3 14.0—14.4 28.0—29.0	7.0— 7.3 14.0—14.4 28.0—29.0	3.7— 4.0 7.0— 7.3 14.0—14.4
Nominal Input Impedance in Ohms	1200 all bands	75 all bands	1200 160—80—20M., and 75 on 40M.	1200 all bands	75 on 40M. 1200 on 20 and 10M.	1200 all bands	1200 all bands

The efficiency of the feeders may run as high as 97% in spite of the impedance mismatch. The feeders weigh approximately 10 pounds and they hang from the center of the antenna, therefore the antenna wire should be copper-clad steel under tension, unless a support in the form of a mast is placed at the center of the antenna. A study of the antenna chart will indicate several possibilities for amateur installation.

Zepp Antenna

● This antenna consists of a half wave section with tuned feeders connected to the end, Fig. 29, or into the center, Fig. 30, of the half wave radiating section.

The purpose of the feeders is to permit the erection of an antenna as high above ground and as clear from nearby objects as possible. The feeders transfer radio-frequency power from the final amplifier of the transmitter to the radiating portion of the antenna. The portion of the antenna called the *Zepp Feeder* (which is a resonant coupling device, and thus forms part of the antenna proper) simply consists of an additional length of antenna which is folded back upon itself in such a way that the standing waves on the two feeders neutralize each other, thus preventing the feeder portion of the antenna from radiating. The first fundamental of Zepp Antenna design is that the flat top portion must be cut to within 10% for the frequency used. Variations of less than 10% can be compensated for by tuning the feeders in the radio room.

When one wire of a Zepp Feeder is connected to the end of a half wave antenna the feeders should be some odd multiple of quarter wavelengths long, because the two wires folded back on each other form half wave resonant sections. The coupling coil and tuning condensers in the feeder circuit

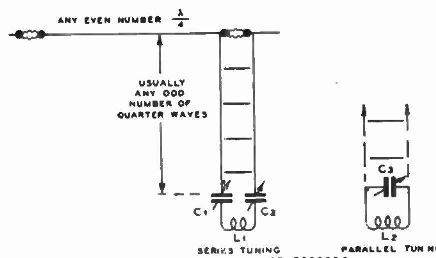


Fig. 29
Zepp Antenna System and Feeder Tuning Methods.

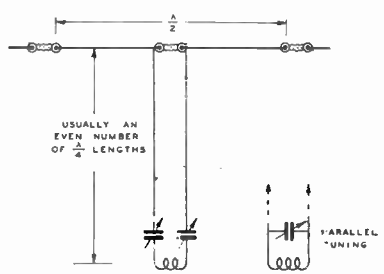


Fig. 30
Zepp Feeders Connected in Center of Half Wave Antenna.

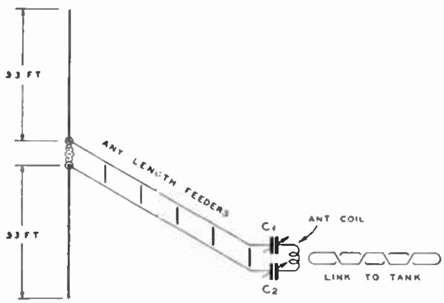


Fig. 30-A
20 and 40 Meter Vertical Antenna with Zepp Freeders. C1-C2 Are .00025 mfd. Condensers.

are part of the tuned feeder system. If the physical length of the two feeders is either longer or shorter than an odd multiple (1, 3, 5, etc.) of quarter waves, this length can be made electrically correct by varying the number of turns on the coupling coil or the capacity of the feeder tuning condensers. Thus when Zepp Feeders are tuned, merely their electrical length is varied. The presence of the coupling coil, or coils, adds electrical length which may be offset by using tuning condensers which reduce the electrical length. Sometimes combinations of series and parallel tuning are necessary when operating a Zepp Antenna on more than one band. If the physical length of the feeders, plus the inductance of the coupling coil is less than a quarter wave, or slightly less than three quarters of a wave, it is necessary to use parallel tuning for the feeders. If the physical length of the feeders is somewhat *greater* than a quarter wave, or three quarters of a wave, the feeders must be tuned with series condensers.

Not all Zepp feeders have coupling coils and tuning condensers; instead, a short-circuiting bar or copper wire can be shunted across the two feeders at the lower end to complete the circuit. In this type of construction the feeders are tuned by sliding the bar up or down across the feeders until resonance is established. Coupling to the transmitter is accomplished by a non-resonant line connected to the resonant feeders at the proper impedance matching points.

Zepp Feeder Spacing

● The spacing between the two wires of the Zepp feeder should be about 6 inches. Glazed ceramic feeder separators which resist moisture absorption should be used to maintain proper spacing between the two wires. If the spacing is too great, the standing waves on the feeders do not properly neutralize each other and excessive feeder radiation will result. If the spacing is too small, there will be excessive loss at the feeder separators along that portion where high radio-frequency voltage exists.

Directional Effects of Zepp Antenna

● When the Zepp antenna is operated on its fundamental frequency, the main portion of the radiation is at right angles to the direction of the wire. For operation at higher frequencies (harmonics), the curves of Fig. 8 indicate the optimum directions for transmitting or receiving.

SUMMARY

● The principal advantage of the Zepp Feeder system is that, no matter how inefficiently it may be built, power will always be drawn from the final amplifier. The power radiated may be only a small fraction of the energy conveyed in transit. Because a Zepp feeder system draws the greatest amount of power from the final amplifier, and gives the greatest meter indication of RF current, is no indication that the system is working efficiently. Other forms of coupling devices usually refuse to draw power from the final amplifier unless the radiating portion of the antenna is functioning properly. Sometimes it is assumed that the non-resonant transmission line is faulty and difficult to adjust because the final amplifier cannot be made to draw enough plate current; however, the fault may be traced to the antenna not having the proper length for operation on the desired frequency. In other words, an effective non-resonant transmission line will ordinarily draw no power from the transmitter *unless it can deliver it to the antenna.*

The most outstanding feature of the Zepp coupling system is its simplicity and ease of adjustment. It is *less efficient* than most non-resonant transmission lines. Theoretically, Zepp feeders do not radiate, but, as a matter of fact, the perfect Zepp feeder exists only on paper.

Another advantage of the Zepp feeder lies in the fact that it can be used for operation on several bands.

Construction

● Zepp feeders should be cut as closely as possible to an odd number of quarter wavelengths long for connection to the end of an antenna, or an even number of quarter wavelengths for connection into the center of a half wave antenna. The feeders should be supported in the clear, and no sharp bends should be tolerated. If the feeders are within one foot of such objects as a stucco wall or other structure in which there is predominance of metal, as much as 50% of the power from the transmitter can be wasted by absorption.

Center-Feed Zepp

● This system differs from the more-common voltage fed type in that it connects to a low impedance point on the antenna instead of at a high impedance point. For this reason it is sometimes known as the *Current Fed Zepp,* or *Doublet,* whereas the more-common type is known as the *Voltage Fed Antenna.* The Center-Fed system provides a better balance because both wires connect into the antenna, whereas the end connection leaves one feeder wire unterminated, resulting in some unbalance of current in the two feeder wires. The directional effect of either system is the same for operation on the fundamental wavelength. When the center-fed system is operated on the second harmonic the flat top portion becomes two voltage fed half wave antennas in phase. This produces an increased directional effect at right angles to the direction of the antenna wire, instead of a four-leaf clover effect which is otherwise obtained when the end-connection is used.

Voltage-Fed vs. Current-Fed

● *Voltage-fed:* The Zepp feeders are connected to the radiating portion at points of high RF voltage. These points exist at the ends of each half wave section, due to standing wave effects.

Current-fed: Connection is into the half wave section at a point of low impedance and high current. Since the voltage and current are approximately 90 degrees out of phase, the point of *maximum* current occurs at the point of *minimum* voltage. See Fig. 30. This point exists at the center of each half wave section for the particular frequency used. In this discussion half wave sections are referred to the particular band in use, such as 130 feet for the 80 meter band, approximately 66 feet for the 40 meter band, and 33 feet for the 20 meter band.

Length of Any Half Wave Antenna

● Antennas which are fed by any type of non-resonant line must be cut to exact length, subject to modification due to the presence of nearby objects. For all practical purposes, the antenna can be cut to the calculated length and the wire should be of a kind that does not stretch. If the wavelength of operation is known, the length can be calculated by multiplying the wavelength by 1.56, giving the result in feet.

$$L = 1.56 \times \lambda$$

where L = length in feet,
λ = wavelength of transmitter.

If the frequency of operation is known, the antenna length in feet can be calculated by dividing the frequency in kilocycles into 468,000.

$$L = \frac{468{,}000}{f}$$

where L = length in feet,
f = transmitter frequency in kilocycles.

These formulas do not apply for long wire antennas.

The values calculated for a Zepp antenna are not critical, and if the flat top portion is within 10% of these values the error can be compensated for by tuning the feeder system. The old popular conception that a Zepp antenna must be cut to exact length is erroneous. No matter how close an antenna is cut to prescribed length the proximity of nearby objects will often change the effective electrical length as much as 5% or 10%. Herein lies one of the advantages of the Zepp antenna, since the antenna can be tuned to exact resonance at the transmitter.

LENGTH OF FEEDERS	Type of Feeder Tuning to Use
Up to One Quarter Wave	Parallel Tuning
Between One and Two Quarter Waves	Series Tuning
Between Two and Three Quarter Waves	Parallel Tuning
Between Three and Four Quarter Waves	Series Tuning
Between Four and Five Quarter Waves	Parallel Tuning
Between Five and Six Quarter Waves	Series Tuning

Zepp Feeder Tuning Chart

For 5 meters one quarter wave is 4 ft.
For 10 meters one quarter wave is 8 ft.
For 20 meters one quarter wave is 16 ft.
For 40 meters one quarter wave is 33 ft.
For 80 meters one quarter wave is 66 ft.
For 160 meters one quarter wave is 132 ft.

For Half Wave Zepp Flat-Tops

Zepp Feeder Lengths

Band	Length of Flat-Top
160 meters	250 feet
80 meters	130 feet
40 meters	66 feet
20 meters	33 feet
10 meters	16.5 feet
5 meters	8 feet

Two Wire Matched Impedance Antenna

● This antenna is useful only for one-band operation, but it is more efficient than a single wire fed antenna. It consists of a half wave section with the two feeders connected to each side of center, as shown in Fig. 31. This method of feeder connection provides the incorrect phase relation for harmonic operation. It is often used for 5-meter communication and is quite effective on 10 and 20 meters.

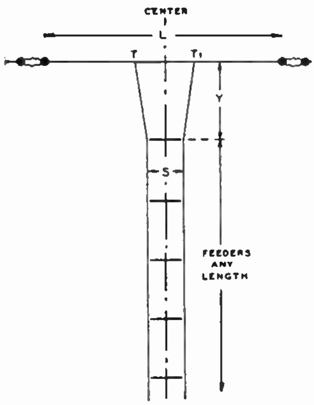


Fig. 31
Two Wire Matched Impedance Antenna System.

The surge impedance of a two wire line can be calculated from the formula:

$$Z_s = 276 \log_{10} \frac{b}{a}$$

where Z_s is the surge impedance in ohms.
a is the radius of the wire.
b is the distance between the two wires.

Since the impedance of an antenna depends upon the points between which measurement is made, and varies from a low value at the center to a very high value at the ends of the antenna, the line must be tapped to the antenna at points where the impedance is equal to the impedance of the line. With the ordinary type of two wire line it is necessary to fan-out the feeders at the far end to evenly increase or transform the feeder impedance so that it matches the antenna. The details of this matching impedance between the 600 ohm line and a half wave antenna are figured as follows:

$$L \text{ (in feet)} = \frac{492{,}000}{f} \times 0.95$$

where L is the antenna length.
f is the frequency in kilocycles.

The portion of the antenna between the two taps, T and T1 where the feeders connect is computed as follows:

$$T \text{ to } T1 \text{ (in feet)} = \frac{492{,}000}{f} \times 0.24$$

The fanned-out "Y" portion is computed as follows:

$$Y \text{ (in feet)} = \frac{147{,}000}{f}$$

The feeder spacing "S" for a 600 ohm two wire line is computed approximately as follows:

$$S = 150 \times r$$

where S is the center-to-center distance between the wires, r is the radius of the wires.

These should be expressed in the same units, whether in inches or centimeters. The spacing of the feeders is rather critical and the line must be kept taut. Each side of the line must be of the same length and symmetrical with respect to ground. The transmission line should be connected at right-angles to the antenna for a distance at least equal to one-third of the antenna length. Bends in the feed line should be gradual because sharp bends cause reflection losses and undesired feeder radiation.

Feeder Adjustment

● The antenna length and taps T and T1 should be adjusted for actual operating conditions in order to minimize standing wave effects on the transmission line. If the feeders are of bare copper wires a small RF milliammeter can be bridged across approximately one foot of wire with a pair of wire hooks, as illustrated in Fig. 32. This device can be moved along a quarter wave section of the RF feeder to check for standing waves. The current will be constant if

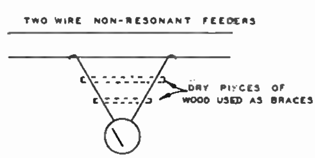


Fig. 32
Method for Locating Standing Waves on Two Wire Non-Resonant Feeder.

no standing waves are present. A more practical device is illustrated in Fig. 95. It can be carried along the feed line, close enough to it so that RF energy coupled into the pickup coil will give an indication on the meter scale. Sometimes the proximity of buildings, trees or antenna towers will affect the electrical length of the half wave antenna. One side of the antenna must sometimes be slightly shorter than the other, in order to eliminate standing waves on the feed line. The positions of the taps T1 and T2 can be moved to obtain this effect after the antenna itself is pruned to exact length for the frequency of operation.

The directive properties of this antenna are such that best results are secured in the direction at right angles to the flat top wire. For ultra-short-wave operation the antenna portion is usually made vertical, and reflector systems are often employed to increase the radiation in the desired direction.

The End Feed Antenna

● When a half wave antenna, or one with multiplies of half waves, has one end brought directly to the radio transmitter it is called an *End Fed Antenna,* or *Fuchs Antenna.* These antennas can be operated on several bands with almost equal efficiency. Their main disadvantage lies in the fact that the antenna is brought directly into the radio room, therefore a material portion of the radiation may be lost by the nearness of loss-creating objects. It is an easy antenna to tune because there are no RF feeders which require adjustment, and the electrical length can be varied at the transmitter in order to obtain exact resonance on any band.

The antenna should have an overall length of an even number of quarter waves in length. By making it a trifle too long, the far end can later be "pruned" until exact resonance is obtained. The tuning process consists of operating the final amplifier of the transmitter at reduced power, tuning it to resonance, and then tapping the antenna across part of the final amplifier plate coil. The antenna should be of such length that no change in the plate tuning condenser is necessary in order to obtain resonance in the amplifier either with or without the antenna connected to the amplifier.

A series coil and condenser, when connected in the antenna near the end, will tune the antenna to resonance for different frequencies. See Fig. 33. Slight errors in length can be compensated for by adjusting the parallel tuned coupling circuit. If the antenna is cut to the correct length this

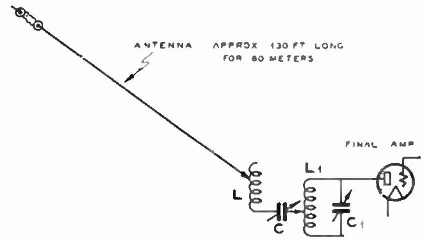
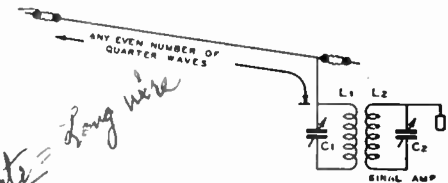


Fig. 33
End Fed Antenna with Series Tuning Circuit.



note = Long wire

Fig. 34
End Fed, Voltage Fed Hertz Antenna.

coupling circuit will be tuned to exactly the same frequency as that of the final amplifier plate circuit, shown in Fig 34.

When an end fed antenna designed for 80 meter operation is used on 160 meters it becomes a Marconi antenna, as shown in Figs. 35 and 36. A good ground connection is necessary. The antenna coupling coil should have approximately 20 turns of wire, wound on a form approximately the same diameter as the final amplifier plate coil. The coupling should be variable.

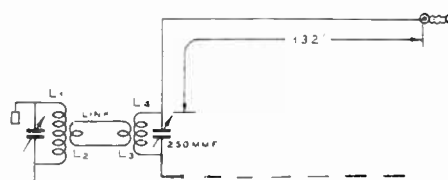


Fig. 35
80 Meter End Fed Antenna with Counterpoise for 160 Meter Operation.

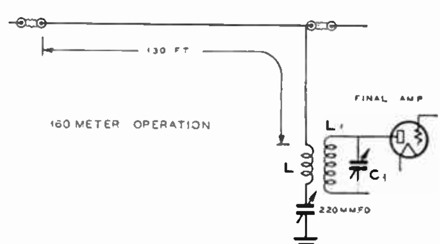


Fig. 36
80 Meter End Fed Antenna with Loading Coil for 160 Meter Operation.

The directional effects of this antenna are similar to those shown in Fig. 8, except when operated on 160 meters. If the antenna stretches out nearly horizontal from the transmitter, these directive patterns are approximately correct. This antenna is most practical for operation where the radio transmitter is located on the top floor of a building. The losses are apt to be excessive if the antenna runs close to the side of a building and into a radio transmitter located near the ground.

The approximate length of the antenna is determined from the formula:

$$L = \frac{492,000}{f}$$

where L is the length in feet of the antenna, f is the frequency in kilocycles.

Long Single Wire Antenna

● Remarkable results for both transmitting and receiving can be secured with a long antenna operated on its harmonics. This antenna is more directional than a half wave antenna. It should be pointed more nearly in the direction in which general long-distance communication is desired. The

If the end of the antenna is brought into the operating room, the system can be tuned to exact resonance for any desired harmonic. Zepp. feeders are also very suitable for this type of antenna. A study of the *"V" Antenna Design* Table will show that an antenna 552 feet long for 7100 KC does not resonate at twice that frequency for 20 meter operation, rather it is resonant at 14,250 KC. Zepp. feeder tuning, or end feed tuning adjustments, will make possible the resonating of the antenna at 14,200 KC if operation from one crystal is wanted for both the 20 and 40 meter bands.

Several of these antennas can be strung in various directions because great height is not absolutely essential.

Twisted Pair Fed Antenna

● A very effective one-band antenna for transmitting and receiving consists of a half wave flat top with a twisted pair feeder. The impedance of a twisted pair ranges from 80 to 175 ohms, depending upon the spacing between the conductors and the diameter of the wire. This impedance is low enough so that the feeders can be connected directly into the center of the antenna. In practice, the last few inches of the feeders are fanned-out into a small triangle, as shown in Fig. 37.

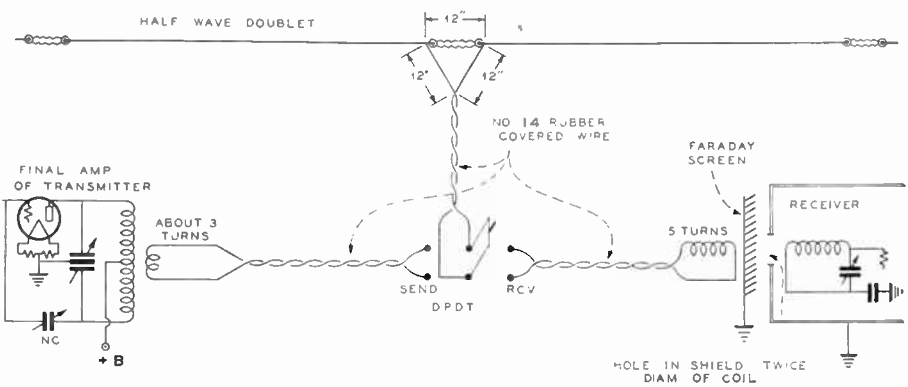


Fig. 37
One-Band Doublet Antenna for Transmitting and Receiving.

horizontal directivity diagrams previously shown in Fig. 11 indicate the main directions of greatest radiation. An actual gain of from 2 to 4 times is obtained by making the wire from 4 to 8 waves in length. Even shorter lengths will provide very noticeable gain, such as can be obtained by a 275-foot wire on 40 meters. This same antenna will be even more effective on 20 meters, but somewhat more directional in the line of the wire. The dimensions for these long wire antennas can be obtained from the Table, *"V" Antenna Design.*

The feeder can be any length, and it can be carried around corners of buildings, through walls and along picture mouldings. Nearby objects have very little effect on the efficiency of the feeders because of their close spacing and the large number of transpositions or twists along the feed line. The losses in the feed line are exceptionally low, largely because the small spacing between the wires causes the line to have a very low characteristic impedance. This means that for a given amount of power the voltage between the two wires is very low, thus insulation and dielectric losses can be held to a minimum. Ordinary stranded lamp-cord should be avoided because of high losses, but single conductor No. 12 to No. 18 twisted pair is satisfactory. The special twisted pair made for RCA double-doublet antennas is satisfactory for power inputs of several hundred watts. Type E01 twisted pair, available from most radio dealers, is designed for an 80 ohm impedance and will handle powers up to 1 KW. These commercially made twisted pairs are covered with a special grade of rubber which has a low dielectric loss and is quite resistant to weather.

Harmonic operation is not recommended because the line is no longer non-resonant for such operation, and standing waves will cause high RF voltage across some portions of the line. If much power input is used, the line insulation will break down and burn. Operation on the second harmonic is possible, but the efficiency of the line then drops approximately 50%. This antenna is excellent for receiving because of reduction in noise pickup. Two of these antennas placed at right angles to each other will provide transmission or reception in all directions.

Problems of Space Limitations

● Countless experimenters are faced with the problem of erecting an antenna in a space too small for a half wave antenna of the desired frequency of operation. For example, only 90 feet of space may be available, yet operation on 75 meter phone would require an antenna approximately 125 feet long. Certain forms of *Marconi Antennas* can be used, since these are a quarter wave in length, or approximately 63 feet. A counterpoise or a good ground connection would be required, and by this means fairly satisfactory results can be obtained. A half wave antenna which is horizontal over its entire length is often preferable from a standpoint of its directivity and efficiency. Such a half wave antenna can be built into a 90 foot space by using an *end loading coil* to make it an electrical half wave in length, as illustrated in Fig. 38. The loading coil can be wound with approximately one-fourth to one-half as much wire as would normally be used for the antenna, in this case, 125 feet long: approximately 10 to 15 feet of wire would therefore be wound on the loading coil. The winding form can be from 2 to 3 inches in diameter and the coil should be space wound with the same size and kind of wire as the antenna. The loading coil should be covered with a weatherproof housing and the antenna strain should be taken up with strain insulators, rather than depending upon the coil form to act as a strain support for the antenna. The newer forms of low-loss tank coils wound on celluloid strips should be suitable in locations where snow and ice are not encountered, thus they need not be protected from the weather.

A single wire feeder or Zepp. feeder can

Chart Showing Theoretical Length of Half Wave Antennas, Such as Single Wire Fed, Collins, Johnson "Q," Matched Impedance, Twisted Pair and Zepp.

BAND	Frequency	Antenna Length
1¼ Meter	224 mc 232 mc 240 mc	25" 24" 23.5"
2½ Meter	112 mc 116 mc 120 mc	4' 2" 4' 3' 10"
5 Meter	56 mc 58 mc 60 mc	8' 4" 8' 1" 7' 10"
10 Meter	28 mc 29 mc 30 mc	16' 8" 16' 1" 15' 6½"
20 Meter	14.05 mc 14.15 mc 14.25 mc 14.35 mc	33' 4" 33' 1" 32' 10" 32' 8"
40 Meter	7.02 mc 7.10 mc 7.20 mc 7.28 mc	66' 7" 65' 9" 64' 11" 64'
80 Meter	3550 KC 3600 KC 3700 KC 9800 KC 3350 KC	131' 6" 129' 10" 126' 4" 123' 118' 4"
160 Meter	1750 KC 1850 KC 2000 KC	267' 252'— 233'

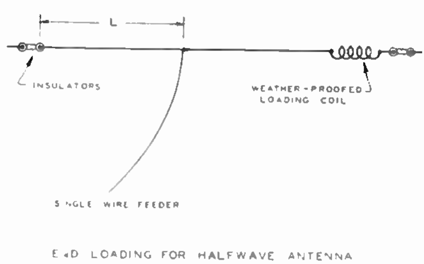


Fig. 38

be used for this type of antenna, and in the case of a single wire feeder the distance *L* in Fig. 38 should be one-third the length which a regulation half wave antenna would ordinarily have *without* the use of a loading coil. Thus the 90 foot wire previously referred to would have the single wire feeder attached to it at a point approximately 42 feet from the unloaded end, just as if it were a 125 foot length of wire. If this antenna is to be operated only on one band, the feeder tap can be moved along the flat-top until standing waves disappear from the feeder, as checked with the simple feeder tuning device described elsewhere in Fig 95.

The approximate adjustment of the loading coil can be made with the antenna suspended only a few feet above the ground, or roof, and coupled loosely to a regenerative receiver. The natural period of the antenna can be found for each adjustment of turns on the loading coil by noting the point at which the regenerative receiver tends to pull out of oscillation, if the receiver dial is calibrated approximately in wavelength or frequency. The receiving antenna for these tests can be a short wire a few inches from the antenna under test, with just enough coupling between the two antennas to tend to stop oscillation in the receiver at resonance. Another method of tuning the antenna system is to use an antenna field strength meter connected to a small antenna, parallel to the antenna under test. In this case the transmitter should be coupled to the main antenna and constant power input maintained to the final amplifier. The field strength meter reading will be a maximum when the antenna is correctly loaded to the frequency of operation.

Another example of end loading would be for a half wave antenna for the 40 meter band, built into a space of only 50 or 60 feet. Normally, such an antenna with its insulators and supports would require a space of at least 70 feet. The loading coil will permit successful operation of a 45 or 50 foot flat-top without great sacrifice in efficiency.

160 Meter Coupling Systems

● A simplified PI coupling system is shown in Fig. 39.

The 150 mmfd. and the 500 mmfd. variable condensers are effectively in series, through the common chassis ground connection. The advantages of this arrangement are: (1) there is no DC on the tuning condensers and the condensers will not flash-over on modulation peaks; (2) there is freedom from filter and rectifier trouble; (3) closer spaced tuning condensers can be used; (4) ample leeway for the tuning circuit because large variable condensers are used. The plate coil L1 consists of 60 turns of No. 20DCC wire, close wound, on a 2-inch diameter form, tapped at the 40th, 50th and 60th turn.

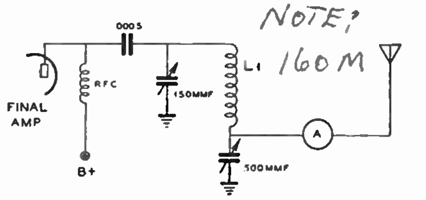


Fig. 39

A Simplified Antenna Coupling System. The 500 mmf. condenser is an ordinary receiving type variable condenser; the 150 mmf. condenser is of the high-voltage type.

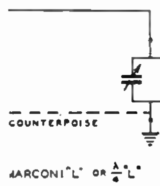


Fig. 40

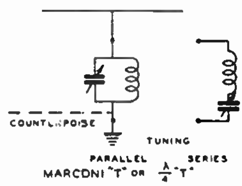
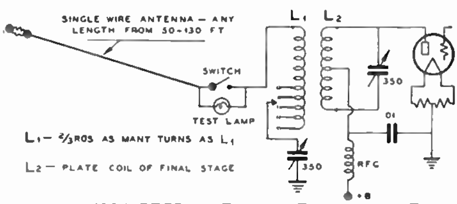


Fig. 41



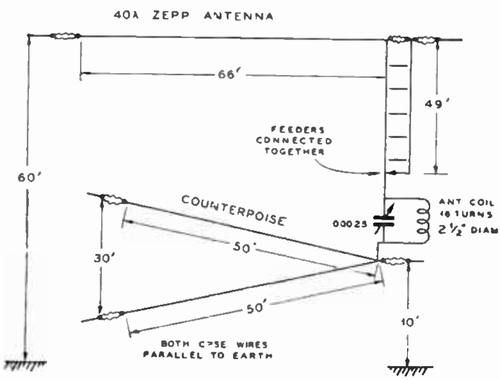
160 METER ANTENNA TUNING SYSTEM

Fig. 42

The circuit shows the use of a tuning lamp in series with the antenna and a shorting switch for bridging the lamp after the antenna is tuned. A better method is to merely wrap a turn or two of wire around the lead-in wire and connect the ends of the loop to the lamp. The lamp can then be left permanently in the circuit.

Fig. 40 shows the common inverted-L Marconi antenna using parallel tuning of the pick-up coil. Fig. 41 shows the same antenna in a T-form, instead of an inverted-L. Practically all 160-meter antennas are of the quarter wave type and are similar to those used in the broadcast band for either transmission or reception.

FIG. 43—How to Use a 40 Meter Zepp Fed Hertz on 160 Meters



The illustration shows a 40 meter Zepp fed Hertz antenna for operation in the 160 meter band. A counterpoise, about 10 feet above earth, completes the circuit to ground and makes a Marconi, or quarter wave grounded antenna out of the combination. The Zepp feeders are connected together and attached to the tuning condenser and to one end of the antenna coupling coil, as shown. The other end of the coupling coil connects to the counterpoise. If the feeders are not of the same length as those shown in the diagram, the number of turns on the coupling coil must be changed in order to establish resonance. The coupling coil should be loosely coupled to the tank circuit of the transmitter. For 40 meter operation, the Zepp feeders are adjusted in the usual manner with the coil and condensers, and the counterpoise is not used.

Marconi Antennas

● Marconi antennas are widely used on the 160 meter band and for longer wave commercial communication. For 160 meter operation the antenna can be from 90 to 150 feet long, with series tuning coils and condensers, with the base of the antenna to a *good* connected ground or counterpoise. Figs. 39 to 46 shows various methods for 160 meter operation. The choice depends largely upon the individual location. It is always important to keep the lead-in and coupling coil remote from all house wiring and metal objects in order to minimize losses. Grounds can be replaced with a counterpoise of one or more wires; usually a network of wires in the counterpoise is more effective because of greater capacity to ground. A Marconi antenna for 160 meters can be adjusted by using series tuning to ground or counterpoise. This requires a tapped antenna loading coil and a series variable condenser of from .00025 to .0005mfd. Resonance is obtained by switching taps and by varying the condenser until the antenna loads the plate current of the final stage to its normal value. If this value is more or less than the rating of the tube, the coupling between the loading coil and the final tank coil should be increased or decreased.

The radiation resistance of a quarter wave Marconi antenna at the point of ground connection is less than 35 ohms. The ground connection should have low resistance in order to convert the power into useful radiation, rather than into resistance heat losses. A Marconi antenna less than a quarter wave long has even lower values of radiation resistance; values of from 5 to 30 ohms have been encountered with an-

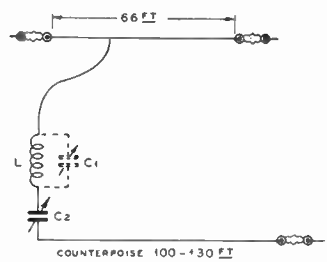


Fig. 44

40-Meter Single Wire Fed Hertz for 160 Meter Operation. If "L" has sufficient turns, C1 is not required. "L" is coupled to the plate tank circuit.

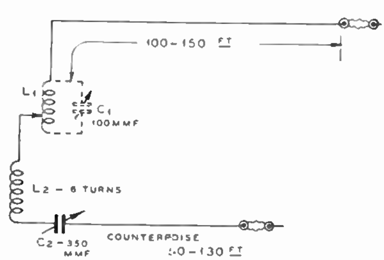


Fig. 45
Another System for Loading an Antenna for 160 Meter Operation.

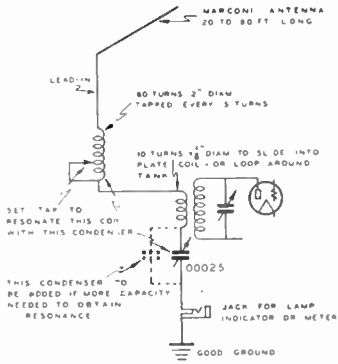


Fig. 46
Loading System for Short Marconi Antenna for Boats, Aeroplanes, Etc.

tennas from 1/16th to 1/5th of a wave in length.

These low values of impedance make it impossible to use the *Collins Pi Antenna Network*. Such antennas must be loaded to a quarter wave, electrically, by means of loading coils, and in some cases the loading coil must be shunted with a variable condenser in order to obtain resonance. These very short Marconi antennas (such as installed on small sea-going craft, see Fig. 46), require a very low resistance connection to the ground or counterpoise in order to avoid excessive power losses.

Directive Antennas

● All antennas have directional properties and these can be increased by properly combining the antenna elements. The various forms of half wave antennas already described have maximum radiation out at right angles to the direction of the wire, but the directional effect is not very great. If this radiation can be confined to a narrow beam, the signal intensity can be increased a great many times in the desired direction of transmission. This is equivalent to increasing the power output of the transmitter. It is more economical to use a directive antenna than to increase transmitter power if general coverage is not desired.

Directive antennas can be designed to give as high as 23 DB gain over that of a single half wave antenna. However, this high gain (nearly 200 times as much power) is confined to such a narrow beam that it can be used only for commercial applications in point-to-point communication. The increase in radiated power in the desired direction is obtained with a corresponding loss in all other directions. Gains of 3 to 10 DB seem to be of more practical value for amateur communication because the angle covered by the beam is wide enough to sweep a fairly large area. 3 to 10 DB means the equivalent of increasing power from 2 to 10 times. For example, an amateur living in the center of the United States would want his beam to be wide enough to cover all of Europe in one direction, and New Zealand in the opposite direction. His beam should be centered about 45° north-of-east, and about 35° wide. Similarly, a 20° beam width, 50° south-of-east, would cover South America and the Orient. Another 35° beam pointing east and west would cover Australia and South Africa. In San Francisco, two beam antennas could be made to cover all DX sections fairly well; a 30° beam, 35° south-of-east for South America and the Orient, and another 35° to 40° beam, 45° north-of-east for Europe, New Zealand and Australia.

In this discussion all antenna arrays are assumed to have two main lobes of radiation in opposite directions (no reflector system). Angles in which the antennas could be pointed can be figured as the Great Circle shortest distance direction with the aid of a globe of the world. Day and night directions in some cases are different, due to the skip distance effects of some of the high-frequency bands, because the signals may go around the world in one direction in the morning, and in the other direction at night, to points near the opposite sides of the world.

Four to six half wave antennas or their equivalent are apparently about all that can be used without securing too much directivity, unless the operator is aiming at one locality of relatively small area. With ultra-short wavelengths below 10 meters, the problem of rotating the beam antenna is simplified and more directional effects with greater power are desirable. Reflector systems can be set up for increasing the beam in one direction and preventing radiation in the opposite direction.

Tables of wire lengths for several arrays and directional types of antennas are given. Local conditions of surroundings will modify these values, but for most purposes the wires can be cut to the values listed, and satisfactory results obtained.

The most simple method of feeding many types of directional antennas (if near the transmitter) is by means of Zepp feeders which are generally some odd multiple of quarter waves in length. In all cases where the system is much more than a wavelength from the transmitter to the feed point, a non-resonant two-wire feeder and quarter wave matching stub should be employed. The problem is greatly simplified in most cases by the use of Zepp feeders, since the feeders can be tuned at the transmitter just as with any Zepp half wave antenna. In some instances the feeders should be electrically an even multiple of quarter waves in length. A simple field strength meter coupled to the antenna system will readily indicate correct feeder tuning.

All directional resonant antenna systems, other than a single long wire system, operate on the one frequency for which they are designed. The "*V*" beam can be operated on two bands with fair satisfaction, although the correct angle δ between the arms of the "V" can only be made for one frequency. A type is generally chosen from a consideration of available space. The "V" beams are less critical in mechanical design; if space is available for pointing the open or closed end of the "V" in the desired direction, this type is excellent.

Horizontal and Vertical Directivity

● The horizontal directivity of any antenna system is that shape of the radiated beam or beams shown looking down at the earth from a point above the antenna system. For example, a beam having a width of 30° horizontally would spread out enough to cover a whole continent, such as Europe, from points in the United States. *Vertical Directivity* is the expression for defining the angle above the horizon at which the major portion of the radiation goes out from the antenna. Directional antenna systems are generally made to have a very low angle of radiation, so that the vertical directivity is outward toward the horizon, rather than upward.

Polarization

● Radio waves are *Polarized* in that they will induce a greater signal in the receiving antenna when the plane of that antenna is parallel to the plane of polarization. For example, a vertical transmitting antenna will produce a vertically-polarized wave which can best be received by a vertical receiving antenna over relatively short distances, such as in the ultra-high-frequency region. Wave-lengths between 10 and 100 meters can be transmitted with either vertical or horizontal antennas, resulting in the wave starting out with a *vertical* or *horizontal* polarization, and by the time it reaches the distant receiving antenna it is apt to be mainly *horizontally* polarized. Reflection and refraction effects in the Heaviside Layer tend to twist the wave polarization so that in most cases a horizontal receiving antenna will give best results.

For ultra-short wavelengths, vertically polarized waves are not reflected upward by the surface of the earth as easily as those of horizontally polarized nature and only the ground wave is useful on wavelengths below 10 meters. Vertical transmitting and receiving antennas have thus proven most satisfactory at these frequencies.

Wavelengths above 100 meters are not as easily twisted as those below 100 meters. With ultra-short wavelengths the plane of polarization may be twisted by such objects as hills or buildings, so that occasionally a horizontal antenna will very efficiently receive signals transmitted by a vertical antenna.

Directive Factors

● Directional antenna systems operate on the principle that the radiation fields add or subtract in space. When several radiating elements, such as half wave antenna, are in close proximity to one another, the radiated fields may aid or oppose each other in different directions. In those directions in which opposition or cancellation occur, the signal is attenuated; similarly in those directions in which the fields aid each other, or add, the signal is increased. All directive antennas depend upon this phenomena. The fields are said to be *in phase* when they are additive, and *out of phase* when they cancel each other. Antenna directivity results from phasing the radiation from adjacent antenna elements so as to neutralize the radiation in the undesired directions, and to reinforce the radiation in the desired direction. Directivity can be obtained in either horizontal or vertical planes. In transmission, directive antennas concentrate energy much like reflectors and lenses concentrate light rays. For receiving, the signal is proportional to the amount of antenna wire exposed to the radio waves when the half wave sections are properly phased.

Reflectors

● A simple reflector consists of a wire approximately a half wave long, either excited directly by the transmitter so as to be out of phase with the antenna, or it can be of the *parasitic* type, A Parasitic Reflector one quarter wave away from the antenna must be slightly longer than the antenna in order to have an inductive reactance. The radiated field from the antenna is re-radiated by the reflector wire so that the radiation in line with the two is reinforced back toward the antenna and cancelled in the opposite direction. If the reflector wire is spaced a half wavelength distant from the antenna the radiated field will be increased in two directions, or tend to cancel in a direction at right angles. The increase is in a plane at right angles to the plane of the antenna and reflector, as shown in Fig. 47.

Two reflector wires spaced a half wave each side of an antenna, and an additional reflector spaced a quarter wave behind the

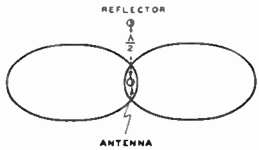


Fig. 47

antenna, will combine to increase the field intensity in a forward direction, and tend to cancel the field in all other directions.

Reflector curtains, a combination of several reflector wires in proper phase relation, are normally used in commercial applications in order to confine a beam to one direction. Without such a reflector curtain, which is usually similar to the antenna array, the beam would be transmitted with less intensity in both a forward and backward direction. The reflector in such cases *doubles* the field in the forward direction.

Parasitic reflectors have no direct connection to the antenna or feeders. Their length can be calculated from the formulas:

$$L = 1.60 \times \lambda$$

where L is the reflector length in feet.
λ is the transmitter wavelength in meters.

$$L = \frac{492{,}000 \times 0.97}{f}$$

where f is the transmitter frequency in kilocycles.

These formulas can be used for determining the length of single half wave reflector wires, such as those used in a parabolic reflector or in a *Yagi* antenna.

Directors

● If a wire is placed in front of an antenna and if it has a capacitive reactance, it will aid the radiation in a *forward* direction. More than one wire may be placed in line of the desired direction, such as shown in the Yagi antenna in Fig. 48 in order to greatly increase the directivity and field intensity in that direction. These are called *director wires* and they are shorter than those used for reflectors. A capacitive reactance is obtained by making the wire less than an electrical half wave in length. A straight wire loses both inductance and distributed capacitance as it is decreased in length. At a given frequency the inductive reactance will predominate if the wire (less its end effects) is over a half wave in length. Similarly, if it is less than a half wave in length the capacitive reactance will be greater than the inductance reactance. The antenna should always be resonant, in which case the inductive reactance is equal to the capacitive reactance and the two will then cancel each other.

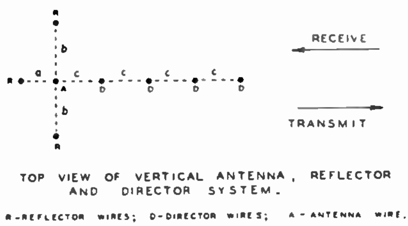


Fig. 48
Yagi Antenna.

Director wires should be spaced at intervals of ⅜ths wavelength in the desired direction from the transmitting antenna. These lengths can be calculated as follows:

$$L = 1.425 \times \lambda$$

where L is the director length in feet.
λ is the transmitter wavelength in meters

$$L = \frac{492{,}000 \times 0.87}{f}$$

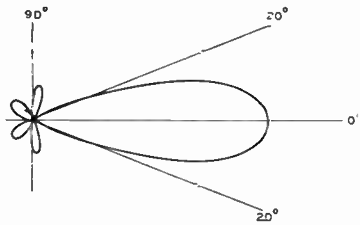
where f is the transmitter frequency in kilocycles.

Directional Antenna Types

The Yagi Antenna

● The Yagi Antenna is useful on the ultra-short and micro-wave bands. It consists of several reflector and director wires grouped around a half wave antenna, such as that shown in Fig. 48, which is a top view of a vertical array. The rear reflector wire *R* is placed a quarter wave behind the antenna wire *A*, two other reflector wires are placed a half wave from the antenna, on each side. The director wires *D* are spaced a distance of ⅜ths of a wave apart. The distances *A*, *B*, and *C* are a quarter, half and ⅜ths of a wave respectively in Fig. 48. In the table (page 64), dimensions are listed for the design of this type of directive antenna for wavelengths of from 1¼ meters to 20 meters (224 to 14.4 mc.).

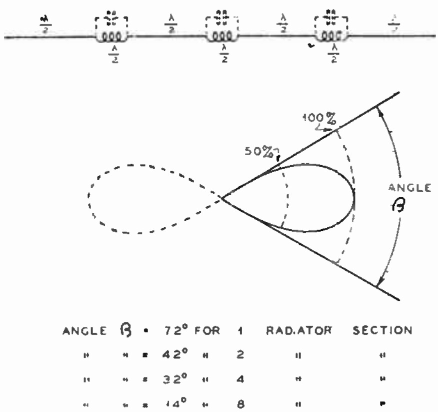
The reflector and director wires are all parasitically excited. The antenna can be



HORIZONTAL DIRECTIVITY OF A SIMPLE YAGI ANTENNA

Fig. 49

fed with any type of RF feeder, such as a two-wire matched impedance feed, Zepp feeders or by a quarter wave matching stub and non-resonant line.



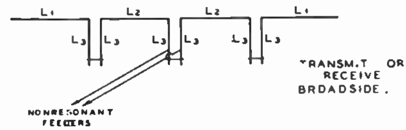
FRANKLIN ANTENNA

Fig. 50

The Franklin Antenna

● A directive antenna array which is quite practical for amateur application is shown in Fig. 50. It consists of two or more half wave sections in phase, so that the radiation field is broadside to the antenna. More than four sections will provide too sharp a beam for most amateur purposes. The half wave sections may be phased with quarter wave sections, as shown in Fig. 51, or by means of phasing coils, as shown in Fig. 52. In either case the phasing coil, or quarter wave section, is equivalent to a half wave antenna which does not radiate. but only serves the purpose of phasing the antenna current in the same direction in adjacent sections of the radiating antenna. The two end sections L_1 should be cut for end effects, thus making these sections slightly shorter physically than the intermediate section L_2.

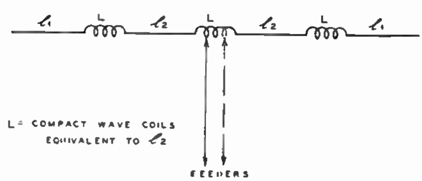
The dimensions listed in the Table for Antenna Arrays are theoretical values which may have to be slightly modified in actual practice, due to the proximity of surrounding objects. Ordinarily, this antenna can be tuned to resonance by varying the lengths of the quarter wave stubs L_3.



BROADSIDE DIRECTOR ANTENNA

Fig. 51

Non-resonant feeders in the form of a 600 ohm line should preferably be tapped across the middle quarter wave section in order to secure a balanced antenna system. If one of these quarter wave sections is near the transmitter, it can be used as a Zepp. feeder of either one quarter or three-quarters of a wave in length. It can be tuned with series condensers and coils, as discussed under Zepp. Antennas.



TYPE OF FRANKLIN ANTENNA

Fig. 52

A 20 meter directional antenna of this type is easily constructed because the required space is only about 135 feet, and the height above ground about 40 feet. A single 6-inch strain insulator can be used to support the L_1 and L_2 sections. The L_3 sections can hang toward the ground, held in position with a small weight. The L_3 quarter wave sections can be spaced with 6-inch ceramic Zepp. feeder separators. Standing waves along the non-resonant feed line can be located by means of the milliammeter, carborundum detector, and coil arrangement described in Fig. 95. The standing waves are indicated by variations of the milliammeter reading as the feeder test set is moved along the feed line at a constant distance from the line. The standing waves can be eliminated or minimized by changing the position of the feeder taps on the quarter wave section, also by a variation of the quarter wave section lengths. In some cases the values of L_1 and L_2 may have to be shortened slightly, and the various sections may sometimes differ from the lengths shown in the Table because of the proximity of some object near one of the sections. In most cases the values shown in the Table can be used without variation, unless the utmost in efficiency is desired. The values of L_1, L_2, L_3 and L_4 are correct for nearly all forms of antenna arrays. This Table greatly simplifies directional antenna array design for amateur operation.

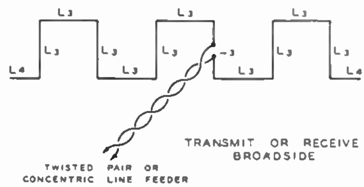
Antenna Array Dimensions

For Franklin, Bruce, Chireix-Mesny, Barrage and Stacked Dipole Arrays.

BAND	Frequency in Megacycles	L_1	L_2	L_3	L_4
40 Meter	7.02	68'2"	70'	35'	17'1"
	7.10	67'6"	69'2"	34'7"	16'11"
	7.20	66'7"	68'4"	34'2"	16'8"
	7.28	65'10"	67'6"	33'9"	16'5"
20 Meter	14.05	34'1"	35'	17'6"	8'6"
	15.15	33'10"	34'8"	17'4"	8'5"
	14.25	33'7"	34'6"	17'3"	8'5"
	14.35	33'5"	34'3"	17'1"	8'4"
10 Meter	28.0	17'1"	17'7"	8'9"	4'3"
	29.0	16'6"	17'	8'6"	4'1½"
	30.0	16'	16'5"	8'2"	4'
5 Meter	56	8'7"	8'9"	4'5"	2'2"
	58	8'3"	8'6"	4'3"	2'1"
	60	8'	8'2"	4'1"	2'
2.5 Meter	112	4'3"	4'5"	26"	13"
	116	4'1½"	4'3"	25"	12½"
	120	4'	4'1"	24½"	12"
1.25 Meter	224	25½"	26½"	13"	6½"
	232	25"	25½"	12½"	6¼"
	240	24"	24½"	12"	6"

The Bruce Antenna

● One of the simplest antenna arrays is shown in Fig. 53. It is not critical as to the length of its elements, and it can be used over a wider frequency range than most other antenna arrays. The antenna is made up of ⅛ and ¼ wave sections, resulting in good horizontal directivity if the overall length is at least five wavelengths long; however, it possesses very little vertical directivity because of its lack of height. The currents in each half of a horizontal section are out of phase and thus these sections tend to cancel their radiation field. The vertical sections are in phase, resulting in broadside radiation or reception, because this antenna is normally used for receiving. A similar bent wire, placed a quarter wave behind the antenna, will act as a reflector and make the system unidirectional.



BRUCE BROADSIDE DIRECTIVE ANTENNA

Fig. 53

This antenna is occasionally used for 5-meter transmission and reception, due to its small size. The dimensions for different amateur bands are listed in the Table showing *Antenna Array Dimensions.*

Reflector and Director Dimensions

Freq.	A	R	D	a	b	c
224	25"	26"	23"	13"	26½"	20"
232	24"	25"	22"	12½"	25½"	19"
240	23½"	24"	21"	12"	24½"	18½"
112	4'2"	4'3"	45½"	26"	4'5"	39"
116	4'	4'1½"	44"	25"	4'3"	38"
120	3'10"	4'	43"	24½"	4'1"	37"
56	8'4"	8'7"	7'½"	4'5"	8'9"	6'7"
58	8'1"	8'3"	7'4½"	4'3"	8'6"	6'4"
60	7'10"	8'	7'1½"	4'1"	8'2"	6'2"
28	16'8"	17'2"	15'3"	8'9"	17'7"	13'2"
29	16'1"	16'6"	14'9"	8'6"	17'	12'8"
30	15'6½"	16'	14'3"	8'2"	16'5"	12'4"
14.05	33'4"	34'1"	30'5"	17'6"	35'	26'3"
14.15	33'1"	33'11"	30'2"	17'4"	34'8"	26'1"
14.25	32'10"	33'8"	30'	17'3"	34'6"	25'11"
14.35	32'8"	33'5"	29'10"	17'1"	34'3"	25'8"

Stacked Dipole Antennas

● A *dipole* is simply another name for a half wave antenna. Several dipoles can be arranged in stacks to form a highly directive antenna system. When an entire "curtain" of these dipoles is used, together with a similar reflector curtain spaced one-quarter wave behind it, the beam becomes very sharp and of great intensity. Actual power gains of 100 to 200 are secured in commercial practice. Both horizontal and vertical directivity can be very great because several elements, such as shown in Fig. 54, (four radiating dipoles), can be built into a curtain with one row on top of the other. For amateur purposes the single unit will provide sufficient directivity in most cases.

The radiating sections L_1 may be either horizontal or vertical, depending on whether horizontal or vertical polarization is desired. The currents in the L_2 and L_3 sections produce fields which neutralize each other, with the result that radiation occurs only from the L_1 sections which are a half wave in length, electrically. The actual physical length is approximately 0.975 of a half wavelength. The L_2 sections are made a half wave in length in order to provide the proper phase in the L_1 sections. In Fig. 55 the radiation is broadside to the antenna, as shown, and end-wise if the two sections L_2 do not cross.

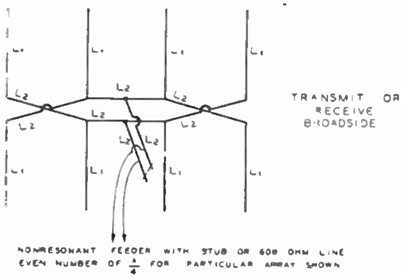


Fig. 54

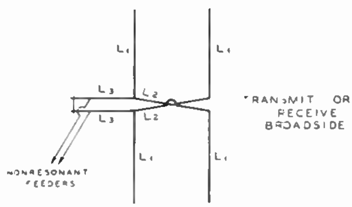


Fig. 55

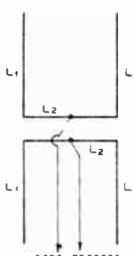


Fig. 56

In the four forms of this antenna shown in Figs. 54 to 57, quarter or half wave matching stubs provide a means of connection to a two-wire non-resonant feeder. In some cases a 600 ohm line can be connected directly into the array when the impedance at the chosen point is 600 ohms. Zepp. feeders are satisfactory if they are not over 5 quarter wavelengths long. These arrays are fairly popular for the ultra-short

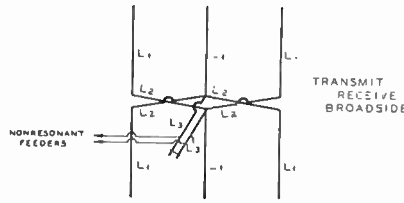


Fig. 57

wavelengths for amateur operation, although commercial application is widespread for wavelengths above 10 meters. These systems must be adjusted for the exact frequency of transmission, and quite rigidly supported.

The arrays shown in Figs. 55 and 56 are similar in performance, even though the L_2 sections do not cross or reverse in one case. The phase of the current in the L_1 sections is maintained by connection of a resonant feeder or quarter wave matching stub at the ends of L_2 in one case, and at the center in the other case.

Figure 58 shows the construction of a framework for an ultra high frequency directional antenna with parasitic reflectors spaced a quarter wave behind the "H"-section antenna. If desired, the reflector wires *D* can be cross-connected at their adjacent ends. The antenna sections *A* are listed in the Table for *Antenna Array Dimensions* as L_1. The reflector wires *D* are listed in the Table for *Reflector and Director Dimensions* as *D*, which in this case is equivalent to L_1. The Zepp. feeders should be an even number of quarter wavelengths, the same as in a center-fed Zepp. antenna.

In practical applications of curtains, the reflector wires should be tuned for maximum current. Usually the lengths will be between 2% and 5% greater than a half wave in length. The antenna elements are sometimes as much as 10% shorter than a half wave in length. The reflector curtain has a reactive effect upon the antenna and thus it is generally tuned-up first, then the antenna wires are cut to length experimentally in order to provide exact resonance under operating conditions. In these curtains, which consist of horizontal rows of half wave elements and often two or three tiers one above the other, RF power is fed in the proper phase relation to several points.

A reflector placed a quarter wave behind an antenna, and properly tuned, will provide a gain of 3 DB, which is a power gain of two. Two half wave antennas spaced a half wave apart and properly excited, will also provide a 3 DB gain over that obtained from a simple half wave antenna. Three and four half wave sections in a line a half

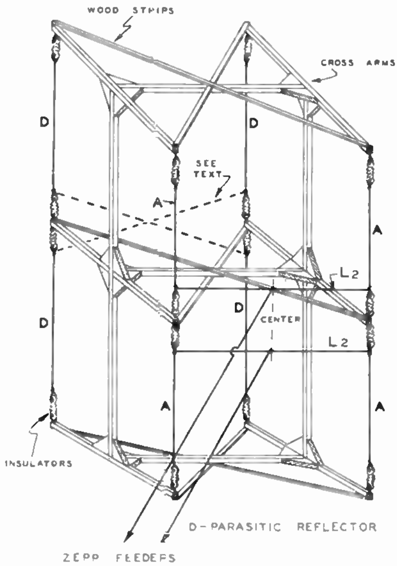


Fig. 58

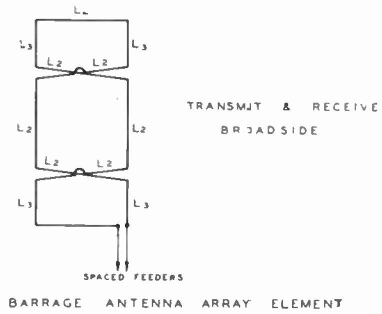


Fig. 59

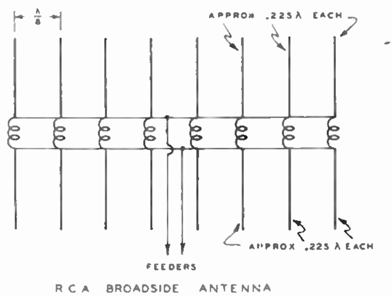


Fig. 60

wave apart will provide gains of 5 DB and 6½ DB, respectively, over that of a single half wave antenna. The simple "H" type of stacked dipole, Fig. 55, which consists of four half wave sections, will give a gain of approximately 6½ DB. The antenna shown in Fig. 57 which has six half wave radiating sections will give a gain of approximately 8½ DB. The one shown in Fig. 54 which has eight sections will give a gain of 10 DB. Adding a reflector section similar to the antenna array, and spaced one-quarter wave behind it, will provide 3 DB additional gain to any of these arrays.

The Barrage Antenna

● Another of the many types of directive arrays is shown in Fig. 59, a broadside radiator of vertically polarized waves.

The horizontally polarized waves which would be radiated by the top and bottom horizontal wires are negligible because of the opposition of current flow in the two halves of each of these members. This is obtained by making the vertical sections at the top and bottom of L_3 a quarter wave long. The middle sections L_2 are half wave in length. The dimensions for this antenna are listed in the Table of *Antenna Array Dimensions* for amateur bands.

RCA Broadside Antenna

● In this array, Fig. 60, all parts of the parallel transmission line connecting the L sections are kept in phase by means of shunt inductances.

The waves are vertically polarized and the beam is broadside to the antenna. A reflector system spaced a quarter wave behind the antenna can be used to make it unidirectional.

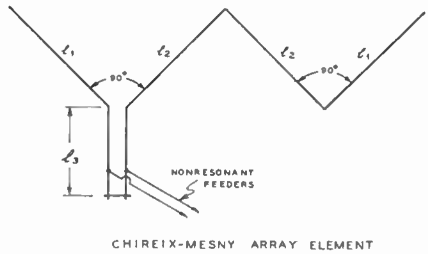


Fig. 61

Chireix-Mesny Antenna

● Numerous elements of the type shown in Fig. 61 are connected to form an antenna and reflector curtain for operation in many French commercial stations. In this case, the feeder system is different from that shown.

For amateur application a Zepp. type feeder is recommended. The dimensions for L_1 and L_2 are approximately a half wave in length, and for the amateur bands the lengths can be found in the Table of *Antenna Array Dimensions.*

"V" Antennas

● The horizontal "V" antenna shown in Fig. 62 is suitable for amateur as well as commercial work. The long wires *L* can be made several waves in length in order to obtain good directivity.

By choosing the proper angle δ, the lobes of radiation from the two long wire antennas aid each other to form a bi-directional beam. The back end radiation can be re-directed forward by a reflecting antenna similar to the radiating antenna, located an odd number of quarter wavelengths behind, and faced so that the two antennas are supplied with current 90° out of phase. Each wire *L* by itself would have a radiation pattern similar to that shown for antennas operated at harmonics; refer back to Fig. 11. Design data for the 10, 20 and 40 meter bands is listed in the Table, together with the proper angle δ.

This type of antenna can be made into a Vertical "V" as shown in Fig. 63, which is particularly adaptable for receiving, because only one antenna mast is required.

The angle δ for different lengths of *L* is shown in the chart for *Diamond Antennas.* A good ground connection is necessary.

Horizontal V antennas are easily constructed and have proven very effective. For amateur operation *L* can be two or four wavelengths long. Commercial antennas are usually made eight waves in length in order to secure a sharper beam with a correspondingly greater power gain.

Diamond Antennas

● A very effective directional antenna having a low angle of radiation of horizontally polarized waves is shown in Fig. 64A. This non-resonant *Diamond* antenna consists of

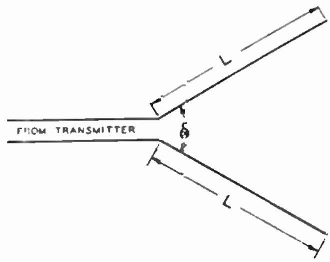


Fig. 62

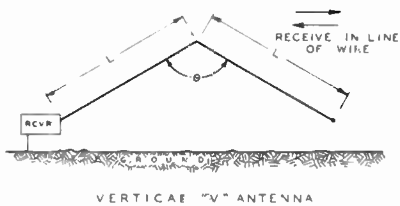


Fig. 63

"V" Antenna Design Table

Frequency in Kilocycles	"Half Wave" Dipole	"Full Wave" $L = \frac{\lambda}{2}$ $\delta = 180°$	$L = \lambda$ $\delta = 104°$	$L = 2\lambda$ $\delta = 75°$	$L = 4\lambda$ $\delta = 52°$	$L = 8\lambda$ $\delta = 39°$
28000	16′ 8″	17′ 1″	34′ 8″	69′ 8″	140′	280′
28500	16′ 4″	16′ 9″	34′ 1″	68′ 6″	137′ 6″	275′
29000	16′ 1″	16′ 6″	33′ 6″	67′ 3″	135′	271′
29500	15′ 8″	16′ 2″	33′	66′ 2″	133′	266′
30000	15′ 6½″	15′ 11″	32′ 5″	65′	131′	262′
14050	33′ 4″	34′	69′	139′	279′	558′
14150	33′ 1″	33′ 10″	68′ 6″	138′	277′	555′
14250	32′ 10″	33′ 7″	68′ 2″	137′	275′	552′
14350	32′ 8″	33′ 5″	67′ 7″	136′	273′	548′
7020	66′ 7″	68′ 2″	138′ 2″	278′	558′	1120′
7100	65′ 9″	67′ 4″	136′ 8″	275′	552′	1106′
7200	64′ 11″	66′ 5″	134′ 10″	271′	545′	1090′
7280	64′	65′ 8″	133′ 4″	268′	538′	1078′

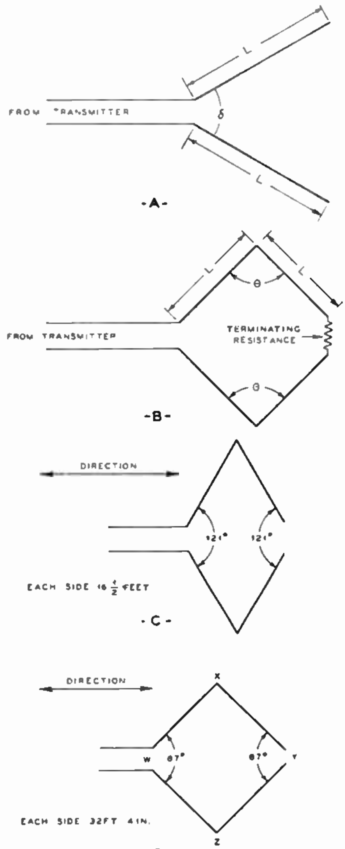
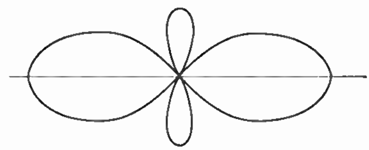


Fig. 64
Diamond and "V" Antennas.

two "V" antennas. The current distribution dies away uniformly from the input corner to the terminating resistance. As a result of this behavior, the Diamond antenna is not critical with respect to frequency. It can be used without any change or adjustment over a frequency range of at least two-to-one. Furthermore, it is unidirectional, since the terminating resistance eliminates the radiation which would otherwise take place in the backward direction. These properties make the Diamond antenna desirable in many ways. It can, for example, be used for 20 meters in the daytime and 40 meters at night, without any change. The terminating resistance should be about 800 ohms, capable of dissipating half of the power supplied by the transmitter. The antenna offers a resistance load of about 800 ohms to the transmission line. Design data is shown in the *Diamond Antenna Charts* and the dimensions L are listed in the Table for *"V" Antenna Design.*

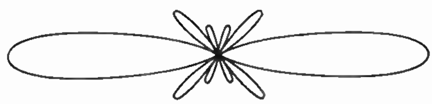
"V" Antenna Design

If the terminating resistance is not used, the Diamond antenna is bi-directional and becomes of the resonant type. Diamond antennas will radiate in an exactly horizontal direction, provided the angle of radiation in degrees and the height of the antenna in wavelengths is correctly calculated. These calculations have been simplified, and the Chart will enable the quick determination of the necessary dimensions. For example, slanting the antenna 6° will cause the energy to be radiated in an exactly horizontal plane.



HORIZONTAL DIRECTIVITY OF A "V" ANTENNA 1 λ LONG ON EACH SIDE

Fig. 65



HORIZONTAL DIRECTIVITY OF A "V" ANTENNA 8 λ LONG ON EACH SIDE

Fig. 66

The Diamond antenna is much more economical in construction than the various forms of antenna arrays employing vertical curtains of wires. It is just as effective in its directivity and power gain, and is not critical with respect to frequency of operation.

Beverage Antenna

● A very long wire terminated in a resistance equal to its characteristic impedance is called a *Beverage*, or *Wave Antenna*, Fig. 71.

The antenna should be several wavelengths long and it can be of any convenient height, from 10 to 20 feet above earth. It is quite satisfactory for long-wave reception and is sufficiently directive to materially reduce static disturbances. It is non-resonant and can be considered as a one-wire transmission line with ground return. It should be pointed toward the station whose signals

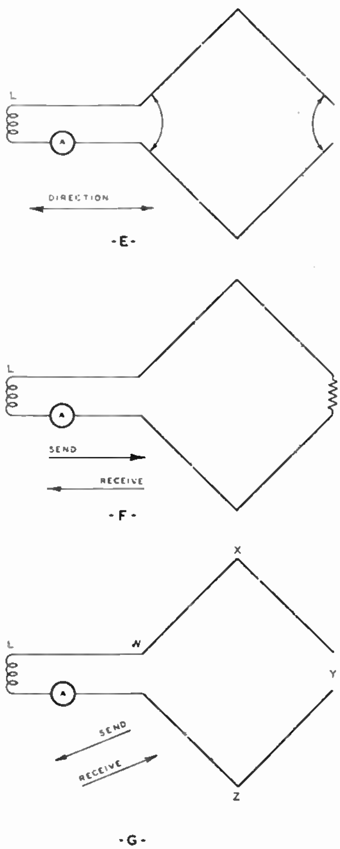


Fig. 67
Diamond Antennas.

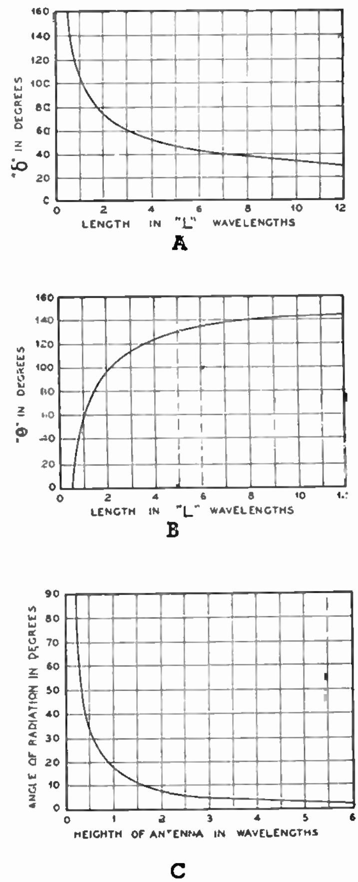
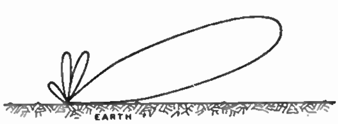
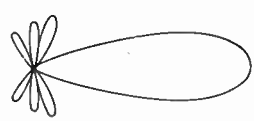


Fig. 68
Diamond and "V" Antenna Design Curves.



VERTICAL DIRECTIVITY OF A 2λ DIAMOND ANTENNA

Fig. 69



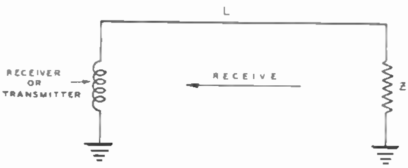
HORIZONTAL DIRECTIVITY OF A 2λ DIAMOND ANTENNA

Fig. 70

are to be received. This antenna operates most effectively when located over poorly conducting earth, since in this case the wave front of the received signal is tilted more than when the wave travels over water or moist earth. This form of Beverage Antenna is not suitable for short-wave reception.

Antenna Coupling Methods

● It is obvious that the power from a transmitter must be transferred or coupled to an antenna in some manner; likewise, the received energy must be coupled into a receiver. There are a great many ways in which this transfer of energy can be accomplished. In some forms, the coupling



BEVERAGE ANTENNA

Fig. 71

device serves the dual purpose of transferring power and tuning the antenna to resonance; in other cases it prevents illegal radiation of harmonics. The impedance match for a final amplifier is accomplished in the coupler circuits which connect to the antenna or feeders. Impedances are matched when the plate current of the final amplifier is at its normal value when all circuits are tuned to exact resonance. When the plate current is below normal it is an indication that the antenna feeder impedance has been transformed into a too-high value, and vice-versa when excessive plate current is drawn by the final amplifier.

Types of Coupling Devices

● The simplest coupling method for a single wire fed or end fed antenna is by means of *Direct Coupling*, wherein the impedance matching is accomplished by tapping to the final amplifier plate coil, as in Fig. 72A.

A blocking condenser (.002 mfd.) should be connected in series with the antenna or feeder to prevent DC plate voltage from reaching the antenna and thereby endangering human life. The final amplifier plate coil has a voltage node either at the center or at one end, depending upon the type of amplifier used. The voltage node occurs at the center of the coil in a push-pull amplifier, and also in a plate neutralized amplifier. This voltage node (zero RF voltage) occurs at the lower end of the coil, both in the case of single-ended screen-grid amplifiers and grid neutralized single-ended amplifiers. The antenna or feeder tap is usually connected near the voltage node. The proper impedance match (normal plate current load) is obtained when the tap is at the proper point on the coil. If the tap is too close to the voltage node, the antenna will not sufficiently load the amplifier; if the tap is too far toward the plate end of the coil, excessive loading will result, with consequent overheating of the amplifier tube and lower efficiency.

Comparative RF Feeder Losses

Frequency	D. B. loss per 100 ft.	Type of Line
7 mc. 14 mc. 30 mc.	0.9 1.5 3	150 ohm impedance, rubber insulated twisted pair with outer covering of braid.
7 mc. 30 mc.	0.4 0.9	W. E. 3/8" concentric pipe feeder with inner wire on bead spacers. Impedance = 70 ohms.
7 mc. 30 mc.	0.05 0.12	Open 2-wire line No. 10 wire. Impedance = 440 ohms.
7 mc. 14 mc. 30 mc.	3 4-1/2 8	Twisted No. 14 solid weather proof wire, weathered for six months (telephone wire).

Inductive Coupling

● Energy can be supplied to the antenna or feeder from the final amplifier by means of induction between two coils. The antenna

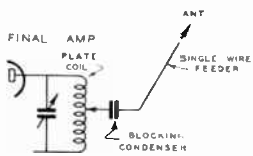
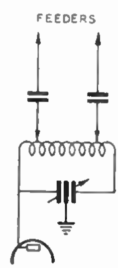


Fig. 72-A



DIRECT COUPLING

Fig. 72-B

coil can be tuned or untuned, as shown for several circuits in Figs. 34, 36, 40, 46 a..d 73.

Zepp. feeders sometimes use a split antenna coil which couples to each end of the final tank coil. A somewhat better system is to link-couple the Zepp. feeder tuning coil to the final amplifier coil because there is less capacity coupling and the coil losses are lower. 160 meter Marconi antennas can be coupled inductively to the final amplifier plate coil by means of some of the arrangements previously illustrated. The antenna should be tuned to resonance with series or parallel tuning and occasionally by adjustment of the tapped antenna loading coil. A suitable value of series condenser would be from .00025 mfd. to .0005 mfd. maximum capacity. The spacing between plates will

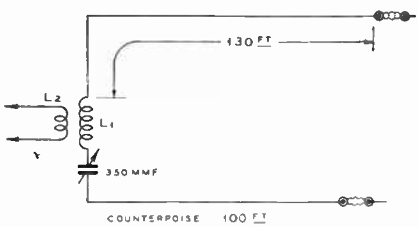


Fig. 73
L2—Final Plate Coil.

depend upon the power output of the transmitter and the RF voltage gradient at the point where the condenser is located. In most cases, plate spacing of .03-to-.07-inch will suffice. Resonance is obtained by switching taps and varying the condenser until the antenna loads the final stage plate current to its normal value. If this value is more or less than the rating for the tube, the coupling between the loading coil and the final tank coil should be increased or decreased.

Single wire fed, and end fed antennas can be tapped across part or whole of a tuned circuit which in turn is inductively or link coupled to the final amplifier tank circuit. The advantage of having an additional tuned circuit for the antenna coupler is in the reduction of harmonic radiation. A better balance can be obtained in the case of push-pull amplifiers than with direct coupling. More detailed information on coupling single wire antennas is given in preceding pages.

Twisted-pair feeders can be inductively coupled to the final tank circuit by using from one to four turns of well-insulated wire, wound over the voltage node of the final tank coil. The number of turns depends upon the frequency of operation and the desired antenna load.

Collins Pi Coupler

● This system consists of one or two coils and two variable condensers connected in the form of a low-pass pi filter. See Figs. 74 to 80. The filter permits the passage of only the fundamental frequency and greatly attenuates the undesirable harmonics, similar to the action of a filter used in AC power supplies. The coupler is tuned to the frequency of the transmitter by varying condensers *C1* and *C2*, also by adjusting the taps on the coil or coils. The impedance of the antenna feeders is matched to the final amplifier by means of the ratio of the capacity of *C1* and *C2*, and by adjustment of the coupler taps across the final amplifier tank coil.

This system can be used with some Zepp feeders, single wire or two wire feeders, and end fed antennas.

The plate tank of the final amplifier must be tuned to resonance with the pi network disconnected from it. It is best to do this with reduced plate voltage, and resonance is indicated by greatest dip in the plate current milliammeter reading. The final amplifier must not be retuned thereafter. Then connect the pi network to the final amplifier and antenna. Tune the two variable con-

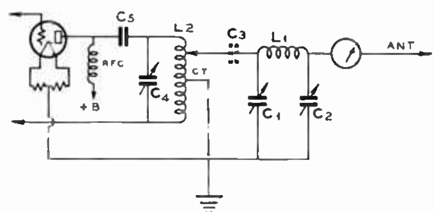


Fig. 74
Single-Wire Feed Line—Single Section Plate Tuning Condenser—Shunt Feed. C1 and C2 in All Circuits Are .00035 mfd.

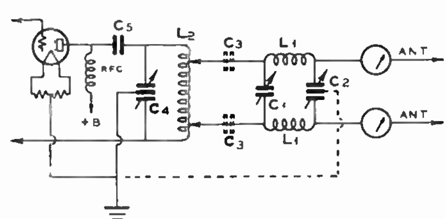


Fig. 75
Two-Wire Feed Line from Single-Ended Amplifier—Split-Stator Plate Tuning and Optional Split-Stator Used as C2. Shunt Feed.

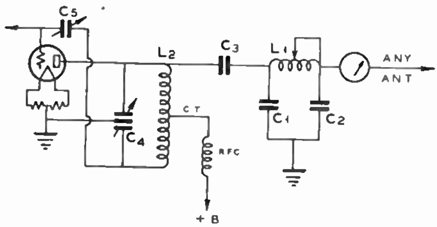


Fig. 76

Single-Wire Feed from End of Low Impedance Output Tube Tank. Split-Stator Tuning and Series Feed. C1 and C2 Should Be Variable.

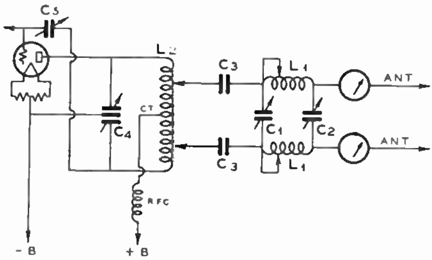


Fig. 77

Two-Wire Line from Single-Ended Amplifier. Split-Stator Tuning and Series Feed.

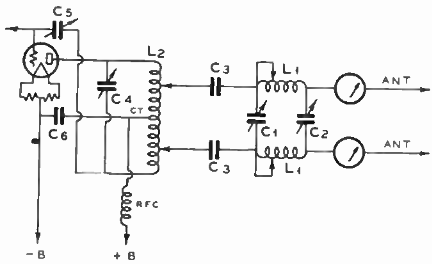


Fig. 78

Same as Fig. 77, But with Single-Section Tuning Condenser.

densers in the pi network until maximum antenna current (or feeder current) is obtained at normal values of final amplifier plate current when normal plate voltage is applied. The pi network condenser which is closest to the final amplifier is used to obtain resonance in the network for any particular setting of the impedance matching condenser (the nearest one to the antenna). The amount of inductance in the network coils must be determined by experiment to obtain best results.

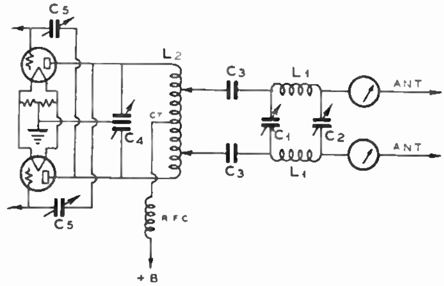


Fig. 79

Coupling a Two-Wire Line to a Push-Pull Final Amplifier. Single-Wire Line Out of a Push-Pull Final Through a PI Network is Not Recommended.

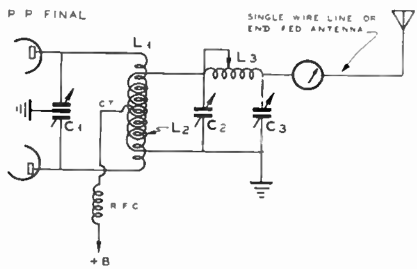


Fig. 80

Coupling a Single Wire Antenna or Feed-Line to a Push-Pull Final Amplifier.

L1 and L2 should be interwound in order to load both tubes equally in a push-pull amplier. L2—⅓ Tank Turns, interwound or otherwise very closely coupled.

L3—Standard Collins coil.

C2-C3—.00035 mfd. each.

Link Coupling

● A tuned feeder circuit can be coupled to the final amplifier tank by means of a twisted or parallel pair of wires, with one or more loops of wire at each end, as shown in Fig. 81. These *link coupled* loops should be wound over the voltage nodes of the two tuned circuits. Variation of coupling can be accomplished by varying the number of loops, or the diameter of the loops with respect to the coil diameters. The number of coupling turns depends upon the ratio of impedances; in the case of a Zepp. antenna more coupling turns are needed around the antenna coil than around the plate amplifier coil. In nearly all cases one to two turns around the plate tank coil will suffice. The number of turns around the antenna coil will vary from 1 to 4, or 5, depending upon the cicuit used, i.e., parallell-tuned or series-tuned.

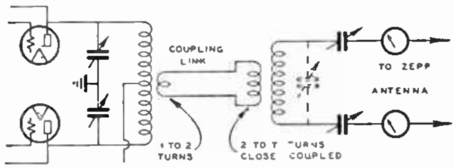


Fig. 81

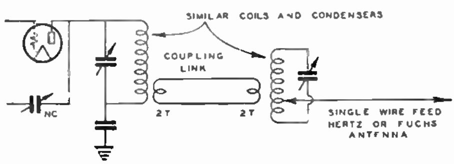


Fig. 82
Link Coupling for End-Fed or Single Wire Feeders.

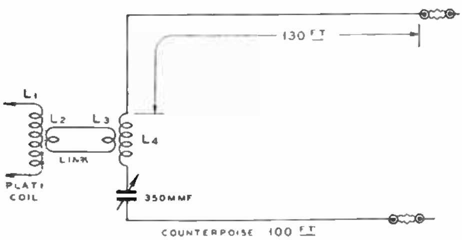
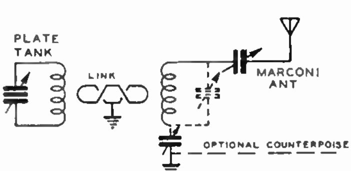


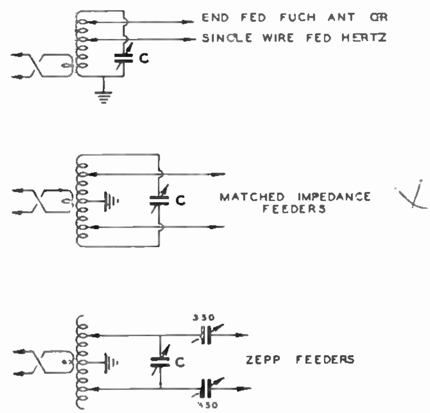
Fig. 83
Link Coupling to 160 Meter Antenna System.



FOR 160 METER OPERATION

Fig. 84

Adjustment of the coupling link and location of antenna taps on the antenna coil can readily be made with the aid of a field strength meter in order to find the adjustment which will provide maximum antenna field strength for normal load on the final



C = 50MMF - 6500V

Fig. 84-A
Link Coupling from Final Amplifier to Tuned Antenna Circuits.

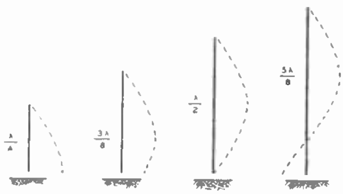
amplifier. When Zepp. feeders are used, RF meters can be connected in series with the feeders as an aid in tuning.

No. 14 or No. 12 rubber-covered solid wire is suitable for the coupling line. The coupling loops should have sufficient insulation to withstand the plate voltage.

Broadcast Type Antennas

● Older types of *"T"* and *"Inverted L"* flat-top antennas are rapidly being replaced with vertical antennas for broadcast transmission. The newer forms confine most of the radiation to very low angles, with the result that fading effects within a radius of 100 miles can be greatly reduced. The *L* and *T* type antennas provide some high angle radiation and the reflected waves from the Heaviside Layer cause fading effect at night within a radius of less than 50 miles. Reduction of sky wave radiation greatly improves the coverage of a broadcast station.

Vertical antennas are sometimes constructed by running a heavy wire conductor through the center of a lattice-work tower; in a great many cases the metal tower itself is the radiator. The base of the antenna usually connects to a tuning device and then to a very extensive ground system. The tuning device also serves to terminate the transmission line, such as shown in the examples given for *Concentric Lines*. The vertical antennas in Fig. 85 have a current distribution as shown, which indicates the relative values of impedance with respect to ground. These antennas connect to ground through tuned circuits and conse-



TYPES OF BROADCAST ANTENNA. BASE CONNECTS THROUGH A TUNING SYSTEM TO GROUND. DOTTED CURVES SHOW CURRENT DISTRIBUTION

Fig. 85

quently they are resonant to the frequency of the transmitter. Antennas more than one quarter wave in vertical height provide a better low angle wave (ground wave); because of their greater effective height they are being used in the newer broadcast station installations.

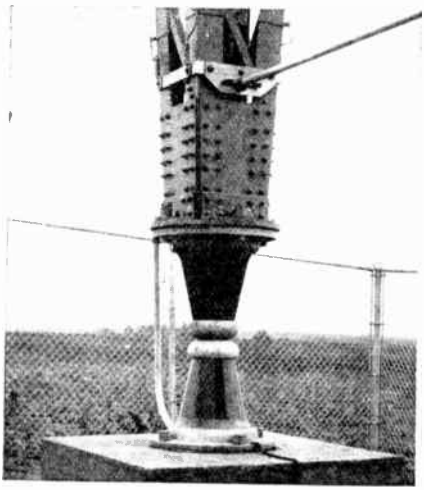
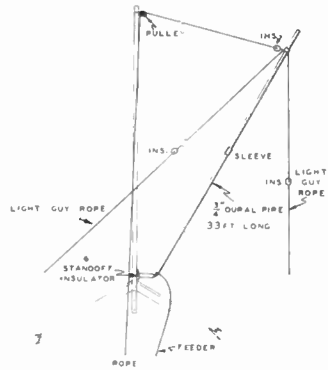


Fig. 86
Base of Vertical Radiator With Heavy Insulator Supports

Two Band Tilt Antenna

● A simple bi-directional antenna for 10 meter operation, and a non-directional 20 meter antenna, is shown in Fig. 87.

This antenna consists of a 33 foot length of ¾-inch diameter *Dural* tube, supported on a large stand-off insulator in such a manner than the angle of tilt can be adjusted and the free end swung through an angle of approximately 180 degrees. The antenna is used in a vertical position for 20 meter operation: for 10 meters it is tilted to an angle of 54 degrees with respect to the horizon, and pointed toward or away from the direction in which it is desired to transmit or receive. The angle of radiation is in a horizontal plane for both 10 and 20 meter operation. A single wire feeder can be connected to the pipe at a point eleven feet up from the bottom end, or a Zepp. or end-fed connection can be employed. The



TWO BAND (10-20 METER) TILT ANTENNA — VERTICAL FOR 20 METERS — TILT 54° FROM HORIZON FOR 10 METERS

Fig. 87

pipe should be guyed near the center by means of heavy cord or light rope in order to facilitate the rotation of the radiator. A 33 foot pipe can be made from two sections, butted together over a smaller inner tube, or outer sleeve, for a forced-fit connection.

Dummy Antennas

● A non-radiating antenna is essential for experimental tests of any transmitter. The name *"Dummy Antenna"* has been applied to such arrangements. It consists of a resistive load which simulates the regular antenna load. The resistors in the dummy antenna must be large enough to dissipate the RF power output delivered by the transmitter. Non-inductive resistors made for this purpose can be connected in series with thermo-ammeters to determine RF power output. Mazda Lamps provide a visual indication of RF power output because this power is converted into light in the same manner as illumination is secured from the 110-volt line. The dummy antenna circuits shown in Figs. 88, 89 and 90 are suitable for all practical purposes.

A 100 watt Mazda Lamp when lighted to normal brilliancy in a dummy circuit indicates that the transmitter is delivering 100 watts of RF output. The resistance of electric lamp bulbs varies widely with filament temperature, therefore it is difficult to accurately determine the power output of the transmitter by Ohm's I^2R Law, because R is a variable factor.

Field Strength Measuring Set

● Actual RF current readings in any portion of an antenna vary with the position of the current nodes, with the result that an antenna may not be correctly tuned to the operating frequency of the transmitter. An actual indication of the power radiated by an antenna can be secured with the aid of a field strength measuring set, which consists of a low-reading milliammeter, diode rectifier and tuned circuit or pick-up coil. A circuit diagram for an effective field strength measuring set and phone monitor is shown in Fig. 91.

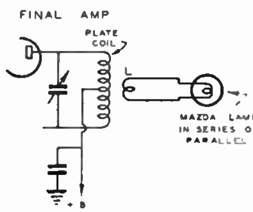


Fig. 88
Mazda Lamp Coupled to Final Tank Coil.

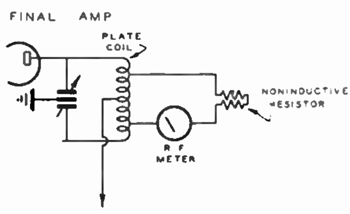


Fig. 89
Dummy Antenna with Non-Inductive Resistor and R-F Meter.

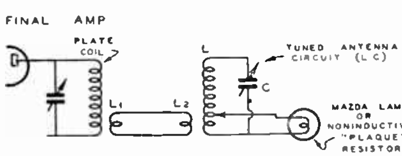


Fig. 90
Dummy Antenna Link Coupled to Plate Coil. L1-L2 Are Wound Over the Plate Coil and Antenna Coil, L.

When the headphones are plugged into the phone jack, the presence of key clicks, excessive carrier hum or quality of voice modulation can be determined. By plugging a 10,000 ohm resistor into the phone jack, the milliammeter will indicate overmodulation peaks as shown by a fluctuation of the steady carrier strength when voice modulation is applied. Furthermore, this field strength meter can be used as a neutralizing indicator by merely connecting a short pick-up antenna wire to the device and placing it near the circuit which is to be neutralized.

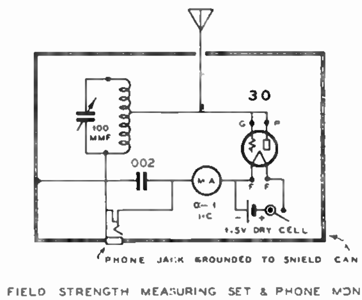


Fig. 91
Simple Circuit of Field Strength Meter.

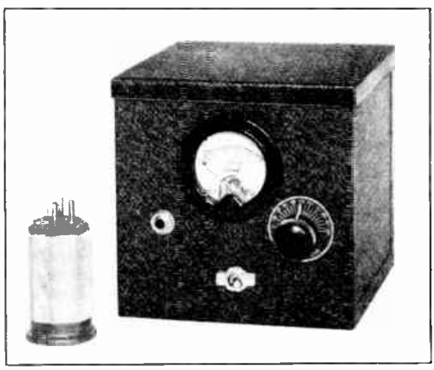


Fig. 92
Exterior View of Field Strength Meter and 40-80 Meter Coil.

Plug-in coils are tuned to the frequency of the transmitter. The pick-up antenna wire which is connected to the field strength measuring set is placed somewhere in the immediate vicinity of the radiating portion of the antenna. The length of the wire and its distance from the transmitting antenna depend upon the power output of the transmitter. The pick-up antenna can be from five to six feet long, depending upon the frequency and the amount of pick-up required to secure a deflection of the meter. The antenna system is tuned for maximum reading on the milliammeter scale, which denotes the greatest amount of field radiated by the antenna.

A type 30 tube is connected as a diode, which will operate satisfactorily with only 1½ volts of filament battery. The diode is connected across a portion of the tuned circuit, which results in more selective tuning and good sensitivity. The 0-1ma. DC miliammeter reads the rectified current produced by the RF energy in the tuned circuit. The diode serves as the rectifier, which can be either a vacuum tube or crystal detector.

A carborundum crystal detector will quite satisfactorily replace the type 30 tube and battery. This type of crystal detector will handle accidental RF overloads without destroying the sensitivity of the crystal, such as in the "Standing Wave Detector" shown in Figs. 94 and 95.

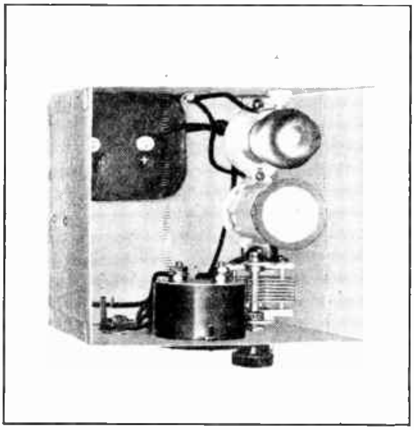


Fig. 93

Looking Into the Set. A Small 1-1½ Volt Dry Cell Is Held in Position by a Metal Bracket.

The coils are wound on plug-in forms, 1½-inch diameter, three coils being required to cover the six amateur bands from 5 to 160 meters. The 5 to 10 meter coil has two turns, spaced ½ in. apart, with a tap at the center. The 20 and 40 meter coil has 12 turns, space-wound to cover a winding length of ¾ in., with a tap taken on the fourth turn from the ground end. For 80 and 160 meters, 60 turns are close wound on the form with a tap taken on the 20th turn from the bottom end of the winding. A midget 100 mmfd. variable condenser will tune the coils in such a manner that the lower values of capacity will cover one end of the band and the higher capacity will cover the other; a single coil thus covers two bands.

The field strength meter should be housed in a completely enclosed metal can.

Grounds

● A good connection to earth is essential for operation of Marconi antennas for both receiving and transmitting. Several pipes driven into the earth, spaced a few feet apart and connected together, will provide a good ground system for amateur operation. Broadcast and commercial transmit-

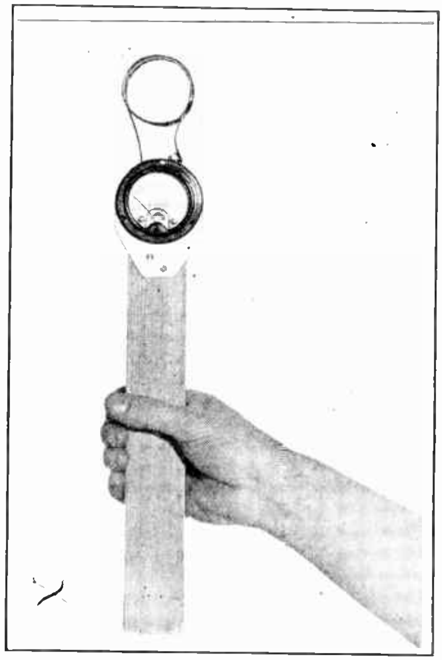


Fig. 94

"Standing Wave Detector" and Field Strength Meter. The Device Is Moved Along the Feeder or Antenna, held close to the wire. A variation of current denotes standing waves.

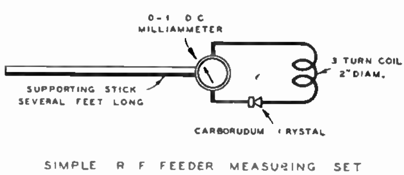


Fig. 95

Simple Circuit Diagram of Device Illustrated in Fig. 94.

ters often require a very elaborate ground system of several miles of copper wire or ribbon, buried under the surface of the earth. Such a system can be constructed so that it fans-out in all directions beneath the antenna. Ordinary water pipes are generally suitable for receiver ground connections.

When a satisfactory ground connection is not available, a *Counterpoise* must be used with Marconi antennas. The radiation resistance of a quarter wave antenna is approximately 37 ohms, therefore the ground resistance must be considerably less than 37 ohms in order that the greatest amount of transmitter power will be radiated into space. A high resistance ground connection can waste more power than is actually radiated by the antenna. This is one reason why half wave antennas are so widely used; they require no ground connection.

Antennas for Ultra-High-Frequency Operation

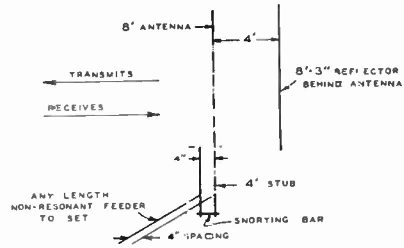
● The fundamental principles of antennas for wavelengths below 10 meters are no different than those discussed elsewhere for short-wave operation. The physical size of these antennas is such that they are economical to construct and they can easily be made portable. In the ultra-high-frequency field of communication the direct, or ground wave is used; for this reason the transmitting and receiving antennas are generally in visual range of each other. It is therefore necessary that the antennas be located as high above ground as possible. Low angle radiation is necessary and antennas which are particularly effective for this purpose should always be used. The earth reflects the ground wave upward, somewhat like the effect which is created by a body of salt water which pushes the somewhat longer wave in an upward direction. The ground acts like a mirror in reflecting light waves. Vertically polarized waves have less tendency for an upward bending, and thus vertical antennas are generally employed.

The simple non-directional antenna for u.h.f. operation consists of a half wave vertical wire or rod, fed with a two-wire matched impedance feeder (Fig. 98), or by means of a quarter wave matching stub and two-wire non-resonant line, Figs. 96 and 99.

Zepp. feeders are seldom employed, because the antenna in most cases is located several wavelengths away from the transmitter or receiver in order to secure ample height above the ground.

A *Concentric Feeder* (Fig. 100) is very effective for feeding either a half wave antenna or a quarter wave Marconi antenna, such as those used for mobile 5-meter work.

Directive antennas often prove of great value in the ultra-high-frequency region because the high power gain which is obtainable gives the same result as a great increase in transmitter power. The cost of increasing power is far more than that of a simple antenna array. Any of the directional antenna systems previously discussed can be used for u.h.f. communication, although those



SIMPLE 5 METER DIRECTIONAL ANTENNA WITH REFLECTOR WHICH DOUBLES OUTPUT & SENSITIVITY

Fig. 96

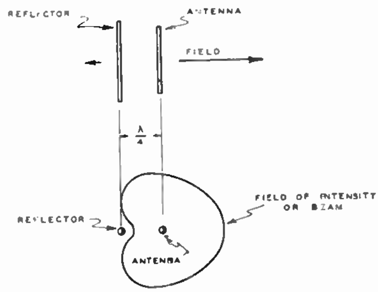


Fig. 97
Directivity Pattern of Antenna Shown in FIG. 96

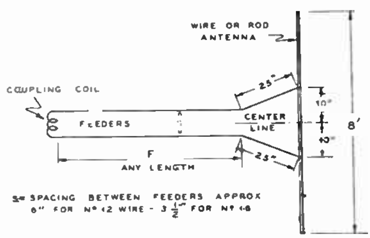
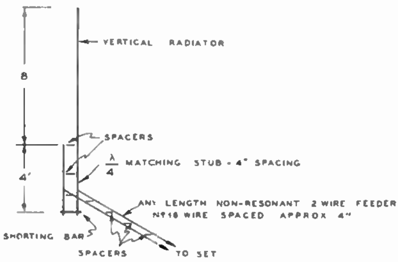


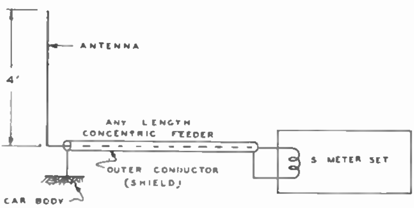
Fig. 98
5-Meter Matched Impedance Antenna.

which give vertical polarization, such as the Stacked Diploe, Yagi, Vertical Franklin, or Bruce are best.



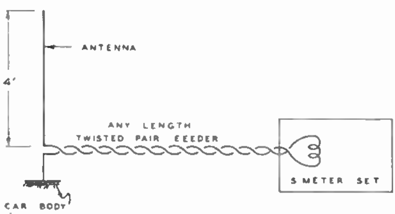
5 METER "J" ANTENNA

Fig. 99



5 METER CONCENTRIC LINE AUTO ANTENNA

Fig. 100



5 METER TWISTED PAIR AUTO ANTENNA

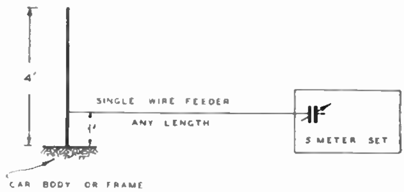
Fig. 101

Types of Mobile U. H. F. Antennas

● A quarter wave vertical Marconi antenna (Fig. 102) is very convenient for automobile installations. A 4-foot rod with the bottom end grounded to the car body can be fed with a single wire feeder several feet long; this feeder connects to the 5-meter set in the car.

Another 5-meter antenna consists of an insulated 4-foot rod, fed by either a twisted pair (solid conductors), or by a concentric transmission line, Figs. 100 and 101. In the case of twisted pair feeders, the impedance match is not very good, but this effect can be overcome to some extent by cutting the twisted pair to some particular length. This can best be determined by experiment, because a few inches more or less of feeder will provide a tuning effect and allow more efficient operation.

Quarter wave rods can be mounted on the roof of an automobile, if some means of flexible coupling is built into the base of the rod so that the antenna can be swung down



SIMPLE 5 METER AUTO ANTENNA

Fig. 102

when it strikes an overhead obstacle, such as a garage entrance, etc. Sometimes the rod is mounted on the front or rear bumper of the car, on the radiator, running board or fender. In many cases the antenna rod is mounted directly on a transmitter housed in the rear trunk of the automobile.

Mobile antenna installations for police radio work differ from the 5-meter types in that the antennas are somewhat longer because the frequency of operation is lower. The length can be calculated from the formula:

$$L_1 = \frac{492{,}000 \times 0.485}{f}$$

where L_1 = The quarter wave antenna length in feet.

f = The transmitter frequency in kilocycles.

The length of a half wave antenna is twice that of a quarter wave antenna.

Fixed Station 5-Meter Antennas

● These antennas can be constructed from copper or aluminum rod, or wire. When a wire antenna is used, the wire can be supported on stand-off insulators attached to a vertical 2"x3" wood pole. The pole should be guyed, preferably with ropes, in order to keep metallic conductors away from the field of the antenna. The antenna should be as high as possible and well remote from surrounding objects.

These same types of antennas can be used for television reception by making the half wave antenna resonant to the frequency of the television transmitter. In this case a twisted-pair feeder of solid wire, such as the *EOI Cable,* can be used in order to reduce automobile ignition interference. The loss in a twisted-pair feeder at these frequencies is rather high and transposition blocks can be used at intervals along the two-wire feeder line.

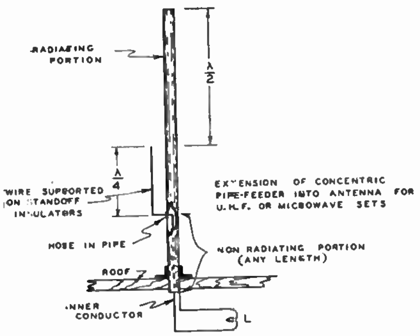


Fig. 103

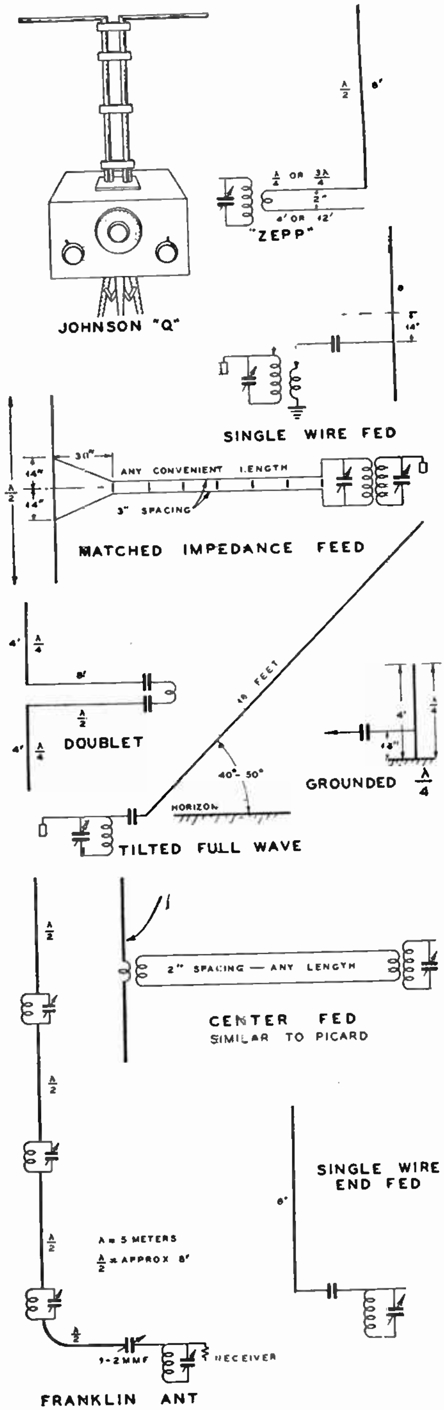
Long wire antennas can be used on 5 meters providing the directional effects are taken into consideration. For example, a 20 or 40 meter single wire fed or Zepp. antenna can be operated on 5 meters with fairly satisfactory results for both transmitting and receiving.

2½-Meter Antennas

● Any of the antennas previously described, and which provide vertical polarization, are suitable for 2½ meter operation. Those shown in Fig. 104 are ideally suitable for use with a 2½ meter transceiver. The figures are self-explanatory, in that all dimensions are clearly shown. The Table showing *Antenna Array Dimensions* lists all of the data for the ultra high-frequency bands, down to 1¼ meters. The Table, *Reflector and Director Dimensions,* shows the data for any form of Yagi or Parabolic Reflector system for wavelengths down to 1¼ meters.

Micro-Wave Antennas

● Antennas for operation in the vicinity of one meter, or less, are classified as *Micro-Wave Antennas.* Half wave vertical rods are suitable for portable operation and in most cases they can be capacitively coupled at one end to the micro-wave transmitter or receiver. Directive arrays, especially those of the Yagi type, are easily constructed; they greatly improve the performance of micro-wave sets.



Group of Typical 5-Meter Antennas.

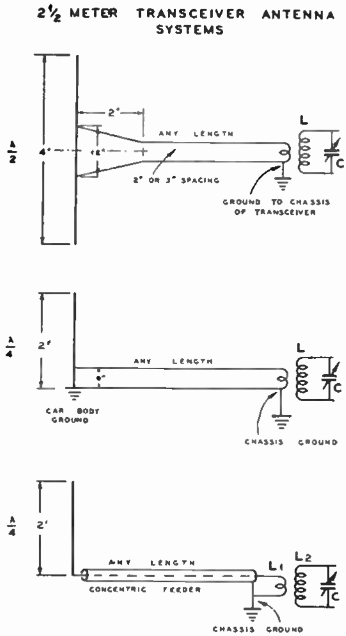


Fig. 104

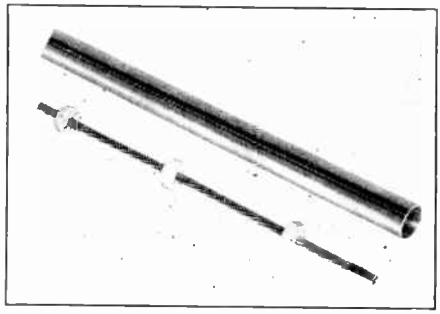


Fig. 105
Heintz & Kaufman Concentric Transmission Line.

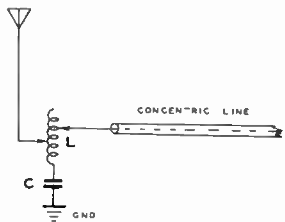


Fig. 106

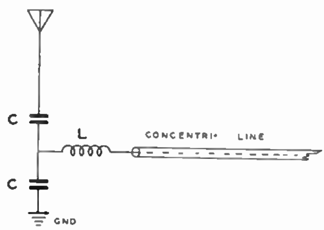


Fig. 107

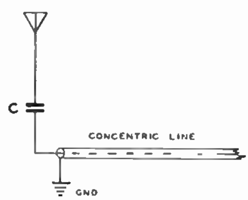


Fig. 108
Concentric Feeder Systems for Broadcast Antennas with Various Terminations.

Concentric Lines

● A concentric transmission line is one of the most satisfactory means for carrying RF power from the transmitter to the radiating antenna. It has low losses, is weather-proof and the outer conductor is at ground potential. No radiation can occur, which is particularly important in a directional antenna system. The characteristic impedance ranges from 50 to 150 ohms, depending upon the ratio of inside diameter of the outer conductor to the outside diameter of the inner conductor. Its impedance can be calculated from the formula:

$$Z = 138 \times \mathrm{Log}_{10} \frac{D}{a}$$

where D is the inside diameter of the outside conductor,
d is the outside diameter of the inner conductor.

The outer conductor can be grounded at any point. The inner conductor is insulated from the outer sheath by glass or isolantite beads which are placed at intervals along the line; the beads also furnish the necessary mechanical spacing.

Concentric line feeders are used for coupling broadcast transmitters to the antenna, as well as in short-wave and u.h.f. installations. See Figs. 105 to 108. The impedance can be made to exactly match the center impedance of a half wave antenna, and very closely matched to a quarter wave antenna. A vertical quarter wave antenna has an approximate radiation resistance of 37 ohms at the current loop (ground connection).

Concentric lines can be buried underground and run for distances of several hundred yards without sacrificing appreciable amounts of RF power.

Reinartz Rotary Beam Antenna

● The John L. Reinartz compact directive antenna, Figs. 109 and 111, has relatively high efficiency on the short and ultra-short wavelengths. It is suitable for 5-meter transmission and reception and its field pattern is similar to that of a half wave vertical antenna with single reflector, Fig. 110.

It consists of two 8-foot lengths of tubing, bent into a circle, with 2 in. to 3 in. spacing between the tubes. The circles are not closed; an opening of one inch remains, as shown in the diagram.

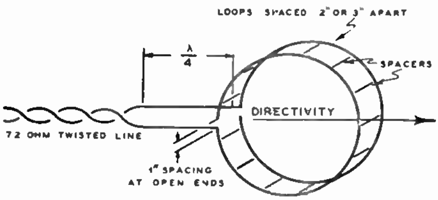


Fig. 109
Reinartz Rotary Beam with Twisted-Pair Feeder and Stub.

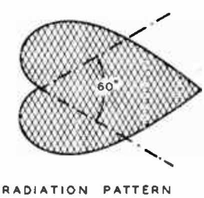


Fig. 110
Directivity of the Reinartz Rotary Beam.

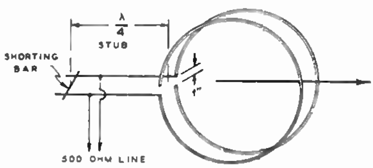


Fig. 111
Reinartz Rotary Beam Antenna with Spaced Feeder and Stub.

The diameter of the circle is a little over 30 inches. The most efficient method of feeder connection to a 5-meter set is by means of a quarter wave matching stub connected to either a twisted pair feeder or two wire 500 ohm line. This type of antenna can be placed in either a horizontal or vertical plane, depending upon whether horizontal or vertical polarization is desired. The actual power gain over that of a vertical half wave antenna in the desired direction is approximately 15%. The power directivity is nearly 6-to-1 in a forward direction away from the open ends.

16½ ft. rods can be used for 10 meter operation, 33 ft. rods for 20 meters. The spacing between the rods, or circles, need not be increased when the antenna is built for operation on the longer wavelengths.

The antenna should be arranged for 360° rotation.

Antennas for Receiving

● All of the transmitter antennas previously described are suitable for receiving; their directive properties are unchanged. All-wave receivers present a difficult problem from the standpoint of a suitable antenna that will cover the wide frequency range of the receiver. Noise reduction is a decided factor in the design of an antenna for receiving all waves. The most prolific noise-creators are electrical devices, such as refrigerator units, violet-ray apparatus, thermostats, diathermy machines, battery chargers, electric signs, buzzers and doorbells, ignition systems of oil-burners and automobiles, elevators, street cars, electric motors, power-line disturbances which are carried along the line, telephone ringers, etc. These disturbances are of a radio nature; however, their intensity dies away rapidly in open space. House wiring and metallic structures convey these electrical disturbances, and noise reduction can therefore be accomplished by locating the antenna in a clear space, also by using a lead-in of such type that pick-up on the lead-in is practically eliminated. The noise interference is sometimes so loud that it will seriously interfere with local reception. It becomes a very troublesome factor in short-wave reception because the received signal strength is much lower than that from local broadcast stations.

Two general types of lead-ins are widely used with noise-reducing antenna systems. The shielded lead-in is effective in the broadcast range, but due to the high capacity between the shield and the lead-in conductor inside the shield, it is not often used for short-wave reception. For short-wave reception a balanced transposed line is more efficient, as shown in Fig. 112. Balanced lines consist of twisted-pair feeders or two-wire lines with transposition blocks. The latter can be tuned by means of a coil and variable condensers at the receiver in order to increase the signal energy for a compara-

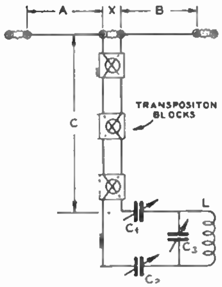


Fig. 112

Noise-Reducing Short-Wave Doublet Feeder System with Transposition Blocks.

A and B are 33 ft. each. C can be any length. The Transposition Blocks are spaced 2 feet apart. C1, C2 and C3 are 350 mmfd. Variable Condensers for tuning the system. L is the Receiver Coupling Coil.

tively wide range of frequencies. Twisted-pair feeders cannot be easily tuned because standing wave effects will cause excessive dielectric losses. In order to cover a wide range of frequencies with twisted-pair feeders, combination *Doublet* antennas are connected through impedance matching transformers to form an efficient all-wave antenna system. A single doublet with a twisted-pair feeder and without special transformers is suitable for operation over a very narrow band of only a few hundred kilocycles on the fundamental and third harmonic. The design of the feeder transformers depends upon the impedance of the twisted-pair feeder, length of line and type of doublet antennas connected to the line. So many complications enter into the design of these feeder transformers that the home constructor cannot easily build them. Complete short-wave antenna kits with all proper components are available from many sources. The choice of an all-wave antenna for the home constructor is the tuned transposed-feeder system, shown in Fig. 112. In noise-free locations, any single wire antenna will give good results.

RCA World-Wide Antenna System

● In this system a double-doublet is connected through a complicated antenna transformer to a twisted-pair transmission line, then through another transformer connected to the all-wave receiver. See Fig. 113.

The smaller doublet is about 33 feet long and it peaks at 14 megacycles. The larger doublet, 58 feet long, resonates near 7½ megacycles and the third harmonic is 22 megacycles. The combination, together with a critical length of feeder line, results in fairly uniform response from 6 to 24 megacycles. See Fig. 114. The twisted-pair feeder has an impedance of 180 ohms and is constructed with submarine cable rubber and paper insulation in order to keep the losses low. Noise reduction depends upon the design of the transformer which couples the line to the radio receiver. This transformer eliminates in-phase signals while at the same time it passed the out-of-phase signals. The expression *"in-phase"* means that the voltages of the two sides of the feeder line are positive or negative at the same instant. *Out-of-phase* signals are those which cause one side of the line to be negative while the other side is positive, and it is this signal which comes from the antenna. In-phase signals are those which are picked-up by the feeder line; they normally have a high ratio of noise signal to radio station signal.

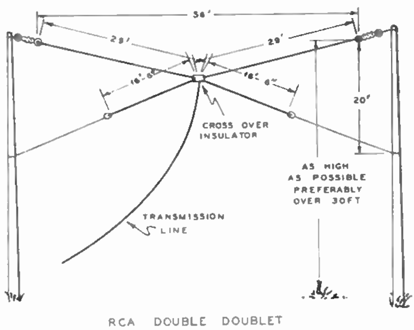


Fig. 113

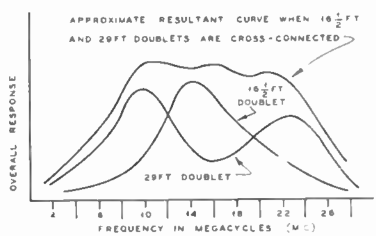


Fig. 114

The radio set transformer has a static shield between primary and secondary windings in order to eliminate capacity coupling. As a result, the in-phase signals and noise picked up by the line are eliminated, while the out of phase signals picked up by the antenna are passed through to the receiver. See Fig. 115.

Several windings are needed in each transformer in order to cover the wide frequency range. Automobile ignition noise is greatly reduced, as can be explained by referring to Fig. 115. "*S*" represents a

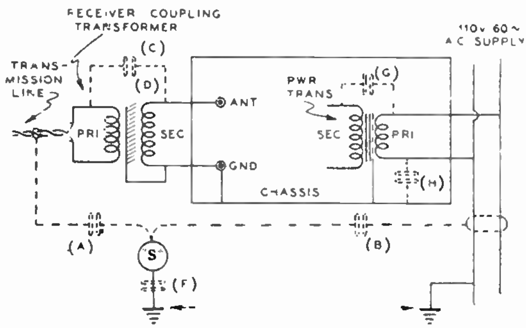


Fig. 115

source of auto ignition noise: (*A*) the capacity coupling from "*S*" to transmission line; (*B*) the capacity coupling from "*S*" to the power supply line; (*H*) the capacity coupling from one side of the power supply line to the metal chassis; (*F*) the capacity coupling from "*S*" to actual earth ground.

The noise voltage that would be induced by capacitive coupling (*A*) into the transmission line would correspond to an in-phase signal and would be fed to the secondary of the coupling transformer by the capacity by the electrostatic shield (*D*). This prevents noise voltage from being developed across the input terminals of the radio receiver.

The noise voltage that would be induced by capacitive coupling (*B*) causes current to flow through the power transformer and develop a noise from ground to chassis through capacity (*H*). If no receiver coupling transformer is used, this voltage would occur across the input terminals of the receiver and cause noise interference. Most power transformers have an electrostatic shield between the primary and secondary windings in order to minimize the capacitive coupling (*G*). 110 volt a-c supply lines often carry noise interference.

RCA Spiderweb Antenna

● The action of this antenna is like that of a "T-type" over the range from 140 to 4000 KC. Above 4000 KC the system automatically operates as an efficient multiple doublet up to 70,000 KC with good noise reduction between 4,000 and 70,000 KC. Half wave doublets operated near resonance are extremely efficient. See Fig. 116. Several doublets of different lengths can be connected to the same transmission line without effecting the performance of any other, resulting in good signal pick-up in several bands of frequency. If the selected resonant frequencies are not too far apart, the overlapping of their characteristics will tend to give fairly uniform response. Five doublets are utilized in the RCA Spiderweb Antenna System.

In Fig. 116 the bottom wires *E* and *F* resonate to 6 MC (49 meters) by means of a small loading coil. *A* and *B*, at 12 MC (25 meters); *C* and *D* at 18 MC (16 meters); *G* and *H* at 35 MC (9 meters); *K* and *L* at 60 MC (5 meters). Loading coils are used in the *G* and *H* doublet, as well as in the *E* and *F* doublet.

The transmission line requires 75 feet of twisted-pair wire, although 45-ft. sections can be added if the 75-ft. length is not sufficient. These lengths must not be changed, because the receiver coupling transformer is matched to the line for these lengths. The transformer has a balanced primary and an electrostatic shield which prevents capacitive coupling. This is necessary for noise elimination. No noise reduction is secured for frequencies below 4,000 KC because the antenna acts as a T-type on the lower frequencies. The space required for this antenna is a span of 38 feet, and a 12 foot vertical clearance.

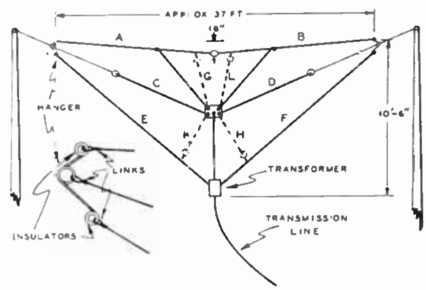
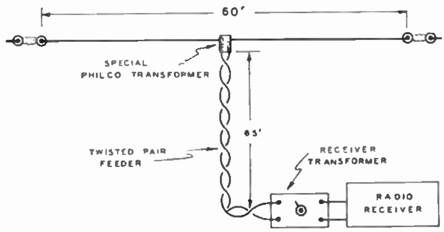


Fig. 116
RCA Spiderweb Antenna

Philco All-Wave Antenna

● This doublet antenna is approximately 60 feet long and has a special antenna transformer connected to a twisted-pair feeder for all-wave reception from 540 KC to 23,000 KC. See Fig. 117.

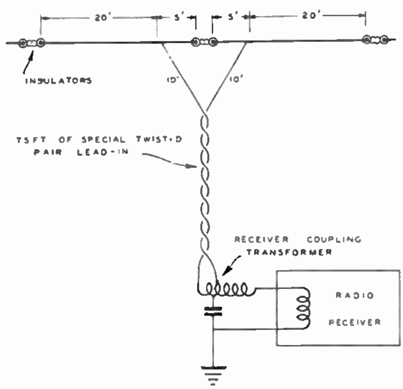
A receiver impedance matching transformer is required for radio receivers which have a high impedance primary circuit. This transformer is not needed with radio receivers which have low impedance primary circuits designed for doublet antenna connection. The transformer is provided with



PHILCO ALL-WAVE ANTENNA

Fig. 117

a switch. The switch permits reception of standard broadcast or short-wave signals at will. The twisted-pair feeder can be altered in length to suit any installation without change in results. Noise reduction is claimed for both standard and short-wave reception.



GENERAL ELECTRIC "V" DOUBLET

Fig. 118

General Electric "V" Doublet

● Another noise-reducing all-wave antenna is the *G. E. "V" Doublet*, consisting of a half wave doublet, matching section and twisted-pair feed line. It also incorporates an impedance matching transformer to the receiver, which is designed to cover a wide frequency range necessary for all-wave reception. This system has a "V" matching section at the center of the antenna instead of the usual complicated antenna-to-line transformer. Standing waves exist on the twisted-pair feeder, as is the case in almost every type of all-wave antenna. The arrangement shown in Fig. 118 provides good efficiency on broadcast and short-wave bands, a condition which is not possible with a simple doublet where the twisted-pair feeder connects directly into the center of the antenna.

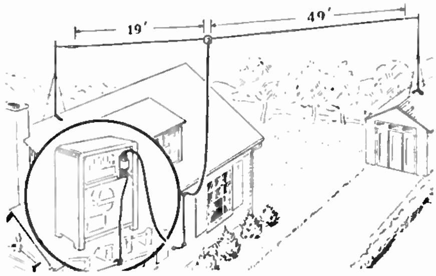


Fig. 119

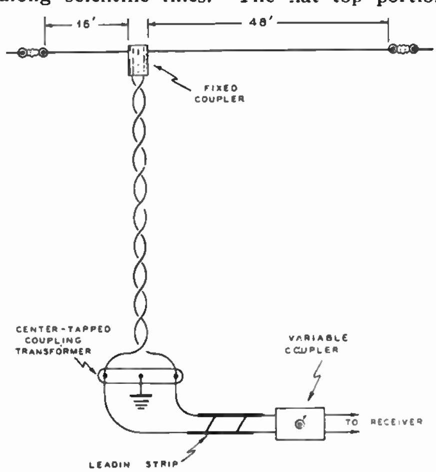
RCA RK-40 Antenna

● The RCA RK-40 Antenna is a simplified antenna system designed to act as an efficient pick-up medium, giving high signal strength over an extremely wide frequency range. See Fig. 119. The flat top portion is 68 feet long, with an RCA transformer 19 feet from one end, as shown in Fig. 119.

The Transmission Line is a special two conductor cable 75 feet long, which terminates in a sealed junction box in which the receiver coupling unit is housed. This coupling unit matches the transmission line to the input receiver circuits. Adequate coverage of all short-and-long-wave broadcast bands is secured with a minimum of installation work.

Belden Off-Center Doublet

● To obtain a broad response over a wide frequency range, the Belden Off-Center Doublet Antenna System is constructed along scientific lines. The flat top portion



BELDEN OFF-CENTER DOUBLET

Fig. 119A

consists of two lengths, 16 and 48 feet respectively, of seven strand twisted No. 24 enameled aerial wire. See Fig. 119A.

A fixed coupler in a weather-proof container is used to connect the twisted feeders to the flat top of the antenna. The surge impedance is of a value which spreads the responsive characteristics of the system. At the receiving end, a center-tapped coupling transformer is employed to divert unwanted in-phase signals picked up by the lead-in to the ground. The secondary of this coupler is in series with a small variable capacitor which may be adjusted to match the input impedance of the receiver to the lead-in. This antenna system may be erected vertically or horizontally. It has practically no directional effect and the length of the lead-in is not critical, due to the variable features of the receiver coupler. This antenna does not have a sharp resonant point and achieves a very uniform response over the short-wave and broadcast frequency bands.

The coupling transformers at the ends of the twisted lead-in also serve to minimize the effect of the capacity of the lead-in, preventing loss in signal strength and at the same time preserving the noise reducing features.

The Belden Receiver Coupler is equipped with a switch with which to convert the antenna system into a conventional Marconi modified "T" antenna for use on broadcast frequencies.

McMurdo Silver "R9+" Antenna

● This system consists of a doublet with two sections, each 25 feet long, feeding into a twisted-pair transmission line which, in turn, couples to a special all-wave transformer coupling system. See Fig. 120.

The 4-pole, 5-position switch effectively matches the antenna system into the receiver for all-band operation. The doublet antenna resonates at approximately 32 meters, but the feeder and the tuning unit effectively increases the signal strength at other frequencies.

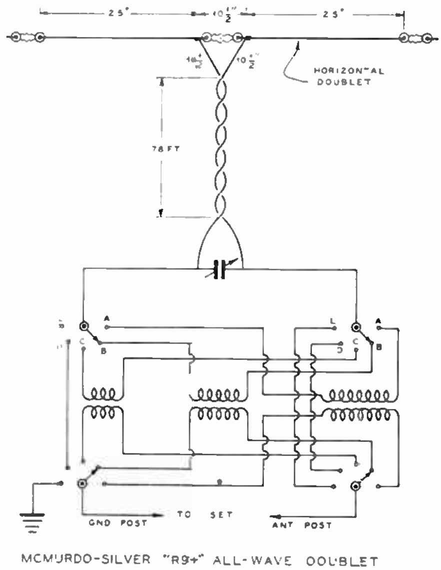


Fig. 120

Antennas for Automobiles

● The amount of available space in an automobile for antenna installation is limited, therefore a compact system with relatively low efficiency is all that can be expected. Earlier types of antennas for automobiles consisted of wire screen or mesh supported in the roof of the car. Later types make use of plate or rods, suspended under the car or beneath the running boards.

Experiments have proven that most of the ignition interference exists above 30 MC, yet the noise is troublesome even in the range of the broadcast band. The principal source of noise comes from the ignition system, and thus a shielded lead-in or shielded transmission line to the antenna will greatly reduce this interference. In some cases, out-of-phase electrical noise is deliberately introduced into the receiver in order to cancel the noise which is picked-up by the antenna. Modern design has practically eliminated the need for spark-plug suppressors.

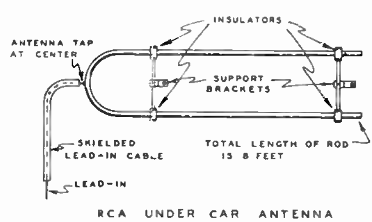


Fig. 121

Steel top automobiles call for the use of an antenna under the car. Because the receiver is connected to both the antenna and the car body, the capacity between the two should be as low as possible. Road clearance dictates the limit of spacing.

Three types of antennas for automobile installation are shown in Figs. 121, 122 and 123. The RCA "U" antenna is interesting because it resonates at about 7 meters, where the maximum ignition noise energy occurs. Noise voltages are picked up by the two sides of this "U" and arrive at the

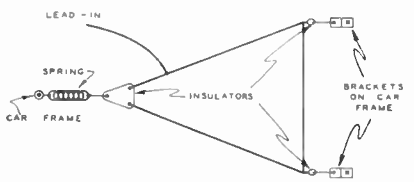


Fig. 122
Triangular Antenna.

lead-in point out-of-phase and thus tend to cancel each other. Broadcast signals, being of longer wavelength, act on the antenna as if the two rods were in parallel, and proceed through the lead-in to the receiver.

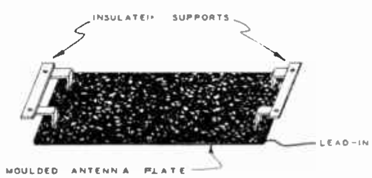


Fig. 123
Solid Metal Plate Antenna.

Front and rear bumpers can be insulated from the car chassis and used as an antenna. Many of these systems use impedance matching transformers for improved performance.

The Faraday Screen

● An electrostatic shield between two coils is often used in receiver circuits in order

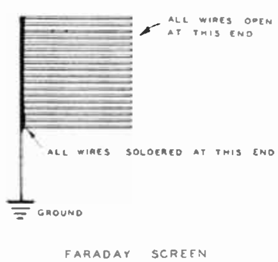


Fig. 125

to prevent capacitive coupling. One very effective arrangement is known as the *Faraday Screen*. It generally consists of a row of small wires, spaced from each other and connected together at one end in order to provide a connection to ground. Eddy current losses are prevented by grounding only one end of the wire, the other end remaining open; see Figs. 124 and 125.

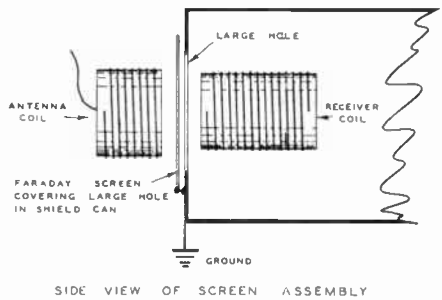


Fig. 124

A Faraday Screen can be constructed by winding a large number of turns of very small insulated wire on a cardboard drum, which has first been treated with insulating varnish. The wire is wound as on any ordinary coil, then a coating of insulating varnish is applied to the winding. After it has dried, the coil is cut in half, along its length, and flattened out. The insulation is then removed from one end and the wires soldered together, as shown in the diagram.

Aircraft Antennas

● Antennas designed for aircraft must have a good effective height and very low wind resistance. The most efficient antenna electrically is a long trailing wire for both transmitting and receiving. It must be reeled-in when a landing is made, and it offers an excessive wind load at high speeds. For beacon reception, a hollow streamlined metal rod approximately six feet in height and mounted on top of the fuselage is quite widely used. The rod must be insulated from the supporting structure. It has an effective height of about one meter, thus making it satisfactory for use with a sensitive receiver. Other forms of antennas, such as wires stretched across the wings, or from the tail to the ends of the wings, or from tail to cockpit, are satisfactory for both transmitting and receiving.

A short trailing wire, approximately 25 feet long, can be used on high speed transport planes because it has less wind resistance than a rod or pole antenna.

Marine Antennas

● Single wire antennas of the Inverted-L, T and Doublet types are used on shipboard. The wire is usually suspended between masts, or between mast and funnel. A separate antenna is widely used for short-wave reception, while for longer wave operation a break-in keying relay connects the receiver to the main transmitting antenna. Marconi antennas for small marine craft can be made more effective when more than one wire is used, such as in a cage or flat top antenna. Refer back to Fig. 46.

Loop Antennas

● When highly-directive transmission or reception is desired, loop antennas are used.

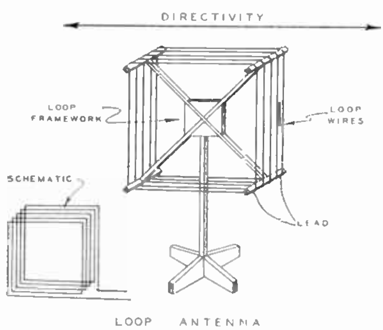


Fig. 126

A conventional type is shown in Fig. 126. Some are circular in shape, others are in the form of a rectangle or square.

The relative efficiency of loop antennas is very low and they are used only for such special applications as direction-finding. The directivity pattern has the same appearance as that of a half wave dipole antenna. The response in the maximum direction (in line with the loop) is very broad, but the minima or zero signal setting is very sharp.

Antenna Mast Construction

● A practical and economical antenna mast is illustrated in Fig. 127. It is constructed of three pieces of 2x3, or 2x4, clear pine, each 20 feet long. The completed mast is light enough in weight for mounting on house-tops, and it can be erected by two people. The mast is guyed at the top and center with three guys at each point. The guys should be broken about every ten feet with egg-type strain insulators. The illustrations give all of the necessary constructional data.

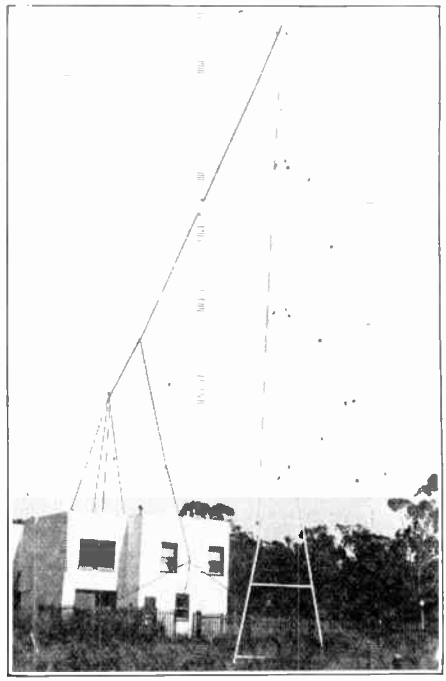


Fig. 128

Photograph of Completed Antenna Mast Described in Fig. 127.

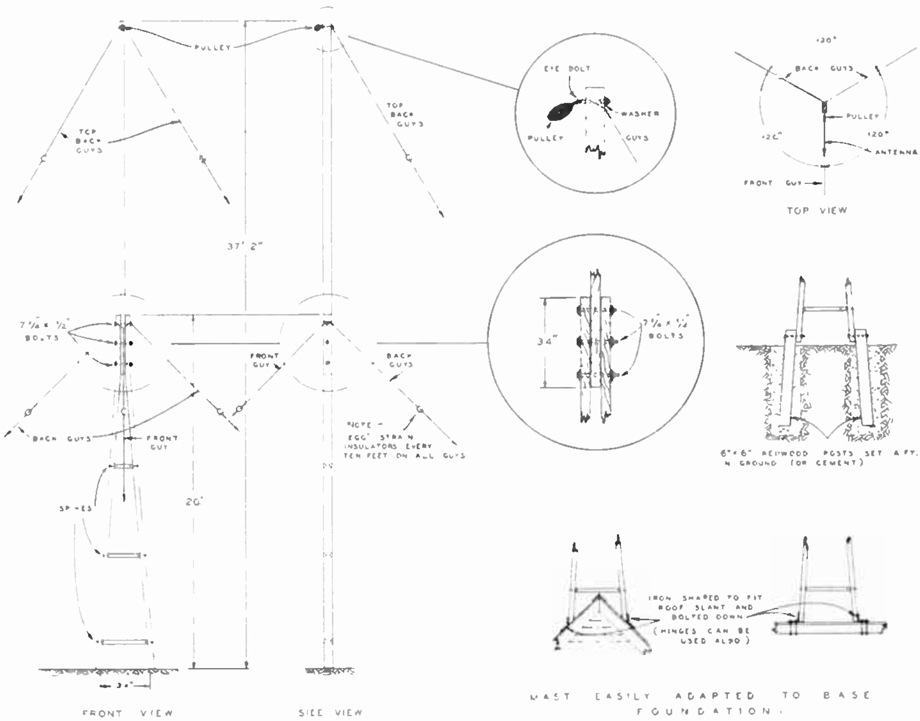


Fig. 127

Constructional Details for 37-Foot Antenna Mast.

Chapter 6

Radio Receiver Theory and Construction

● Resonant circuits are the major electrical tuning units in all amateur, communication, and broadcast receivers. The importance attached to the tuning circuit and other associated elements requires a detailed analysis; however, the following considerations are all that are necessary.

Electro-magnetic and Electro-static Coupling

● When an electro-magnetic wave is intercepted by an antenna, a small radio-frequency voltage is induced in the conductor, which surges to-and-fro in an oscillatory manner. Tapping the antenna at a suitable point by a *lead-in* or *feeder* and causing the voltage to pass through an inductance will produce a current in the coil in proportion to its reactance.

Assuming that the inductance in the antenna circuit is untuned; that is, an inductance without any shunt capacity, the voltage induced across the coil will be equal to the current times the inductive resistance. Hence, anything done to increase the voltage developed across the coil will also increase its magnetic flux; and furthermore, when a secondary winding is coupled to the antenna coil a greater voltage will be induced on account of the increased flux density cutting the secondary inductors. Anything to cause the antenna voltage to increase, before being applied to the grid of the detector tube, will augment the over-all amplification of the signal strength.

Now, by changing the untuned antenna coil to a tuned parallel resonant circuit by the simple expedient of adding a variable capacity across the inductance, the voltage will no longer equal the current times the inductive reactance; but, instead, will equal the current times the ratio of the reactance and resistance. The impedance of such a circuit drops off rather rapidly at either side of resonance; the voltage, and consequently the signal diminishes proportionately. In other words, a circuit that is tuned exactly to the signal frequency will give considerably more gain than one that is untuned or that may differ in some respects from the resonant frequency by an appreciable amount.

The energy from the antenna can be connected directly across a coil and induced into another coil without being physically connected to the former; this is known as *inductive coupling*. On the other hand, if the energy is connected across the plates of a condenser, then fed to the grid side of the coupling coil, the connection is known as *electro-static coupling*. From the foregoing explanations it will be apparent that this type of coupling has no voltage gain in itself, and is therefore inferior, though possibly more convenient to use than inductive coupling.

Whenever an antenna circuit is coupled closely to the grid circuit, some electro-static coupling is bound to exist, due to the capacity between the metals in the respective coils. A combination of coupling is undesirable in most cases, since electro-static coupling permits steep wave-front voltages, such as static and noise, to have greater paralyzing effect on the grid. Pure inductive coupling is only practicable if the separation between the two coils is made large or through the use of an electro-static shield, commonly known as a "Faraday screen."

In inductively coupled circuits, the amplitude of the induced voltage will depend upon the strength of the magnetic field set up, the proximity of the two "coils" and the impedance of the grid circuit to the particular frequency.

The impedance of the grid will follow the same rules set forth for the antenna circuit, since they are both parallel resonant circuits and are both maintained at resonance with the incoming frequency. At this point it is necessary to take into consideration another property of resonant circuits known as the "Q."

"Q" of Resonant Circuits

● "Q" may be defined as the inductive reactance divided by the resistance. The Q of a coil is the factor of merit; the higher the Q, the better the coil. Authorities differ quite widely on the ideal shape for a coil, but, in general, agree that very long, or very short coils are to be avoided. A coil whose length is approximately equal to its diameter is often considered best.

The diameter of the wire used to form the coil also has a definite influence on the Q. Hence the wire size should be as large as possible to get into a given winding space. NOTE: Practically all the resistance in a parallel resonant circuit is contributed by the inductance; the condenser, if well designed, has negligible resistance. But nearly all the resistance in the inductance is contributed by the "skin effect." This effect increases almost directly with frequency and is introduced at high-frequencies because the current is not equally distributed throughout the conductor, but travels only on the outermost surface. Thus, in order to provide ample surface for the current to pass along, it is necessary to use a much larger size conductor than would be the case if the current was equally distributed throughout the conductor.

Round conductors are always better than flat strips because, even if the flat strip has more surface area, the fact remains that the current does not distribute evenly over the entire surface but has a maximum density at the edges, with low density on the sides.

Distributed capacity, or the capacity existing between successive turns and also between these turns and the ends, is to be avoided in any receiver coil, since this capacity has the effect of lowering the Q. Space winding is one means of lessening this effect. Where the conductor is large in diameter, "space winding" reduces the skin-effect, due to currents set up in adjacent turns. Dielectric loss due to poor insulating material in coil forms also has the bad effect of lowering the Q.

Summarizing: The ideal inductance would be one having the following properties:

1—A shape such as to make the length approximate the diameter.

2—Entirely air-supported. Since this condition is practically impossible, a compromise must be adopted taking the form of a coil support of a low-loss dielectric, such as Isolantite.

3—A wire size of ample proportions. This must also be a compromise, since with excessive wire diameters the skin-effect and distributed capacity more than offset the gain due to increased surface. For all practical purposes a wire size larger than No. 16 need not be used in receiver coil design.

4—A space type of winding. The spacing will be more or less governed by the length-to-diameter rule. In general, the spacing ought not to exceed twice the diameter of the wire.

Considering the coil and condenser as a unit (a parallel resonant circuit), it is required in good design to adhere to the following:

1—In order for the circuit Q to be as high as possible, the inductance-to-capacity ratio should be very high.

2—The tuning condenser should have excellent mechanical and electrical properties and be preferably insulated with Isolantite, or similar material. Some type of pig-tail connection or positive wiping contact must be included in the assembly for contacting the rotor; this reduces high-resistance during rotation.

Selecting a Receiver

● The selection of the proper type of receiver best suited to one's needs is a problem that confronts every beginner. Incidentally, there are practically as many types of receivers as there are kinds of amateurs. No perfect receiver exists for all-around operation under all operating conditions; hence, it is largely the personal choice of the operator that governs the receiver type. All receivers represent a compromise between such factors as cost, size, accessibility, convenience, dependability, versatility, output desired and the purpose for which it is to be used.

If a receiver is to be built, instead of being purchased, and if the constructor has had no experience in receiver construction, it is advisable to first build the more simple types of receivers, using from one to three tubes, instead of the more complicated multi-tube superheterodyne receivers, which may have from six to twelve or more tubes.

The constructor who chooses the regenerative autodyne receiver must weigh the compromises involved in its design. If the receiver is located in a metropolitan area, where power lines, street cars, oil furnaces and other sources of man-made static interference are prevalent, the receiver must be particularly well shielded. If the set is battery-operated, the noise pick-up will be minimized, as no interference will be introduced through AC power lines feeding a mains-operated plate or filament supply. If the receiver is used in the country, remote from man-made static. shielding is a matter of lesser importance, and thus a somewhat simpler receiver will give entirely satisfactory results.

If a receiver is located in the neighborhood of a powerful radio transmitter, the strong radiations may block or paralyze the RF or detector circuits, making it necessary to provide a tuned stage of radio-frequency amplification or some other form of volume control to obtain satisfactory selectivity. At the same time it may also be necessary to choose a somewhat less sensitive detector circuit in order to make the detector less susceptible to overload.

One of the salient points of receiver construction is that of cost. The actual design of a receiver is a simple problem. Of course, the design may become complex if all late engineering refinements are incorporated into the construction. In general, the most elaborately designed receiver is actually more modest in cost than might otherwise be expected. Although every set builder will desire the most expensive coil forms, tuning condensers and vernier dials, it is essential to strive for a happy medium when selecting a receiver circuit which makes the best use of the parts available.

A receiver which is to operate on one band is much easier to build than one which must operate satisfactorily in the entire range of from 160 meters to 10 meters. A band-spread arrangement of condenser combinations which give excellent results on 20 meters will not be satisfactory when used to cover the 160-meter band. Thus, if the constructor desires to operate on two such widely different frequencies, a sacrifice must be made of both convenience and efficiency on one or both of these bands.

Methods of Band-Spreading

● Band-spreading is an electrical means of obtaining tremendous gear reduction on the tuning condenser dial of a receiver. High-frequency receivers must cover a very wide range of frequencies and therefore it is difficult to design a dial and drive mechanism which will cover the desired ranges, yet still provide sufficient "vernier" (geared down) drive so that weak signals will not be passed over without hearing them. In newer all-wave broadcast receivers this problem is solved by the use of a two-speed dial arrangement, the low reduction being provided for rough tuning and the high reduction for fine tuning. This is usually accomplished mechanically by means of planetary gear. The system is quite satisfactory, but rather difficult to manufacture by the average amateur or experimenter. Practically the same effect can be obtained by means of electrical band-spread. Almost all receiver circuits use a variation in the capacity of the tuned circuit for tuning purposes. In order to obtain a small variation in tuning it is essential that the capacity be increased or decreased by a small amount. However, difficulty is encountered in varying the capacity of a large condenser by small increments or decrements, but in an electrical band-spreading system utilizing two tuning condensers—one large condenser to give rough tuning, the other. a very small condenser (two or three plates) may be connected in a wide variety of combinations to give the electrical effect of "fine" or "vernier" tuning. The first system is shown in Figure 1 (A). It is the most common system and consists of a small condenser C_2, connected directly in parallel with the large condenser C_1. In most high-frequency receivers the capacity of C_1 will be chosen so that the coil and the condenser combination will cover a frequency range of between 2-and-3-to-1. The condenser C_2 is much smaller than C_1 and will often be chosen so as to cover a band of approximately 1000KC.

METHODS OF BAND SPREADING

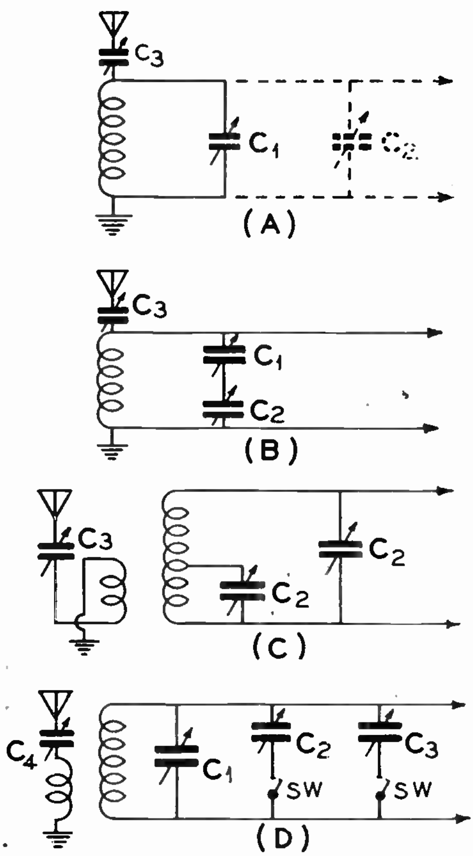


Fig. 1

Figure 1 (B) shows a band-spread condenser in series with the main tuning condenser. Because the capacity of two condensers in series is always smaller than the capacity of the smaller of the two condensers. it will be seen that both condensers in Figure 1 (B) must be considerably larger in capacity than the corresponding condensers in Figure 1 (A) in order to cover the same frequency ranges. Both of the systems shown in Figures 1 (A) and 1 (B) have the disadvantage in that the degree of band-spread varies with the tuning of C_1, and thus if a given coil covered both 40 and 20 meters, the system may provide too much band-spread for 40 meters and not enough band-spread for 20 meters. In Figure 1 (C) the band-spread effect can be kept constant over a wide range of frequencies by tapping the band-spread condenser across part of a coil, instead of being tapped across the entire coil, as in Figure 1 (A). The position of the tap varies with frequency. On the larger low-frequency coils, the tap will be placed near the top of the coil. On small high-frequency coils, the tap will be placed proportionately farther down on the coil in order to maintain an approximately constant degree of band-spread. This system has the disadvantage in that some selectivity is lost in the tuned circuit. Figure 1 (D) shows another means of equalizing the degree of band-spread over a wide range of frequencies. C_1 is the conventional large tuning condenser of between 140 and 350 mmfd.

C_2 and C_3 are both band-spread condensers. C_2 has approximately 50 mmfds. for band-spreading the 80 and 160 meter bands; C_3, from 15 to 20 mmfd., is best for use on the 40 and 20 meter bands. The proper condenser is chosen by means of switches, as shown in Fig. 1 (D). A disadvantage of switching is that rather long leads are required, as well as a possibility of losses in the switch contact.

Plug-in Coils

● Practically all regenerative receivers use plug-in coils. This is also true of some of the highest-priced amateur receivers and commercial superheterodynes. The advantages of plug-in coils are only obtained when low-loss materials and low-loss design are featured as a complement. The very best low-loss coil form is "dry-air," or self-supported coil winding. Next best are the ceramic forms which use Isolantite, Mycalex, or their equivalents. Then follow the special mica compounds, such as the XP-53 and R-39 compounds. Whereas celluloid is a more inferior dielectric than the afore-mentioned materials, its advantage is that a very thin form will serve as an excellent coil support. In addition, because losses are a function of the volume of dielectric material in an electric field, the thin celluloid makes possible the construction of an extremely low-loss coil form.

Wire for Coil Winding

● Bare wire, having as large a diameter as possible, is better than insulated wire in winding coils, because the larger the wire diameter, the lower will be the radio-frequency resistance. In coil winding, the space-wound method is superior to others, while grooved coil forms are undesirable on account of increasing distributed capacity. It is essential that all coils be placed as far away as possible from metallic shields or other metal bodies, such as the chassis.

Coil Winding Data for Simple Receivers

● Coil winding tables vary with the size of the coil form used. The standard form is 1½ inches outside diameter. A table is given below for the number of turns required on a coil form to cover the four popular amateur bands. If forms larger than 1½ inches in diameter are on hand, obviously fewer turns will be required. Conversely, a smaller form will require a greater number of turns per coil. It is a simple matter to use the "cut and try" method when winding coils; however, the accompanying table will greatly simplify matters. It is assumed that the coils are to be wound on standard forms and tuned with a 100 mmfd. midget variable condenser.

Wave-length	L1, Secondary Winding	L2, Tickler Winding
20 M	7 turns, No. 18 DCC, spaced two diameters.	4 turns, No. 22 DSC, close wound.
40 M	18 turns, No. 22 DSC wire, spaced one diameter.	Ditto.
80 M	36 turns, No. 22 DSC wire, close wound.	6 turns, No. 22 DSC, close wound.
160 M	72 turns, No. 32 DSC or SCC wire, close wound.	11 turns, No. 22 DSC or SCC, close wound.
Spacing Between Secondary and Tickler Windings ⅛-inch.		

Tickler Winding

● If the detector does not regenerate, reverse the tickler connections or add one or two turns of wire to the tickler coil, until smoothest regeneration is obtained.

The Detector in a Regenerative Autodyne

● The detector is the heart of the regenerative autodyne receiver, and a wide variety of tubes may be used for this purpose, each having certain advantages and disadvantages. The four most commonly used detector tubes are the 76 and 6C6, for operation from house lighting current, and the 30 and 32 types for battery-operated sets. The 76 and 30 are triodes, while the 6C6 and 32 are screen-grid types. Screen-grid detectors are somewhat more sensitive than triodes, although are more susceptible to overload and more difficult to get going. In place of the 6C6 or 32, it is often desirable to utilize a tube with a variable mu, such as the 6D6 or 34. This type of tube is slightly less susceptible to overload than the sharp cut-off detectors, such as 6C6 and 32. Variable mu tubes afford a smoother control of regeneration but necessitate a sacrifice in sensitivity.

The 24, 36 and 57 tubes are very similar to the 6C6. By the same token, the 39 and 58 are similar to the 6D6. Likewise the 27, 37 and 56 will act exactly like the 76 in most circuits. In the battery-operated field there is less choice, although the 99, 201A and 12A are quite similar in characteristics to the 30, and type 22 can be used in a circuit designed for a 32.

Audio Coupling

● The detector can be coupled to an audio amplifier in three different ways, which are known as resistance coupling, impedance coupling, and transformer coupling.

In general, resistance coupling is the least desirable of the three methods when working out of a regenerative detector, because the question of fidelity is relatively unimportant and fidelity is the principal advantage of a resistance coupled amplifier. Resistance coupling can be used out of either triode or screen-grid detectors.

Impedance coupling (or choke coupling) is particularly recommended when working out of a screen-grid detector because it enables the full plate voltage to be applied to the detector and also has enough distributed capacity so that any radio-frequency present is easily by-passed to ground. The only disadvantage of impedance coupling is that it affords no voltage step-up, as does transformer coupling. An impedance to work out of a triode detector should be approximately 30 henrys at 15 to 20 milliamperes. An impedance designed to give best results out of a screen-grid or pentode detector should be rated at more than 250 henrys at 5 milliamperes.

Transformer coupling is unsuited when using a screen-grid or pentode detector, although it is recommended when working out of a triode detector. A step-up ratio of approximately three-to-one gives the best all-around results.

Impedance or transformer coupling sometimes gives trouble, due to fringe audio howl in a regenerative receiver. A 50,000 to 250,000 ohm resistor shunted across the impedance coil or transformer secondary will usually cure this trouble.

Audio Tubes

● The choice of the audio output tube is largely dictated by the amount of audio power required. If loudspeaker operation is desired, two stages of audio amplification will ordinarily suffice; for example, a triode type 76, in the first stage, and a pentode, such as a 41, in the second stage.

If headphone operation is desired, the second stage may be eliminated and the phones connected in the plate circuit of the first amplifier stage. For loudspeaker use, pentodes are recommended, such as types 38, 41, 42, 47, 59, 89, 33, or 43. Triodes may also be used, but will require somewhat more amplification; they are the 12A, 71A, 45, 46, 2A3, 31, 120, and others.

Any of the following tubes are entirely satisfactory for headphone reception in the audio stage: 99, 30, 201A, 112A, 27, 37, 56, 76 and either of the following pentodes when connected as triodes (screen and suppressor grids tied to plate): 57 and 6C6.

Notes for Set Builders

● *Sockets:* The socket material is as important as the material from which the coil forms are made because the socket is in the direct field of the coil. In receiver construction it is essential that only the very best material is used in socket assemblies; thus, ceramic. Isolantite and other good insulators will suffice.

Leads and Connections: Leads to the tube socket and tuning condenser must be short and direct, sharp bends being avoided whenever possible. All joints must be carefully soldered with rosin-core solder, and a clean, hot iron should be used for all soldering operations. Make all connecting wires mechanically secure to all connecting points and keep all wiring well remote from metal shielding and chassis.

Calculating Filament Dropping Resistor Values: It is important that the filaments of all tubes, either in a transmitter or receiver, be operated at the rated filament voltage. If the voltage is too low or too high, tube life is materially reduced. When in doubt, it is advisable to operate the filament at a slightly higher than normal voltage, rather than at lower voltage. The value of a filament resistor can be calculated by means of Ohm's Law, a very simple formula which indicates the relationship between voltage, current and resistance. If any two are known, the third can be determined. The three forms of this equation are:

$$E = IR \qquad R = \frac{E}{I} \qquad I = \frac{E}{R}$$

Where E = the voltage; I, current (amperes); R, resistance (ohms):

For example, assume the two type 30 tubes are being operated with their filaments in parallel and a 3 volt battery is to supply the filament power. But, since 3 volts is too high, it must be dropped to 2 volts through a series dropping resistor, which will give the normal operating voltage. To calculate the value of the series resistor, it is first necessary to determine the current drawn by the two tubes. The current in this case is 120 milliamperes, or .12 amperes. From the equation R = E/I, the resistance is computed by dividing the desired voltage drop by one volt (which is "I" in this case) by 12/100, which is the same as multiplying 100/12. The equation then is 1/1 × 100/12, which equals 8.3 ohms. Therefore, 8 ohms is the proper value of resistor to use, because fractional value resistors are not obtainable. When connecting two tubes in series, it becomes necessary to provide twice as much heating voltage as when only one tube is used; however, there is no increase in heating current.

When the filaments of two type 30 tubes are connected in series, it is necessary to provide 4 volts at 60 milliamperes (0.06 amperes). Either a 4½ volt "C" battery or three 1½ volt dry cells connected in series provide a convenient means for operating the two tubes in series. The dropping resistor should be 8 ohms, which is determined by dividing the voltage drop of ½ volt by the total filament current of .06 amperes. Care should be taken to see that tubes which draw different values of filament current are not connected in series unless special precautions are taken, as shown in Figure 2. A shunt resistor must be connected across the filament of the tube drawing the least current, so that the sum of the current through the resistor, plus the current through the filament which it shunts, is equal to the current drawn by the other tube.

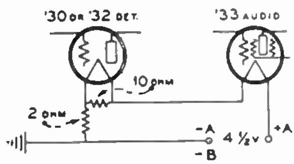


Fig. 2. Series connection for dissimilar filament currents.

Calculating Value of Self-Biasing Resistors: In practically all receivers utilizing either radio or audio frequency amplifying stages, some method of self-biasing the grids is employed. This bias is obtained by inserting a resistor in the cathode lead return wire and taking the necessary voltage drop across the resistor. The value of self-biasing resistors can be calculated by the formula:

$$\text{Ohms} = \frac{\text{grid bias} \times 1000}{\text{plate current}}$$

Thus, for a 45 tube which has a plate current of 34 ma. for which a grid bias of 50 volts is needed:

$$\frac{50 \text{ Volts} \times 1000}{34} = 1{,}470 \text{ Ohms}$$

The wattage or power consumed in the resistor equals E $\times$ I or .034 $\times$ 50 or 1.7 watts. For push-pull amplifiers combine the plate currents of each tube. For screen-grid and pentodes use the sum of the plate and screen currents.

Receiver Measurements

● Satisfactory results can only be obtained from a radio receiver when it is properly aligned and adjusted. The most practical technique for making these adjustments is given in the following discussion.

The simplest type of regenerative receiver requires little adjustment other than those necessary to insure correct tuning and smooth regeneration over some desired range. Receivers of the tuned radio-frequency type and superheterodynes require almost precision alignment to obtain the highest possible degree of selectivity and sensitivity.

Testing Instruments

● Only a very small number of instruments are necessary to check and align any multi-tube receiver. The most important of these testing units being a modulated oscillator and a DC and AC voltmeter. The meters are essential in checking the voltage applied at each circuit point from the power supply. NOTE: If the AC voltmeter is of the oxide-rectifier type, it can be used, in addition, as an output meter when connected across the receiver output when tuning to a modulated signal. If the signal is a steady tone, such as from a test oscillator, the output meter will indicate the value of the detected signal. In this manner line-up adjustments may be visually noted on the meter rather than by increases or decreases of sound intensity as detected by ear.

Tuned RF and Regenerative Detector

● In Figure 1 is shown a single stage of tuned RF and a regenerative detector. For proper performance, these two tuned circuits must resonate to the same frequency throughout the desired tuning range. It is required, therefore, that L_2 and L_5 have equal values of inductance and equal values of effective shunt capacity at each point on the tuning dial. The inductances may be closely matched by using similar coil forms and

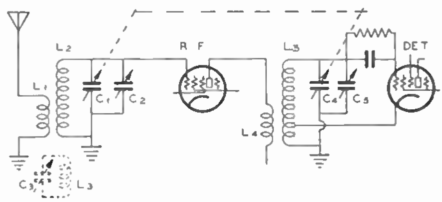


FIG. 1
R-F stage and regenerative detector.

windings. If one coil is closer to some metal object, such as the chassis or shield, it will be difficult to obtain a good match unless coil turns are removed or shifted along the coil-form to change the effective coil length. A resonant antenna will unbalance the RF stage unless L_1 is loosely coupled to L_2.

Circuit Capacities

● The shunt capacities are due to coil distributed capacity, wiring capacity, shunt condensers and tube capacity. Usually trimmer condensers C_2 and C_5 are needed to equalize the fixed circuit capacities. These should be adjusted for maximum signal sensitivity toward the high-frequency end of the tuning dial, that is, minimum capacity position for C_1 and C_4. After making this adjustment (usually with a screw driver) the alignment can be checked throughout the tuning range by bending "in" or "out" one of the outside rotor plates of tuning condenser C_1. Some receivers have condensers with slotted end-plates to facilitate bending to correct circuit alignment over the whole tuning range after C_2 and C_5 have been correctly set. The RF tube and primary L_4 reflect a capacity across L_5 which can be exactly balanced by having a duplicate primary winding L_3 on the RF grid coil. A small trimmer condenser simulates the RF tube plate circuit—this refinement is seldom used in receivers, but is well merited.

Multi-Stage Tuned RF Receivers

● The alignment procedure in a multi-stage RF receiver is exactly the same as aligning a single stage. If the detector is regenerative, each preceding stage is successively aligned while keeping the detector circuit tuned to the test signal, the latter being a station signal or one locally generated by a test oscillator loosely coupled to the antenna lead. During these adjustments the RF amplifier gain control is adjusted for maximum sensitivity, assuming that the RF amplifier is stable and does not oscillate. Oscillation is indicative of improper by-passing or shielding. Often a sensitive receiver can be roughly aligned by tuning for maximum noise-pick-up, such as parasitic oscillations originating from static or electrical machinery.

Superheterodynes

● A superheterodyne presents an involved alignment procedure since it is necessary to align both the oscillator and first detector as well as the intermediate frequency amplifier. In this case, the latter should be aligned first. METHOD: A calibrated modulated oscillator is set to the frequency of the IF amplifier; this is usually between 175 KC and 500 KC. A lead from the oscillator is connected to the grid of the last IF stage, and C_5 and C_6 of Figure 2, varied until maximum signal strength is obtained in the output of the 2nd detector or audio amplifier. The adjustment can be simplified if the receiver has AVC, the tuning meter being used to indicate the maximum signal strength. Since the coupling inductances L_5 and L_6 are generally fixed, the only possible adjustment will be by varying the trimmer condensers. After C_5 and C_6 are properly set, the oscillator power is decreased, then coupled to the grid of the first IF amplifier tube. C_3 and C_4 may then be adjusted for maximum signal strength. The RF input to the receiver must be kept at an optimum value to insure signal readability. The procedure is repeated to align C_1 and C_3, providing the receiver has two IF stages. Sometimes it is necessary to disconnect the first detector grid lead from the coil, it then being grounded in series with a 1000 or 5000 ohm grid leak, and the test oscillator coupled through a small capacity to the grid. The oscillator should have some form of attenuator; however, the coupling may be varied by moving the oscillator lead further away from the tube grid into which it is coupled. For test purposes, the 1000 ohm resistor prevents the RF coil from short-circuiting the IF of the test oscillator so the first detector acts as an amplifier. After the IF is aligned, the first detector grid lead is connected back to its RF coil.

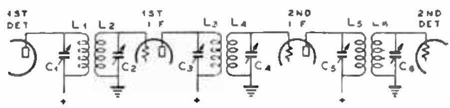


FIG. 2

I. F. Amplifier.

The technique of lining-up the first detector and RF stages, if any, is precisely the same as that described in aligning a tuned RF receiver. However, the line-up with the RF oscillator is slightly modified. METHOD: The HF oscillator is used to provide a signal in the first detector which will beat with the desired signal to form a new signal at the frequency to which the IF amplifier is tuned. If this is 450 KC, the HF oscillator should tune to 450 KC higher frequency than that of the first detector and RF stage. Figure 3 illustrates this circuit. In general, coil L_2 must have less inductance than L_1, and C_4 must have less tuning range than C_1. These requirements necessitate that L_2 have less turns than L_1 and less capacity in C_4 than in C_1. If C_1 and C_4 are of the same capacity and are coupled in tandem, a fixed or variable condenser C_3 is placed in series with C_4 to reduce its maximum capacity. C_2 and C_5 may be either trimmer or band-setting condensers. C_3 is required at longer wavelengths where the ratio of the oscillator to detector frequency is not approaching unity of equality. For example: at 14,000 KC with the oscillator at 14,450 KC no series

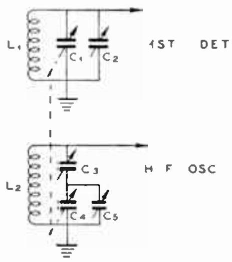


FIG. 3

Front-End of Superheterodyne.

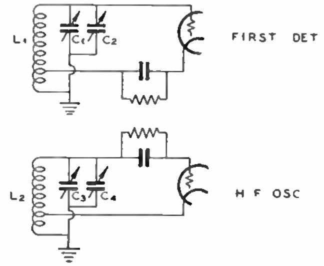


FIG. 4

Another type of front-end.

condenser is necessary, but one would be required at frequencies of 2,000 KC and 2,450 KC if the tuning condensers C_1 and C_4 were very large.

Alignment Procedure

● Actual alignment of the front end of a "superhet," such as shown in Figure 3, follows: The test oscillator is set at the highest frequency which can be tuned-in with a given set of coils. This may require a little manipulation, but if the tuning range is known or can be estimated, an approximate frequency setting of the test oscillator can be made. The test signal is increased in value until it is heard or can be measured at the output of the receiver. C_2 is then adjusted to bring the dial reading to the desired point for a given frequency, that is, providing the dial is calibrated. C_1 and C_4, of course, being tuned simultaneously; afterwards, C_2 is adjusted for maximum sensitivity. Next, the tuning dial is rotated through to nearly full capacity setting of C_1 and C_4, of Figure 3, and the oscillator set for this lower frequency. These circuits can be aligned by moving the tuning dial while adjusting C_3 with a screwdriver or plate bending of C_1. A middle dial setting can be checked by means of a third setting of the test oscillator and plate bending of C_1. If alignment cannot be obtained by plate bending adjustments, a new value of trimmer condenser settings of C_5 and C_2 will have to be used and the whole procedure repeated. Sometimes L_2 has to have considerably less turns than L_1, and a few turns added or subtracted to allow the HF oscillator to tune through the whole range at precisely 450 KC higher in frequency than the detector and RF stages.

Multi-band Receivers

● Individual coils in multi-band receivers with coil switching arrangements must have small trimmer condensers shunted across the inductive circuits, as shown in Figure 5. This allows fairly accurate alignment in each band by following the procedure previously outlined. In assembling a superheterodyne, the labor of checking is rather long and tedious since each coil must have

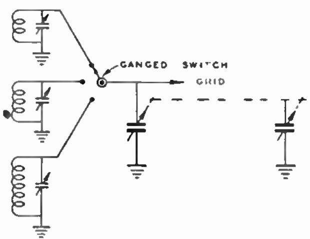


FIG. 5

Tuned circuits for coil switching.

exactly the correct number of turns because bending the main tuning condenser plates would unbalance or misalign all other coils. Unfortunately in receivers incorporating coil switching arrangements, it is impossible to obtain accurate circuit alignment. Many commercially built receivers use two stages of RF ahead of the first detector, tuned rather broadly to overcome this defect and obtain better signal-to-noise and image ratios.

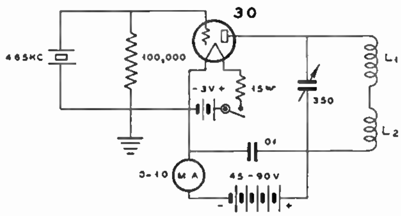
If either the circuits of the RF stage are regenerative, they must track exactly with the HF oscillator. This type of circuit is shown in Figure 4, where C_1 and C_3 are approximately 20 to 30 mmfds. ganged tuning condensers on the main tuning dial, and C_2 and C_4 are band setting condensers of 100 to 140 mmfds. In this instance, C_2 can be used as a panel operated trimmer condenser to hold the circuits exactly in line at high degrees of regeneration. The series condensers C_5 of Figure 3 are not required in this class of receiver due to the very narrow band tuning-range of C_1 and C_3. The coil turns on L_1 and L_2 can be adjusted so that at random settings of C_2 and C_4 they will give practically perfect alignment. In practice, adjustment occurs at slightly greater capacity settings of C_2 than for C_4, together with a small increase in inductance L_1. Varying the coil turns and spacing between turns will insure good tracking throughout all the amateur bands with the possible exception of the 160 meter band. This form of receiver invariably uses plug-in coils which must be adjusted properly, the turns being cemented in place with celluloidal cement.

Beat-frequency Oscillator

● A beat-frequency oscillator, BFO, is lined up by tuning it so that its hiss is loudest in the receiver output; later, a signal is impressed to give a 1000 or 800 cycle beat-note. For example: If the IF amplifier is lined up to 450 KC, the BFO must be tuned to either 499 or 451 KC. If a crystal filter forms part of the IF amplifier complement, a vernier adjustment for the BFO should be available on the front panel in order to exactly set the beat-note for best results. The BFO input to the second detector need only be sufficient to give a good beat-note on a fairly strong signal. Too much coupling to the second detector will mean excessive hiss level with loss of very weak signals in the noise background. The BFO must be well shielded to prevent harmonics of the circuit from radiating and setting up unwanted signals. The oscillating circuit must have a high C to L ratio in order to generate oscillatory currents of high stability.

Crystal Filters

● In lining up the IF amplifier for use with a crystal-filter, it is necessary to employ the crystal itself as an oscillator, providing a calibrated test oscillator is unavailable and the exact frequency of the crystal unknown. When the crystal itself functions as the oscillating medium, the circuit shown in Figure 6 should be used. In the diagram, the crystal is connected as a conventional crystal-oscillator in a transmitter, with the



TEST OSCILLATOR CIRCUIT
FIG. 6

Crystal Filter Aligning.

exception that a small air-gap is used and the grid-leak and choke combination eliminated. A winding from an IF transformer for the plate inductance with the trimmer attached are all that are required for tuning. For lining-up purposes, a type 30 tube with 2 volts AC on the filament will suffice; the AC modulates the signal and simplifies the adjusting procedure. Plate voltage (180 volts) is secured from a tap on the voltage divider. A milliammeter inserted in the plate circuit will indicate oscillation, the plate current dipping as the trimmer condenser tunes the inductance to the resonant frequency of the crystal. A piece of insulated wire is brought near the inductance and the far end of the wire hooked over the grid input to the first IF. Tuning the IF to exact resonance with the crystal then becomes a simple matter. Exact IF alignment should be made with the crystal in the circuit for best results after the preliminary adjustment is made, because the crystal frequency is not exactly the same in a resonator as in an oscillator.

In adjusting the crystal filter, the phasing condenser and input tuning condenser should be adjusted simultaneously for maximum signal response, then a slight readjustment of the phasing condenser will allow elimination of the other sideband.

Notes

● In lining up a receiver which has automatic volume control (AVC), it is considered good practice to keep the test-oscillator signal near the threshold sensitivity at all times to give the effect of a very weak signal relative to the audio amplifier output with the audio gain control on maximum setting.

In checking over a receiver certain troubles are often difficult to locate. In general, by making voltage or continuity tests, blown-out condensers, or burned-out resistors, coils or transformers may be easily located. Oscillators are usually checked by means of a DC voltmeter connected from ground to screen or plate-return circuits. Short-circuiting the tuning condenser plates should usually produce a change in voltmeter reading. A vacuum-tube voltmeter is also very handy for the purpose of measuring the correct amount of oscillator RF voltage supplied to the first detector circuit. The value of the RF voltage is approximately one volt less than the fixed grid bias on the first detector when the voltage is introduced into either the grid or the cathode circuit.

Incorrect voltages, poor resistors or leaky bypass or blocking condensers will ruin the audio tone of the receiver. Defective tubes can be checked in a tube tester. Loudspeaker rattle is not always the defect in the voice coil or spider support, or metallic filings in its air-gap; more often the distortion is caused by overloading the audio amplifier. An IF amplifier can also impair splendid tone due to a defective tube or overloading the final IF tube. In some AVC circuits, the last IF tube will easily overload if too much bias is fed back on strong carrier signals. Diode detectors give best fidelity when operated at fairly high input levels which means that there must be ample voltage swing delivered to the output of the last IF tube.

Quartz Crystal Filters

● The subject of quartz-crystals is confusing to many users, which may be attributed to the complexities underlying the technical nature of the device.

Briefly, a quartz-crystal cut on certain axes and with parallel faces, has the property of mechanically oscillating in alternating-current electric fields of certain frequency. In addition, it has the very unique property of functioning as a resonator. In CW reception, the self-resonant feature is utilized in a filter circuit to limit the received signal to a band of approximately 100 cycles wide, such an electrical combination improves the signal-to-noise ratio as well as assures the highest selectivity obtainable for CW radio telegraphic reception.

General Details

● To generally illustrate the function of the crystal and filter circuit, assume that the latter is replaced with its electrical equivalent in inductance and capacity. A crystal of 451.5 has an equivalent inductance of 3.5 henrys and a capacity of less than 0.1 micromicrofarad. The effective "Q" of such a circuit ranges from 1000 to 10,000. Since "Q" is the property which governs the shape of the resonance curve, the circuit would have a very narrow shoulder with a sharply peaked characteristic. Apparently no combination of inductance and capacity could eclipse these effects. Similarly, to an electrical equivalent circuit, the crystal has also properties of a series-resonant circuit. A circuit of this type offers very low impedance to the resonant frequency (that frequency where the inductive reactance and capacitive reactance are equal), while at the same time presents very high impedance to all other frequencies. A series-resonant circuit will pass the resonant frequency (in this case the frequency to which the receiver is tuned) and reject all other adjacent signals. In general, resonance curves do not have vertical sides, they slope. The "steepness" of the slope is dependent, among other things, upon the "Q" of the circuit. With a circuit having a resonance curve with gradual sloping sides, an interfering signal removing 10 KC from the desired signal may only be ten points down in stength from the desired signal at the output of the receiver. In contrast, a quartz-filter circuit with extremely steep sides can cause interfering signals to be cut down from the unwanted signal 10,000 times. These figures are merely illustrative of the effect of the extreme discrimination of such circuits as compared with ordinary tuned-parallel resonant circuits used in an IF amplifier.

Technical Discussion

● The impedance of a quartz-crystal oscillator to an AC electrical current is exceptionally low and it can therefore be used as a series element of an electrical filter for CW reception. The quartz-crystal may be compared to the electrical equivalent circuit shown in Figure 7, where C1 is the capacity across the quartz plate when not vibrating; R, the resistance equivalent to the frictional effects of the vibrating crystal; L, the inductance corresponding to inertia; and C, the capacity corresponding to the elasticity. One side of resonance the circuit has capacitive reactance due to the elastic forces which control the crystal vibrations, while on the other side of resonance the reactance is inductive on account of the inertia effects. At resonance, the crystal vibrates freely, its amplitude being limited by the frictional effects; in the resonating state, L and C are equal in reactance and the resonant frequency is the same as the mechanical vibratory mode.

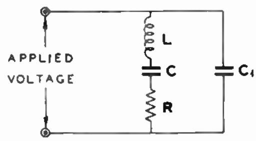


Fig. 7

Equivalent circuit of a quartz crystal.

If the impressed voltage is at the resonant frequency, the current through it will be large, limited only by the resistance R. There is also a leading component due to C1 which can be balanced out by means of a "phasing" condenser. (Note: A phasing condenser is used in all single-signal receiver circuits to eliminate the by-passing effect of C1, of Figure 7, or to use it as a means of eliminating one sideband.) C1 combined with L and C have a sufficient inductive effect to provide a parallel circuit at a frequency slightly different from series resonance.

By placing the phasing condenser in the circuit so that the voltage across it is out of phase with that across the crystal, the parallel resonance can be shifted above or below crystal-resonance. Thus, the phasing condenser can be adjusted so that the parallel resonance causes a sharp dip in the response curve at some desired point, such as 2 KC away from the desired signal peak.

This means that the other sideband 1 KC away from zero-beat can be practically eliminated with a beat-frequency oscillator. The series-resonant effect is used to pass the desired signal through an IF amplifier for further amplification.

Quartz-Filter Circuits

● In reception, it is required that the noise-to-signal ratio be kept at a very low value; to obtain the optimum noise ratio requires circuits having selective and highly-peaked response curves. Thus, it is desirable to have a band-width only about 100 cycles wide, down to a point at where the gain of the receiver will discriminate against undesired signals audible in the output. A well-designed crystal filter will provide an attenuation of about 60 DB to signals more than 5 KC off resonance with, of course, that much more attenuation of the opposite sideband, 1 KC from zero-beat on the opposite side from the peak response.

Quartz-crystals have a greater "Q" at lower frequencies. For this reason most filters are designed for operation at 500 to 450KC, and used in an IF amplifier resonating at the crystal frequency. From a selectivity standpoint, frequencies lower than 450 KC would be desirable because the crystal "Q" would be greater; however, in the lower ranges image interference becomes a problem.

In quartz-crystal filter circuits, the R value ranges between 2,500 and 10,000 ohms which requires that the circuit be designed to minimize its loading effect on any tuned circuits, otherwise the impedance irregularity will cause an excessive loss at the desired signal frequency. This latter condition occurs in the popular circuit shown in Figure 8.

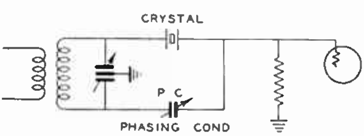


Fig. 8

Lamb's crystal filter circuit.

Some of the undesirable effects of the circuit shown in Figure 8 are eliminated in the circuit of Figure 9. Here, the grid-leak is replaced by a tapped resonant RF choke. The resonant effect, plus the mid-point connection, gives a step-up in impedance from the series element (the quartz-crystal) with only a slight loss in signal strength. To realize the full possibilities of this system requires that the resonant choke be properly designed; unfortunately, the design is difficult.

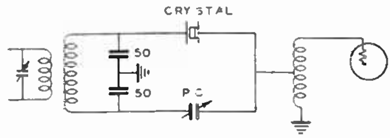


Fig. 9

McMurdo Silver's crystal filter.

The difference between the circuits of Figures 8 and 9 is in the manner of obtaining an out-of-phase voltage across the crystal. The coil can be center-tapped to ground, or the center point of the two condensers may be used. In either case, the crystal-input circuit tuning condenser and phasing condenser are simultaneously adjusted for maximum signal response and greatest signal effect.

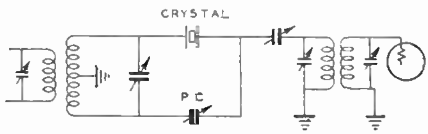


Fig. 10

Frank C. Jones' crystal filter.

In the circuit of Figure 10 the crystal is used as a series element, connecting two parallel resonant circuits together in a band-pass circuit. The small condenser C of 20 to 30 mmfds. is necessary to prevent over-coupling between the tuned IF transformers, because at series resonance, only a few thousand ohms is offered as impedance. The small condenser C does not appreciably decrease the signal strength, its function is that of coupling the two tuned circuits together. The extra tuned circuits, which cause only an effective loss, eliminate the usual spurious side-band responses of most quartz crystals. The side-band responses are a few kilocycles away from resonance, but by careful tuning of the IF transformers, these effects can be attenuated to practically zero value.

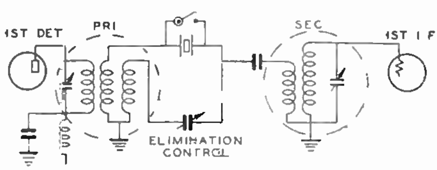
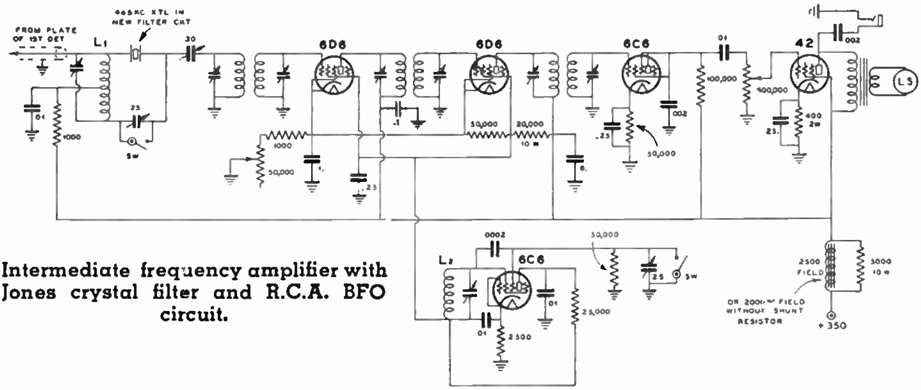


Fig. 11

Comet "Pro" crystal filter.

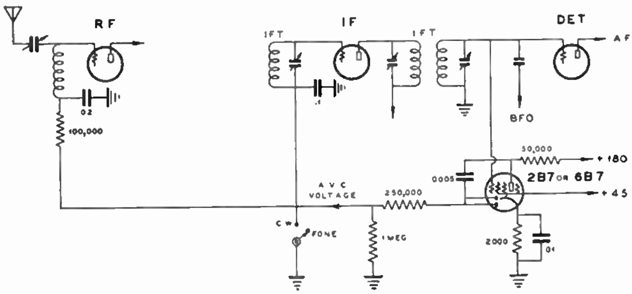
Another method for matching impedances is shown in Figure 11. Here the low impedance of the crystal at resonance does

A. V. C. and Audio Circuits



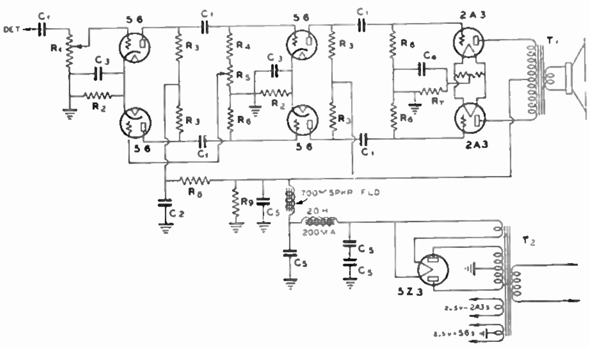
Intermediate frequency amplifier with Jones crystal filter and R.C.A. BFO circuit.

IMPROVED BFO CIRCUIT



AMPLIFIED A V C FOR 222 RECEIVER OR ANY OTHER SHORT WAVE SUPERHET

Automatic volume control is a distinct advantage when the receiver is used for phone reception. It automatically compensates for signal fading. Briefly, its action depends upon the carrier signal strength which causes a control voltage to vary in proportion to the actual carrier intensity.



High quality audio amplifier with a maximum output of 15 watts. Legend—

C1—0.1. C2—4 mfd. C3—4 mfd. C4—10 mfd. C5—8 mfd. R1—500,000 ohm Potentiometer. R2—1250 ohms, 1 watt. R3—100,000 ohms, 1 watt. R4—250,000 ohms, 1 watt. R5—250,000 ohm Potentiometer. R6—500,000 ohms, 1 watt. R7—750 ohms, 10 watts. R8—20,000 ohms, 1 watt. R9—25,000 ohms, 20 watts. T1—Output Transformer from 2A3s Push-Pull to Dynamic Speaker. T2—Power Transformer, 300 volts each side of center-tap at 150 MA.

not over-couple the two parallel tuned circuits. A 30-1 step-down ratio of impedance works into the crystal, and a similar step-up ratio couples it into the tuned-grid circuit. In this circuit, as well as in the one above, a small series condenser prevents over-coupling. Laboratory and field tests show that very little, if anything, is gained by the step-down transformers as compared with the system shown in Figure 10. The circuits shown in Figures 9, 10 and 11 are better than that of Figure 8.

Band Pass Crystal Filters

● An ideal characteristic for an I.F. amplifier in a c-w receiver would be a band width 500 cycles broad at the top, and practically straight-sided. The total attenuation would be down at least 120 D.B. at approximately 100 cycles either side of this band-pass. The attenuation should extend down to 120 D.B. in order to eliminate "slop-over" from very powerful local stations.

A multiple quartz crystal filter, combined with a number of tuned I.F. circuits, would approach this ideal condition for phone reception; on the other hand its use would not be desirable for c-w reception. Series crystal filter circuits as used in single signal superheterodynes give a very narrow width, but the shape of the curve resembles the outline of a volcano. It is too sharp for easy tuning on the peak, and altogether too wide at the base; therefore the strong local signals cannot be eliminated. The peak portion of the curve is too selective for phone reception, and for this reason the series crystal circuits will eventually be discarded.

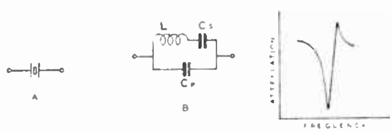


Fig. 12

The equivalent circuit of a quartz crystal is shown in Fig. 12, wherein both series and parallel resonance occur. Series resonance is due to the equivalent inductance and series capacity.

$$F_s = \frac{1}{2\pi\sqrt{LC_s}}$$

The crystal holder introduces a shunt or parallel capacity C_p across the crystal, and parallel resonance occurs at:

$$F_p = \frac{1}{2\pi}\sqrt{\frac{C_s + C_p}{LC_sC_p}}$$

The parallel resonance effect can be varied by means of a "phasing" condenser in a single signal receiver in such a manner that it will nearly eliminate the second beat note of a c-w signal which is tuned-in on the peak of resonance. The parallel resonance is too sharp to make possible the elimination of the entire undesired beat note, except over a certain range, such as from 800 to 900 or 1,000 cycles. Thus a weak, undesired signal of higher or lower beat note can still be heard, especially if the lower beat note signal is of sufficient intensity.

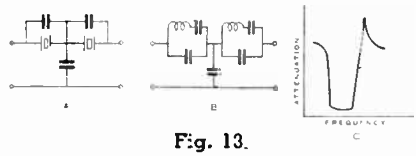


Fig. 13.

Fig. 13 shows two crystals in a band-pass circuit. The crystals used in band-pass circuits are slightly different in frequency. In Fig. 13 the response curve is wider at the base, which is the point of least attenuation (the peak of response in a receiver) than for the single series crystal shown in Fig. 12C.

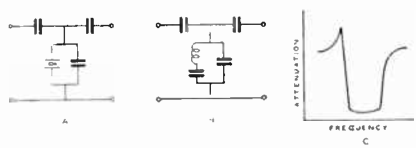


Fig. 14

Fig. 14 shows a shunt single crystal filter circuit with series condensers. The circuit is similar to that of Fig. 13, except for the reversal in the point of greatest attenuation. The curve of (c) depends upon the proper impedance terminations, as well as the correct values of shunt and series condensers.

Fig. 15 shows a system with three crystals for better band-pass characteristic. The band-pass width is less than 0.4% of the series resonance frequency of the crystals; consequently for a 465 KC crystal the band width would not be greater than 1750 cycles.

These band-pass filters have a low impedance, depending upon their band widths. The narrower the band, the lower is the value of impedance to match. This impedance ranges from a few hundred ohms, downward. Impedance matching can be accomplished with tuned I.F. coils which have low inductance untuned secondary and primary windings.

The attenuation of these band-pass crystal filters is from 30 to 40 D.B., except at the points of highest attenuation, which may run from 60 to 100 D.B. This sliding-

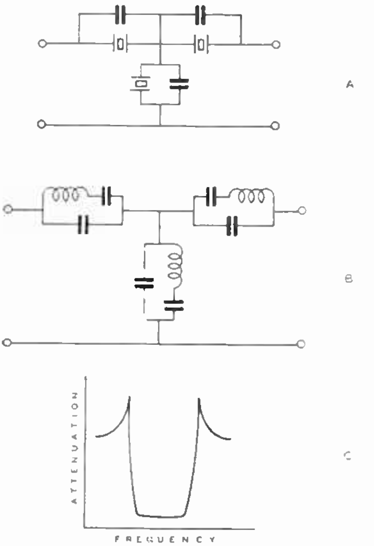


Fig. 15

off effect on the sides beyond the parallel resonant cut-off points means that additional attenuation in the I.F. amplifier is required, or more than one section of crystal filter must be used between stages.

Simple Battery Receiver Circuit

● This receiver does not in any sense represent a new development in the short-wave construction field. Instead, it is one in which the designer combined well-known and accepted principles to produce a set that is simple and inexpensive to build.

From a casual examination of the schematic diagram it will be seen that the receiver is of the single-circuit regenerative type, with tickler feed-back. The placement of the parts is extremely important for effective results. As in all receiver designs where the maximum efficiency is desired, only the highest quality of parts should be used. Equipment of inferior design, carelessly assembled, will not bring the desired results.

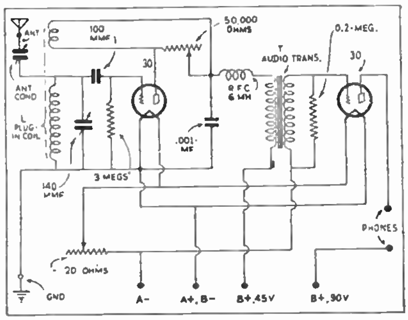
For economical operation, two type 30 low drain two-volt tubes are used. The first serves as a regenerative detector; the second as an audio amplifier. The tuning range of the receiver is 15 to 200 meters, covered by a set of four plug-in coils. Regular broadcast reception is optional, by adding a set of two plug-in coils to cover 200-500 meters.

Only two dry-cells and two 45 volt "B" batteries are required for complete operation.

Regeneration is controlled by a 50,000 ohm variable resistor connected across the tickler leads. The output of the detector is transformer-coupled to the audio tube by a shielded transformer having a ratio of 1 to 5. A load resistor of 200,000 ohms is connected across the secondary of the audio-transformer to eliminate any possibility of "fringe howl."

The antenna is coupled to the tuning coil by a semi-variable "postage stamp" condenser having a maximum capacity of 80 uufds.

Tuning is accomplished by a 140 uufd midget variable condenser mounted on the front panel. A smooth vernier-type dial is used to insure proper tuning.



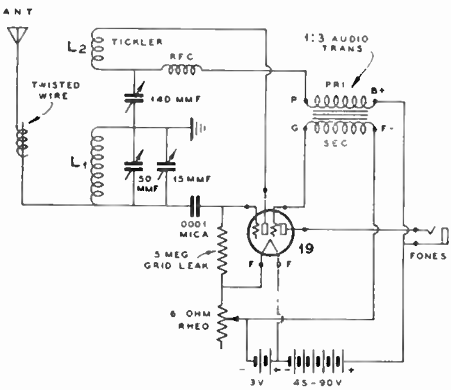
Simple 2-Tube Regenerative Receiver.

Operating Notes: Phone signals are loudest just below the oscillation point, and CW signals just above the oscillation point. When tuning the receiver, set the regeneration control to the point where the detector just starts to oscillate; then the tuning dial should be carefully turned until a "whistle" is heard. Careful tuning at this point and further adjustment of the regeneration control will bring in the intelligible signal.

Simple Receiver With One '19 Tube

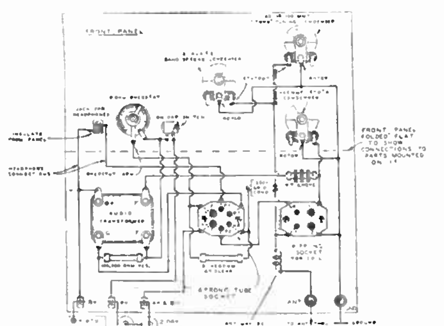
This receiver gives surprisingly good volume on DX signals; it is especially recommended for the beginner who is contemplating the design of a simple and inexpensive set.

The circuit diagram is self-explanatory; however, there are some details that need explanation. The grid and plate connections must be properly made, as shown in the circuit diagram. The grid bias is secured by means of the rheostat in the filament circuit. The constructor, therefore, is cautioned to connect the movable arm of the rheostat to the negative A, and also to the negative F on the audio transformer. Best results are secured with a 5 megohm grid-leak; smaller values may cause the detector to regenerate with an unpleasant roar. Smooth regeneration is sometimes secured by connecting a 250,000 ohm ½ watt resistor across the secondary (GF) terminals of the audio transformer.



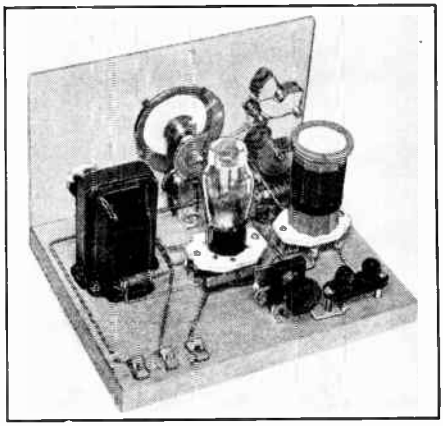
Schematic circuit diagram of the one-tube receiver. L1 is the secondary, or grid coil. L2 is the "tickler," or regeneration coil.

The band-spread tuning condenser is a 3-plate midget variable; the tank tuning condenser is a 50 mmfd. (or 100 mmfd.) midget variable. A 140 mmfd. midget variable condenser is used for the regeneration control. The secondary and tickler coils are both wound on the same form, and both coils *must* be wound in the same direction; otherwise the detector will not oscillate.

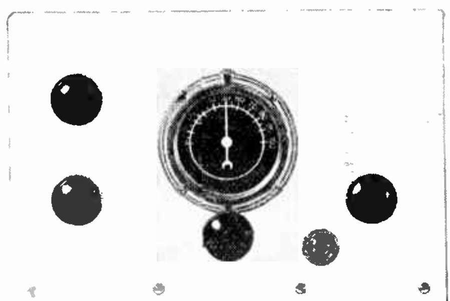


Pictorial layout of parts for 1-tube receiver. This arrangement should be closely adhered to.

The front panel is made of a piece of No. 12 or No. 14 gauge aluminum, 7 in. x 9 in. The wood baseboard is 9 in. x 11 in. The band-spread, tank condenser and regeneration condenser are mounted directly on the panel and the rotors of these condensers are grounded to the panel. The rotors may be connected together, and the connecting wire bonded to the ground or panel. An inexpensive airplane dial enhances the symmetry of the front panel. This dial controls the 3-plate band-spread tuning condenser.



Rear View of the Completed Receiver.



Front Panel Layout.

Top, left—"Tank" tuning condenser.
Bottom, left—Regeneration condenser.
Center—Airplane tuning dial.
Extreme right—Rheostat control.

The headphone jack is mounted between the airplane dial and the rheostat control. This jack MUST be insulated from the metal front panel and a hole at least ⅛-inch larger in diameter than the outside diameter of the screw thread on the jack should be drilled in the panel.

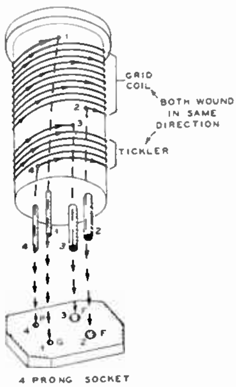
Ordinary Fahnestock battery connection-clips can be used for headphone connections in place of the phone jack; these connectors can be secured to the baseboard in any convenient location, preferably near the audio frequency transformer.

An on-off switch can be added, or the dry cells can be disconnected from the receiver when not in use. Two 1½-volt dry cells are required. These will give excellent service for a long period of time. The

B-battery voltage may be as low as 22 volts, but at a sacrifice in audio volume; 45 to 90 volts is more suitable for normal operation, except when the receiver is used as a portable. With 22 volts the tickler coil must be placed very close to the secondary coil.

The antenna is coupled to the "high potential end" of the secondary coil by a few turns of lead-in wire twisted around the grid-lead of coil L1; a single turn loop wound around the top of L1 will give the same results. The small midget condenser shown in rear view photograph of the receiver is connected in series with the antenna lead and the top lead of L1. It can be used as a substitute for the twisted-wire coupling arrangement.

COIL DATA



The upper coil is the grid (secondary) coil. Start the winding at point 1, make the connection to prong 1. The bottom of the grid coil (2) connects to prong 2. The top of the tickler coil (3) connects to prong 3; the bottom of the tickler (4) connects to prong 4. Mark the coil prongs and the coil socket contacts to correspond with these numbers. See the pictorial layout to show how the connections are made to the coil socket. Make certain that Connection No. 1 goes to the stators of both tuning condensers, and also to one side of the .0001 mfd. grid condenser. Likewise, take care to see that Connection No. 4 goes to the plate of the detector portion (P2) of the type 19 tube. If these connections are not properly made, the receiver will not function. The antenna lead-in wire can be looped around the No. 1 connecting lead.

COIL FORM LEGEND

Terminal No. 1 connects to one side of the .0001 mfd. mica fixed condenser and to the stator of the 100 mmf. (or 50 mmf.) condenser, as well as to the stator of the 3-plate midget variable tuning condenser. Likewise, the insulated antenna lead-in wire is twisted around the lead which connects to Terminal No. 1.

Terminal No. 2 connects to the **rotors** of all three variable condensers, and at the point where the three are connected together another lead is run to the **"ground"** terminal of the receiver.

Terminal No. 3 connects to the **stator** of the 140 mmf. variable condenser which is used for regeneration, and the same terminal also connects to one end of the 2.5 mh. RF choke.

Terminal No. 4 connects to the **P2** terminal on the type '19 tube.

COIL WINDING DATA

The secondary coil and the tickler coil are **both** wound in the same direction.

20-Meter Coil: Secondary winding—7 turns of No. 22 DSC wire, space-wound to cover a winding space of 1-in.
Tickler Winding—5 turns of No. 22 DSC wire, close-wound, and spaced about 1/8-in. from the secondary winding.

40 Meter Coil: Secondary Winding — 14 turns of No. 22 DSC wire, space-wound to cover a winding space of 1-in.
Tickler Winding—11 turns of No. 22 DSC wire, close-wound, and spaced 1/8-in. from secondary winding.

80-Meter Coil: Secondary Winding — 27 turns of No. 22 DSC wire, close wound.
Tickler Winding—11 turns of No. 22 DSC wire, close wound, and spaced 1/8-in. from secondary winding.

160-Meter Coil: Secondary Winding—60 turns of No. 22 DSC wire, close-wound.
Tickler Winding—17 turns of No. 32 Enameled wire, close-wound, and spaced 1/8-inch from secondary winding.

Simple 1, 2 and 3 Metal Tube Regenerative Receivers

● A modern receiver for the newcomer consists of a single 6J7 metal tube in a conventional circuit with cathode regeneration, i. e., a circuit in which a single tuned circuit covers the desired frequency band and also provides regeneration.

Regeneration is secured by means of "cathode tap" connected to the tuned coil at its lower (ground) end, in addition to a variable source of "B" voltage for the screen of the 6J7. If the cathode tap is placed at the proper point on the coil, and if the correct screen voltage is applied to the tube, the circuit will go into oscillation very smoothly and both voice and code reception is had with ease.

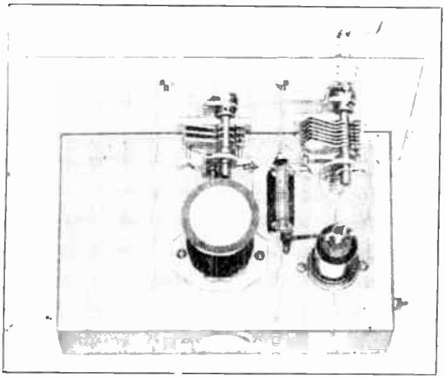


FIG. 1.
Simple One-Tube Receiver with Rengerative Detector.

The newcomer will find it advisable to first build a receiver with a single metal tube; an additional stage of audio amplification, or a "front-end" stage of tuned-radio-frequency amplification, can be added later. Even though more than one tube is to be eventually used, it is desirable to first wire the receiver for one-tube operation, then other tubes can be added at will. Circuits for the simple newcomers' receiver are shown in Figs. 4 and 5. The single-tube receiver will give good results, pick-up many DX stations, even though the signal strength is low. An audio amplifier stage can be added at any time, thus the original receiver does not become obsolete. For ordinary reception in rural locations the two-tube receiver leaves little to be desired.

Technical Data

The detector circuit for a single-tube receiver is the same as that for a two-tube receiver. The antenna lead is twisted around the grid wire (one or two twists), or around the wire which connects from the

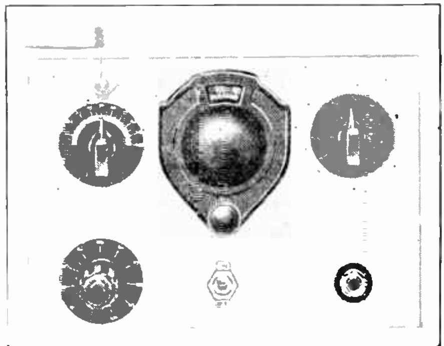


FIG. 2.
Front Panel View of One- or Two-Tube Receiver. The Control dial in the Upper Right Corner Is Not Used in a One-Tube Receiver.

top of the tuned coil to the grid condenser and grid-leak. This twisted lead acts as a small capacity (condenser) and by varying the number of turns, or twists, the capacity is varied. Dead spots in the antenna are

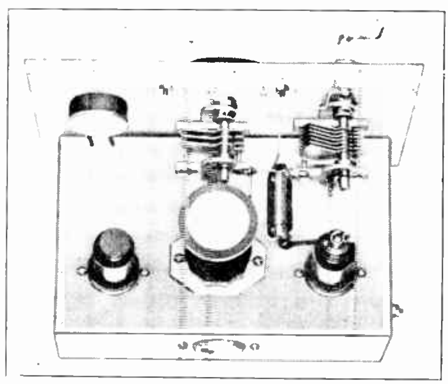


FIG. 3.
Two-Tube Regenerative Receiver with Same Detector Circuit as One-Tube Receiver.

compensated for by varying the number of twists, or by sliding the twisted portion along the grid wire, away from the coil and grid,

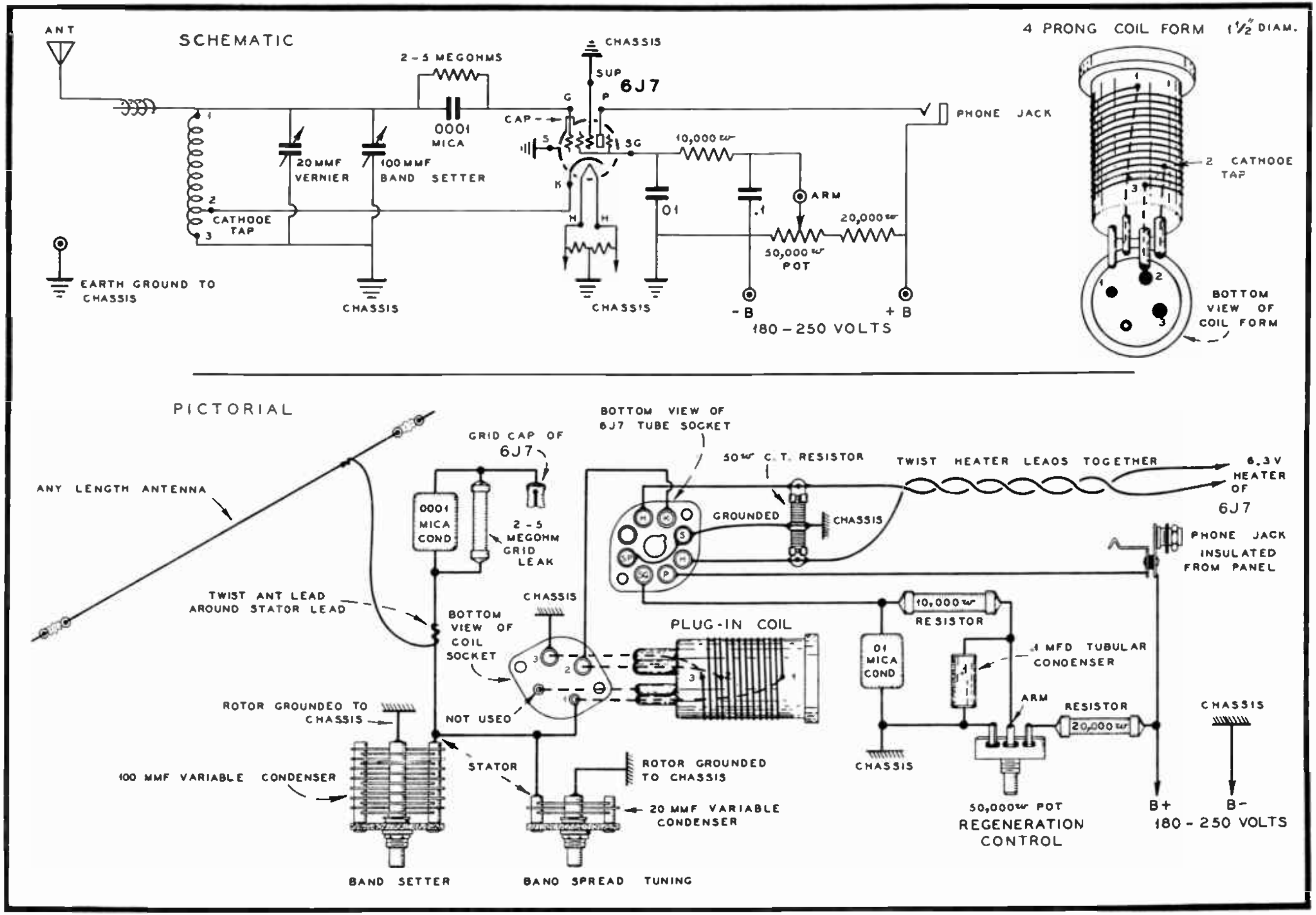


FIG. 4—Simple One-Tube Regenerative Receiver.

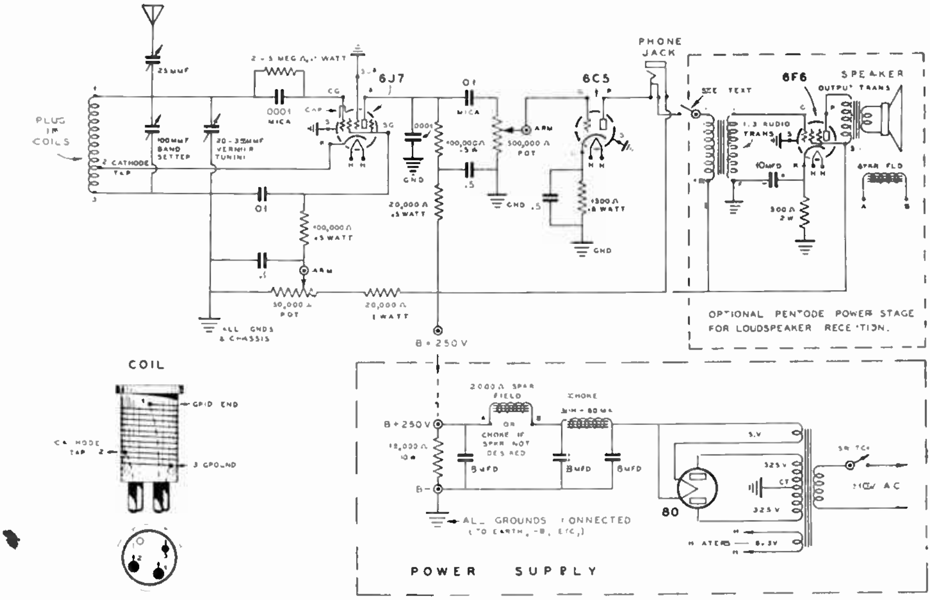


FIG. 5—Showing how additional stages are added to the one-tube receiver. The dotted-line portion shows a pentode power output stage for loud-speaker operation. The coil winding data is unchanged.

in order to reduce the capacity. For ordinary reception, the twisted portion remains fixed over the entire band and the position of this "condenser" is varied only when coil changes are made.

The detector is of the grid-leak variety. A .0001 mfd. mica fixed condenser, shunted with a 5 to 10 megohm grid-leak, is in series with the grid of the detector tube. The coil is shunted by two variable condensers, one for "band setting," or "band finding," the other for band-spread tuning. The "band setter" condenser roughly tunes the circuit to the desired band, whereas the band-spread condenser permits of very close (vernier) tuning. The condenser with the fewer plates is the band-spread condenser.

The cathode tap must be carefully located on the tuned coil. The coil-winding table gives correct data, which should be closely adhered to. If the receiver fails to regenerate, the cathode tap should be moved slightly farther away from the ground end of the coil. If regeneration is too harsh, the tap should be moved closer to the ground end of the coil.

Construction

● The detailed drawing shows the parts required and the method of connection. Coil construction data is also given. The "ground" connections, a number of which can be seen by referring to the schematic circuit diagram, are all connected to a common wire, and then to the rotors of the tuning condensers. This common ground connection is then attached to the chassis, and the latter connected to an earth ground.

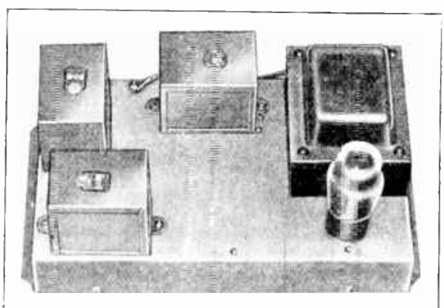


FIG. 6.

Hum-Free Power Supply for any receiver with 8 tubes or less. The circuit details are in the Power Supply Chapter.

The coils should be wound exactly as shown in the sketch. The top turn, No. 1, is connected to one side the grid leak and grid condenser. The cathode tap, No. 2, connects directly to the cathode (K) of the 6J7 tube.

The bottom end of the coil, No. 3, connects to the common ground lead under the chassis, and also to the rotors of both variable condensers. Carefully check these connections to make certain that the leads are properly made to the coil socket and coil prongs.

The plate voltage should be from 180 to 250 volts. The heater voltage for metal tubes is 6.3 volts. Dry batteries or a conventional power supply unit can be used for operating the receiver. The antenna can be a single wire, any length. The usual antenna would be approximately 100 feet long.

Coil Winding Table for 1, 2 or 3 Tube Regenerative Receiver

160-225 Meters: Wind 70 turns of No. 24 DSC wire on a 1½" dia. form. Connect cathode tap 1½ turns up from ground end.

70-110 Meters: Wind 36 turns of No. 22 DSC wire on a 1½" dia. form. Connect cathode tap 1½ turns up from ground end.

32-60 Meters: Wind 21 turns of No. 22 DSC wire on a 1½" dia. form and space-wind the wire over a winding space of 1¾". Connect cathode tap ½ turn up from ground end.

19-30 Meters: Wind 11 turns of No. 22 DSC wire on a 1½" dia. form and space-wind the wire over a winding space of 1¾". Connect cathode tap ½ turn up from ground end. The location of the cathode tap is quite critical on the 19-30 meter coil, and a slight amount of experimenting must sometimes be done in order to find the point where smooth oscillation control is obtained.

10-25 Meters: Wind 5 turns of No. 16 DSC wire on a 1½" dia. form and space-wind the wire over a winding space of 1½". Connect Cathode tap 1/3rd turn up from ground end. Experiment with cathode tap connecting point until best control of regeneration is secured.

Note: This receiver will not cover the broadcast band unless a 350 mmf. variable condenser is connected in parallel with the 100 mmf. band-setting condenser. A coil which will cover the broadcast band can be made with a 2-inch winding length of No. 28 or 30 DSC or Enameled wire on a 1½" dia. form. Connect cathode tap 2½ turns up from ground end.

T. R. F. Receiver with Metal Tubes

● Extreme receiver selectivity is not always required and in such cases a tuned radio-frequency receiver will give very satisfactory results. The sensitivity of a regenerative detector preceded by an RF amplifier is very good, and often the signal-to-receiver-noise-ratio is better than in a superheterodyne. A T. R. F. receiver is more easily built and adjusted than a superheterodyne, and it does not cost as much.

The receiver here illustrated is suitable for all-wave reception, also for long-wave commercial reception, if suitable coils are wound. With the coils described, continuous band-spread tuning can be had from 8 to 200 meters. One dial tunes a two-gang 140 mmfd. condenser for broad range coverage, the other tunes a two-gang 25 mmfd. condenser for band-spread tuning over a narrow range. Obviously, the band-spread feature applies to any portion of the tuning range, not only for the amateur bands.

Technical Notes

● Metal or glass tubes can be used with equal satisfaction. A 6K7 RF stage increases the strength of weak signals and also provides greater selectivity. The regenerative 6J7 detector has high sensitivity and is impedance-coupled into a 6C5 audio amplifier stage. An audio volume control regulates the degree of signal strength in the telephone receiver headset. For loudspeaker reception an additional power stage should be added.

Circuit tracking of the RF and detector tuned circuits is accomplished by winding the secondaries of all coils in a similar manner. The secondary coil turns are pushed together slightly, or they are more widely spaced, before they are securely fastened to the coil form with a few drops of celluloidal or Duco cement. The detector circuit has many miscellaneous capacities across part or all of the circuit and thus a 3-to-30 mmfd. mica trimmer condenser is connected across the RF tuned circuit. This trimmer can be set to a compromise value for all coils, or it can be set separately for each coil. Different antennas will cause slight detuning, particularly if the antenna happens to resonate in any of the tuning ranges. Tight antenna coupling tends to broaden the tuning of the RF stage to some extent, and for all practical purposes this stage will track satisfactorily with the sharply-tuned detector stage.

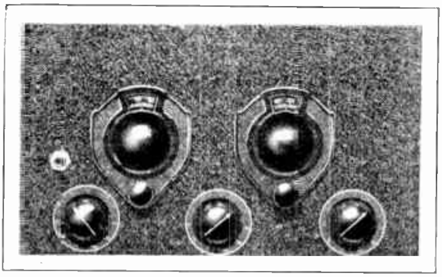


FIG. 7.
Front Panel View of T. R. F. Receiver. The large dials are for the tuning condensers, the one to the left is the "tank" tuning dial or "band locater." The other large dial is for band-spread tuning, and it alone is used to tune the receiver, once the band is located on the other dial. Thus this is a "single-dial" tuning receiver. The smaller controls along the bottom are, left to right—(1) 50,000 ohm "Pot" RF Gain Control. (2) 50,000 ohm "Pot" Detector Regeneration Control. (3) 250,000 ohm "Pot" Volume Control for 6C5 audio stage.

A cathode RF volume control adjusts the receiver gain. Powerful signals from nearby stations are found in some amateur bands, in which case a reduction in RF gain will improve the apparent selectivity and permit reception of fairly weak signals. The RF stage is somewhat regenerative at high gain settings and there may be a tendency for it to oscillate with some coils and some antennas. The RF volume control will prevent regeneration in the RF stage, if it is properly manipulated.

The detector screen voltage is varied in order to control regeneration. A series 100,000 ohm resistor and an additional 0.1 mfd. by-pass condenser keeps the 50,000 ohm regeneration control from introducing noise into the audio circuit. Impedance coupling, shunted by a 100,000 ohm resistor, permits the use of high plate voltage at the detector plate without "fringe howl" effects.

Resistance-condenser coupling into the headset isolates the latter from DC voltage and plate current. The plate supply should be very well filtered, otherwise the AC hum will be excessive. Generally about three filter chokes and three or four 8 mfd. condensers are needed to provide pure DC output without any appreciable trace of hum from the power supply. A 6.3 volt winding for the metal tube heaters should have its midpoint grounded, or a 50 ohm center-tapped resistor can be used for this same purpose.

Constructional Notes

● The front panel is of 14 gauge iron or, preferably, 12 gauge aluminum, 7 in. high and 12 in. long. The chassis is 7 in. wide, 11 in. long and 2 in. deep, No. 18 gauge steel. Two aluminum baffle shields are placed between the coils to shield the RF and detector circuits. The larger shield is 8½ in. long, 4½ in. high, with a ½ in. lip bent along the bottom for mounting to the chassis. Two irregular slots must be cut out of the shield to allow space for the two tuning condensers. The upper portion of each of these slots is only wide enough to clear the ¼-in. condenser shaft, whereas the wider slot must clear the base of the tuning condensers. A smaller aluminum baffle, 4½ in. x 2½ in., mounts about ⅛ in. from the larger one, and fits between the tuning condensers without touching them.

The isolantite coil sockets are mounted on small metal sleeves in order to keep the sockets above and away from the steel chassis. A large hole is punched under these sockets so as to facilitate wiring. Conven-

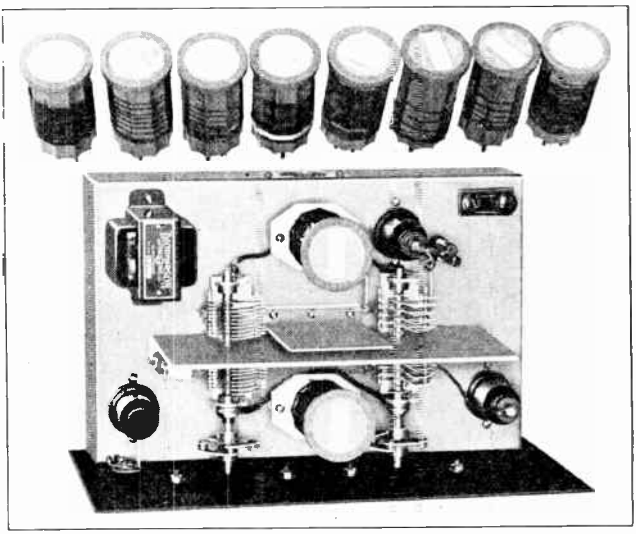


FIG. 9—Looking into the T. R. F. Receiver. The two aluminum shields are clearly shown.

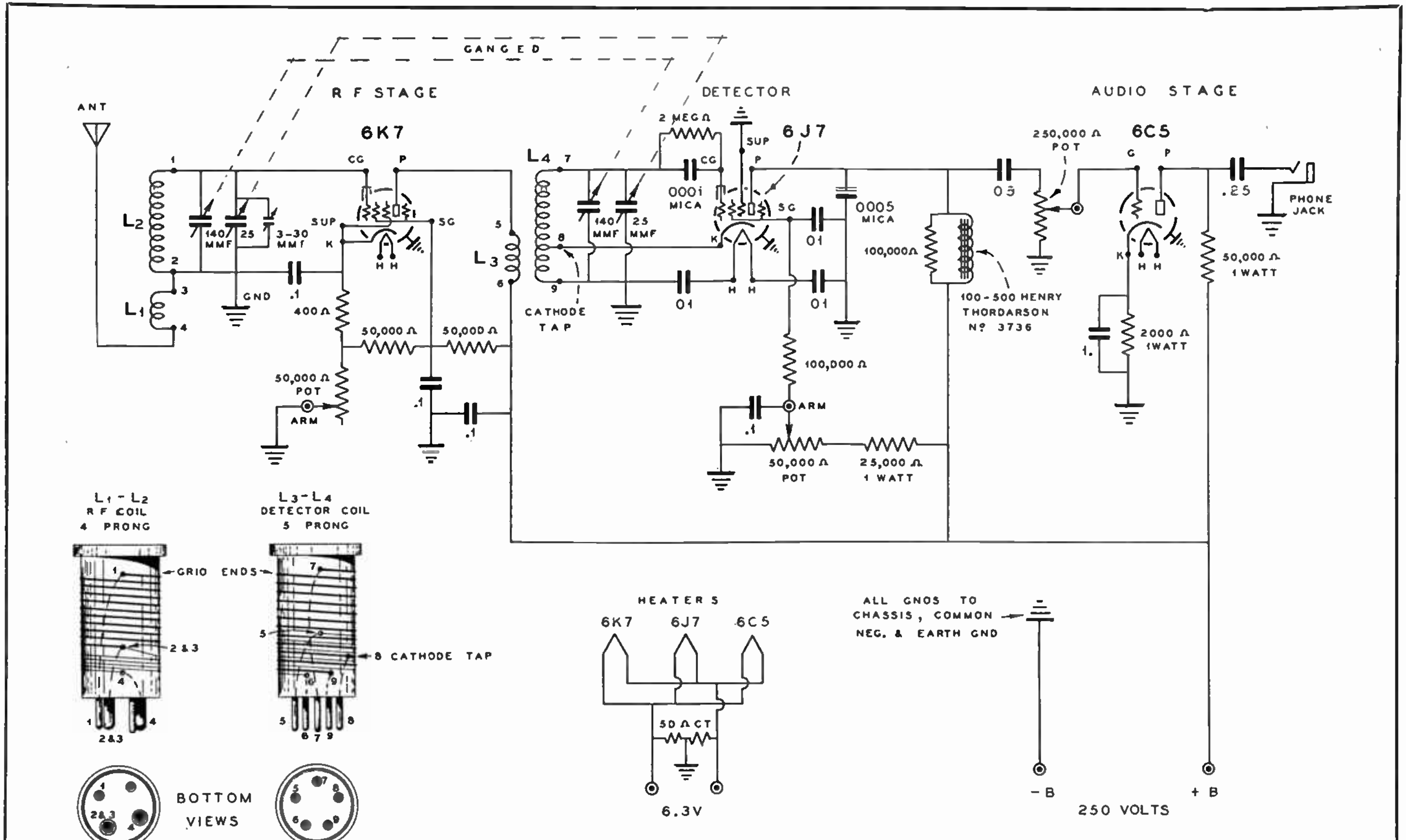


FIG. 8—3-Tube Metal "Gainer" Receiver Circuit.

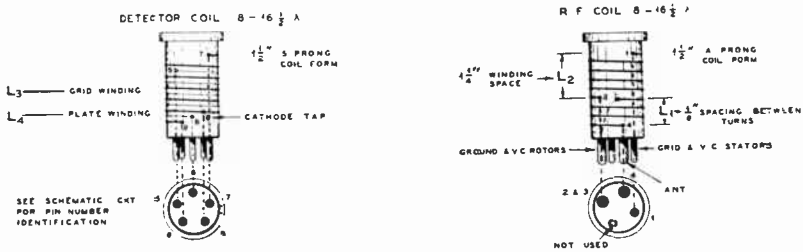


FIG. 10—Coil Construction for 8 to 16½ Meter Band.

tional metal tube wafer sockets mount under the chassis; the tubes pass through 1⅛ in. holes in the chassis.

Insulated condenser shaft couplings serve two purposes. The mechanical line-up to the tuning dials is simplified and noise which would otherwise be very troublesome on 10 or 20 meters is eliminated. The latter effect would be caused by poor contact of the metal shaft to the front panel, thus changing the ground return paths of the RF coil circuits. Separate ground leads are connected to each coil from its tuning condensers, then to a common ground point for each stage on the chassis at the point where the by-pass condensers are grounded to the chassis. The tuning condensers are equipped with contacts for soldering the ground leads, and the RF stage ground leads can be secured to the chassis with machine screws and nuts. Even when separate ground leads are connected to each condenser, there is still a common ground coupling effect through the tuning condenser shafts, which causes a slight reaction between stages.

The front and rear rotor plates of each section of the original two-gang 35 mmfd. condenser are removed in order to reduce the capacity to about 25 mmfd., maximum. In the model shown, the antenna and ground posts are mounted near the rear of the chassis, a little too close to the detector stage. These posts should preferably be mounted at the rear side of the chassis in such a way that they will protrude through a cabinet, if one is used, thus shielding the leads from the detector. A piece of Belden shield braid is slipped over the antenna lead under the chassis in order to prevent RF stage coupling into the detector circuit leads.

Resistors and by-pass condensers are connected directly to the socket terminals, or to tie-strip lugs beneath the chassis. A 4-prong wafer socket on the rear edge of the chassis provides a means for connecting an external power supply of 6.3 volts at 0.9 amperes, and 200 to 250 volts B supply to the receiver.

After the receiver is completely wired, it is a good plan to check the circuit diagram, one wire at a time, throughout the entire set. It is easy to forget a small part or a wiring lead, and a recheck of the wiring circuit should always be made.

Operating Notes

● The coil data should be closely followed and all coils should first be tested for "tracking" before the turns are cemented in place on the ribbed coil forms. When the detector and RF stage are correctly in line, the detector will not oscillate as easily as when it is detuned, providing the RF gain control is at full, or nearly full, gain setting (minimum resistance).

Excessive hum when the detector is oscillating can usually be traced to an inferior 0.1 mfd. RF plate by-pass condenser. The cathode tap must be advanced a fraction of a turn if regeneration is not secured because of a weak 6J7 tube or too-low plate voltage. Oscillation in the detector can be heard in the form of a slight click, or thump, as the regeneration control is varied. If the tube is oscillating, touching the detector tuning stator plates with a finger will produce a click in the headphones, and another click when the finger is removed. If there is no oscillation, the noise or click will be much weaker, but the "double" click will not be heard. For cw reception the detector must oscillate weakly, and for phone reception the regeneration should be advanced to the "edge" of oscillation. The RF stage should not oscillate.

Winding the Coils

● The method of inter-winding the plate and grid coils for the detector stage may confuse the average experimenter unless he refers to the pictorial diagram which shows how these coils are wound. A specimen pictorial is also shown separately for the coils that cover the 8 to 16½ meter band The RF coil construction is simple; there are two windings, L1 for the antenna-ground coil, and L2 for the secondary coil. L2 occupies the top portion of the coil form, L1 is wound below L2 and spaced from L2. The spacing varies for different coils, as the coil-winding chart shows. The detector coil form is the one on which the coils L3 and L4 are inter-wound. L4 (grid winding) is first wound; the turns are spaced to occupy the winding length shown in the chart. After L4 is wound, L3 is then *inter-wound*, i.e., another coil (L3) is wound between the turns of L4. This winding, L3, has fewer turns than L4, (except for the 8 to 16½ meter coil), consequently the winding of L3 begins farther down on the coil form. The pictorials clearly show how this winding, L3, is inter-wound with L4. In order to acquaint himself with the method of coil winding, the experimenter is advised to first wind the coils which cover the 29-62 meter band.

All coils are wound on standard Hammarlund 1½ in. diameter ribbed plug-in-coil forms. The coil form for the RF stage has four prongs, the detector coil has five.

Cathode Tap

● The cathode tap on coil L4 in the large circuit diagram may confuse the reader because it appears that this tap is taken far up on the coil. This is not the case. The tap is actually made to either the bottom turn of L4, or on the second turn from the bottom, as the coil chart shows. The tap, as shown in the large circuit diagram was shown in this manner only in order to simplify the drafting.

T. R. F. Receiver Coil Table

All Coils Wound on 1½" Diameter Forms.

Approx. Range in Meters	Ant. Coil L1	Secondary Coil L2	Primary Coil L3	Secondary Coil L4	Cathode Tap on L4
8 to 16	3 turns, spaced ⅛-in. from ground end end of L2.	3½ turns No. 20 DSC. ¾-in. long.	2½ turns No. 24 DSC. interwound with L4. + B at bottom.	3½ turns No. 20 DSC. ¾-in. long.	Tap at ⅓ turn on bottom turn.
15½ to 32	5 turns, ⅛-in. from L2.	7 turns No. 24 DSC. 1½-in. long.	3 turns No. 24 DSC. interwound with L4.	7 turns No. 24 DSC. 1½-in. long.	Tap at ½ turn on bottom turn.
29 to 62	8 turns, ⅛-in. from L2.	16 turns No. 24 DSC. 1½-in. long.	6 turns No. 24 DSC. interwound with L4.	16 turns No. 24 DSC. 1½-in. long.	Tap at ¾ turn on bottom turn.
59 to 107	10 turns, ⅛-in. from L2.	31 turns No. 24 DSC. 1½-in. long.	8 turns No. 34 DSC. interwound with L4 at ground end.	31 turns No. 24 DSC. 1½-in. long.	Tap at 1 turn up from bottom.
97 to 215	12 turns, ⅛-in. from L2.	54 turns No. 24 DSC. 1½-in. long.	12 turns No. 34 DSC. wound over bottom end of L4 over celluloid layer of insulation.	54 turns No. 24 DSC. 1½-in. long.	Tap at 1¼ turns up from bottom.

Improved Two-Tube Jones Super-Gainer

● For simplicity of construction, ease of operation and economy in cost the new improved *Super Gainer* has no equal. It is highly recommended to the experimenter because of its remarkable selectivity and sensitivity, because it is a super-heterodyne, with only two tubes, yet it performs like a 5 or 6 tube super. This new 1937 *Super Gainer* is an improvement over the one shown in previous printings of this *Handbook*. Those who have built the earlier model can make the improvements by adhering to the newer specifications.

Although the new *Super Gainer* is in itself an adequate instrument for all ordinary amateur reception, increased selectivity and signal strength can be secured by connecting the new *Regenerative Pre-Selector* ahead of the receiver. This *Pre-Selector* is described elsewhere in this Chapter. First build the receiver, then if additional selectivity and signal strength is needed, the *Pre-Selector* can be added at any future time. It is difficult for the experimenter to conceive that a two tube super-heterodyne can perform in such a surprising manner as this little *Super Gainer*.

Like the earlier models of the *Super Gainer*, this receiver is an exclusive development, and therefore no data is found in contemporary literature.

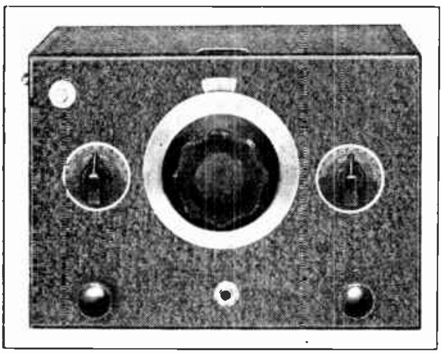


FIG. 11.
Front View of Two-Tube Super-Gainer.

The function of the receiver is as follows: A 6F7 combination triode and pentode tube serves as a high-frequency oscillator and regenerative first detector for a superheterodyne system. The pentode portion of this tube is tuned to the frequency of the desired signal and regeneration is obtained by connecting the cathode across a small portion of the tuned circuit. The cathode is common to both sections of the 6F7, therefore it also provides coupling between the detector and oscillator circuits. The triode section of the tube has a circuit which is tuned to a frequency 465 KC above the frequency of the desired signal. Oscillation is obtained by a tickler coil coupled to the tuned circuit L2. Regeneration in the detector portion is controlled by variation of the screen-grid voltage. The plate of the detector section of the tube is connected to an *Aladdin* iron-core I.F. transformer which is tuned to 465 KC. The proper *iron-core* I.F. transformer for this receiver is the *Aladdin Type A-100*.

The high degree of selectivity is obtained by means of the two 465 KC tuned circuits in the iron-core I.F. transformer, then aided by means of regeneration in the following tube. The 6A6 tube serves as a regenerative second detector and audio amplifier in its two triode sections. The regeneration not only enables beat-frequency c-w reception, but also greatly increases the sensitivity of the receiver for phone reception. Regeneration is kept below the point of oscillation in the 6A6 for phone reception, but turned up slightly beyond the point of oscillation for c-w reception. The regeneration control is a variable resistance connected across the cathode coil Lc. A 10,000 ohm tapered potentiometer is shunted with a fixed 1,000 ohm resistor, the two combining to provide very smooth control of regeneration when connected across the cathode coil.

The cathode coil consists of 100 turns of No. 30 DSC wire, jumble-wound on a ½-inch diameter dowel rod, over a winding length of approximately ⅜-inch. This coil should be mounted under the chassis, close to the 10,000 ohm potentiometer.

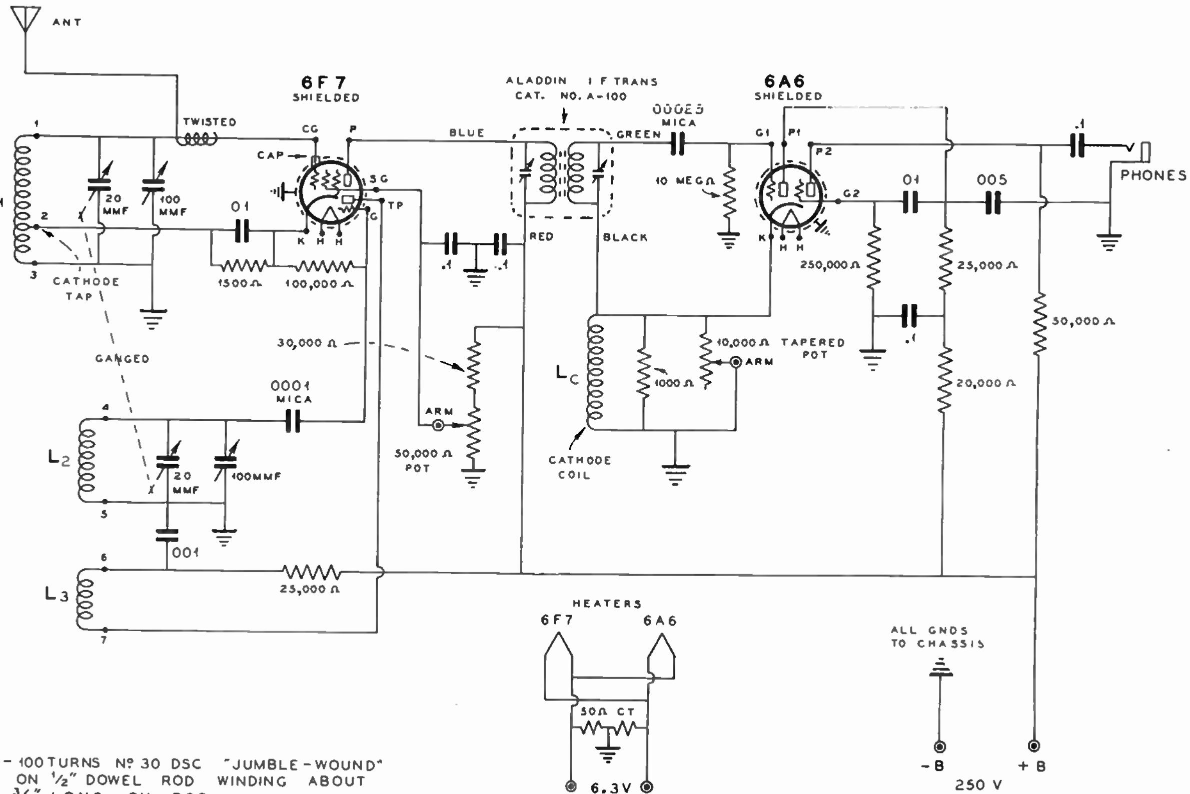
The 6A6 tube has two high-mu triode sections in a single envelope. One of these sections is connected in a grid-leak detector circuit, the other is in a resistance coupled audio circuit. The 6A6 detector plate voltage is reduced to the proper value through two resistors connected in series; the junction point of the two resistors is then bypassed to ground through a 0.1 mfd. condenser in order to prevent "motor-boating" and hum pickup from the power supply. The audio section of the 6A6 tube is connected to positive B through a 50,000 ohm resistor in order to reduce the plate voltage to a value which will be suitable for operation at zero grid bias. This also enables the phone jack to be insulated by means of a 0.1 mfd. condenser from the 250 volt plate supply.

All resistors shown in the circuit diagram should be of the one-watt size. All fixed condensers are Cornell-Dubilier 600-volt tubular paper condensers, except those marked "Mica." All ground connections should be bonded together and then connected to the rotor shafts of all variable condensers.

Single dial tuning over any amateur band is accomplished by means of two 20 mmfd. midget variable condensers, ganged together through an insulated flexible coupling, then connected with a shaft to the Crowe tuning dial, which is also insulated from the shaft by means of another flexible coupling. An aluminum shield separates the oscillator from the detector tuned circuit. This shield is a piece of No. 12 ga. aluminum, 5 in. wide x 8 in. long, with a ½ in. right-angle bend to fasten the shield to the chassis.

The detector coil is at the rear left of the chassis, the oscillator at the front right. (See photograph). The 6F7 tube (with shield can) is at the left front of the chassis. The 6A6 is at the right rear corner, covered with a large tube shield can. The I.F. transformer is directly alongside the 6A6 tube. The

JONES IMPROVED 2 TUBE SUPER GAINER



Lc – 100 TURNS Nº 30 DSC "JUMBLE-WOUND" ON ½" DOWEL ROD WINDING ABOUT ⅜" LONG ON ROD.

FIG. 12.

band-setting 100 mmfd. midget variable condensers are mounted directly on the front panel. Small indicator scales are fastened under the band-setting condenser knobs. The remaining front panel controls are variable resistors for first and second detector regeneration. The receiver is mounted in a standard 7½ in. wide, 10 in. long, 7 in. high Bud Radio Co. metal cabinet with chassis, Catalog No. 871.

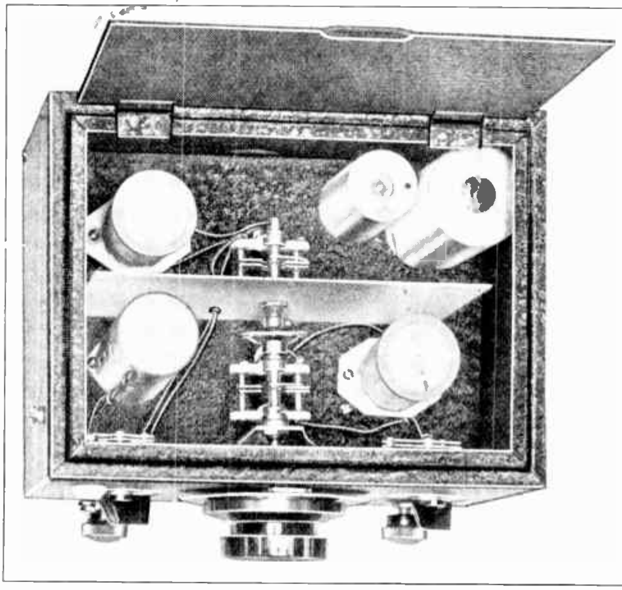


FIG. 13—Interior View of Two-Tube Super-Gainer.

The Power Supply previously shown in this Chapter is suitable for this receiver. A 6-volt storage battery and 180 to 225 volts of B battery can be substituted for the AC power supply.

The simplest method for aligning this receiver is with the aid of an all-wave test or signal oscillator. If such a device is not available, the set can be lined-up by listening to commercial or amateur signals. The I.F. transformer tuning should be adjusted to a point where the primary (plate winding) tends to pull the 6A6 detector out of oscillation. If this pulling effect is too great, the coupling between the I.F. coils should be loosened, or a few more turns added to the cathode coil Lc. The first detector regeneration control should be kept below the point of oscillation at all times. The oscillator padder condenser (100 mmf. midget variable) should be varied across its dial range until a signal is received. The detector 100 mmf. padder condenser can be varied until the signal strength is maximum. After the amateur bands are located, the particular padder condenser settings for each band should be marked on the coils for future reference. The antenna coupling should be varied by changing the number of turns of insulated wire twisted around the grid lead of 6F7 tube until the detector can be set into oscillation within range of the 50,000 ohm potentiometer. In making this adjust-

2 TUBE SUPER-GAINER COIL DATA

All Coils Wound on 1½" Diameter Forms. Detector Coils Wound on 4-Prong Forms. Oscillator Coils Wound on 5-Prong Forms.

Wavelength	L_1 Detector	L_2 Oscillator	L_3 Tickler
160 Meter	79 turns #28E. Tapped at 4 turns. Closewound.	58 turns #28E. Closewound. Grid on top end.	20 turns #28E. Closewound ⅛" from L2. Same direction as L2 with plate on far end.
80 Meter	40t #20 DSC., Spaced to cover 1¾". Tap at 2 turns.	33t #20 DSC., Spaced to cover 1¾".	10t #28 DSC. Closewound 1/16" from L2.
40 Meter	12t #20 DSC., Spaced to cover 1½". Tap at 1½ turn.	11t #20 DSC., Spaced to cover 1¼".	7t #24 E. Closewound. Spaced ⅛" from L2.
20 Meter	7t #20 DSC., Spaced to cover 1⅛". Tapped at one turn.	7t #20 DSC., Spaced to cover 1⅛".	4t #20 DSC. Closewound. Spaced ⅛" from L2.
10 Meter	3½t #20 DSC., Spaced to cover 1". Tap at ⅓ turn.	3½t #20 DSC., Spaced to cover 1".	3t #20 DSC., ⅛" from L2 and 1/16" between turns.

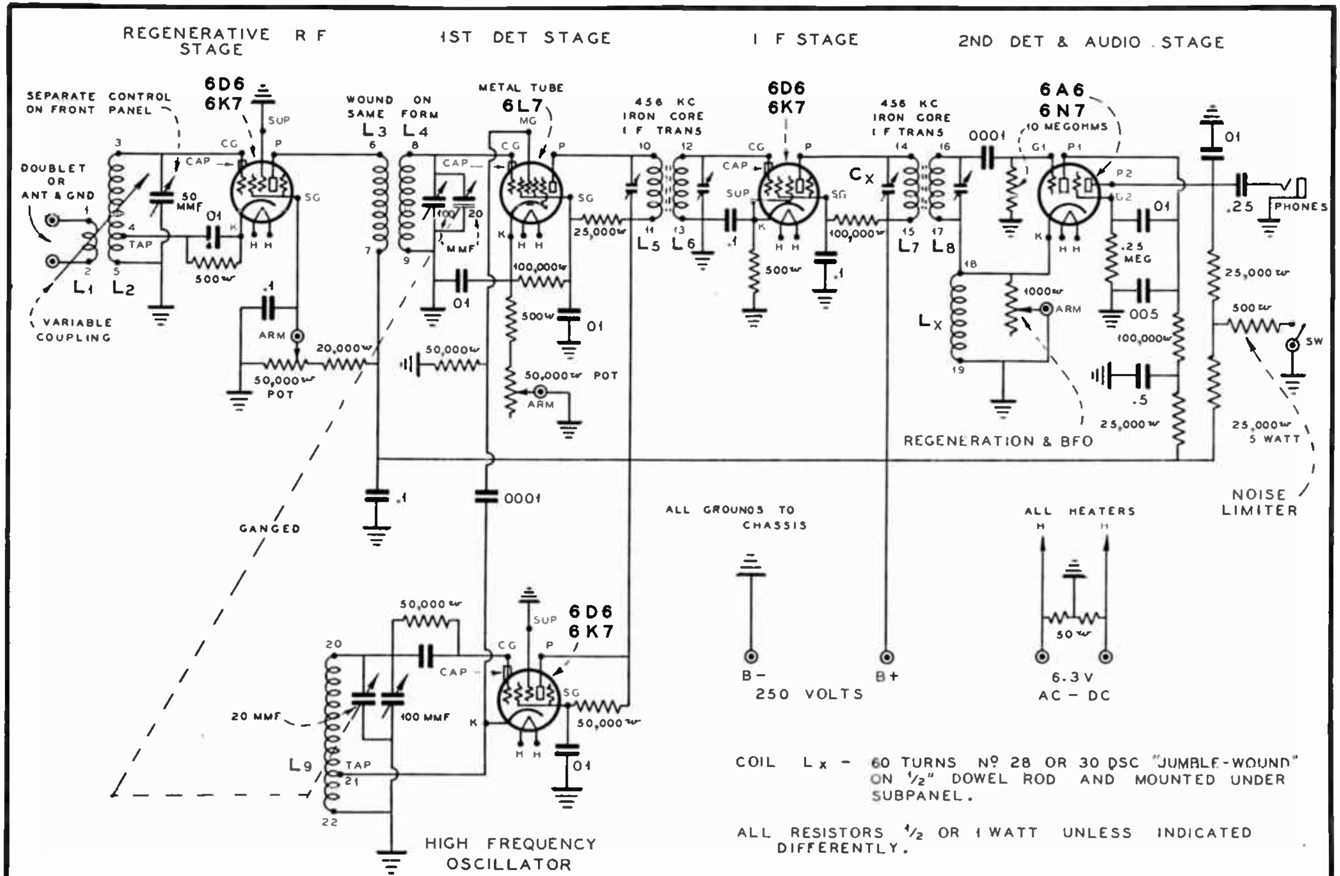


FIG. 16—Jones Ultra-Gainer with Noise Limiter, but without Crystal Filter.

ment, the detector band-setting condenser must be set in the exact position for maximum signal strength. The circuit diagram shows how the antenna lead-in is wrapped around the grid lead of the 6F7 tube, but the photograph shows this connection brought through the cabinet by means of a small push-thru insulator, in order to simplify mechanical design. *Note*: Oscillation in the 6F7 triode circuit can be checked by connecting a 0-250 volt voltmeter between ground and the point marked 6 in the circuit diagram. A temporary short-circuit across the plates of the oscillator tuning condenser should produce a change in the voltmeter reading. This simple test is useful in adjusting the tickler turns and coupling for any coil range.

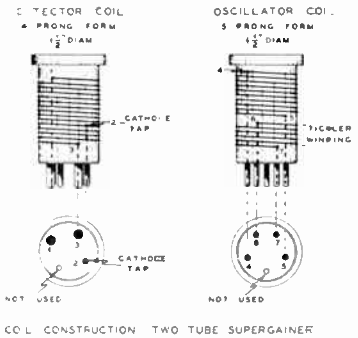


FIG. 14—Coil Construction. Both windings must be in the same direction.

The Ultra-Gainer Receiver

● This receiver is a de-luxe version of the *Two-Tube Super-Gainer.* Its performance is comparable with that of other receiver having twice as many tubes. It is more sensitive than commercial receivers because it has a regenerative RF amplifier stage and variable antenna coupling. This design gives unusual sensitivity for 10 and 20 meter operation. The sensitivity is much greater than that of the smaller Super-Gainer receivers, and it works as well on phone as for cw. The cost of the parts, except for the power supply, is less than $35.00, including 5 metal tubes, 15 plug-in coils, cabinet and an excellent Crowe Vernier Tuning Dial.

The circuit and mechanical construction permits for the addition of a crystal filter at a future date. Either glass or metal tubes are suitable, with the exception of the 6L7 first detector for which there is no glass tube equivalent. The 6N7 metal tube is similar to the 6A6 and the 6K7s are similar to 6D6 tubes. An optional *noise limiting circuit* in the output holds the amplitude of ignition or static noise impulses to the level of a moderate signal. This simple noise limiter enables one to copy a weak signal thru a barrage of auto ignition or other form of static. A switch cuts the noise limiter in or out at will.

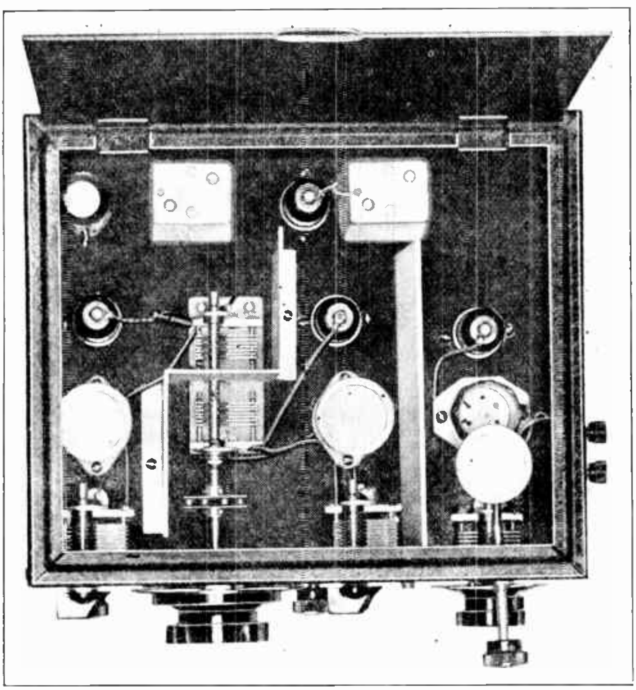


FIG. 15—Interior View of Ultra-Gainer.

Technical Notes

● Five tubes comprise the line-up in a superheterodyne circuit. Metal tubes require less space than glass tubes and they are self shielded. A regenerative RF stage adds greatly to the sensitivity and practically eliminates image interference. Variable antenna coupling, controlled by a rod thru the front panel, makes best use of regeneration for any kind of antenna in any location. Regeneration on 10 and 20, or even 40 meters, greatly improves the sensitivity of very weak signals, because regeneration is properly controlled in this receiver. Variation of screen-grid voltage provides an additional control of regeneration.

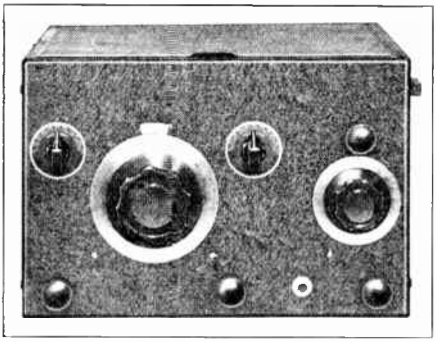
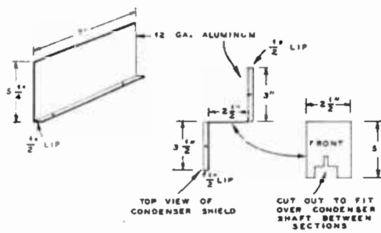


FIG. 17.
Front View of Ultra-Gainer. The controls for the RF stage are at the far right.

The first detector employs a 6L7 mixer tube in a conventional circuit, except for the cathode volume control. The receiver volume control is placed in this part of the receiver rather than in the I.F. stage, because any variation in the latter would have a slight effect on the beat. An electron-coupled high-frequency oscillator supplies a mixing voltage 456 KC higher in frequency than the desired signal. Coupling to the detector is between the mixing grid of the 6L7 and the 6K7 oscillator cathode. This system eliminates harmonics from the oscillator and provides good tuning isolation between the detector and oscillator circuits. There is practically no inter-lock effect, even on 10 meters, and thus the detector band-setting condenser can be properly set without losing the signal due to oscillator de-tuning.

A single I.F. stage provides more than ample gain and sufficient selectivity. Two Aladdin air-tuned iron-core 456 KC I.F. transformers provide very good selectivity. The I.F. stage has a slight tendency to oscillate, due to very high gain, but this difficulty occurs only at full gain setting when the I.F. coils are exactly peaked. The last coil must be tuned 1-KC off resonance in order to obtain a 1000 cycle beat note on cw. Fixed cathode and screen voltages insure a constant plate impedance across the second I.F. transformer and good stability can be had in the second detector circuit, which must oscillate for cw reception. This characteristic is of more importance when a crystal filter is added between the 6L7 and 6K7 tubes, since the selectivity would be greater and exact setting of the B.F.O. would be necessary.

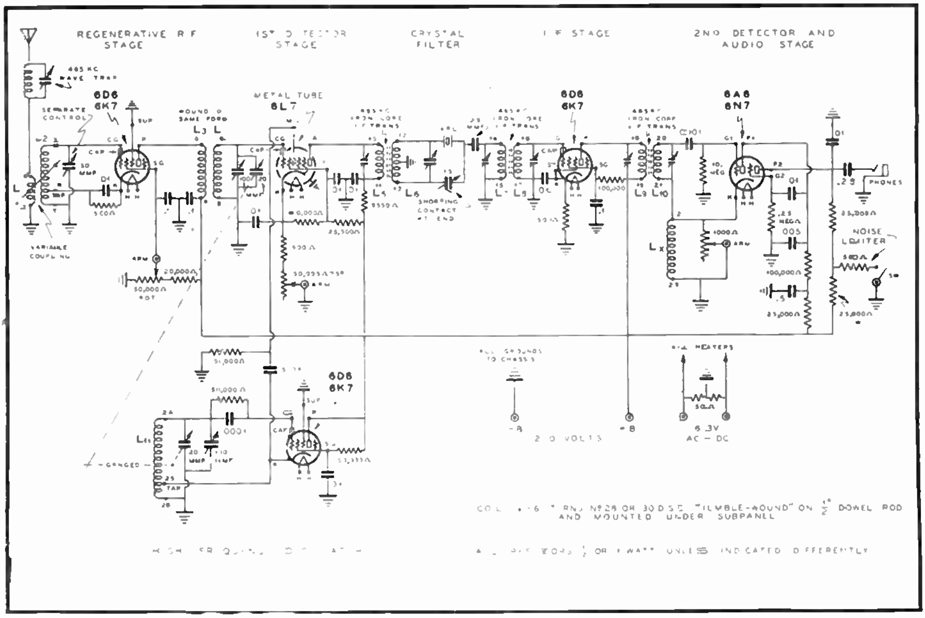
The second detector and audio amplifier is a 6N7, which is similar to the 6A6. It serves as a regenerative detector which gives a high degree of selectivity and sensitivity to the I.F. system, as a B.F. Oscillator on cw reception, and also as an audio amplifier. The audio amplifier section is resistance-coupled to the detector, and it also has



The above drawing will aid the constructor in properly cutting and forming the shield partitions.

resistance coupling to the telephone receiver jack. This isolates the telephone receivers from high DC voltage and prevents DC current from flowing thru the windings. Resistance-coupling provides a simple and inexpensive form of noise limiter in the audio amplifier. When the switch is closed, connecting the 500 ohm resistor from the mid-point of the A.F. resistors to ground, the plate voltage on the audio section of the 6N7 is reduced to less than 5 volts, which limits the audio output to a very comfortable level in the telephone receivers. A strong burst of static can only be amplified as much as the desired signal itself, since the tube operates on the upper saturated portion of its characteristic curve. With the switch (located at the rear of the set) open, normal plate voltage is applied and strong signals and bursts of static are amplified to such an extent as to rattle the diaphragms of the headset.

A cathode coil is in the 6N7 detector section in order to provide inductive reactance, just as in an electron-coupled oscillator. The detector plate circuit is by-passed to ground with a .005 mfd. condenser and therefore the I.F. frequency does not pass into the audio amplifier. The amount of regeneration or oscillation is controlled by a 1000 ohm variable resistor connected across the cathode coil. Grid-leak detection, with a very high value of grid-leak, provides a smooth control of oscillation. A lower value causes



Wave Trap, Aladdin No. R 4563. Crystal Input Transformer, Aladdin No. G.A. 100-C. I.F. Transformers, Aladdin No. G.A. 101-A.

FIG. 18—Jones Ultra-Gainer with Noise Limiter and Crystal Filter.

the regeneration control setting to differ for the point at which oscillation starts, and at which it stops, when rotation is reversed. Such a high grid-leak resistance produces an audio howl when regeneration is excessive (far beyond the point of oscillation for normal cw reception).

The plug-in coils are designed to give good results on the amateur bands. Wide band-spread is made possible without complication, and coil losses can be made very small. Band-switching complicates a receiver for the home constructor and is not at all efficient on 10 meters.

Constructional Notes

● A metal can 12 in. long, 10 in. wide, and 8 in. high houses the receiver. The chassis is of heavy plated iron, about 18 gauge, 11¼ in. x 9¾ in. x 2 in. A rigid chassis is needed in order to prevent change of beat note, while receiving, when the receiver is moved slightly, such as when tuning or adjusting controls.

All by-pass condensers connect from the tube sockets directly to the chassis. The chassis should be plated so that it will take solder.

The main tuning condenser has a shield in the form of "Z" between the detector and oscillator sections. The condenser was originally a two-gang double-spaced midget, 35 mmfd. per section. One stator plate is removed from each section by means of a pair of long-nosed pliers. Similarly, three rotor plates are removed from each rotor section, leaving a maximum capacity of approximately 20 mmfd. per section. This provides better band-spread, still covering the 80 and 160 meter bands with correctly designed coils.

No. 12 gauge aluminum partitions shield the RF stage from the first detector, and the detector from the H.F. oscillator. The two 100 mmfd. band-setting condensers mount in their respective shielded compartments, one on either side of the main tuning dial. The latter is a *Crowe* slow-speed vernier dial, with very smooth action, which makes tuning easy. A flexible shaft coupling connects the dial to the tuning condenser.

The RF stage tuning condenser mounts directly on the front panel and is controlled by a 2¾ inch dial. A separate control on this stage simplifies construction and circuit isolation and also allows exact tuning of this stage in order to secure maximum benefit from regeneration.

The space at the right hand rear part of the chassis is reserved for a crystal filter which can be added at any time. The *Aladdin* air-tuned iron core I.F. transformers give excellent selectivity without need of two I.F. stages. They are tuned with air dielectric condensers and no drift is encountered.

If glass tubes are substituted for metal, tube shields must be placed on all stages including the 6A6 tube. The cathode coil may require an additional 25 to 50 turns for a 6A6 tube than for the 6N7. This cathode coil consists of 60 turns of No. 28

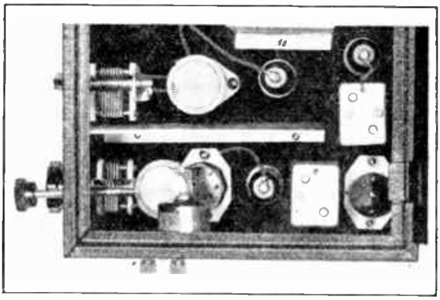


FIG. 19—Crystal Filter Stage for the Ultra-Gainer. An Aladdin Wave Trap is mounted to the side of the shield cabinet. See Fig. 18 for circuit details.

DSC wire, a ½ inch diameter, jumble or universal wound to occupy not more than ¼ inch of winding space. A small aluminum can is placed around this coil in order to prevent radiation of harmonics into the RF portion of the receiver. A little care in locating second detector leads, plus some shielding, will prevent 95 per cent of the trouble usually encountered from the B.F.O. harmonics getting into the RF front end of the receiver. These parasitics are heard as steady cw signals, and are some multiple of the intermediate frequency which sometimes hits the amateur bands in the form of harmonics. No trouble was experienced from this source in the receiver here shown.

The antenna coil has 10 turns of No. 24 DSC wire, wound on the sawed-off portion of one of the RF coils. All of the RF stage coil forms are cut down one inch, which brings the coil winding to within about 1/16-inch from the top edge or rim. The antenna coil is fastened to a 3¾-inch piece of ¼-inch diameter brass rod which slides in and out through the front panel. A telephone jack provides a bearing and the jack spring holds the brass rod in any desired position. Coupling to the RF coil is varied by pulling the rod in or out by means of a knob, so that the antenna coil slides over the RF coil. Pulling the rod far out clears

Ultra-Gainer Coil Chart

Meters	H. F. Osc. Coil	Detector Grid Coil	R. F. Plate Winding on Det. Coil	R. F. Grid Coil
10	3½ turns No. 18 DSC. 1-in. long (winding length). Tap at 1 turn.	3½ turns No. 18 DSC. 1-in. long.	3 turns No. 32 DSC. interwound (+B at bottom). Ground of Detector grid coil at bottom also.	5 turns No. 18 DSC. 1-in. long tap at ¼ turn.
20	6 turns No. 18 DSC. 1-in. long, tap at 1½ turns.	6 turns No. 18 DSC. 1-in. long.	4t No. 32 DSC. interwound with Detector grid coil.	10 turns No. 18 DSC. 1-in. long, tap at ¼ turn.
40	11 turns No. 24 DSC. 1½-in. long. Tap at 3 turns.	12 turns No. 24 DSC. 1⅜-in. long.	8 turns No. 32 DSC. interwound with Detector grid coil.	18 turns No. 18 DSC. 1-in. long, Tap at 1/3 turn.
80	32 turns No. 24 DSC. 1¾-in. long. Tap at 10 turns.	38 turns No. 24 DSC. 1¾-in. long.	16 turns No. 32 DSC. interwound with Detector grid coil.	40 turns No. 24 DSC. Closewound. Tap at ½ turn.
160	53 turns No. 24 Enam. Closewound. Tap at 15 turns.	80 turns No. 24 Enameled. Closewound.	25 turns No. 32 DSC. Closewound over lower end of Detector grid coil over a layer of celluloid for insulation.	70 turns No. 28 Enam. Closewound. Tap at ¾ turn.

the RF coil and allows the coil to be changed, as well as giving very loose coupling. Flexible leads from the sliding coil are connected to antenna and ground posts mounted on the side of the cabinet.

A four-prong wafer socket is mounted on the rear of the cabinet for cable connection to an external power supply.

The RF coils should have the grid end of the coil *toward the coil socket* in order to prevent capacity coupling to the grid from the antenna coil.

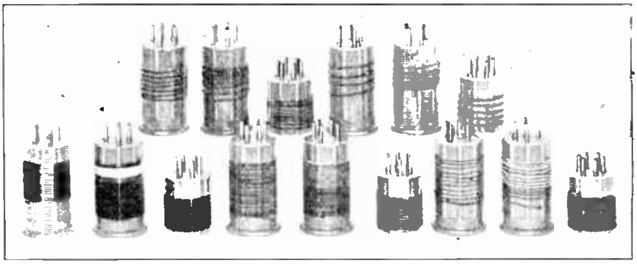


Fig. 19A—Complete Set of Coils, 10 to 150 Meters, for the Ultra-Gainer.

Operating and Line-Up Notes

● An all wave test oscillator or signal generator is needed for proper alignment of the receiver. The I.F. transformers should be tuned to approximately 456 KC by coupling into the I.F. tube grid, then into the 6L7 grid with a 456 KC signal. The second detector should go into oscillation smoothly as the 1000 ohm variable resistor is rotated toward maximum resistance. The I.F. tuning can be adjusted so the detector breaks into oscillation easily by tuning it very slightly to one side of maximum sensitivity. With the 6L7 gain control full on, i.e., no resistance, tube hiss should be audible due to high gain in the I.F. stage. The hiss level is very low unless the detector is oscillating, in which case it is about equal to that caused by any B.F.O. for cw reception.

Too few cathode coil turns will not allow the 6N7 tube to oscillate. Too many turns will not allow smooth control of regeneration, besides causing a noticeable detuning effect as the regeneration control is varied when adjusting the I.F. transformers.

The detector and H.F. oscillator coils can next be checked by means of the test oscillator. This is not a difficult problem if the test oscillator is calibrated in frequency. The coil turns can be spaced or pushed together slightly in order to give good tracking over the narrow limits of each amateur band. The band setting condenser readings should be marked on each coil for its proper setting, once each amateur band is located. In some cases, two such readings are obtained on the oscillator dial, the lower capacity value being the correct one for tracking. The H.F. oscillator should always oscillate 456 KC higher in frequency than the frequency to which the RF and detector circuits are tuned.

The RF stage should be operated with regeneration below the oscillating point. Proper adjustment of the RF tuning, antenna coupling, and regeneration control are easily determined because the static or noise level picked-up by the antenna will be at a relatively high value at resonance. The signals will also be amplified several fold at the proper adjustment. Generally, the antenna and RF regeneration controls need little adjustment once they are set for any one band. Only the large vernier dial is rotated when tuning over a narrow band.

The 6L7 volume control should always be adjusted for each signal, because too strong a cw signal will tend to prevent beat note reception: the second detector is adjusted for weak signal reception at all times. Oscillation or lack of it in the H.F. oscillator can be checked by touching the grid of the 6K7 oscillator with a finger while reading the screen-grid voltage on a voltmeter RF stage oscillation can be checked in the same manner, although tests by ear on the output of the receiver will give an indication of all these factors if one is familiar with short wave receiver adjustment.

The Curnutt DeLuxe Superheterodyne

● Only the experienced amateur or set-builder is advised to attempt the construction of the elaborate superheterodyne here described. The original model was built by Mr. T. Curnutt, W6BAY. Its performance is outstanding. The circuit is conventional and incorporates all of the best features of superheterodyne design. It has a regenerative tuned RF stage, crystal filter, noise silencer and the tubes are of the latest metal types.

The particular points of interest are its mechanical details. The high-frequency portion is housed in an individual heavy aluminum container which can be removed from the chassis of the receiver by merely disconnecting a wiring terminal strip and a few machine screws and nuts that hold the unit in place. Various photographs of this unit are shown, and from these the interested constructor can get a clear picture of the mechanical design.

The individual high-frequency unit contains the regenerative RF stage, the mixer, and the high-frequency oscillator. This type of construction completely isolates the "heart" of the receiver from the other components by means of perfect shielding between stages. All negative returns are carried to a common ground bus-bar which runs along one side under the chassis. Although the rotors of all condensers are separately grounded, they are insulated from each other in order to avoid possibility of common coupling. The oscillator is mounted closest to the front panel, the mixer in the center, and the RF stage in the rear of the separate compartment. This reason for this arrangement is that back-lash could be introduced in the far-end condenser, which would be bothersome in tuning the oscillator, were it placed in the rear. Another reason is that this line-up permits the antenna to be connected to the coil at a point only one inch from where it enters the receiver, which is most advantageous for high-frequency operation.

It has not been considered good practice to place the oscillator adjacent to the front panel because of hand-capacity effects, but with the special type of construction here used the shielding is so good that there is no effect of hand-capacity no matter where the receiver is touched.

Only three connections from this unit are carried through the panel or chassis; (1) The shaft that extends through the front panel to the main tuning dial; (2) The cable to the filament and plate supply; (3) The connection to the RF trimmer condenser. The latter is mounted directly beneath the RF stage under the sub-panel and a push-through insulator equipped with a G.R. jack makes contact with a G.R. plug.

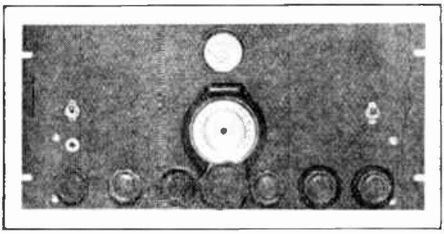
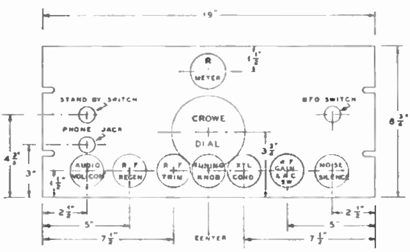


FIG. 20.
Front View of the Curnutt (W6BAY) DeLuxe Superheterodyne.



FRONT PANEL LAYOUT

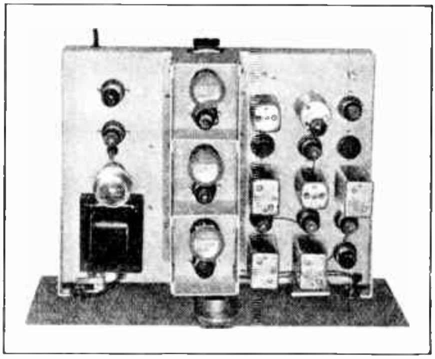


FIG. 21.
Looking into the Curnutt Superheterodyne.

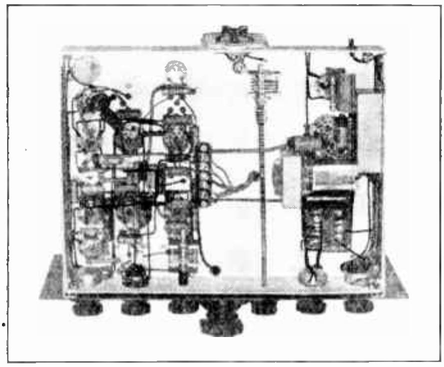


FIG. 22.
Under-chassis view showing neat arrangements of parts and circuit wiring.

All filament leads from the high-frequency unit are carried through flexible copper braid and grounded to the bus under the chassis.

Conventional plug-in coils are used for all but the 10 meter band, for which ceramic forms are used instead. Each coil has a self-contained variable air-padder condenser.

This arrangement permits permanent alignment of each stage for each set of coils and also eliminates the problem of "hunting" for the band each time the coils are changed. The oscillator coil has four prongs, the mixer 5 prongs, the RF stage 6 prongs. This leaves one unused prong on each coil. On the 20 meter coils, however, this extra prong is used to tap the tuning condenser across only a part of the coil. This arrangement provides greater bandspread. The coils for all bands other than 20 meters have a jumper-wire inside the coil form so as to connect the condenser across the entire coil.

The intermediate - fre-

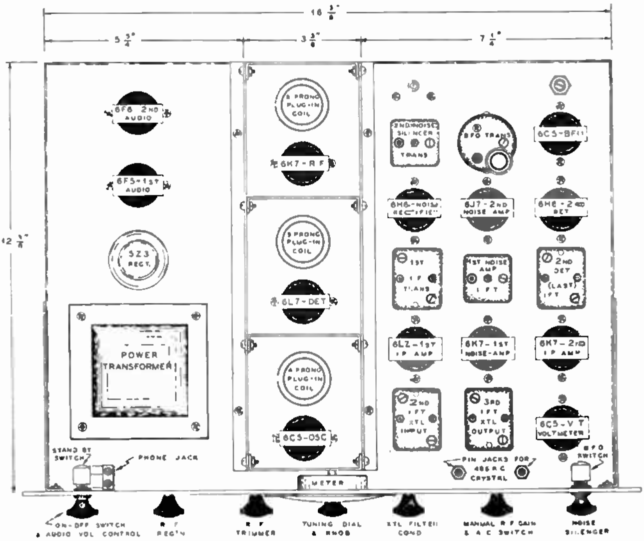
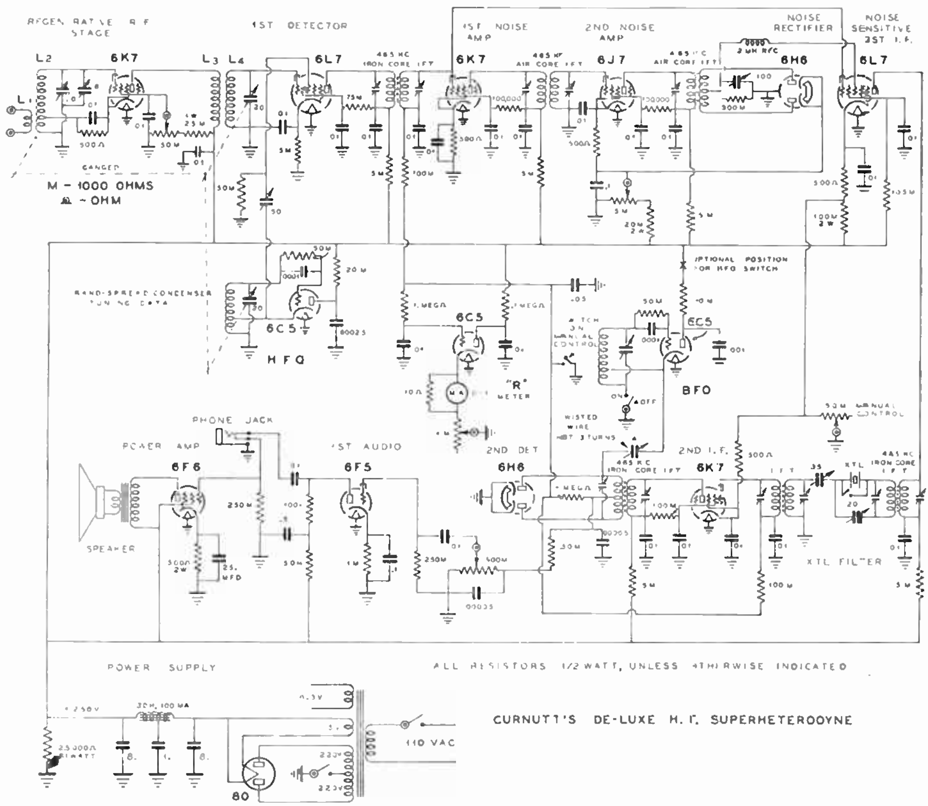


FIG. 23—Pictorial Drafting showing location of components above chassis.



I.F. Iron Core Transformers, Aladdin No. GA-101-A. Crystal Input Air Tuned I.F. Transformer, Aladdin No. G.A. 100-C.

FIG. 24.

quency amplifier has *Aladdin,* iron-core transformers, a crystal filter, noise silencer circuit and a diode detector. The noise silencer circuit is ahead of the crystal filter, where it is most effective and where it also aids in reducing some types of man-made interference.

The Jones crystal filter is incorporated in

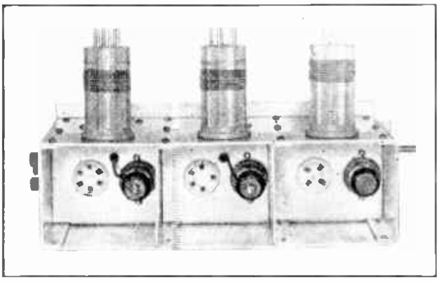


FIG. 25.

this receiver, with input and output transformer of the iron-core type. Proper adjustment of the coupling and phasing condensers will give almost any desired degree of selectivity. For fone operation, it was found that good voice intelligibility could be secured with the crystal in series-connection,

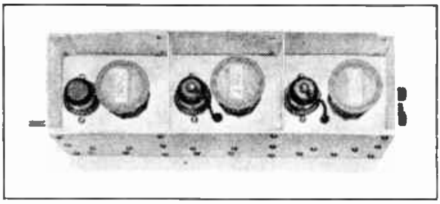


FIG. 26.

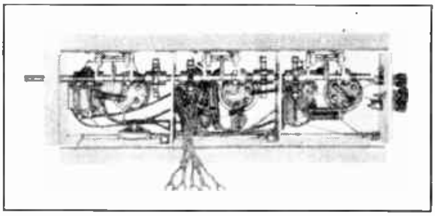


FIG. 27.

Coil Table for Curnutt's De-Luxe Superheterodyne

Band	R. F. Coil	Mixer Coil (Detector)	Oscillator Coil
160	L1 — 20 turns No. 28 Enam., close-wound. L1 — 60 turns No. 28 Enam., close-wound. Tap 2½ turns from bottom.	L3 — 20 turns No. 28 Enam., close-wound. L4 — 60 turns No. 28 Enam., close-wound.	L5—54 turns No. 28 Enam., close-wound. Tap 10 turns from bottom.
80	L1 — 10 turns No. 28 Enam. L2 — 35 turns No. 20 Enam. Tap 2½ turns from bottom.	L3 — 15 turns No. 28 Enam. L4 — 35 turns No. 20 Enam.	L5 — 35 turns No. 20 Enam., spaced one diameter. Tap 5 turns from bottom.
40	L1—6 turns No. 28 Enam. L2 — 18 turns No. 20 Enam. Tap 2 turns from bottom.	L3 — 8 turns No. 28 Enam. L4 — 18 turns No. 28 Enam.	L5 — 18 turns No. 20 Enam., spaced one diameter. Tap 6 turns from bottom.
20	L1—5 turns No. 28 DSC. L2—8¾ turns No. 16 Enam. Tap 1 turn from bottom.	L3 — 6 turns No. 28 DSC. L4—8¾ turns No. 16 Enam.	L5—8¾ turns No. 16 Enam., spaced one diameter. Band-spread Tap 5 turns from bottom. Cathode tap 1 turn from bottom.
10	L1—3 turns No. 28 DSC. L2 — 3¾ turns No. 16 Enam. Tap ½ turn from bottom.	L3 — 3 turns No. 28 DSC. L4—3¾ turns No. 16 Enam.	L5 — 3 turns No. 16 Enam. Spaced 2 diameters. Cathode tap ½ turn from bottom.

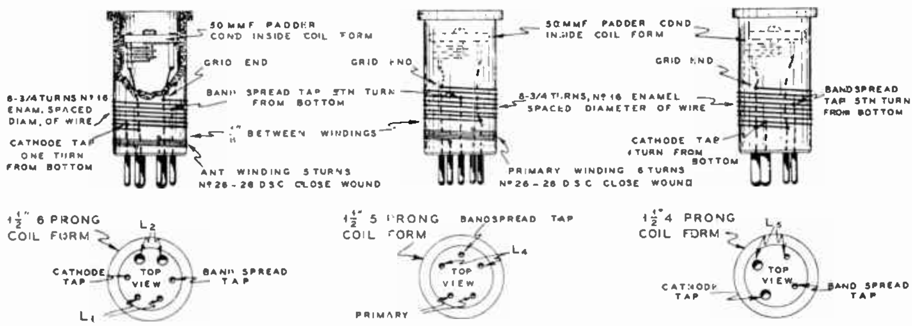


FIG. 28.

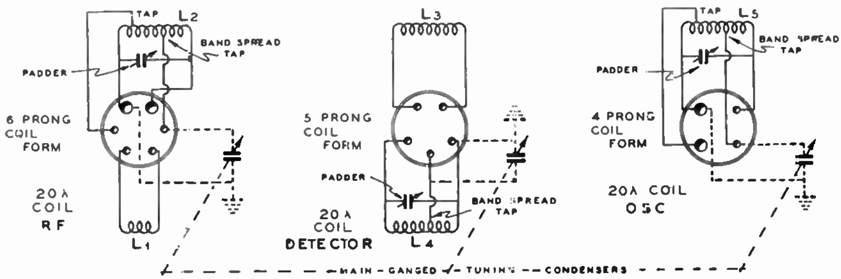
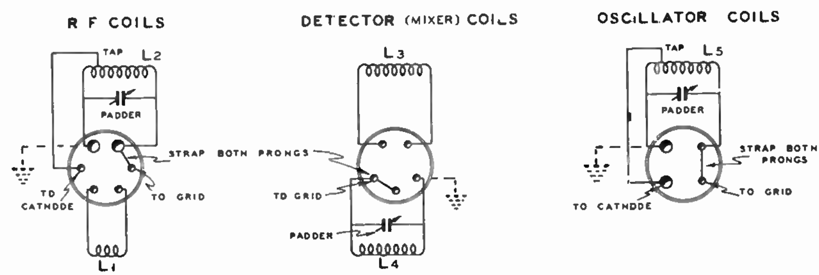


FIG. 29.



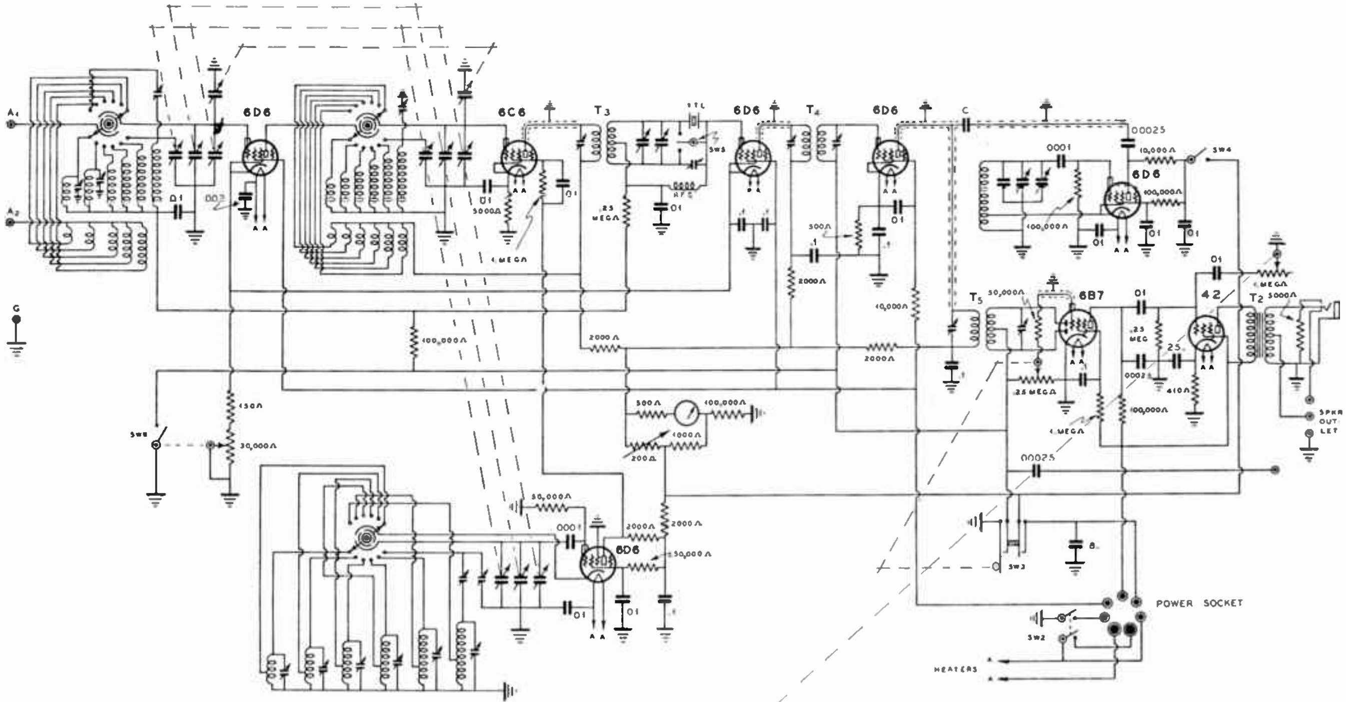
COIL CONNECTIONS FOR ALL BANDS OTHER THAN 20 METER

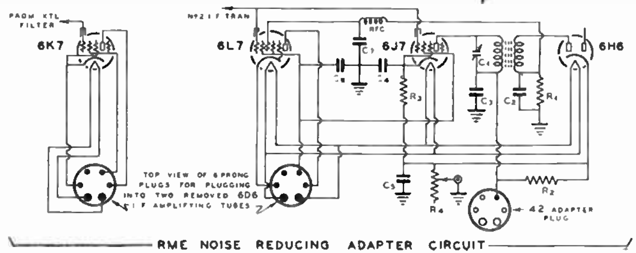
FIG. 30.

if comparatively tight coupling is used between the input and output crystal filter transformers. This gives the selectivity curve of the crystal stage a rather flat top instead of the usual sharp peak, and also eliminates the difficulty of keeping a modulated signal tuned to the peak of the crystal, which is a common source of trouble in many other receivers. When used in this manner, the crystal does not add as much selectivity to the circuit but the loss of selectivity in this stage is not a disadvantage because the four iron-core transformers give so much selectivity in the intermediate stages that the side-bands are cut appreciably even with the crystal in the *off* position. In the series position, the crystal makes an ideal combination with the noise silencer; the crystal discriminates against one type of noise, the silencer circuit against another. The result is a very marked improvement in signal-to-noise ratio.

Construction

● There is nothing complicated about the mechanical construction of the receiver. The draftings which accompany this treatise give many of the physical measurements. Heavy-gauge aluminum is used throughout,





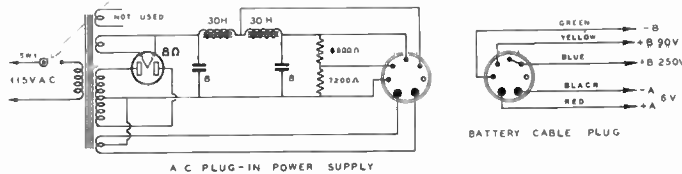


FIG. 31—RME-69 Single-Signal Superheterodyne with Noise Silencer.

the chassis being of ⅛-inch material. Any sheet-metal shop can be called upon to do the chassis cutting and bending.

Alignment

● The vacuum tube voltmeter ("R"-Meter) on the front panel serves as a simple device for aligning the receiver. The crystal is first inserted in an oscillator circuit, such as an amateur crystal oscillator in which a BCL-size plate coil is included, and then loosely coupled to the grid of the 6L7 mixer tube. The "R"-Meter will show a deflection if the intermediate frequency is in the proximity of the crystal frequency. Starting with the second detector, each stage is adjusted for maximum deflection of the meter. Repeat the process and make a double-check on the alignment. The RF stages are aligned by setting the oscillator to the desired band, plus the intermediate frequency. Then a signal is tuned-in, either from the air or from a local oscillator, and the mixer and RF stage is adjusted for maximum response on the "R"-Meter.

Super-Selective Phone Receiver

● A remarkable improvement in operating performance is accomplished in this receiver by the use of duplex I.F. circuits. In addition to super-selectivity as a result of the special band-pass I.F. circuits, it has high sensitivity on both 10- and 20-meter bands. The receiver is primarily designed for phone reception and therefore does not have a separate beat-frequency oscillator.

The receiver must be lined up by means of an all-wave test oscillator. The I.F. may be aligned by connecting the test oscillator to the first detector grid. The first detector must oscillate in actual operation and the RF stage should tune sharply when the regeneration control is well advanced. The second detector should go into oscillation smoothly. The same receiver can be used on 5-meters providing the transmitters are crystal-controlled. The set selectivity is very high due to the regeneration in the second detector.

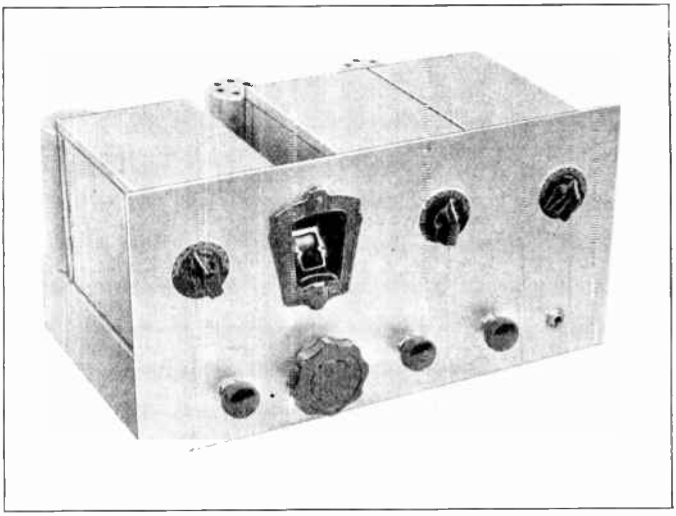


FIG. 32—Super-Selective Phone Receiver.

Technical Details

● Besides the conventionality of the circuit, emphasis is placed on the following details: The I.F. transformers are connected so as to have four tuned circuits between each stage, intercoupling being accomplished by means of three 30 mmfd. trimmer condensers set to about 5 mmfds. Air dielectric tuning condensers would be desirable in the I.F. units.

I.F. oscillation will take place with two stages of Aladdin iron-core transformers if the 6D6 tubes are operated at normal voltages. Since full gain of the two stages is not needed, a large fixed cathode resistor holds the maximum obtainable I.F. gain to a value only a little higher than can be secured with a single stage. The two stages merely serve as a coupling convenience and to compensate for the "band pass" circuit losses.

The second detector oscillator coil is made by winding 100 turns of No. 32 DSC wire on a ¼-inch diameter dowel rod. Too many turns will cause strong oscillation, and turns should therefore be removed until the second detector goes smoothly into oscillation. In the circuit diagram, this coil is shunted by a 10,000 ohm tapered potentiometer. Smoother control of regeneration can often be obtained by using a 1,000 ohm potentiometer, or by shunting the 10,000 ohm potentiometer with a 1,000 ohm fixed resistor.

If this receiver is to be used extensively for cw reception, the I.F. transformer preceding the 6A6 tube should have air-tuned padder condensers in order to minimize frequency drift in the receiver.

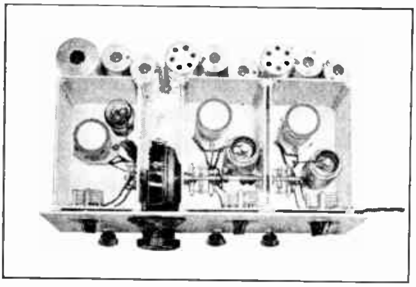


FIG. 33.
Receiver with shield compartment covers removed.

The set is built on a 14 x 9 x 2-inch plated steel chassis with an 8 x 15-inch 10-gauge aluminum front panel. The three RF shield cans are 5-inches high, 6½-inches long, and 4-inches wide in their outside dimensions, and are made of No. 12-gauge aluminum. A drum dial drives three midget condensers for band tuning. Shunt 100 mmfd. band-setting condensers are individually controlled from the front panel. The R.F. and detector tuning condensers are rated at 20 mmfd. maximum capacity and the oscillator at 15. By resorting to bending the condenser plates and by expanding or compressing the coil-turns, good track-

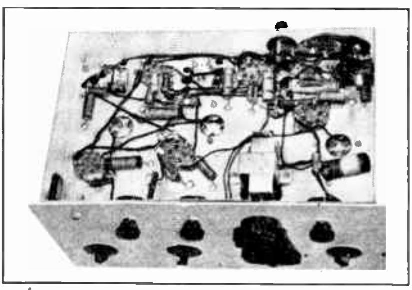


FIG. 34.
Under-chassis parts placement and wiring.

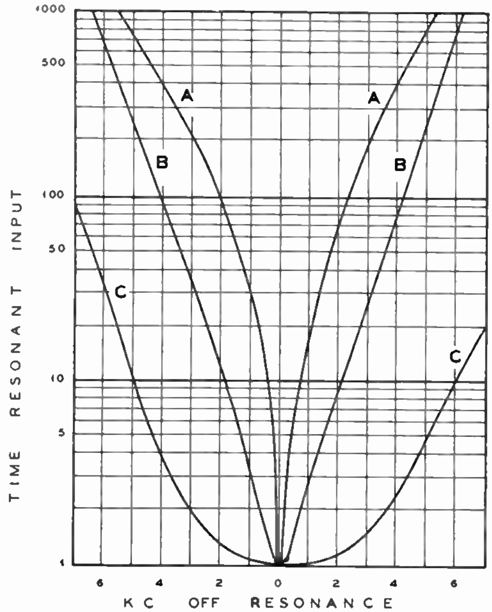
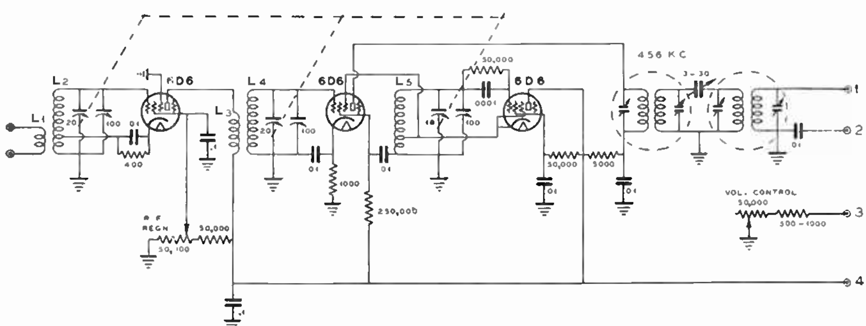


FIG. 35.
Curves A and C show the selectivity of a standard factory-made amateur superheterodyne, with and without quartz crystal filter. Curve B was made with the receiver here described.



Iron Core Transformers, Aladdin No. A-101A.

FIG. 36—Jones Super-Selective 10-20 meter phone receiver.

Coil Data for Super-Selective Phone Receiver

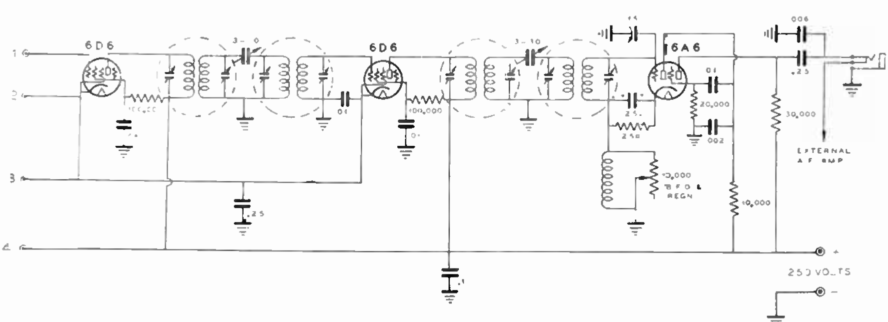
Wavelength	L_1	L_2	L_3	L_4	L_5
160 Meter	12 turns No. 32 DSC.	1¾" of No. 24 e. tapped at 1¼ turn closewound	25 turns No. 34 DSC. closewound over lower end of L_4	Same as L_2 no tap	1¼" of No. 24 e. closewound Tap at 2/5 of turns.
80 Meter	8 turns No. 32 DSC.	38 turns No. 22 DSC. 1¾" long. Tap at ¾ turn.	15 turns No. 34 DSC. interwound	Same as L_2 no tap	32 turns No. 22 DSC. 1¾" long. Tap at 10 turns.
40 Meter	6 turns No. 32 DSC.	12 turns No. 22 DSC. 1½" long. Tap at ½ turn.	8 turns No. 32 DSC. interwound	Same as L_2 no tap	11 turns No. 22 DSC. Tap at 3 turns. 1¼" long.
20 Meter	2 turns No. 22 DSC.	6 turns No. 20 DSC. 1" long. Tap at ¼ turn.	4 turns No. 32 DSC. interwound	Same as L_2 no tap	6 turns No. 20 DSC. 1" long. Tap at 1½ turns.
10 Meter	2 turns No. 22 DSC.	3½ turns No. 20 DSC. 1" long. Tap at ¼ turn.	3 turns No. 32 DSC. interwound	Same as L_2 no tap	3½ turns No. 20 DSC. 1" long. Tap at 1 turn.

ing can be obtained over the narrow amateur bands. The antenna coupling has to be capable of slight variation in order to obtain regeneration with different antennas.

A separate midget condenser with knob control out of the rear of the chassis is shunted across the second detector input. This allows oscillation frequency control for single signal effect. Regeneration or oscillation is accomplished by means of a small coil shunted by a tapered variable resistor in series with the cathode circuit. This coil consists of about 100 turns of small wire wound on a ¾th-inch diameter over a winding length of approximately one inch. Too many turns will cause strong oscillation, whereas the effect should function smoothly in a manner similar to an autodyne.

Circuit Alignment

● The I.F. system alignment is quite difficult as each circuit must be accurately peaked to about 465 KC. A test oscillator should be coupled into the individual transformers starting with the one feeding into the second detector. As each transformer is aligned, the oscillator can be capacitively coupled to the next preceding transformer until the whole system is completely lined up to the desired I.F. frequency. The R.F. circuits may be lined up with the same oscillator, providing it is of the all-wave type. When proper alignment is obtained phone signals that would ordinarily be unreadable on a conventional "sharp" super-heterodyne can be copied with ease, though the fidelity may be impaired very slightly due to attenuation of the higher frequency sidebands.



I.F. Transformers, Aladdin No. A-101A.

FIG. 37—Continuation of Fig. 36 from preceding page.

note red

Regenerative Pre-selector

● A good RF pre-selector will greatly improve the operation of any radio receiver. In nine cases out of ten, a weak dx signal can be "boosted" out of the receiver noise background and made readable, especially if the RF stage is regenerative. Unwanted image signal interference is also practically eliminated when a regenerative pre-selector is used. Thousands of receivers, commercial or homemade, of a year or two in age, can be brought up-to-date and amazing results obtained with simple pre-selector here shown.

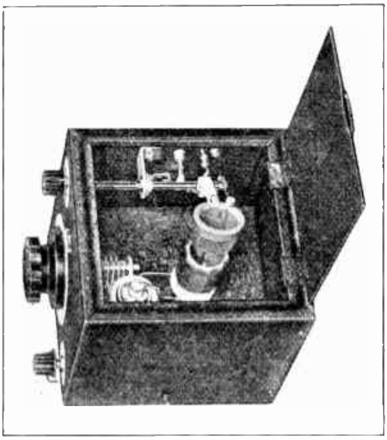


FIG. 38.
Regenerative Pre-Selector in Shield Can.

Even the most modern receivers can be improved for 10 and 20 meter reception by the use of a regenerative RF stage connected between the antenna and the receiver antenna-ground binding posts. Circuit losses are very high at 10 meters, and the input grid impedance of present day screen-grid RF tubes becomes of such a low value that little gain or selectivity is secured without regeneration. The pre-selector here shown is simple to build, costs very little, and is not difficult to operate.

Technical Notes

● This circuit consists of a 6D6 or 58 tube with cathode regeneration and screen-grid voltage control of regeneration. The grid circuit is tuned to the desired signal and a slight amount of regeneration is introduced by tapping the cathode ¼ to ¾ of a turn from the grounded end of the coil in the tuned circuit. A potentiometer varies the screen voltage from zero to approximately 100 volts, thus a smooth control of regeneration and volume is available.

A very important feature of this pre-selector is the variable antenna coupling system, which can be adjusted to suit various conditions and receiving antennas. If a strong local signal is bothersome, the antenna coupling can be loosened and regeneration brought up to a point where it will bring in the desired weak signal. Antenna resonance, which would otherwise prevent adequate use of regeneration can be taken advantage of rather than becoming a loss, by simply varying the antenna coupling. If a twisted-pair feeder is used to a noise reducing doublet antenna, the antenna coupler in the pre-selector will minimize capacity coupling and enhance inductive coupling, with a resultant balancing-out effect of noise pickup from the antenna feeders. In localities where extremely heavy static is encountered, these charges can be grounded-out by center-tapping the antenna coil to ground when using a two-wire feeder to a doublet antenna.

The plate voltage is fed through a pair of RF chokes for all-band operation. The choke nearest the plate of the tube is a special 10-meter choke, because most pie-wound RF chokes cause a dead spot near, or in, the 10 meter band. The coupling to the receiver antenna binding post is through a small fixed mica condenser. The grounds of the pre-selector and receiver should be connected together, and by twisting this lead around the pre-selector plate to receiver antenna post lead, very little external pick-up is possible, except through the pre-selector itself. The plate lead should be as short as possible, and it should be brought through the pre-selector can at the side nearest the receiver antenna input lead.

Constructional Notes

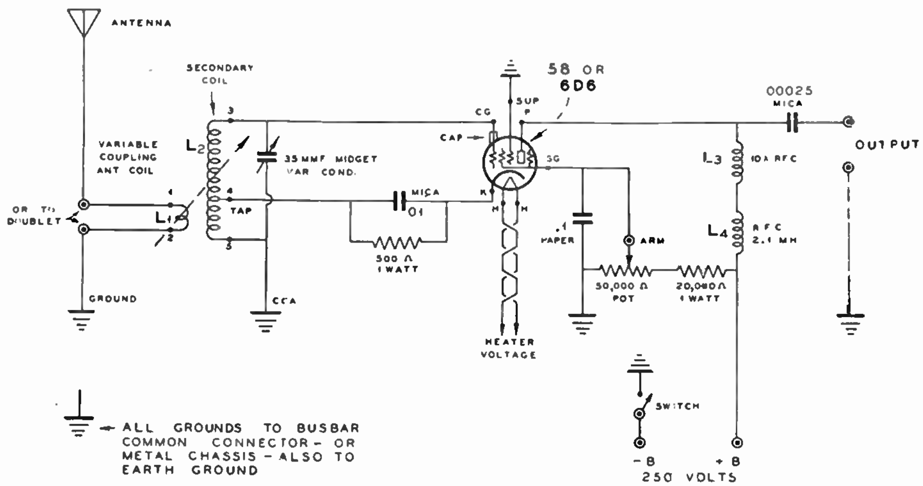
● The unit is built into a black crackle finished metal can with hinged lid. The can is 7 in. high, 7½ in. long, and 7½ in. wide and it has a chassis 1¾ in. deep. These "Bud Radio" cans are readily available from radio dealers, or they can be built by any sheet metal shop.

The 6D6 or 58 tube is shielded. The grid coils are wound on sawed-off plug-in coil forms. All the coils are sawed 1 inch from the top rim, and one of these "rings" is used for the variable coupling antenna coil by winding 10 turns of No. 18 or 20 DSC wire on the ring. Flexible leads to this coil form connect to two insulated antenna binding posts on the side of the metal can.

This antenna coil can be varied through a 45° arc by means of the knob in the upper left corner of the front panel. A small metal bracket 2 in. long has an ordinary short telephone jack mounted through it about 1½ in. from the base of the bracket. The latter mounts on the inside of the can near the antenna binding post assembly. A 6-in. piece of ¼-in. diameter bakelite rod supports the antenna coil and turns through the stiff jack bearing and ¼-in. hole in the front panel. The jack spring pressure against the rod provides sufficient friction to hold the antenna coil in any position. Additional tension could be applied at the rear of the front panel by means of a spring washer between the panel and a brass collar, if needed. This collar fastens to the shaft by ratio built into the dial drive assembly is needed because the tuning is sharp on all bands when regeneration is used. The 10-meter RF choke consists of 75 to 100 turns of No. 34 DSC wire, closewound, on a ⅜-in. diameter bakelite rod

For symmetry, the regeneration control potentiometer is mounted in the lower right hand corner of the pre-selector front panel. A 4 or 5 prong wafer socket mounted in the rear of the chassis or can serves as a cable connection to the receiver power supply. The plate voltage can be any value from 180 to 275 volts, with a current drain of less than 10 ma.

The coils are wound on 4 prong plug-in



L3 10 METER R.F CHOKE 75 TURNS No. 34 DSC ON ⅜" DOWEL ROD.

FIG. 39.

New Jones Regenerative Preselector with Variable Antenna Coupler

means of a set screw; it prevents the shaft from pulling out through the front panel. The front panel knob prevents motion in the opposite direction.

The antenna coil is fastened to this shaft by a small aluminum strip, clamped around the shaft and held in position by a 6-32 machine screw through the shaft. The other end fastens by a similar screw to the top edge of the coil form.

The RF chokes, resistors and condensers are mounted on small tie strips beneath the chassis. All ground leads are connected to one common point, or bonded to that point, including the lead from the rotor of the tuning condenser. A 35 mmfd. midget variable condenser will completely cover any of the amateur bands with the specified coils. A smooth action vernier tuning dial, such as shown in the photograph, with a reduction coil forms. The grid end is at the bottom, and the ground end at the *top*. This method of winding minimizes antenna capacity coupling to the grid of the RF tube. The cathode tap on each coil is also near the sawed-off edge (top). For 160 meters, the coil consists of 80 turns of No. 30 enameled wire, closewound, with a tap ¾ of a turn from the ground end. For 80 meters, the coil consists of 40 turns of No. 24 DSC wire, closewound, with a tap at ½ turn. For 40 meters, the winding has 23 turns of No. 18 DSC, closewound, with a tap at ⅓ to ½ turn. For 20 meters, the coil has 12 turns of No. 18 DSC, space-wound to cover 1¼-in. of winding length, with a cathode tap at ¼ turn. For 10 meters, the winding has 5 turns of No. 18 DSC wire, space-wound to cover 1 inch, with the cathode tap at ¼ turn. The grid end of each connects through the iso-

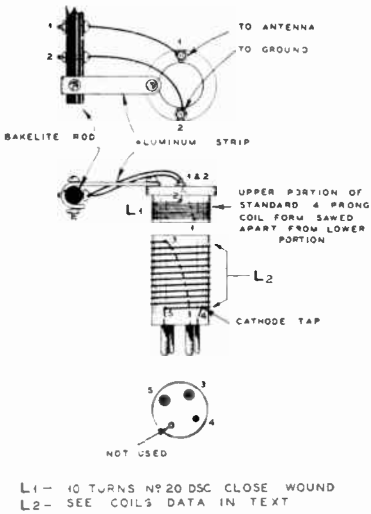


FIG. 40.

Coil Construction for Regenerative Pre-Selector and constructional details for Antenna Coupler. The grid end of coil L2 is at the bottom; the ground is at the TOP.

lantite coil socket to the *stator* of the tuning condenser.

Operating Notes

● With loose antenna coupling, the RF pre-selector should oscillate when the regeneration control is turned toward the higher screen voltage. This can be detected in the receiver as a carrier signal or squeal as the pre-selector is tuned across the receiver frequency. Closer antenna coupling, plus a lower setting of the regeneration control, will bring the pre-selector tube out of oscillation and into a state of regeneration. The tuning is quite sharp at the point of highest regeneration without oscillation, and the signal is greatly increased in strength.

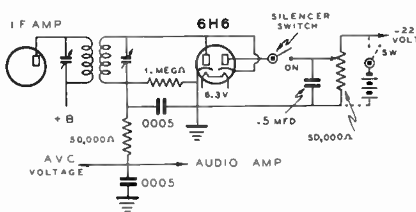
The location of the cathode tap on the coil depends to a certain extent upon the antenna coupling system used in the receiver itself. Slight modifications in the location of the cathode tap may sometimes be necessary. All forms of antenna coupling in the various receivers tested with this pre-selector have proven satisfactory because a great deal of lee-way is possible when there is good control of regeneration. In general, tight antenna coupling in the receiver will allow more gain to be realized from the pre-selector stage. Usually a few additional antenna coil turns, or greater capacity in the antenna condenser can be added if the utmost in performance is desired from any particular receiver. Closer coupling to the receiver first tuned circuit provides greater plate impedance load for the pre-selector tube, resulting in more gain.

When this pre-selector was connected ahead of the two-tube Super-Gainer described elsewhere in these pages, the signal strength increased from 2 to 4 "R" points when weak stations were tuned-in. This pre-selector can be connected ahead of any short-wave superheterodyne receiver or even a T. R. F. or autodyne regenerative detector receiver. The increase in signal strength is even more pronounced when receiving phone signals, especially in the 10 and 20 meter bands.

Watzel Noise-Reducing System

● A new noise reducer or "silencer" has recently been developed by C. E. Watzel and described in "*All-Wave Radio*" magazine. It functions as effectively as *Lamb's* silencer, yet it is less complicated. The circuit requires an additional diode tube if the receiver already uses a diode detector. The extra diode is connected across the detector. When the noise (or signal voltage) is above the bucking value on this diode, it acts as a short-circuiting resistance of about 2,000 ohms across the detector input. The bucking voltage can be adjusted so that the desired signal does not cut out, then the noise components which are greater in amplitude will block or dampen-out the detector. If these impulses of noise are of extremely short duration, such as automobile ignition noise, the time interval over which the detector is inoperative is so short that the human ear does not detect the interruption in the desired signal.

The negative voltage of 20 or 30 volts can



THE NEW C. E. WATZEL NOISE-REDUCING CIRCUIT FOR RECEIVERS

be obtained from a 22½-volt C battery, or from the voltage drop across a 500 ohm resistor in the negative B lead of most receivers. The 50,000 ohm potentiometer should be adjusted for each signal in order to secure best results in extremely noisy locations. The circuit is very simple, and easy to get into operation. Two separate diode tubes or a 6H6 double-diode can be used in the circuit.

Chapter 7

RECEIVER TUBES, CHARACTERISTICS, CIRCUITS AND CHARTS

RCA ALL-METAL RADIO TUBE CHARACTERISTICS CHART

TYPE	NAME	BASE	SOCKET CONNECTIONS	DIMENSIONS MAXIMUM OVERALL LENGTH x DIAMETER	CATHODE TYPE ■	RATING: FILAMENT OR HEATER VOLTS	RATING: FILAMENT OR HEATER AMPERES	RATING: PLATE MAX. VOLTS	RATING: SCREEN MAX. VOLTS	USE Values to right give operating conditions and characteristics for indicated typical use	PLATE SUPPLY VOLTS	GRID VOLTS ■	SCREEN VOLTS	SCREEN MILLI-AMP.	PLATE MILLI-AMP.	A-C PLATE RESISTANCE OHMS	MUTUAL CONDUCTANCE MICROMHOS	VOLTAGE AMPLIFICATION FACTOR	LOAD FOR STATED POWER OUTPUT OHMS	POWER OUTPUT WATTS	TYPE
6A8	PENTAGRID CONVERTER ⊡	SMALL OCTAL 8-PIN	FIG. 8A	3¼" x 1 5/16"	HEATER	6.3	0.3	250	100	CONVERTER	250	−3.0 min.	100	3.2	3.3	Anode Grid (#2): Supply**, 250 max. volts; Current, 4.0 ma. Oscillator-Grid (#1) Resistor, 50000 ohms. Conversion conductance, 500 micromhos.					6A8
6C5	DETECTOR ★ AMPLIFIER TRIODE	SMALL OCTAL 6-PIN	FIG. 6Q	2⅝" x 1 5/16"	HEATER	6.3	0.3	250	—	CLASS A AMPLIFIER	250	−8.0	—	—	8.0	10000	2000	20	—	—	6C5
										BIAS DETECTOR	250	−17.0 approx.	—	—	Plate current to be adjusted to 0.2 milliampere with no signal.						
6F5	HIGH-MU TRIODE	SMALL OCTAL 5-PIN	FIG. 5M	3¼" x 1 5/16"	HEATER	6.3	0.3	250	—	CLASS A AMPLIFIER	250	−2.0	—	—	0.9	66000	1500	100	—	—	6F5
6F6	POWER AMPLIFIER PENTODE	SMALL OCTAL 7-PIN	FIG. 7S	3¼" x 1 5/16"	HEATER	6.3	0.7	315	315	CLASS A AMPLIFIER	250	−16.5	250	6.5	34.0	80000	2500	200	7000	3.0	6F6
								375	250	PUSH-PULL CLASS AB, AMPLIFIER	375	−26.0	250	—	Power output value is for 2 tubes at indicated plate-to-plate load.				10000	19.0	
6J7	TRIPLE-GRID DETECTOR AMPLIFIER	SMALL OCTAL 7-PIN	FIG. 7R	3¼" x 1 5/16"	HEATER	6.3	0.3	250	125	SCREEN-GRID R-F AMPLIFIER	250	−3.0	100	0.5	2.0	exceeds 1.5 meg.	1225	exceeds 1500	—	—	6J7
										BIAS DETECTOR	250	−4.3	100	Cathode current 0.43 ma.		—	Plate coupling resistor 500000 ohms. **Grid coupling resistor 250000 ohms.				
6K7	TRIPLE-GRID SUPER-CONTROL AMPLIFIER	SMALL OCTAL 7-PIN	FIG. 7R	3¼" x 1 5/16"	HEATER	6.3	0.3	250	125	SCREEN-GRID R-F AMPLIFIER	250	−3.0 min.	125	2.6	10.5	600000	1650	990	—	—	6K7
										MIXER IN SUPERHETERODYNE	250	−10.0	100	—	—	Oscillator peak volts = 7.0					
6L6	BEAM POWER AMPLIFIER	SMALL OCTAL 7-PIN	FIG. 7AC	4 5/16" x 1⅝"	HEATER	6.3	0.9	375	250	SINGLE-TUBE CLASS A, AMPLIFIER	300	−12.5	200	2.5	48.0	—	—	—	4500	6.5	6L6
								400	300	PUSH-PULL CLASS AB, AMPLIFIER	400	−25	300	—	Power output value is for 2 tubes at indicated plate-to-plate load.				6600	34.0	
								400	300	PUSH-PULL CLASS AB, AMPLIFIER	400	−25	300	—	Power output value is for 2 tubes at indicated plate-to-plate load.				3800	60.0	
6L7	PENTAGRID MIXER ▲ AMPLIFIER	SMALL OCTAL 7-PIN	FIG. 7T	3¼" x 1 5/16"	HEATER	6.3	0.3	250	150	MIXER IN SUPERHETERODYNE	250	−3.0	100	6.2	2.4	Oscillator Grid (#3) bias, −10 volts. Grid #3 peak swing, 12 volts min. Conversion conductance, 350 micromhos.					6L7
										CLASS A AMPLIFIER ◀	250	−3.0	100 max.	5.5	5.3	800000	1100	880	—	—	
6N7	TWIN-TRIODE AMPLIFIER	SMALL OCTAL 8-PIN	FIG. 8B	3¼" x 1 5/16"	HEATER	6.3	0.8	300	—	CLASS B AMPLIFIER	250 300	0 0	— —	— —	Power output value is for one tube at stated load, plate-to-plate				8000 10000	8.0 10.0	6N7
6Q7	DUPLEX-DIODE HIGH-MU TRIODE	SMALL OCTAL 7-PIN	FIG. 7V	3¼" x 1 5/16"	HEATER	6.3	0.3	250	—	TRIODE UNIT AS CLASS A AMPLIFIER	250 ■	−2.2	—	—	0.5	—	Gain per stage = 43				6Q7
6R7	DUPLEX-DIODE TRIODE	SMALL OCTAL 7-PIN	FIG. 7V	3¼" x 1 5/16"	HEATER	6.3	0.3	250	—	TRIODE UNIT AS CLASS A AMPLIFIER	250	−9	—	—	9.5	8500	1900	16	10000	0.28	6R7
25A6	POWER AMPLIFIER PENTODE	SMALL OCTAL 7-PIN	FIG. 7S	3¼" x 1 5/16"	HEATER	6.3	0.3	180	135	CLASS A AMPLIFIER	95 180	−15 −20	95 135	4.0 7.5	20.0 38.0	45000 40000	2000 2500	90 100	4500 5000	0.9 2.75	25A6
5W4	FULL-WAVE RECTIFIER	SMALL OCTAL 5-PIN	FIG. 5T	3¼" x 1 5/16"	FILAMENT	5.0	1.5	—	—	FULL-WAVE RECTIFIER	Maximum A-C Voltage per Plate ...... 350 Volts, RMS Maximum D-C Output Current ..... 110 Milliamperes										5W4
5Z4	FULL-WAVE RECTIFIER	SMALL OCTAL 5-PIN	FIG. 5L	3¼" x 1 5/16"	HEATER	5.0	2.0	—	—	FULL-WAVE RECTIFIER	Maximum A-C Voltage per Plate ..... 400 Volts, RMS Maximum D-C Output Current ..... 125 Milliamperes										5Z4
6H6	TWIN DIODE	SMALL OCTAL 7-PIN	FIG. 7Q	1⅝" x 1 5/16"	HEATER	6.3	0.3	—	—	TWIN-DIODE DETECTOR RECTIFIER	Maximum A-C Voltage per Plate .... 100 Volts, RMS Maximum D-C Output Current .... 4 Milliamperes										6H6
6X5	FULL-WAVE RECTIFIER	SMALL OCTAL 6-PIN	FIG. 6S	3¼" x 1 5/16"	HEATER	6.3	0.6	—	—	FULL-WAVE RECTIFIER	Maximum A-C Voltage per Plate .... 350 Volts, RMS Maximum D-C Output Current .... 75 Milliamperes										6X5
25Z6	RECTIFIER-DOUBLER	SMALL OCTAL 7-PIN	FIG. 7Q	3¼" x 1 5/16"	HEATER	25.0	0.3	—	—	VOLTAGE DOUBLER	Maximum A-C Voltage per Plate .... 125 Volts, RMS Maximum D-C Output Current .... 100 Milliamperes										25Z6
										HALF-WAVE RECTIFIER	Maximum A-C Voltage per Plate .... 250 Volts, RMS Maximum D-C Output Current per Plate ... 85 Milliamperes										

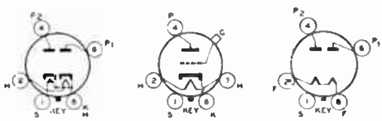
⊡ Grids #3 and #5 are screen. Grid #4 is signal-input control grid.
★ For Grid-leak Detection—plate volts 45-100.
▲ Grids #2 and #4 are screen. Grid #1 is signal-input control grid.
◀ Grid #3 connected to grid #1.
** Applied through 20000-ohm voltage-dropping resistor.
■ Applied through 200000-ohm plate-coupling resistor.
** For grid of following tube.
■ Either A.C. or D.C. may be used on heater.

● Plate voltages greater than 125 volts RMS require 100-ohm series-plate resistor.

AND ACCUMULATED STUBS

If you wish to discard daily pages singly, keep the screws holding the top plate slightly loose. The drilling of each page is slit so that a light tug at the bottom of the page will remove it.

If you wish to tear off the pages from day to day, discarding the stubs periodically, keep the top plate screws tight. When you are ready to remove the old stubs, loosen the screws, slip off the top plate and pull stubs out.



Bottom Views of Metal Tube Socket Connections

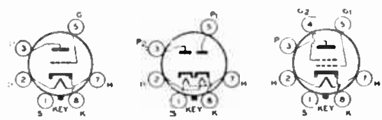


FIG. 5-L FIG. 5-M FIG. 5-T FIG. 6-Q FIG. 6-S FIG. 7-Ac

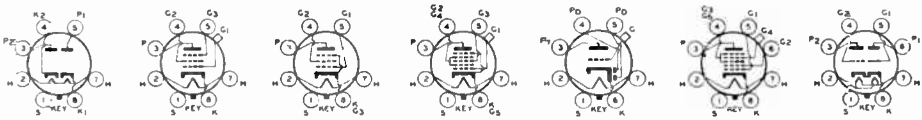


FIG. 7-Q FIG. 7-R FIG. 7-S FIG. 7-T FIG. 7-V FIG. 8-A FIG. 6-B

See Chart on Facing Page for Symbol Identifications

METAL TUBES WITH SIMILAR CHARACTERISTICS

Metal	Metal-Glass	Octal Base Glass	Glass, Standard Base
		1C7G	1C6
		1D5G	1A4
		1D7G	1A6
		1E5G	1B4
		1E7G	Twin 1F4
		1F5G	1F4
		1F7G	1F6
		1H4G	30
		1H6G	1B5/25S
		1J6G	19
		5V4G	83v
5W4		5W4G	
		5X4G	5Z3
5Z4	5Z4MG	5Y3G	80
		5Y4G	80
6A8	6A8MG	6A8G	6A7
		6B4G	6A3
		6B6G	75
		6B8G	6B7
6C5	6C5MG	6C5G	
6F5	6F5MG	6F5G	Tri. of 75
6F6	6F6MG	6F6G	42
6H6	6H6MG	6H6G	
		6J5G	76
6J7	6J7MG	6J7G	77
		6K5G	
		6K6G	41
6K7	6K7MG	6K7G	78
6L6		6L6G	
6L7	6L7MG	6L7G	
	6N6MG	6N6G	6B5
6N7	6N7MG	6N7G	6A6
6P7	6P7MG	6P7G	6F7
6Q7	6Q7MG	6Q7G	
6R7	6R7MG	6R7G	
6X5	6X5MG	6X5G	84
25A6	25A6MG	25A6G	43
25Z6	25Z6MG	25Z6G	25Z5

Electrical Equivalent Tube-Type Reference Chart

In order to avoid repetition, Tube Types shown in LEFT Column are NOT described in the Tube Data Pages, because they are similar to Tube Types shown in RIGHT Column, and which are described.

1C7G 2v. Fil.	Refer To	**1C6**
1D5G 2v. Fil.	Refer To	**1A4**
1D7G 2v. Fil.	Refer To	**1A6**
1E5G 2v. Fil.	Refer To	**1B4**
1E7G 2v. Fil.	Refer To	**Twin 1F4**
1F5G 2v. Fil.	Refer To	**1F4**
1F7G 2v. Fil.	Refer To	**1F6**
1H4G 2v. Fil.	Refer To	**30**
1H6G 2v. Fil.	Refer To	**1B6**
1J6G 2v. Fil.	Refer To	**19**
2A5 2.5v. 1.75a.	Refer To	**42**
2A6 2.5v. 0.8a.	Refer To	**75**
2A7 2.5v. 0.8a.	Refer To	**6A7**
2B7 2.5v. 0.8a.	Refer To	**6B7**
2E5 2.5v. 0.8a.	Refer To	**6E5**
2G5 2.5v. 0.8a.	Refer To	**6G5**

(Continued on Next Page)

Equivalent Tube Types—Continued

53 2.5v, 2.0a.	Refer To	**6A6**
55 2.5v, 1.0a.	Refer To	**85**
56 2.5v, 1.0a.	Refer To	**76**
57 2.5v, 1.0a.	Refer To	**6C6**
58 2.5v, 1.0a.	Refer To	**6D6**
5V4G	Refer To	**83V**
5X4G	Refer To	**5Z3**
5Y3	Refer To	**80**
5Y4G	Refer To	**80**
6A3 6.3v, 1.0a.	Refer To	**2A3**
6B4G 6.3v, 1.0a.	Refer To	**2A3**
6B6	Refer To	**75**
6B8	Refer To	**6B7**
6D8G 6.3v, 0.15a.	Refer To	**6A8**
6J5G	Refer to	**Low Capacity 6C5**
6F5	Refer To	**6Q7**
6K6G	Refer To	**41**
6L5G 6.3v, 0.15a.	Refer To	**76**
6N6	Refer To	**6B5**
6N7	Refer to	**6A6**
6P7	Refer To	**6F7**
6Q6G	Refer To	**75**

(Note: 6Q6G has single diode. 6.3v, 0.15a. heater.)

6S7G 6.3v, 0.15a.	Refer To	**6K7**
6X5	Refer To	**84**
77	Refer To	**6J7**
78	Refer To	**6K7**
25A6	Refer To	**43**
25Z6	Refer To	**25Z5**
OZ3	Refer To	**OZ4**

Replacement Tube Types

Type No.	Replaceable by	Type No.	Replaceable by	Type No.	Replaceable by
2A3H	2A3	44	39/44	224-A	24A
5Y3	5Z4	64*	36	226	26
5Z4G	5Z4	64A	36	227	27
5Z4-MG	5Z4	65*	39/44	230	30
6Z3	1-V	65A	39/44	231	31
6C5-G	6C5	67*	37	232	32
6C5-MG	6C5	67A	37	233	33
6D5-G	6D5	68*	38	234	34
6D5-MG	6D5	68A	38	235	35/51
6F5-G	6F5	83	83-V	236	36
6F5-MG	6F5	84	6Z4/84	238	38
6F6-G	6F6	95	2A5	239	39/44
6F6-MG	6F6	KR-98	6Z4/84	240	40
6H6-G	6H6	112	12A	245	45
6H6-MG	6H6	112A	12A	247	47
6J7-G	6J7	120	20	250	50
6J7-MG	6J7	171	71A	280	80
6K7-G	6K7	171A	71A	280-M	83-V
6K7-MG	6K7	171AC	71A	281	81
6L6-G	6L6	171-B	71A	288	83-V
6L7-G	6L7	182-A	71A	C-299	V-99
6L7-MG	6L7	V-199	V-99	X-299	X-99
6A8-G	6A8	X-199	X-99	482-A	71A
6A8-MG	6A8	200	200A	551	35/51
14Z3	12Z3	201	01A	585	50
1	1-V	201A	01A	586	50
RE-1	80	210	10	P-861	6Z4/84
RE-2	81	213	80	986	83
SO-2	50	216	81	AD	1-V
KR-5	6A4/LA	216-B	81	AF	82
WD-12	WX-12	220	20	AG	83
25S	1B5/25-S	222	22	LA	6A4/LA
27-HM	56	224	24A	PZ	47
				PZH	2A5

—*Courtesy RAYTHEON.*

Tube Symbols and Bottom Views of Socket Connections

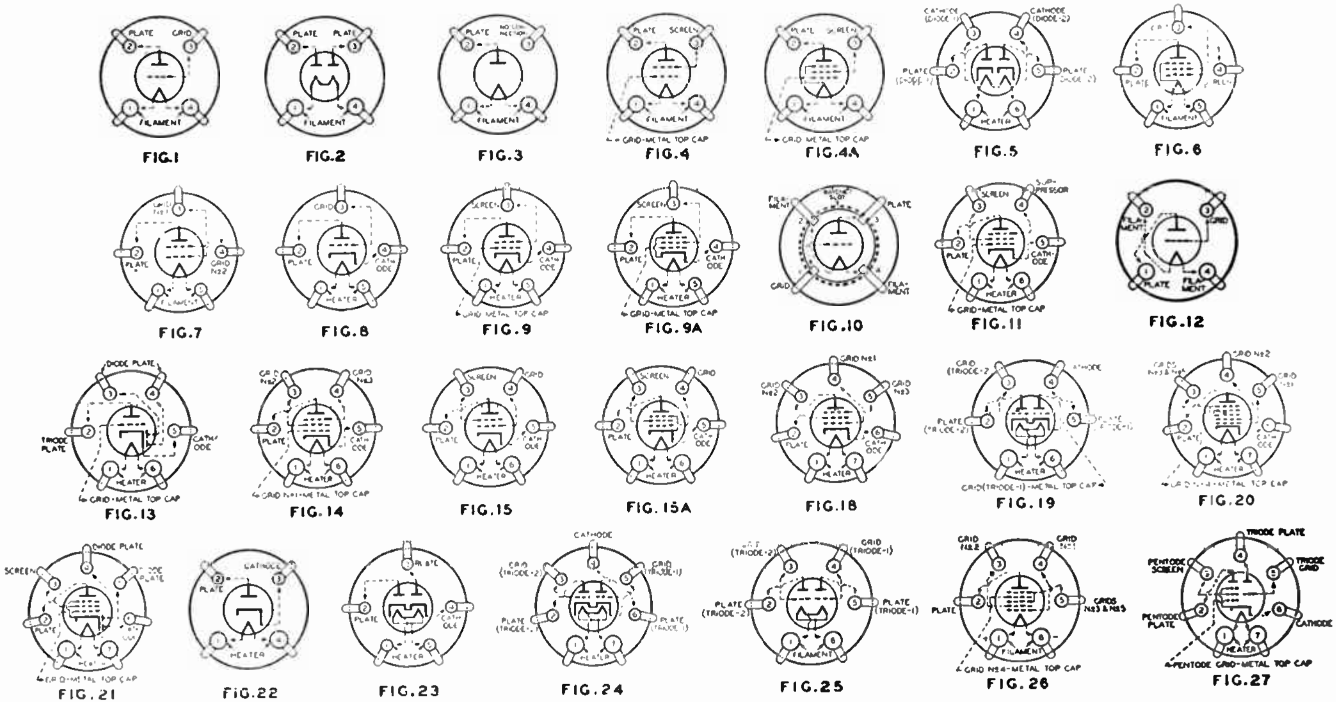


FIG.1 FIG.2 FIG.3 FIG.4 FIG.4A FIG.5 FIG.6 FIG.7 FIG.8 FIG.9 FIG.9A FIG.10 FIG.11 FIG.12 FIG.13 FIG.14 FIG.15 FIG.15A FIG.18 FIG.19 FIG.20 FIG.21 FIG.22 FIG.23 FIG.24 FIG.25 FIG.26 FIG.27

Tube Characteristics and Socket Connections courtesy RCA Cunningham Radiotron Co., Inc.

Characteristics of Glass Receiving Tubes

TYPE	NAME	BASE	SOCKET CONNECTIONS	DIMENSIONS MAXIMUM OVERALL LENGTH x DIAMETER	CATHODE TYPE ■	RATING: FILAMENT OR HEATER VOLTS	RATING: FILAMENT OR HEATER AMPERES	RATING: PLATE MAX. VOLTS	RATING: SCREEN MAX. VOLTS	USE (Values to right give operating conditions and characteristics for indicated typical use)	PLATE SUPPLY VOLTS	GRID VOLTS ■	SCREEN VOLTS	SCREEN MILLI-AMP.	PLATE MILLI-AMP.	A-C PLATE RESISTANCE OHMS	MUTUAL CONDUCTANCE MICROMHOS	VOLTAGE AMPLIFICATION FACTOR	LOAD FOR STATED POWER OUTPUT OHMS	POWER OUTPUT WATTS	TYPE
1A6	PENTAGRID CONVERTER ●	SMALL 6-PIN	FIG. 28	4 17/32" x 1 9/16"	D-C FILAMENT	2.0	0.06	180	67.5	CONVERTER	180	−3.0 min.	67.5	2.4	1.3	500000	Anode-Grid (#2) 135 max volts, 2.3 ma Oscillator Grid (#1) Resistor, 50000 ohms Conversion conductance, 300 micromhos				1A6
1C6	PENTAGRID CONVERTER ●	SMALL 6-PIN	FIG. 28	4 17/32" x 1 9/16"	D-C FILAMENT	2.0	0.12	180	67.5	CONVERTER	180	−3.0 min.	67.5	2.0	1.5	750000	Anode Grid (#2) 135 max volts, 3.3 ma Oscillator Grid (#1) Resistor, 50000 ohms Conversion conductance, 325 micromhos				1C6
2A3	POWER AMPLIFIER TRIODE	MEDIUM 4-PIN	FIG. 1	5 5/8" x 2 1/16"	FILAMENT	2.5	2.5	250	—	CLASS A AMPLIFIER	250	−45	—	—	60.0	800	5250	4.2	2500	3.5	2A3
								300	—	PUSH-PULL AMPLIFIER	300 300	−62 −62	Self-bias Fixed-bias		40.0 40.0	Power Output is for 2 tubes at stated load, plate-to-plate			5000 3000	10.0 15.0	
2A5	POWER AMPLIFIER PENTODE	MEDIUM 6-PIN	FIG. 15A	4 11/16" x 1 13/16"	HEATER	2.5	1.75	250	250	CLASS A AMPLIFIER	250	−16.5	250	6.5	34.0	100000	2200	220	7000	3.0	2A5
2A6	DUPLEX-DIODE HIGH-MU TRIODE	SMALL 6-PIN	FIG. 13	4 17/32" x 1 9/16"	HEATER	2.5	0.8	250	—	TRIODE UNIT AS CLASS A AMPLIFIER	250✖	−1.35	—	—	0.4	—	—	Gain per stage = 50-60			2A6
2A7	PENTAGRID CONVERTER ●	SMALL 7-PIN	FIG. 20	4 17/32" x 1 9/16"	HEATER	2.5	0.8	250	100	CONVERTER	250	−3.0 min.	100	2.2	3.5	360000	Anode Grid (#2) 200 max volts, 4.0 ma Oscillator Grid (#1) Resistor, 50000 ohms Conversion conductance, 520 micromhos				2A7
2B7	DUPLEX-DIODE PENTODE	SMALL 7-PIN	FIG. 21	4 17/32" x 1 9/16"	HEATER	2.5	0.8	250	125	PENTODE UNIT AS R-F AMPLIFIER	100 250	−3.0 −3.0	100 125	1.7 2.3	5.8 9.0	300000 650000	950 1125	285 730	—	—	2B7
										PENTODE UNIT AS A-F AMPLIFIER	250✝	−4.5	50		0.65	—	—	—	—	—	
6A4 also LA	POWER AMPLIFIER PENTODE	MEDIUM 5-PIN	FIG. 6	4 11/16" x 1 13/16"	FILAMENT	6.3	0.3	180	180	CLASS A AMPLIFIER	100 180	−6.5 −12.0	100 180	1.6 3.9	9.0 22.0	83250 45500	1200 2200	100 100	11000 8000	0.31 1.40	6A4 also LA
6A7	PENTAGRID CONVERTER ●	SMALL 7-PIN	FIG. 20	4 17/32" x 1 9/16"	HEATER	6.3	0.3	250	100	CONVERTER	250	−3.0 min.	100	2.2	3.5	360000	Anode Grid (#2) 200 max volts, 4.0 ma Oscillator Grid (#1) Resistor, 50000 ohms Conversion conductance, 520 micromhos				6A7
6B7	DUPLEX-DIODE PENTODE	SMALL 7-PIN	FIG. 21	4 17/32" x 1 9/16"	HEATER	6.3	0.3	250	125	PENTODE UNIT AS R-F AMPLIFIER	100 250	−3.0 −3.0	100 125	1.7 2.3	5.8 9.0	300000 650000	950 1125	285 730	—	—	6B7
										PENTODE UNIT AS A-F AMPLIFIER	250✝	−4.5	50	—	0.65	—	—	—	—	—	
6C6	TRIPLE-GRID DETECTOR AMPLIFIER	SMALL 6-PIN	FIG. 11	4 11/16" x 1 9/16"	HEATER	6.3	0.3	250	100	SCREEN GRID R-F AMPLIFIER	250	−3.0	100	0.5	2.0	exceeds 1.5 meg	1225	exceeds 1500	—	—	6C6
										BIAS DETECTOR	250	−1.95	50	Cathode current 0.65 ma.		—	Plate coupling resistor 250000 ohms. Grid coupling resistor 250000 ohms **				
6D6	TRIPLE-GRID SUPER-CONTROL AMPLIFIER	SMALL 6-PIN	FIG. 11	4 11/16" x 1 9/16"	HEATER	6.3	0.3	250	100	SCREEN GRID R-F AMPLIFIER	250	−3.0 min.	100	2.0	8.2	800000	1600	1280	—	—	6D6
										MIXER IN SUPERHETERODYNE	250	−10.0	100	—	—		Oscillator peak volts = 7.0.				
6F7	TRIODE-PENTODE	SMALL 7-PIN	FIG. 27	4 17/32" x 1 9/16"	HEATER	6.3	0.3	100	—	TRIODE UNIT AS AMPLIFIER	100	−3.0	—	—	3.5	17800	450	8	—	—	6F7
								250	100	PENTODE UNIT AS AMPLIFIER	250	−3.0 min	100	1.5	6.5	850000	1100	900	—	—	
								250	100	PENTODE UNIT AS MIXER	250	−10.0	100	0.6	2.8	Oscillator peak volts = 7.0. Conversion conductance = 300 micromhos.					
'00-A	DETECTOR TRIODE	MEDIUM 4-PIN	FIG. 1	4 11/16" x 1 13/16"	D-C FILAMENT	5.0	0.25	45	—	GRID LEAK DETECTOR	45	Grid Return to (−) Filament			1.5	30000	666	20	—	—	'00-A
01-A	DETECTOR★ AMPLIFIER	MEDIUM 4-PIN	FIG. 1	4 11/16" x 1 13/16"	D-C FILAMENT	5.0	0.25	135	—	CLASS A AMPLIFIER	90 135	−4.5 −9.0	—	—	2.5 3.0	11000 10000	725 800	8.0 8.0	—	—	01-A
10	POWER AMPLIFIER TRIODE	MEDIUM 4-PIN	FIG. 1	5 5/8" x 2 3/16"	FILAMENT	7.5	1.25	425	—	CLASS A AMPLIFIER	350 425	−31.0 −39.0	—	—	16.0 18.0	5150 5000	1550 1600	8.0 8.0	11000 10200	0.9 1.6	10
11 12	DETECTOR★ AMPLIFIER TRIODE	WD 4-PIN MEDIUM 4-PIN	FIG. 12 FIG. 1	4 1/4" x 1 3/16" 4 11/16" x 1 3/16"	D-C FILAMENT	1.1	0.25	135	—	CLASS A AMPLIFIER	90 135	−4.5 −10.5	—	—	2.5 3.0	15500 15000	425 440	6.6 6.6	—	—	11 12
19	TWIN-TRIODE AMPLIFIER	SMALL 6-PIN	FIG. 25	4 1/4" x 1 9/16"	D-C FILAMENT	2.0	0.26	135	—	CLASS B AMPLIFIER	135 135	0 −3.0	—	—	Power output value is for one tube at stated load, plate-to-plate.				10000 10000	2.1 1.9	19
'20	POWER AMPLIFIER TRIODE	SMALL 6-PIN	FIG. 1	4 1/8" x 1 1/16"	D-C FILAMENT	3.3	0.132	135	—	CLASS A AMPLIFIER	90 135	−16.5 −22.5	—	—	3.0 6.5	8000 6300	415 525	3.3 3.3	9600 6300	0.045 0.110	'20
22	R-F AMPLIFIER TETRODE	MEDIUM 4-PIN	FIG. 4	5 3/32" x 1 13/16"	D-C FILAMENT	3.3	0.132	135	67.5	SCREEN GRID R-F AMPLIFIER	135 135	−1.5 −1.5	45 67.5	0.6• 1.3•	1.7 3.7	725000 325000	375 500	270 160	—	—	22
24-A	R-F AMPLIFIER TETRODE	MEDIUM 5-PIN	FIG. 9	5 3/32" x 1 13/16"	HEATER	2.5	1.75	275	90	SCREEN GRID R-F AMPLIFIER	180 250	−3.0 −3.0	90 90	1.7• 1.7•	4.0 4.0	400000 600000	1000 1050	400 630	—	—	24-A
										BIAS DETECTOR	250●	−5.0 approx	20 to 45	—	Plate current to be adjusted to 0.1 milliampere with no signal.						
26	AMPLIFIER TRIODE	MEDIUM 4-PIN	FIG. 1	4 11/16" x 1 13/16"	FILAMENT	1.5	1.05	180	—	CLASS A AMPLIFIER	90 180	−7.0 −14.5	—	—	2.9 6.2	8900 7300	935 1150	8.3 8.3	—	—	26
27	DETECTOR★ AMPLIFIER TRIODE	MEDIUM 5-PIN	FIG. 8	4 1/4" x 1 9/16"	HEATER	2.5	1.75	275	—	CLASS A AMPLIFIER	135 250	−9.0 −21.0	—	—	4.5 5.2	9000 9250	1000 975	9.0 9.0	—	—	27
										BIAS DETECTOR	250	−30.0 approx	—	—	Plate current to be adjusted to 0.2 milliampere with no signal.						
30	DETECTOR★ AMPLIFIER TRIODE	SMALL 4-PIN	FIG. 1	4 1/4" x 1 9/16"	D-C FILAMENT	2.0	0.06	180	—	CLASS A AMPLIFIER	90 135 180	−4.5 −9.0 −13.5	—	—	2.5 3.0 3.1	11000 10300 10300	850 900 900	9.3 9.3 9.3	—	—	30

● Grids #3 and #5 are screen. Grid #4 is signal-input control-grid.

✝ Applied through plate coupling resistor of 200000 ohms.

✖ Applied through plate coupling resistor of 250000 ohms.

** For grid of following tube.

Characteristics of Glass Receiving Tubes
(Continued)

TYPE	NAME	BASE	SOCKET CONNEC-TIONS	DIMENSIONS MAXIMUM OVERALL LENGTH x DIAMETER	CATHODE TYPE ■	RATING FILAMENT OR HEATER VOLTS	RATING FILAMENT OR HEATER AMPERES	RATING PLATE MAX. VOLTS	RATING SCREEN MAX. VOLTS	USE Values to right give operating conditions and characteristics for indicated typical use	PLATE SUP-PLY VOLTS	GRID VOLTS ■	SCREEN VOLTS	SCREEN MILLI-AMP.	PLATE MILLI-AMP.	A-C PLATE RESIS-TANCE OHMS	MUTUAL CON-DUC-TANCE MICRO-MHOS	VOLT-AGE AMPLI-FICATION FACTOR	LOAD FOR STATED POWER OUTPUT OHMS	POWER OUT-PUT WATTS	TYPE
31	POWER AMPLIFIER TRIODE	SMALL 4-PIN	FIG. 1	4 1/2" x 1 9/16"	D-C FILAMENT	2.0	0.13	180	—	CLASS A AMPLIFIER	135 180	−22.5 −30.0	—	—	8.0 12.3	4100 3600	925 1050	3.8 3.8	7000 5700	0.185 0.375	31
32	R-F AMPLIFIER TETRODE	MEDIUM 4-PIN	FIG. 4	5 1/32" x 1 13/16"	D-C FILAMENT	2.0	0.06	180	67.5	SCREEN GRID R-F AMPLIFIER	135 180	− 3.0 − 3.0	67.5 67.5	0.4* 0.4*	1.7 1.7	950000 1200000	640 650	610 780	—	—	32
										BIAS DETECTOR	180▼	− 6.0 approx	67.5	—	Plate current to be adjusted to 0.2 milliampere with no signal.						
33	POWER AMPLIFIER PENTODE	MEDIUM 5-PIN	FIG. 6	4 11/16" x 1 13/16"	D-C FILAMENT	2.0	0.26	180	180	CLASS A AMPLIFIER	180	−18.0	180	5.0	22.0	55000	1700	90	6000	1.4	33
34	SUPER-CONTROL R-F AMPLIFIER PENTODE	MEDIUM 4-PIN	FIG. 4A	5 1/32" x 1 13/16"	D-C FILAMENT	2.0	0.06	180	67.5	SCREEN GRID R-F AMPLIFIER	135 180	− 3.0 min	67.5 67.5	1.0 1.0	2.8 2.8	600000 1000000	600 620	360 620	—	—	34
35	SUPER-CONTROL R-F AMPLIFIER TETRODE	MEDIUM 5-PIN	FIG. 9	5 1/32" x 1 13/16"	HEATER	2.5	1.75	275	90	SCREEN GRID R-F AMPLIFIER	180 250	− 3.0 min	90 90	2.5* 2.5*	6.3 6.5	300000 400000	1020 1050	305 420	—	—	35
36	R-F AMPLIFIER TETRODE	SMALL 5-PIN	FIG. 9	4 17/32" x 1 9/16"	HEATER	6.3	0.3	250	90	SCREEN GRID R-F AMPLIFIER	100 180 250	− 1.5 − 3.0 − 3.0	55 90 90	— — 1.7*	1.8 3.1 3.2	550000 500000 550000	850 1050 1080	470 525 595	—	—	36
										BIAS DETECTOR	100● 250●	− 5.0 − 8.0	55 90	—	Plate current to be adjusted to 0.1 milliampere with no signal.						
37	DETECTOR★ AMPLIFIER TRIODE	SMALL 5-PIN	FIG. 8	4 1/4" x 1 9/16"	HEATER	6.3	0.3	250	—	CLASS A AMPLIFIER	90 180 250	− 6.0 −13.5 −18.0	—	—	2.5 4.3 7.5	11500 10200 8400	800 900 1100	9.2 9.2 9.2	—	—	37
										BIAS DETECTOR	90 250	−10.0 −28.0	—	—	Plate current to be adjusted to 0.2 milliampere with no signal						
38	POWER AMPLIFIER PENTODE	SMALL 5-PIN	FIG. 9A	4 17/32" x 1 9/16"	HEATER	6.3	0.3	250	250	CLASS A AMPLIFIER	100 180 250	− 9.0 −18.0 −25.0	100 180 250	1.2 2.4 3.8	7.0 14.0 22.0	140000 115000 100000	875 1050 1200	120 120 120	15000 11600 10000	0.27 1.00 2.50	38
39-44	SUPER-CONTROL R-F AMPLIFIER PENTODE	SMALL 5-PIN	FIG. 9A	4 17/32" x 1 9/16"	HEATER	6.3	0.3	250	90	SCREEN GRID R-F AMPLIFIER	90 180 250	− 3.0 min.	90 90 90	1.6 1.4 1.4	5.6 5.8 5.8	375000 750000 1000000	960 1000 1050	360 750 1050	—	—	39-44

★For Grid-leak Detection—plate volts 45, grid return to + filament or to cathode.
■Either A. C. or D. C. may be used on filament or heater, except as specifically noted. For use of D. C. on A-C filament types, decrease stated grid volts by 1/2 (approx.) of filament voltage.

●Applied through plate coupling resistor of 250000 ohms or 500 henry choke shunted by 0.25 megohm resistor.
▼Applied through plate coupling resistor of 100000 ohms.

*Maximum.

40	VOLTAGE AMPLIFIER TRIODE	MEDIUM 4-PIN	FIG. 1	4 11/16" x 1 13/16"	D-C FILAMENT	5.0	0.25	180	—	CLASS A AMPLIFIER	135✖ 180✖	− 1.5 − 3.0	—	—	0.2 0.2	150000 150000	200 200	30 30	—	—	40
41	POWER AMPLIFIER PENTODE	SMALL 6-PIN	FIG. 15A	4 1/4" x 1 9/16"	HEATER	6.3	0.4	250	250	CLASS A AMPLIFIER	100 180 250	− 7.0 −13.5 −18.0	100 180 250	1.6 3.0 5.5	9.0 18.5 32.0	103500 81000 68000	1450 1850 2200	150 150 150	12000 9000 7600	0.33 1.50 3.40	41
42	POWER AMPLIFIER PENTODE	MEDIUM 6-PIN	FIG. 15A	4 11/16" x 1 13/16"	HEATER	6.3	0.7	250	250	CLASS A AMPLIFIER	250	−16.5	250	6.5	34.0	100000	2200	220	7000	3.00	42
43	POWER AMPLIFIER PENTODE	MEDIUM 6-PIN	FIG. 15A	4 11/16" x 1 13/16"	HEATER	25.0	0.3	135	135	CLASS A AMPLIFIER	95 135	−15.0 −20.0	95 135	4.0 7.0	20.0 34.0	45000 35000	2000 2300	90 80	4500 4000	0.90 2.00	43
45	POWER AMPLIFIER TRIODE	MEDIUM 4-PIN	FIG. 1	4 11/16" x 1 13/16"	FILAMENT	2.5	1.5	275	—	CLASS A AMPLIFIER	180 250 275	−31.5 −50.0 −56.0	180 250 275	—	31.0 34.0 36.0	1650 1610 1700	2125 2175 2050	3.5 3.5 3.5	2700 3900 4600	0.82 1.60 2.00	45
46	DUAL-GRID POWER AMPLIFIER	MEDIUM 5-PIN	FIG. T	5 1/4" x 2 1/16"	FILAMENT	2.5	1.75	250	—	CLASS A AMPLIFIER □	250	−33.0	—	—	22.0	2380	2350	5.6	6400	1.25	46
								400	—	CLASS B AMPLIFIER ◆	300 400	0 0	—	—	Power output values are for 2 tubes at indicated plate-to-plate load.				5200 5800	16.0 20.0	
47	POWER AMPLIFIER PENTODE	MEDIUM 5-PIN	FIG. 8	5 1/4" x 2 1/16"	FILAMENT	2.5	1.75	250	250	CLASS A AMPLIFIER	250	−16.5	250	6.0	31.0	60000	2500	150	7000	2.7	47
48	POWER AMPLIFIER TETRODE	MEDIUM 6-PIN	FIG. 15	5 1/8" x 2 1/16"	D-C HEATER	30.0	0.4	125	100	CLASS A AMPLIFIER	96 125	−19.0 −20.0	96 100	9.0 9.5	52.0 56.0	— —	3800 3900	— —	1500 1500	2.0 2.5	48
49	DUAL-GRID POWER AMPLIFIER	MEDIUM 5-PIN	FIG. T	4 11/16" x 1 13/16"	D-C FILAMENT	2.0	0.12	135	—	CLASS A AMPLIFIER □	135	−20.0	—	—	6.0	4175	1125	4.7	11000	0.17	49
								180	—	CLASS B AMPLIFIER ◆	180	0	—	—	Power output values are for 2 tubes at indicated plate-to-plate load.				12000	3.5	
50	POWER AMPLIFIER TRIODE	MEDIUM 4-PIN	FIG. 1	6 1/4" x 2 11/16"	FILAMENT	7.5	1.25	450	—	CLASS A AMPLIFIER	300 400 450	−54.0 −70.0 −84.0	—	—	35.0 55.0 55.0	2000 1800 1800	1900 2100 2100	3.8 3.8 3.8	4600 3670 4350	1.6 3.4 4.6	50
53	TWIN-TRIODE AMPLIFIER	MEDIUM 7-PIN#	FIG. 24	4 11/16" x 1 13/16"	HEATER	2.5	2.0	300	—	CLASS B AMPLIFIER	250 300	0 0	—	—	Power output value is for one tube at stated load, plate-to-plate.				8000 10000	8.0 10.0	53
55	DUPLEX-DIODE TRIODE	SMALL 6-PIN	FIG. 13	4 17/32" x 1 9/16"	HEATER	2.5	1.0	250	—	TRIODE UNIT AS CLASS A AMPLIFIER	135 180 250	−10.5 −13.5 −20.0	—	—	3.7 6.0 8.0	11000 8500 7500	750 975 1100	8.3 8.3 8.3	25000 20000 20000	0.075 0.160 0.350	55
56	SUPER-TRIODE AMPLIFIER DETECTOR★	SMALL 5-PIN	FIG. 8	4 1/4" x 1 9/16"	HEATER	2.5	1.0	250	—	CLASS A AMPLIFIER	250	−13.5	—	—	5.0	9500	1450	13.8	—	—	56
										BIAS DETECTOR	250	−20.0 approx	—	—	Plate current to be adjusted to 0.2 milliampere with no signal.						
57	TRIPLE-GRID DETECTOR AMPLIFIER	SMALL 6-PIN	FIG. 11	4 11/16" x 1 9/16"	HEATER	2.5	1.0	250	100	SCREEN GRID R-F AMPLIFIER	250	− 3.0	100	0.5	2.0	exceeds 1.5 meg.	1225	exceeds 1500	—	—	57
										BIAS DETECTOR	250	− 1.95	50	Cathode current 0.65 ma.		—	Plate coupling resistor 250000 ohms. Grid coupling resistor 250000 ohms**				

★For Grid-leak Detection—plate volts 45, grid return to + filament or to cathode. ●Applied through plate coupling resistor of 250000 ohms or 500-henry choke shunted by 0.25 megohm resistor. *Maximum.

Characteristics of Glass Receiving Tubes
(Continued)

TYPE	NAME	BASE	SOCKET CONNECTIONS	DIMENSIONS MAXIMUM OVERALL LENGTH x DIAMETER	CATHODE TYPE ■	RATING FILAMENT OR HEATER VOLTS	AMPERES	PLATE MAX. VOLTS	SCREEN MAX. VOLTS	USE Values to right give operating conditions and characteristics for indicated typical use	PLATE SUPPLY VOLTS	GRID VOLTS ■	SCREEN VOLTS	SCREEN MILLI-AMP.	PLATE MILLI-AMP.	A-C PLATE RESISTANCE OHMS	MUTUAL CONDUCTANCE MICRO-MHOS	VOLTAGE AMPLIFICATION FACTOR	LOAD FOR STATED POWER OUTPUT OHMS	POWER OUTPUT WATTS	TYPE
58	TRIPLE-GRID SUPER-CONTROL AMPLIFIER	SMALL 6-PIN	FIG. 11	4 13/16" x 1 9/16"	HEATER	2.5	1.0	250	100	SCREEN GRID R-F AMPLIFIER	250	(−3.0 min.)	100	2.0	8.2	800000	1600	1280	—	—	58
										MIXER IN SUPERHETERODYNE	250	−10.0	100	—	—	Oscillator peak volts = 7.0.					
59	TRIPLE-GRID POWER AMPLIFIER	MEDIUM 7-PIN#	FIG. 18	5 3/8" x 2 1/16"	HEATER	2.5	2.0	250	—	AS TRIODE ¶ CLASS A AMPLIFIER	250	−28.0	—	—	26.0	2300	2600	6.0	5000	1.25	59
								250	250	AS PENTODE ●● CLASS A AMPLIFIER	250	−18.0	250	9.0	35.0	40000	2500	100	6000	3.00	
								400	—	AS TRIODE ● CLASS B AMPLIFIER	300 400	0 0	—	—	Power output values are for 2 tubes at indicated plate-to-plate load.				4600 6000	15.0 20.0	
71-A	POWER AMPLIFIER TRIODE	MEDIUM 4-PIN	FIG. 1	4 11/16" x 1 11/16"	FILAMENT	5.0	0.25	180	—	CLASS A AMPLIFIER	90 180	−19.0 −43.0	—	—	12.0 20.0	2170 1750	1400 1700	3.0 3.0	3000 4800	0.125 0.790	71-A
75	DUPLEX-DIODE HIGH-MU TRIODE	SMALL 6-PIN	FIG. 13	4 17/32" x 1 9/16"	HEATER	6.3	0.3	250	—	TRIODE UNIT AS CLASS A AMPLIFIER	250 ⌘	−1.35	—	—	0.4	—	—	Gain per stage = 50-60			75
76	SUPER-TRIODE AMPLIFIER DETECTOR★	SMALL 5-PIN	FIG. 8	4 1/4" x 1 9/16"	HEATER	6.3	0.3	250	—	CLASS A AMPLIFIER	250	−13.5	—	—	5.0	9500	1450	13.8	—	—	76
										BIAS DETECTOR	250	−20.0	—	—	Plate current to be adjusted to 0.2 milliampere with no signal.						
77	TRIPLE-GRID DETECTOR AMPLIFIER	SMALL 6-PIN	FIG. 11	4 17/32" x 1 9/16"	HEATER	6.3	0.3	250	100	SCREEN GRID R-F AMPLIFIER	100 250	−1.5 −3.0	60 100	0.4 0.5	1.7 2.3	650000 1500000	1100 1250	715 1500	—	—	77
										BIAS DETECTOR	250	−1.95	50	Cathode current 0.65 ma.		—	Plate coupling resistor 250000 ohms. Grid coupling resistor 250000 ohms**				
78	TRIPLE-GRID SUPER-CONTROL AMPLIFIER	SMALL 6-PIN	FIG. 11	4 17/32" x 1 9/16"	HEATER	6.3	0.3	250	125	SCREEN GRID R-F AMPLIFIER ●	90 180 250 250	(−3.0 min.)	90 75 100 125	1.3 1.0 1.7 2.6	5.4 4.0 7.0 10.5	315000 1000000 800000 600000	1275 1100 1450 1650	400 1100 1160 990	—	—	78
79	TWIN-TRIODE AMPLIFIER	SMALL 6-PIN	FIG. 19	4 17/32" x 1 9/16"	HEATER	6.3	0.6	250	—	CLASS B AMPLIFIER	180 250	0 0	—	—	Power output value is for one tube at stated load, plate-to-plate.				7000 14000	5.5 8.0	79
85	DUPLEX-DIODE TRIODE	SMALL 6-PIN	FIG. 13	4 17/32" x 1 9/16"	HEATER	6.3	0.3	250	—	TRIODE UNIT AS CLASS A AMPLIFIER	135 180 250	−10.5 −13.5 −20.0	—	—	3.7 6.0 8.0	11000 8500 7500	750 975 1100	8.3 8.3 8.3	25000 20000 20000	0.075 0.160 0.350	85
89	TRIPLE-GRID POWER AMPLIFIER	SMALL 6-PIN	FIG. 14	4 17/32" x 1 9/16"	HEATER	6.3	0.4	250	250	AS TRIODE ¶ CLASS A AMPLIFIER	160 180 250	−20.0 −22.5 −31.0	—	—	17.0 20.0 32.0	3300 3000 2600	1425 1550 1800	4.7 4.7 4.7	7000 6500 5500	0.300 0.400 0.900	89
										AS PENTODE ●● CLASS A AMPLIFIER	100 180 250	−10.0 −18.0 −25.0	100 180 250	1.6 3.0 5.5	9.5 20.0 32.0	104000 80000 70000	1200 1550 1800	125 125 125	10700 8000 6750	0.33 1.50 3.40	
										AS TRIODE ● CLASS B AMPLIFIER	180	0	—	—	Power output values are for 2 tubes at indicated plate-to-plate load.				13600 9400	2.50 3.50	
V-'99 X-'99	DETECTOR★ AMPLIFIER TRIODE	SMALL 4-NUB SMALL 4-PIN	FIG. 10 FIG. 1	3 3/8" x 1 1/16" 4 1/8" x 1 3/16"	D-C FILAMENT	3.3	0.063	90	—	CLASS A AMPLIFIER	90	−4.5	—	—	2.5	15500	425	6.6	—	—	V-'99 X-'99
112-A	DETECTOR★ AMPLIFIER TRIODE	MEDIUM 4-PIN	FIG. 1	4 11/16" x 1 11/16"	D-C FILAMENT	5.0	0.25	180	—	CLASS A AMPLIFIER	90 180	−4.5 −13.5	—	—	5.0 7.7	5400 4700	1575 1800	8.5 8.5	—	—	112-A

★For Grid-leak Detection—plate volts 45, grid return to + filament or to cathode.
■Either A. C. or D. C. may be used on filament or heater, except as specifically noted. For use of D. C. on A-C filament types, decrease stated grid volts by ½ (approx.) of filament voltage.
Requires different socket from small 7-pin.
●●Grid #1 is control grid. Grid #2 is screen. Grid #3 tied to cathode.
¶Grid #1 is control grid. Grids #2 and #3 tied to plate. ⌘ Applied through plate coupling resistor of 250000 ohms.
●Grids #1 and #2 connected together. Grid #3 tied to plate. **For grid of following tube.

RECTIFIERS

TYPE	NAME	BASE	SOCKET CONNECTIONS	DIMENSIONS	CATHODE TYPE	VOLTS	AMPERES	PLATE	SCREEN	RATINGS	TYPE
5Z3	FULL-WAVE RECTIFIER	MEDIUM 4-PIN	FIG. 2	5 3/8" x 2 1/16"	FILAMENT	5.0	3.0	—	—	Maximum A-C Voltage per Plate ......500 Volts, RMS Maximum D-C Output Current ......250 Milliamperes	5Z3
12Z3	HALF-WAVE RECTIFIER	SMALL 4-PIN	FIG. 22	4 1/4" x 1 9/16"	HEATER	12.6	0.3	—	—	Maximum A-C Plate Voltage ......250 Volts, RMS Maximum D-C Output Current ...... 60 Milliamperes	12Z3
25Z5	RECTIFIER-DOUBLER	SMALL 6-PIN	FIG. 5	4 1/4" x 1 9/16"	HEATER	25.0	0.3	—	—	Maximum A-C Voltage per Plate ......125 Volts, RMS Maximum D-C Output Current ......100 Milliamperes	25Z5
1-v°	HALF-WAVE RECTIFIER	SMALL 4-PIN	FIG. 22	4 1/4" x 1 9/16"	HEATER	6.3	0.3	—	—	Maximum A-C Plate Voltage ......350 Volts, RMS Maximum D-C Output Current ...... 50 Milliamperes	1-v°
80	FULL-WAVE RECTIFIER	MEDIUM 4-PIN	FIG. 2	4 11/16" x 1 11/16"	FILAMENT	5.0	2.0	—	—	A-C Voltage per Plate (Volts RMS) 350 400 550 D-C Output Current (Max. MA.) 125 110 135 The 550 volt rating applies to filter circuits having an input choke of at least 20 henries.	80
'81	HALF-WAVE RECTIFIER	MEDIUM 4-PIN	FIG. 3	6 1/4" x 2 1/16"	FILAMENT	7.5	1.25	—	—	Maximum A-C Plate Voltage ......700 Volts, RMS Maximum D-C Output Current ...... 85 Milliamperes	'81
82	FULL-WAVE▶ RECTIFIER	MEDIUM 4-PIN	FIG. 2	4 11/16" x 1 11/16"	FILAMENT	2.5	3.0	—	—	Maximum A-C Voltage per Plate ... 500 Volts, RMS Maximum D-C Output Current ... 125 Milliamperes Maximum Peak Inverse Voltage ...1400 Volts Maximum Peak Plate Current ... 400 Milliamperes	82
83	FULL-WAVE▶ RECTIFIER	MEDIUM 4-PIN	FIG. 2	5 3/8" x 2 1/16"	FILAMENT	5.0	3.0	—	—	Maximum A-C Voltage per Plate ... 500 Volts, RMS Maximum D-C Output Current ... 250 Milliamperes Maximum Peak Inverse Voltage ...1400 Volts Maximum Peak Plate Current ... 800 Milliamperes	83
84 also 6Z4	FULL-WAVE RECTIFIER	SMALL 5-PIN	FIG. 23	4 1/4" x 1 9/16"	HEATER	6.3	0.5	—	—	Maximum A-C Voltage per Plate ......350 Volts, RMS Maximum D-C Output Current ...... 50 Milliamperes	84 also 6Z4

▶Mercury Vapor Type. ° Interchangeable with Type 1.

★For Grid-leak Detection—plate volts 45, grid return to + filament or to cathode. □Grid next to plate tied to plate. ◇Two grids tied together. ●Requires different socket from small 7-pin. ❖Applied through plate coupling resistor of 250000 ohms. **For grid of following tube.

RECEIVER TUBE CHARACTERISTICS AND CIRCUITS

The more common types of receiver tubes are listed here in the order of their Filament or Heater Voltage, arranged in alphabetical sequence. Special tubes and rectifiers are at the end of the chapter. Circuit applications are given for many tubes. Socket connections are shown in the Tube Charts in previous pages.

1.1 & 1.5 Volt Series

864

Non-microphonic triode audio amplifier. Recommended for low level microphone pre-amplifiers.

Characteristics:

Filament Voltage (D.C.)		1.1 volts
Filament Current		0.25 amps.
Plate Voltage	90	135 volts
Grid Voltage	—4.5	—9 volts
Plate Current	2.9	3.5 ma.
Plate Resistance	13.500	12,700 ohms
Amplification Factor	8.2	8.2
Mutual Conductance	610	615 micromhos
Load Resistance	15.000	15.000 ohms

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WD-11, WX-12

Triode detectors and amplifiers for old style battery operated radio receivers.

Note: Practically obsolete.

Characteristics:

Filament Voltage		1. volts
Filament Current		0.25 amps.
Plate Voltage	90	135 volts
Grid Voltage	—4.5	—10.5 volts
Plate Current	2.5	3.4 ma.
Plate Resistance	15.500	15,000 ohms
Amplification Factor	6.6	6.6
Mutual Conductance	425	440 micromhos
Power Output	7	40 milliwatts
Grid to Plate Capacitance		3.3 mmfd.
Grid to Filament Capacitance		2.5 mmfd.
Plate to Filament Capacitance		2.5 mmfd.

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26

Audio amplifier or detector. Used in older radio receivers as neutralized RF amplifiers. Now obsolete.

Note: Filament often introduced excessive hum into radio receivers.

Characteristics:

Filament Voltage (A.C. or D.C.)			1.5 volts
Filament Current			1.05 amps.
Plate Voltage	90	135	180 max. volts
Grid Voltage	—7	—10	—14.5 volts
Plate Current	2.9	5.5	6 2 milliamps.
Plate Resistance	8900	7600	7300 ohms
Amplification Factor	8.3	8.3	8 3
Mutual Conductance	935	1100	1150 micromhos
Grid-Plate Capacitance			8.1 mmfd.
Grid-Filament Capacitance			3.5 mmfd.
Plate-Filament Capacitance			2.2 mmfd.

2-Volt Series

Sylvania 15

RF Amplifier. Regenerative detector or electron-coupled oscillators for battery operated receivers.

Characteristics:

Heater Voltage	2.0 volts
Heater Current	0.22 amps.
Plate Voltage	135 volts
Screen Voltage	67.5 volts
Grid Voltage	—1.5 volts
Plate Current	1.85 ma.
Plate Resistance	.8 megohm
Amplification Factor	500
Mutual Conductance	750 micromhos

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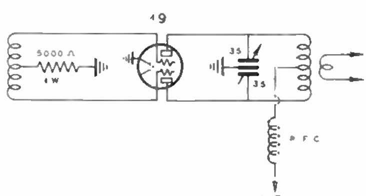
19

Twin triode class B audio amplifier for portable radio receivers. Class B Modulator in portable U.H.F. transmitters and transceivers. U.H.F. oscillator in push-pull circuits.



TNT UHF OSCILLATOR

Characteristics:

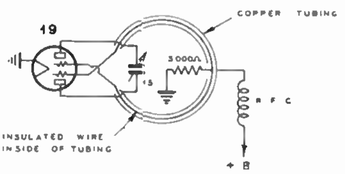
Filament Voltage (D.C.)	2.0 volts
Filament Current	0.26 amps.

As Class B Power Amplifier:

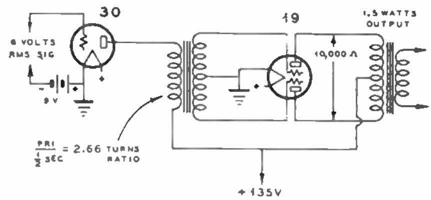
Plate Voltage	135 max. volts
Dynamic Peak Plate Current (per plate)	50 max. ma.

Typical Operation:

Filament Voltage			2.0 volts
Plate Voltage	135	135	135 volts
Grid Voltage	—6	—3	0 volts
Static Plate Current	1	4	10 ma.
Load Resistance (plate-to-plate)	10000	10000	10000 ohms
Average Power Input	95	130	170 ap. mw.
Nominal Power Output	1.6	1.9	2.1 watts



UNIT COUPLED U H F OSCILLATOR



CLASS B AUDIO AMP & DRIVER FOR PORTABLE OPERATION

30

Triode Detector. Audio Amplifier and Oscillator for battery-operated radio receivers. Also used in 5 meter transceivers.

Characteristics:

Filament Voltage (D.C.)	2.0 volts
Filament Current	.06 amps.
Grid to Plate Capacitance	6.0 mmfd.
Input Capacitance	3.0 mmfd.
Output Capacitance	2.1 mmfd.
Base	small 4 pin

Class A Amplifier:

Plate Voltage	90	135	180 max. volts
Grid Voltage	—4.5	—9	—13.5
Plate Current	2.5	3.0	3.1 ma.
Plate Resistance	11000	10300	10300 ohms
Amplification Factor	9.3	9.3	9.3
Mutual Conductance	850	900	900 micromhos
Output	...	0.07	0.13 watts

Class B Amplifier—2 Tubes:

Plate Voltage	180 volts (max.)
Maximum Signal Plate Current	50 ma. (per tube)
Zero Signal Plate Current	1.5 ma. (per tube)

Typical Operation:

Plate Voltage	157.5 volts
Grid Voltage	—15 volts
Zero Signal Plate Current (per tube)	0.5 ma.
Eff. Load Resistance (plate to plate)	8000 ohms
Power Output	2.1 watts
Total Distortion	6 to 7%
Grid Driving Power	260 milliwatts

Driver Stage—Type 30 operating at 157.5 volts plate, —11.3 volts grid bias.

Input transformer $\frac{\text{primary}}{\text{½ sec.}}$ = 1.165 ratio

Detector	Biased			Grid Leak
Plate Voltage	90	135	180	45
Grid Voltage	—9	—13.5	—18	return to + fila.
Plate Current	Adjusted to 0.2 ma. with no signal			
Grid Leak	1 to 5 megohms			
Grid Condenser	0.00025 mfd.			

31

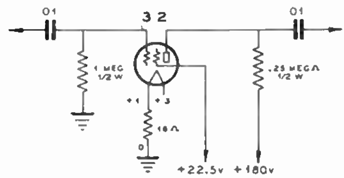
Triode Power Amplifier for battery operated radio receivers. Not in general use. Occasionally used as a 5 meter oscillator in portable 5 meter transmitters because it has a heavier filament than a type 30 tube. It is not suitable for 5 meter transceivers.

Characteristics:

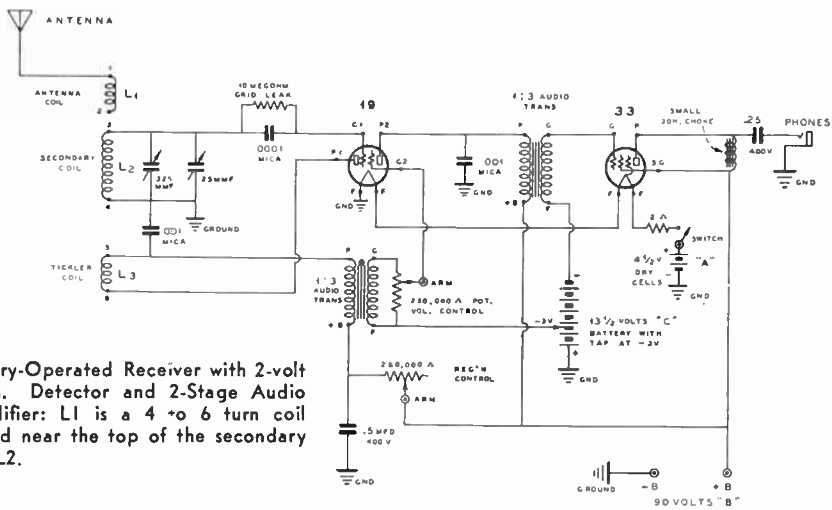
Filament Voltage	2.0 volts	
Filament Current	0.130 amps.	
Plate Voltage	135	180 volts
Grid Voltage	—22.5	—30 volts
Plate Current	8	12.3 ma.
Plate Resistance	4100	3600 ohms
Amplification Factor	3.8	3.8
Mutual Conductance	925	1050 micromhos
Power Output	0.185	0.375 watts
Load Resistance	7000	5700 ohms

32

Screen-grid detector and amplifier for battery operated receivers where low filament drain is necessary.



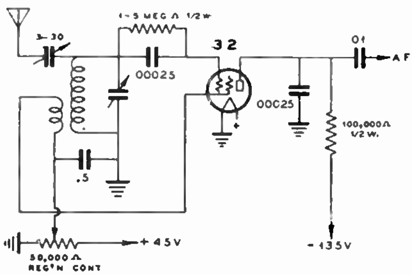
AUDIO AMPLIFIER CIRCUIT



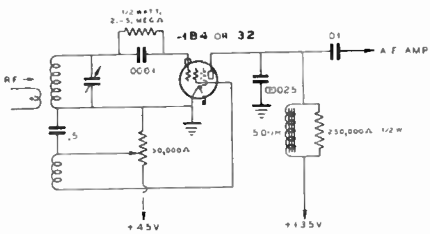
Battery-Operated Receiver with 2-volt tubes. Detector and 2-Stage Audio Amplifier: L1 is a 4 to 6 turn coil wound near the top of the secondary coil L2.

Characteristics:

Filament Voltage (D.C.)		2.0 volts
Filament Current		0.060 amp.
Plate Voltage	135	180 max. volts
Screen Voltage	67.5	67.5 max. volts
Grid Voltage	—3	—3 volts
Plate Current	1.7	1.7 ma.
Screen Current	0.4	0.4 max. ma.
Plate Resistance	950.000	1,200.000 ohms
Amplification Factor	610	780
Mutual Conductance	640	650 micromhos
Grid-Plate Capacitance (with shield-can)		0.015 max. mmfd.
Input Capacitance		6.0 mmfd.
Output Capacitance		11.7 mmfd.



Screen Grid Detector Circuit for Receivers



NOTE - THERE IS NO SUPPRESSOR GRID IN THE 1B4-32 SERIE.

GRID LEAK DETECTOR IN BATTERY OPERATED SHORT WAVE AUTODYNE RECEIVER

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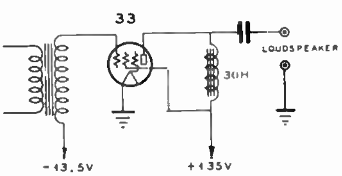
33

Pentode Power Amplifier for output stages of battery operated radio sets. Used in U.H.F. transceivers as modulator and audio amplifier.



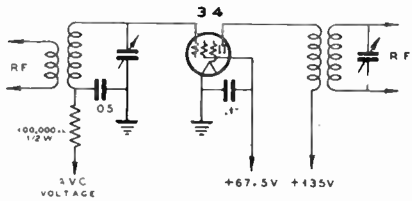
AUDIO AMPLIFIER (OR MODULATOR) FOR PORTABLE RADIO SETS

Characteristics:

Filament Voltage (D.C.)	2.0 volts
Filament Current	0.260 ampere
Plate Voltage	135 max. volts
Screen Voltage	135 max. volts
Grid Voltage	—13.5 volts
Plate Current	14.5 milliamperes
Screen Current	3 milliamperes
Plate Resistance	50000 ohms
Amplification Factor	70
Mutual Conductance	1450 micromhos
Load Resistance	7000 ohms
Power Output	0.7 watt

34

Screen-Grid R-F or I-F amplifier for portable and battery operated radio receivers. Its super control feature allows AVC voltage application. As a mixer in superheterodyne receivers, approx. —5 volts bias is recommended.



Characteristics:

Filament Voltage (D.C.)			2.0 volts
Filament Current			0.060 ampere
Plate Voltage	67.5	135	180 max. volts
Screen Voltage (Max.)	67.5	67.5	67.5 volts
Grid Voltage, Variable (Min.)	—3	—3	—3 volts
Plate Current	2.7	2.8	2.8 milliamperes
Screen Current	1.1	1.0	1.0 milliamperes
Plate Resistance	0.4	0.6	1.0 megohm
Amplification Factor	224	360	620
Mutual Conductance	560	600	620 micromhos
Mutual Conductance (At —22.5 volts bias)	15	15	15 micromhos
Grid-Plate Capacitance (With shield-can)			0.015 max. mmfd.
Input Capacitance			6.0 mmfd.
Output Capacitance			12.6 mmfd.

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49

Double-grid tube for battery operated radio receivers. Occasionally used in U.H.F. portable transmitters.

Note: Class B amplifier uses 2 tubes with grids of each tied together.

Class A amplifier has adjacent grid tied to plate for low mu operation.

Characteristics:

Filament Voltage (D.C.)	2.0 volts
Filament Current	0.12 ampere.

As Class B Power Amplifier:

Plate Voltage	180 max. volts
Dynamic Peak Plate Current	50 max. milliamperes
Typical Operation (2 tubes)	
Filament Voltage	2.0 volts
Plate Voltage	180 volts
Grid Voltage (both grids tied together)	0 volts
Static Plate Current (per tube)	2 milliamperes
Load Resistance (plate-to-plate)	12000 ohms.
Nominal Power Output (2 tubes)	3.5 watts

As Driver—Class A Amplifier:

Filament Voltage	2.0 volts
Plate Voltage	135 max. volts
Grid Voltage (grid adjacent to plate tied to plate)	—20 volts
Plate Current	5.7 milliamperes
Plate Resistance	4000 ohms.
Amplification Factor	4.5
Mutual Conductance	1125 micromhos
Load Resistance	11000 ohms.
Nominal Power Output	0.170 watt

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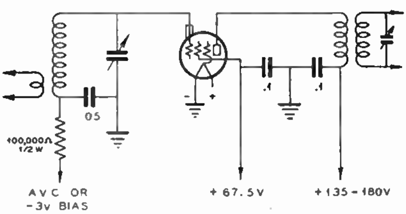
1A4-1B4

1A4 — Super-control R.F. or I.F. amplifier for battery operated radio receivers. Similar to type 34, except small bulb.

1B4—R.F. amplifier with sharp cut-off, or as detector for battery operated radio receivers. Similar to 32, except for smaller bulb.

34 OR 1A4



TYPICAL RF AMPLIFIER FOR BATTERY-OPERATED SETS

Characteristics:	Type 1A4	Type 1B4
Filament Voltage	2.0	2.0 volts
Filament Current	.06	.06 amps.
Plate Voltage (Max.)	180	180 volts
Screen Voltage (Max.)	67.5	67.5 volts
Grid Voltage (Min.)	—3	—3 volts
Plate Current	2.3	1.7 ma.
Screen Current (Approx.)	0.7	0.4 ma.
Plate Resistance	.96	1.2 megohms.
Amplification Factor	720	780
Mutual Conductance	750	650 micromhos.
Mutual Conductance at —15 volts bias	15	
Grid to Plate Capacitance	.007	.007 mmfd.
Input Capacitance	4.6	4.6 mmfd.
Output Capacitance	11	11 mmfd.
Base—small 4 pin.		

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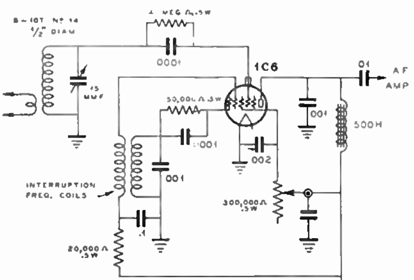
1A6-1C6

Mixer and oscillator combination tube for battery operated superheterodyne receivers. Can also be used as a super-regenerative detector in 5-meter receivers.

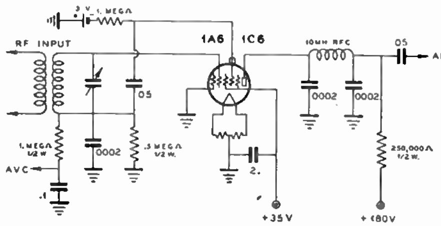
Note: The 1C6 has a more rugged filament than the 1A6, but places more drain on the filament battery, which might be of importance in portable radio receivers. The 1C6 can be operated up to 25 megacycles as a converter, while the 1A6 has an upper limit of about 10 megacycles. Either tube can have AVC voltage applied to the control grid for variation of signal voltage gain.



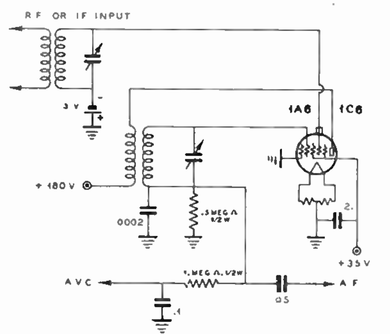
5-METER SUPER-REGENERATIVE DETECTOR CIRCUIT. VIRTUAL CATHODE PROVIDES 5-METER REGENERATION AND OSCILLATION, MODULATED BY THE 100KC I.F. OSCILLATOR TO OBTAIN SUPER-REGENERATION.

Characteristics:		1A6		1C6
Filament Voltage (DC)		2.0	...	2.0 volts
Filament Current		.06	...	.12 amps.
Inter-electrode Capacities:				
R-F Input		10.5	...	10 mmfd.
Mixer Output		9	...	10 mmfd.
Oscillator Input		5	...	6 mmfd.
Oscillator Output		6	...	6 mmfd.
Plate Voltage	135	180	135	180 volts
Screen Voltage	67.5	67.5	67.5	67.5 volts
Anode-Grid Voltage	135	135	135	135 volts
Control-Grid Voltage	—3	—3	—3	—3 volts
Total Cathode Current (Max.)		9	...	9 ma.
Plate Current	1.2	1.3	1.3	1.5 ma.
Screen Current	2.5	2.4	2	2 ma.
Anode-Grid Current	2.3	2.3	2.6	3.3 ma.
Oscillator Grid Current	0.2	0.2	0.2	0.2 ma.
Plate Resistance	0.4	0.5	0.55	0.75 megohms.
Conversion Conductance	275	300	300	325 micromhos.
Conversion Conductance	*	*	†	†
Base—small 6 pin.				

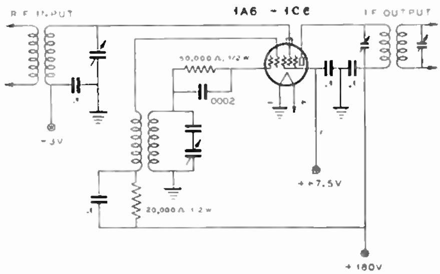
*4 at —22½v. †4 at —14v.



HALF WAVE DETECTOR WITH AVC AND FIXED BIAS AF RESISTANCE COUPLED AMPLIFIER



RF OR IF AMPLIFIER & HALF WAVE DETECTOR WITH AVC



PENTAGRID CONVERTER

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1B5-25S

Duplex - Diode - Triode Detector and Audio Amplifier, resistance or impedance coupled to a 33 or 1F4 pentode output amplifier for battery operated radio receivers.

Characteristics:

Filament Voltage (DC)	2.0 volts
Filament Current	.060 amps.
Grid to Plate Capacitance	3.6 mmfd.
Grid to Filament Capacitance	2 mmfd.
Plate to Filament Capacitance	3 mmfd.
Plate Voltage	135 volts
Grid Voltage	—3 volts
Plate Current	0.8 ma.
Amplification Factor	20
Plate Resistance	35000 ohms
Mutual Conductance	575 micromhos

1F4

Pentode Power Amplifier for battery operated radio receivers and 5-meter portable sets or transceivers.

Note: The 1F4 requires less C bias than the 33 tube; the plate current and power output are also lower.

Characteristics:

Filament Voltage (DC)	2.0 volts
Filament Current	0.120 amps.
Plate Voltage	135 volts
Screen Voltage	135 volts
Grid Voltage	—4.5 volts
Plate Current	8.0 ma.
Screen Current	2.6 ma.
Amplification Factor	340
Plate Resistance	0.2 megohms
Mutual Conductance	1700 micromhos.
Power Output	0.34 watts
Plate Load	16000 ohms.

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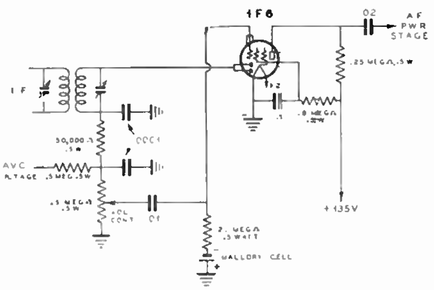
1F6

Duo Diode-Pentode. Second detector for battery operated radio receivers. Diodes can furnish AVC voltage and pentode section can be operated as an IF amplifier, or as an audio amplifier. Will furnish sufficient output as an audio amplifier to drive a 33 or 1F4 output tube to rated values.



SECOND DETECTOR CIRCUIT FOR BATTERY OPERATED SUPERHETERODYNE RECEIVERS

Characteristics:

Filament Voltage (DC)	2.0 volts
Filament Current	.060 amperes
Grid-to-Plate Capacitance	.007 mmfd.
Grid-to-Filament Capacitance	4 mmfd.
Plate-to-Filament Capacitance	9 mmfd.
Plate Voltage	180 volts
Screen Voltage	67½ volts
Grid Voltage	—1.5 volts
Plate Current	2 ma.
Amplification Factor	650
Plate Resistance	1 megohm.
Mutual Conductance	650 micromhos.
Cut-off Bias	—12 volts

2.5 Volt Series

24A

Screen grid detector, audio amplifier. RF amplifier in radio receivers. Electron-coupled oscillator for receivers or frequency meters.

Note: Nearly obsolete. (Replaced for general use by *57*.)

Characteristics:

Heater Voltage (AC) or (DC)		2.5 volts
Heater Current		1.75 amperes
Plate Voltage	180	250 volts
Grid Voltage	—3	—3 volts
Screen Voltage	90	90 max. volts
Plate Current	4	4 milliamperes
Screen Current	1.7	1.7 max. milliamperes
Plate Resistance	400000	600000 ohms
Amplification Factor	400	630
Mutual Conductance	1000	1050 micromhos.
Grid-Plate Capacitance (With shield-can)		0.007 max. mmfd.
Input Capacitance		5.3 mmfd.
Output Capacitance		10.5 mmfd.

27

General purpose triode with heater-cathode. Used as an AF and neutralized RF amplifier and detector in radio receivers of early AC design.

Note: Nearly obsolete.

Characteristics:

Heater Voltage (AC or DC)				2.5 volts
Heater Current				1.75 amperes
Plate Voltage	90	135	180	250 volts
Grid Voltage	—6	—9	—13.5	—21 volts
Plate Current	2.7	4.5	5.0	5.2 milliamperes
Plate Resistance	11000	9000	9000	9250 ohms.
Amplification Factor	9	9	9	9
Mutual Conductance	820	1000	1000	975 micromhos.
Grid-Plate Capacitance				3.3 mmfd.
Grid-Cathode Capacitance				3.5 mmfd.
Plate-Cathode Capacitance				3.0 mmfd.

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35

Super-control screen grid R-F amplifier tube. Can be used as a mixer in superheterodyne circuits with —7 volts grid bias.

Note: Nearly obsolete.

Characteristics:

Heater Voltage (AC or DC)		2.5 volts
Heater Current		1.75 amperes
Plate Voltage	180	250 volts
Screen Voltage (Max.)	90	90 max. volts
Grid Voltage, Variable (Min.)	—3	—3 volts
Plate Current	6.3	6.5 milliamperes
Screen Current (Max.)	2.5	2.5 milliamperes
Plate Resistance	300000	400000 ohms.
Amplification Factor	305	420
Mutual Conductance	1020	1050 micromhos.
Mutual Conductance (At —40 volts bias)	15	15 micromhos.
Grid-Plate Capacitance (With shield-can)		0.007 max. mmfd.
Input Capacitance		5.3 mmfd.
Output Capacitance		10.5 mmfd.

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45

Equivalent to Metal Tube 6D5. Triode Power Tube for push-pull Class A or AB service. The output in Class AB is sufficient to drive Class B modulators of 100 to 200 watts output. Also useful as a low power R-F buffer tube in transmitters.

Characteristics for Class A Amplification:

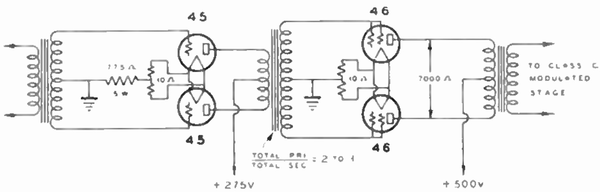
Filament Voltage	2.5 volts
Filament Current	1.5 amps.
Plate Voltage	250 volts
Grid Voltage	—50 volts
Plate Current	34 ma.
Plate Resistance	1610 ohms.
Amplification Factor	3.5
Mutual Conductance	2175 micromhos.
Load Resistance	3900 ohms.
Power Output	1.6 watts
Grid-plate Capacitance	7 mmfd.
Input Capacitance	4 mmfd.
Output Capacitance	3 mmfd.

Class AB Push-Pull Amplifier:

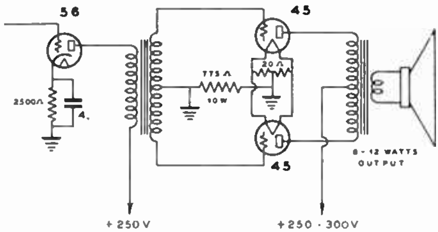
	Fixed Bias	Self Bias
Plate Voltage	275	275 volts
Grid Voltage	—68	...
Zero Signal Plate Current (per tube)	35	36 ma.
Max. Signal Plate Current (per tube)	69	45 ma.
Load Resistance (plate to plate)	3200	5060 ohms
Self Bias Resistor	..	775 ohms
Total Harmonic Distortion	5	5%
Power Output	18	12 watts

Class C R-F Amplifier:

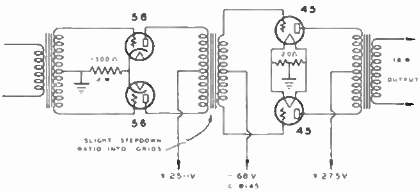
Plate Voltage	400 volts
Plate Current	50 ma.
Peak Plate Current (AC)	90 ma.
Grid Bias Voltage	—200 volts
Grid Bias Current	4 ma.
Plate Power Input	20 watts
Grid Power Input	1.0 watts
Grid-Bias Power Loss	0.8 watt
Power Output	15 watts
Efficiency	75%
Plate load impedance	3700 ohms



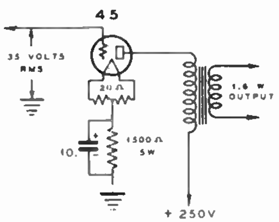
CLASS B MODULATOR FOR PHONE TRANSMITTER
AVERAGE POWER OUTPUT 20 WATTS - PEAK OUTPUT 40 WATTS



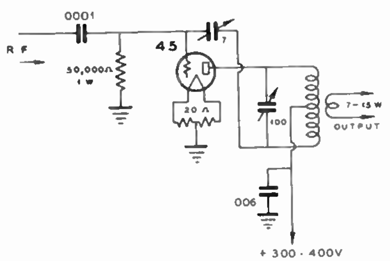
Low Distortion Audio Amplifier for Radio Receivers



Push-Pull Class AB Amplifier for Class B Driver or P.A. Service



AUDIO AMPLIFIER, - OR MODULATOR FOR GRID MODULATED TUBES

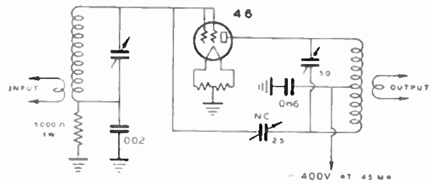


Neutralized Class C Buffer for RF Stage

46

Class B Amplifier for radio receivers and public address systems. More often used in modulator systems for small radiophone transmitters. Frequently serves as a doubler in RF circuits of radio transmitter.

Note: Audio peak outputs of 40 watts for speech can be secured if a 500 volt plate supply is available, although this exceeds the manufacturers ratings of 400 volts plate supply.



INPUT REQUIRED		OUTPUT
1.6 WATTS	AS AN AMPLIFIER	10 WATTS
2.3 "	AS A DOUBLER	5 "

Characteristics:

Filament Voltage	2.5 volts
Filament Current	1.75 amps.

As Class A Amplifier (grid adjacent to plate tied to it):

Plate Voltage	250 volts
Grid Voltage	—33 volts
Plate Current	22 ma.
Plate Resistance	2380 ohms
Amplification Factor	5.6
Mutual Conductance	2350 micromhos
Load Resistance	6400 ohms
Power Output	1.25 watts

As Class B Amplifier (grids tied together):

Plate Voltage	300	400 volts
Grid Voltage	0	0 volts
Zero Signal Plate Current (per tube)	4	6 ma.
Load Resistance (plate to-plate)	5200	5800 ohms
Power Output	16	20 watts
Grid Driving Power	950	650 milliwatts

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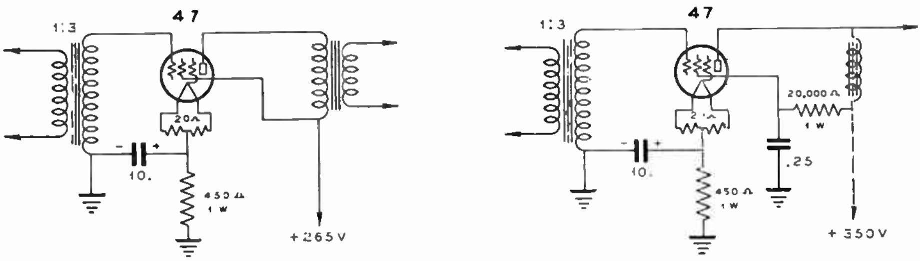
47

Audio power amplifier for radio receivers or modulator service in small AC operated 5-meter transmitters. Crystal oscillator in radio transmitters.

Note: This tube has been replaced for most services by tubes with a separate cathode and heater.

Characteristics:

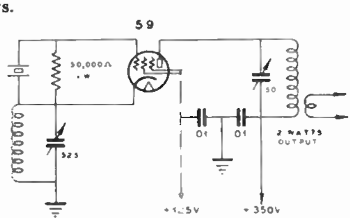
Filament Voltage	2.5 volts
Filament Current	1.75 amps.
Plate Voltage	250 volts
Screen Voltage	250 volts
Grid Voltage	—16.5 volts
Plate Current	31 ma.
Screen Current	6 ma.
Amplification Factor	150
Plate Resistance	60,000 ohms
Mutual Conductance	2500 micromhos
Power Output	2.7 watts
Load Resistance	7000 ohms
Plate to Grid Capacitance	1.2 mmfd.
Input Capacitance	8.6 mmfd.
Output Capacitance	13 mmfd.



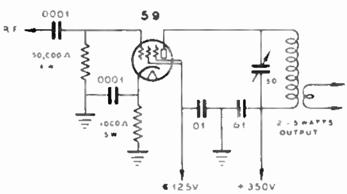
AUDIO AMPLIFIERS OR MODULATORS

59

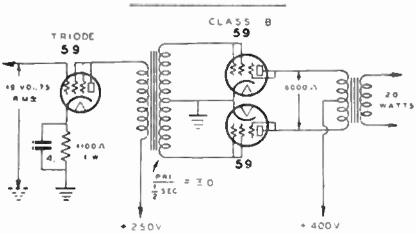
Triple Grid Pentode Amplifier. Class A Audio amplifier. Triode Class A driver for Class B stage of 59 tubes. Crystal oscillator and frequency-doubler in radio transmitters.



TRITET CRYSTAL OSCILLATOR DOUBLER



REGENERATIVE FREQUENCY DOUBLER
(CATHODE CONDENSER TYPE)



Characteristics:

Heater Voltage	2.5 volts
Heater Current	2.0 amps.

Class A Amplifier	**Triode**	**Pentode**
Plate Voltage	250	250 volts
Screen Voltage	...	250 volts
Grid Voltage (No. 1)	—28	—18 volts
Plate Current	26	35 ma.
Screen Current	...	9 ma.
Amplification Factor	6	100
Plate Resistance	2300	40,000 ohms
Mutual Conductance	2600	2500 micromhos
Load Resistance	5000	6000 ohms
Self-Bias Resistor	1083	410 ohms
Power Output	1.25	3 watts
Grid No. 2	tied to plate	Screen
Grid No. 3	tied to plate	Tied to cathode

Class B Amplifier:

Plate Voltage	300	400 volts
Avg. Plate Dissipation	10	10 watts max.
Grids No. 1 and 2 tied together, Grid No. 3 tied to plate		
Zero Signal Plate Current (per tube)	10	13 ma.
Max. Signal Plate Current	...	200 ma.
Load Resistance (plate to plate)	4600	6000 ohms
Power Output (2 tubes)	15	20 watts

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2A3

Triode Power Amplifier. Normally used in push-pull in radio receivers and as a P.P. driver stage for Class B modulators which have outputs of from 100 to 300 watts. The low plate resistance load with fixed grid bias makes these tubes desirable as Class B stage drivers. Sometimes operated as a Class C RF amplifier in radio transmitters, in which case the maximum plate voltage is 400 volts.

Note: As a Class C RF amplifier, approx. 15% more output can be obtained than from a 45 tube. Not recommended for Class C service above 7 mc.

Characteristics:

Filament Voltage	2.5 volts
Filament Current	2.5 amps.
Grid to Plate Capacitance	13 mmfd.
Input Capacitance	9 mmfd.
Output Capacitance	4 mmfd.
Plate Voltage	250 max. volts
Grid Voltage	—45 volts
Plate Current	60 ma.
Plate Resistance	800 ohms
Amplification Factor	4.2
Mutual Conductance	5250 micromhos
Load Resistance	2500 ohms
Self Bias Resistor	750 ohms
Power Output	3.5 watts

Push-Pull Class AB Amplifier (2 tubes):

	Fixed Bias	**Self Bias**
Plate Voltage	300	300 max. volts
Grid Voltage	—62	... volts
Self Bias Resistor	...	750 ohms
Plate Current (per tube)	40	40
Load Resistance (Plate to Plate)	3000	5000 ohms
Harmonic Distortion	2.5	5%
Power Output	15	10 watts

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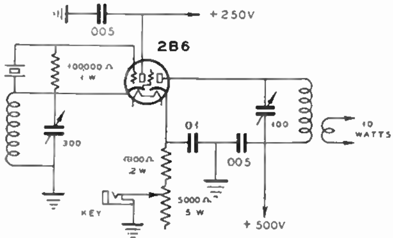
2B6

Power Amplifier for radio receivers. More often used as a crystal oscillator-amplifier or doubler in radio transmitters.

Unusual Characteristics: Two triodes in one envelope. The power amplifier grid is direct-coupled to the driver cathode, and the driver plate connects directly to plus B.



2B6 "LES-TET" CRYSTAL OSCILLATOR-DOUBLER
WHEN SECOND TRIODE IS USED AS AN R F AMPLIFIER IT MUST BE NEUTRALIZED

Characteristics:

Heater Voltage	2.5 volts
Heater Current	2.25 amps.
Plate Supply	250 volts
Grid Bias	—24 volts
Plate Current	40 ma.
Plate Resistance	5150 ohms
Mutual Conductance	3500 micromhos
Amplification Factor	18
Load Resistance	5000 ohms
Power Output	4 watts
Base	med. 7 pin

3 Volt Series

22

Screen Grid RF Amplifier for battery operated radio receiver.
Note: Practically obsolete.

Characteristics:

Filament Voltage (D.C.)	3.3 volts
Filament Current	0.132 amps.
Plate Voltage	135 volts (max.)
Screen Voltage	67.5 volts (max.)
Grid Voltage	—1.5 volts
Plate Current	3.7 ma.
Screen Current	1.3 ma.
Plate Resistance	0.325 megohm
Amplification Factor	160
Mutual Cond.	500 micromhos
Grid to Plate Capacitance (shielded)	0.02 mmfd.
Input Capacitance	3.5 mmfd.
Output Capacitance	10 mmfd.

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120

Triode audio amplifier for battery operated radio receivers.
Note: Practically obsolete.

Characteristics:

Filament Voltage (D.C.)		3.0-3.3 volts
Filament Current		0.125-0.132 amp.
Plate Voltage	90	135 max. volts
Grid Voltage	—16.5	—22.5 volts
Plate Current	3.0	6.5 milliamps.
Plate Resistance	8000	6300 ohms
Amplification Factor	3.3	3.3
Mutual Conductance	415	525 micromhos
Load Resistance	9600	6500 ohms
Undistorted Power Output	0.045	0 11 watt
Grid-Plate Capacitance		4.1 mmfd.
Grid-Filament Capacitance		2.0 mmfd.
Plate-Filament Capacitance		2.3 mmfd.

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199

General purpose triode for dry cell operation.
Note: Practically obsolete.

Characteristics:

Filament Voltage (D.C.)	3.0-3.3 volts
Filament Current	0.060-0.063 ampere
Plate Voltage	90 max. volts
Grid Voltage	—4.5 volts
Plate Current	2.5 milliamps.
Plate Resistance	15,500 ohms
Amplification Factor	6.6
Mutual Conductance	425 micromhos
Grid-Plate Capacitance	3.3 mmfd.
Grid-Filament Capacitance	2.5 mmfd.
Plate-Filament Capacitance	2.5 mmfd.
Base	Type '99—small 4-nub; X-Type '99—Small 4-pin

5 Volt Series

01-A

Triode storage battery tube for use as a detector and amplifier in radio receivers.
Note: Practically obsolete.

Characteristics:

Filament Voltage (D.C.)		5.0 volts
Filament Current		0.25 amps.
Plate Voltage	90	135 max. volts
Grid Voltage	—4.5	—9 volts
Plate Current	2.5	3.0 milliamps.
Plate Resistance	11,000	10,000 ohms
Amplification Factor	8	8
Mutual Conductance	725	800 micromhos
Grid-Plate Capacitance		8.1 mmfd.
Grid-Filament Capacitance		3.1 mmfd.
Plate-Filament Capacitance		2.2 mmfd.

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71-A

Triode power amplifier of low output impedance.
Note: Practically obsolete.

Characteristics:

Filament Voltage (A.C.) or (D.C.)			5.0 volts
Filament Current			0.25 amps.
Plate Voltage	90	135	180 max. volts
Grid Voltage	—16.5	—27	—40.5 volts
Plate Current	10	17.3	20 milliamps.
Plate Resistance	2170	1820	1750 ohms
Amplification Factor	3	3	3
Mutual Conductance	1400	1650	1700 micromhos
Load Resistance	3000	3000	4800 ohms
Undistorted Power Output	0.125	0.4	0.79 watt

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112-A

Triode detector or amplifier for storage battery operated receivers. Filament type tube.
Note: Practically obsolete.

Characteristics:

Filament Voltage (D.C.)			5.0 volts
Filament Current			0.25 amp.
Plate Voltage	90	135	180 max. volts
Grid Voltage	—4.5	—9	—13.5 volts
Plate Current	5.0	6.2	7.7 milliamps.
Plate Resistance	5400	5100	4700 ohms
Amplification Factor	8.5	8.5	8.5
Mutual Conductance	1575	1650	1800 micromhos
Load Resistance	5000	9000	10,650 ohms
Undistorted Power Output	0.035	0.13	0.285 watts
Grid-Plate Capacitance			8.5 mmfd.
Grid-Filament Capacitance			4.0 mmfd.
Plate-Filament Capacitance			2.0 mmfd.

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240

Triode bias detector, resistance-coupled audio amplifier for storage battery operated radio receivers.
Note: Practically obsolete.

Characteristics:

Filament Voltage	5.0 volts
Filament Current	0.25 amp.

Direct Interelectrode Capacitances:

Grid to Plate	8.8 mmfd.
Grid to Filament	3.4 mmfd.
Plate to Filament	1.5 mmfd.

Amplifier—Operating Conditions and Characteristics:

Filament	5.0	5.0 volts
Plate Supply	135	180 volts
Grid	—1.5	—3 volts
Load Res.	250,000	250,000 ohms
Amplification Factor	30	30
Plate Resistance	150,000	150,000 ohms
Mut. Cond.	200	200 micromhos
Plate Current	0.2	0.2 ma.

Detector—Operating Conditions as Biased Detector:

Filament	5.0	5.0 volts
Plate Supply	135	180 volts
Grid	—3	—4.5 volts
Load Res.	250,000	250,000 ohms

Operating Conditions as Grid-Leak Detector:

Filament	5.0	5.0 volts
Plate Supply	135	180 volts

Grid condenser of 0.00025 uf. capacity; grid leak of from 2 to 5 megohms.

Load Resistance	250,000	250,000 ohms

6.3 Volt Series

36

Screen-Grid RF and IF amplifier for automobile radio receivers. Detector with grid-leak or grid-bias circuits
Note: Nearly obsolete.

Characteristics:

Heater Voltage (A.C. or D.C.)				6.3 volts
Heater Current				0.3 amp.
Plate Voltage	100	135	180	250 max. volts
Screen Voltage	55	67.5	90*	90 max. volts
Grid Voltage	—1.5	—1.5	—3	—3 volts
Plate Current	1.8	2.8	3.1	3.2 milliamps.
Screen Current	...	...	...	1.7 max. milliamp.
Plate Resistance	0.55	0.475	0.5	0.55 megohm
Amplification Factor	470	475	525	595
Mutual Conductance	850	1000	1050	1080 micromhos
Grid-Plate Capacitance (with shield-can)				0.007 max. mmfd.
Input Capacitance				3.7 mmfd.
Output Capacitance				9.2 mmfd.

*Maximum.

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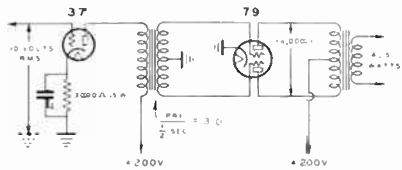
37

Triode detector and audio amplifier for automobile radio receivers. Occasionally used as a super regenerative detector in U.H.F. receivers.
Note: Replaced for general use by the 76 and 6C5 tubes.



Characteristics:

Heater Voltage				6.3 volts
Heater Current				0.3 amps.
Plate Voltage	90	135	180	250 volts (max.)
Grid Voltage	—6	—9	—13.5	—18 volts
Plate Current	2.5	4.1	4.3	7.5 ma.
Plate Resistance	11,500	10.000	10.200	8400 ohms
Amplification Factor	9.2	9.2	9.2	9.2
Mutual Conductance	800	925	900	1100 micromhos
Grid to Plate Capacitance				2.0 mmfd.
Grid to Cathode Capacitance				3.5 mmfd.
Plate to Cathode Capacitance				2.9 mmfd.

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38

Pentode power amplifier for automobile radio receivers, and series-heater receivers.
Note: Not in general use.

Characteristics:

Heater Voltage (A.C. or D.C.)				6.3 volts
Heater Current				0.3 amp.
Plate Voltage	100	135	180	250 maximum volts
Screen Voltage	100	135	180	250 maximum volts
Grid Voltage	—9	—13.5	—18	—25 volts
Plate Current	7	9	14	22 milliamperes
Screen Current	1.2	1.5	2.4	3.8 milliamperes
Plate Resistance	0.14	0.13	0.11	0.10 megohm
Amplification Factor	120	120	120	120
Mutual Conductance	875	925	1050	1200 micromhos
Load Resitance	15000	13500	11600	10000 ohms
Power Output	0.27	0.55	1.0	2.5 watts

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39/44

Super-control RF or IF amplifier for automobile super-heterodyne receivers employing automatic volume control. Can be used as a mixer with —7 volts grid bias.
Note: Not in general use.

Characteristics:

Heater Voltage (A.C. or D.C.)			6.3 volts
Heater Current			0.3 amp.
Plate Voltage	90	180	250 max. volts
Screen Voltage	90	90	90 max. volts
Grid Voltage	—3	—3	—3 min. volts
Plate Current	5.6	5.8	5.8 milliamps.
Screen Current	1.6	1.4	1.4 milliamps.
Plate Resistance	0.375	0.750	1.0 megohm
Amplification Factor	360	750	1050
Mutual Conductance	960	1000	1050 micromhos
Mutual Conductance (at —42.5 volts bias)	2	2	2 micromhos
Grid-Plate Capacitance (with shield-can)			0.007 max mmfd.
Input Capacitance			3.5 mmfd.
Output Capacitance			10 mmfd.

41

Power Amplifier for radio receivers. Crystal oscillator. U.H.F. oscillator.

Note: More output than a 38, same as 89 pentode, but greater power sensitivity than an 89.

Characteristics:

Heater Voltage (A.C. or D.C.)				6.3 volts
Heater Current				0.4 ampere
Plate Voltage	100	135	180	250 max. volts
Screen Voltage	100	135	180	250 max. volts
Grid Voltage	—7	—10	—13.5	—18 volts
Plate Current	9.0	12.5	18.5	32 milliamperes
Screen Current	1.6	2.2	3.0	5.5 milliamperes
Plate Resistance	103500	94000	81000	68000 approx. ohms
Amplification Factor	150	150	150	150 approx.
Mutual Conductance	1450	1600	1850	2200 micromhos
Load Resistance	12000	10400	9000	7600 ohms
Power Output	0.33	0.75	1.5	3.4 watts

42

Pentode Power Amplifier for radio receivers.

Equivalent Metal Tube—6F6.

Uses:

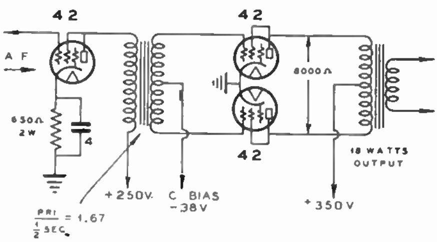
(1) Single or push-pull audio amplifier for radio receivers (pentode).

(2) Crystal oscillators in transmitters.

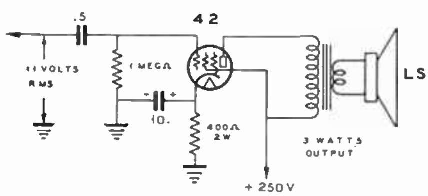
(3) Frequency doublers in transmitters.

(4) Triode driver stage or Class AB push-pull power amplifier.

(See 6L6 applications.)



CLASS AB TRIODE AUDIO AMPLIFIER



PENTODE AUDIO AMPLIFIER FOR RADIO RECEIVERS

Characteristics:

Heater Voltage	6.3 volts
Heater Current	0.7 amp.
Plate Voltage	250 volts
Screen Voltage	250 volts
Grid Voltage	—16.5 volts
Plate Current	34 ma.
Screen Current	6.5 ma.
Plate Resistance	100,000 ohms
Amplification Factor	220
Mutual Conductance	2200 micromhos
Load Resistance	7000 ohms
Power Output (7% distortion)	3.0 watts

Characteristics:

Heater Voltage	6.3 volts
Heater Current	0.3 amps
Grid to Plate Capacitance	1.7 mmfd.
Grid to Cathode Capacitance	1.7 mmfd.
Plate to Cathode Capacitance	3.8 mmfd.
Plate Voltage	250 max. volts
Grid Voltage	—2 volts
Amplification Factor	100
Plate Resistance	91000 ohms
Mutual Conductanse	1100 micromhos
Plate Current	0.8 ma.

Typical Operation:

Plate Supply	180	250 volts
Grid Bias	—1.3	—1.35 volts
Cathode Resistor	5000	3500 ohms
Plate Resistor	0.25	0.25 megohms
Following Grid Resistor	0.5	0.5
Plate Current	0.26	0.39
Voltage Amplification	56	59
Peak Voltage Output	32 to 40	36 to 46

76

General purpose triode for detector and audio amplifier operation in radio receivers and amplifiers. U.H.F. oscillator and super-regenerative detector.

Note: Somewhat similar to 6C5 metal tube.

Characteristics:

Heater Voltage (A.C. or D.C.)	6.3 volts
Heater Current	0.3 amps.
Plate Voltage	250 max. volts
Grid Voltage	—13.5 volts
Plate Current	5 milliamperes
Plate Resistance	9500 ohms
Amplification Factor	13.8
Mutual Conductance	1450 micromhos
Grid-Plate Capacitance	2.8 mmfd.
Grid-Cathode Capacitance	3.5 mmfd.
Plate-Cathode Capacitance	2.5 mmfd.

79

Class B Twin Triode. Class B audio amplifier in automobile radio receivers.

Characteristics:

Heater Voltage (A.C. or D.C.)	6.3 volts
Heater Current	0.6 amps.
Plate Voltage	250 max. volts
Dynamic Peak Plate Current (per plate)	90 max. milliamps.
Average Plate Dissipation	11.5 max. watts

Typical Operation:

Heater Voltage	...	6.3 volts
Plate Voltage	180	250 volts
Grid Voltage	0	0 volts
Static Plate Current	7.5	10.5 milliamps.
Load Resistance (plate-to-plate)	7000	14000 ohms
Nominal Power Output	5.5	8.0 watts

75

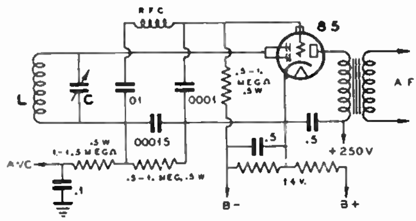
Duplex Diode, High Mu Triode. Combined detector, AVC tube and audio amplifier in super-heterodyne receivers. The triode section is often used in speech amplifier circuits for radiophone transmitters.

Note: AVC circuits are similar to those shown for 6B7 tube.

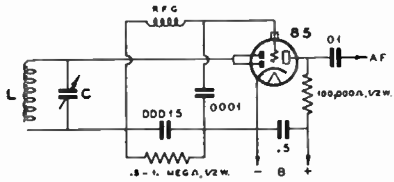
85

Metal Tube Equivalent—6R7. Duplex-Diode Triode. Combined detector, AVC tube and audio amplifier for super-heterodyne receivers.

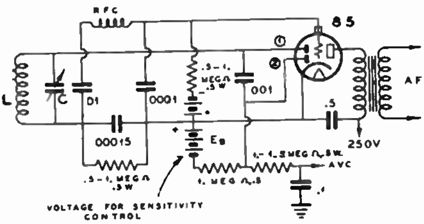
Note: The power output shown in the table only holds true with transformer or impedance coupling where full values of plate voltage and current are applied to the tube. Under optimum conditions, the output is sufficient to drive a Class AB amplifier.



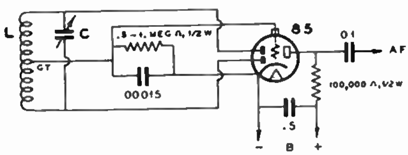
HALF WAVE DETECTOR FIXED BIAS AMPLIFIER



HALF WAVE DETECTOR DIODE BIASED AMPLIFIER



HALF WAVE DETECTOR, SEPARATE A. V. C., FIXED BIAS AMPLIFIER



FULL WAVE DETECTOR DIODE BIASED AMPLIFIER

Characteristics:

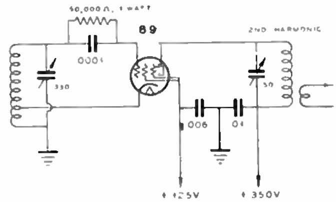
Heater Voltage			6.3 volts
Heater Current			0.3 amps.
Grid to Plate Capacitance			1.5 mmfd.
Grid to Cathode Capacitance			1.5 mmfd.
Plate to Cathode Capacitance			4.3 mmfd.
Plate Voltage	135	180	250 max. volts
Grid Voltage	—10.5	—13.5	—20 volts
Amplification Factor	8.3	8.3	8.3
Plate Resistance	11000	8500	7500 ohms
Mutual Conductance	750	975	1100 micromhos
Plate Current	3.7	6.0	8 ma.
Load Resistance	25000	20000	20000 ohms
Power Output	75	160	350 milliwatts

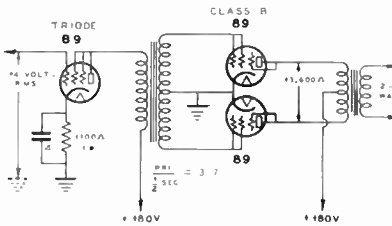
89

Triple Grid Power Amplifier. Designed for storage battery operation, such as in automobile radio receivers. Can be used with AC supply. Occasionally used as an electron-coupled or crystal oscillator in short-wave transmitters.

Note: The triple-grid construction makes operation possible as a Class A triode or pentode amplifier and as a Class B triode.

Not in general use. Not very desirable for operation at RF frequencies above 10 mc.





Characteristics:

Heater Voltage (A.C. or D.C.) .... 6.3 volts
Heater Current .... 0.4 amps.
Base .... Small 6-pin

Class B Power Amplifier—Triode Connection:

(Grids No 1 and No. 2 tied together; grid No. 3 tied to plate)

Plate Voltage .... 250 max. volts
Dynamic Peak Plate Current .... 90 max. milliamperes
Average Grid Dissipation (Grids No. 1 and No. 2 together) .... 0.35 max. watt

Typical Operation (2 Tubes):

Heater Voltage .... 6.3 volts
Plate Voltage .... 180 volts
Grid Voltage (Grids No. 1 and No. 2 together) .... 0 volts
Static Plate Current (per tube) .... 3 milliamperes
Load Resistance (plate-to-plate) .... 9400 ohms
Nominal Power Output (2 tubes) .... 3.5 watts

Class A Power Amplifier—Triode Connection:

(Grids No. 2 and No. 3 tied to plate).

Heater Voltage			6.3 volts
Plate Voltage	160	180	250 max. volts
Grid Voltage (Grid No. 1)	—20	—22.5	—31 volts
Amplification Factor	4.7	4.7	4.7
Plate Resistance	3300	3000	2600 ohms
Mutual Conductance	1425	1550	1800 micromhos
Plate Current	17	20	32 milliamperes
Load Resistance	7000	6500	5500 ohms
Undistorted Power Output	0.3	0.4	0.9 watt

Class A Power Amplifier—Pentode Connection:

(Grid No. 3 tied to cathode).

Heater Voltage				6.3 volts
Plate Voltage	100	135	180	250 max. volts
Screen Voltage (Grid No. 2)	100	135	180	250 max. volts
Grid Voltage (Grid No. 1)	—10	—13.5	—18	—25 volts
Amplification Factor	125	125	125	125
Plate Resistance	104000	92500	80000	70000 ohms
Mutual Conductance	1200	1350	1550	1800 micromhos
Plate Current	9.5	14	20	32 milliamperes
Screen Current	1.6	2.2	3.0	5.5 milliamperes
Power Output*	0.33	0.75	1.5	6750 ohms
Load Resistance	10700	9200	8000	3.4 watts

*9% total harmonic distortion.

6A4

Pentode filament type power pentode for last stage of automobile receivers. Not in general use.

Characteristics:

Filament Voltage (A.C. or D.C.)				6.3 volts
Filament Current				0.3 amps.
Plate Voltage	100	135	165	180 max. volts
Screen Voltage	100	135	165	180 max. volts
Grid Voltage	—6.5	—9	—11	—12 volts
Plate Current	9	14	20	22 milliamperes
Screen Current	1.6	2.5	3.5	3.9 milliamperes
Plate Resistance	83250	52600	48000	45500 approx. ohms
Amplification Factor	100	100	100	100 approx.
Mutual Conductance	1200	1900	2100	2200 micromhos
Load Resistance	11000	9500	8000	8000 ohms
Power Output	0.31	0.7	1.2	1.4 watts

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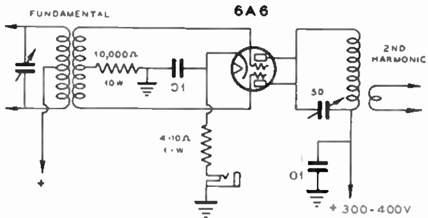
6A6

Equivalent Metal Tube—6N7. Twin Triode Power Tube designed for Class B audio amplifiers in radio receivers. Also very useful as crystal oscillator and frequency doubler in transmitters, for frequencies up to 30 mc. Often used in 5 meter transmitters and receivers as oscillators and detectors.

Precautionary Measures: 300 volt plate supply is maximum as a Class B audio amplifier. As an RF oscillator or doubler, the plate potential must not exceed 400 volts if cathode bias is used, and not over 300 for grid-leak bias. For RF purposes the DC plate current per plate should not exceed 35 ma. and excessive grid excitation should be avoided.



6A6 Push-Push RF Frequency Doubler

Characteristics:

Heater Voltage	6.3 volts
Heater Current	0.8 amp.
Plate Dissipation	10 watts

As Class A Amplifiers (Triodes in Parallel):

Plate Voltage	250	300 volts
Plate Current	6	7 ma.
Grid Voltage	—5	—6 volts
Amplification Factor	35	35
Plate Resistance	11300	11000 ohms
Mutual Conductance	3100	3200 micromhos.

As Class B Amplifier (Triodes in Push-Pull):

Plate Voltage	250	300 volts
Grid Voltage	0	0 volts
Zero Signal Plate Current (per plate)	14	17.5 ma.
Maximum Plate Current	125	125 volts
Load Resistance (plate-to-plate)	8000	10000 ohms
Power output (with 350 millwatt input to grids)	8	10 watts

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6A7

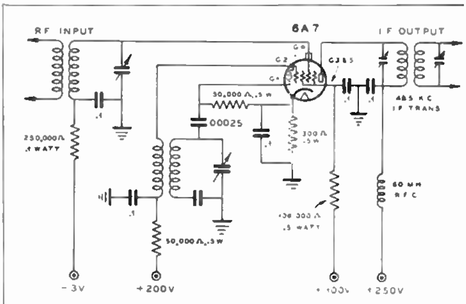
Metal Tube Equivalent—6A8. Pentagrid Converter same as 6A8—mixer (first detector) and oscillator for super-heterodyne receivers.

Frequency Range: Not recommended above 25 mc. Conversion gain drops and apparent tube noise increases above 10 mc.

Characteristics:

Heater Voltage	6.3 volts
Heater Current	0.3 amps.
Control Grid No. 4 to Plate Capacitance	0.3 mmfd.
R-F Input	8.5 mmfd.
Mixer Output	9.0 mmfd.
Oscillator Grid No. 1 to Anode Grid No. 2	1.0 mmfd.
Oscillator Grid No. 1 Input	7.0 mmfd.
Oscillator Anode-Grid No. 2 Output	5.5 mmfd.

Other characteristics are similar to 6A8 metal tube.



PENTAGRID CONVERTER

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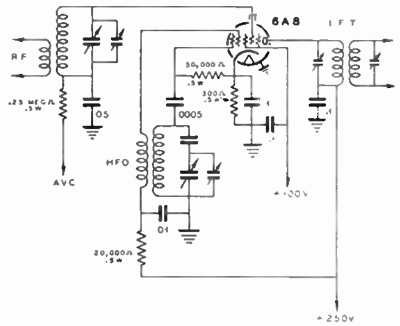
6A8

Glass Tube Equivalent — 6A7. Metal Tube Pentagrid Converter. Combined mixer (first detector) and H.F. oscillator in super-heterodyne receivers. Remote cut-off of control grid allows connection in AVC circuits.

Note: Due to inter-action effects, the 6A8 conversion gain drops rapidly below 10 megacycles, resulting in high tube noise and poor signal sensitivity in most receivers using this tube at 15 or 20 mc.



6A8 FREQUENCY CONVERTER CIRCUIT FOR SUPERHETERODYNE RECEIVER.

Characteristics:

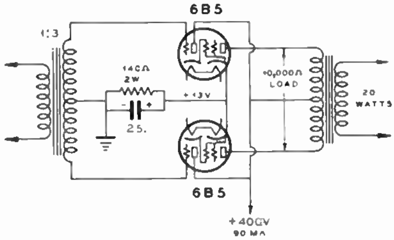
Heater Voltage	6.3 volts
Heater Current	0.3 amps.
R-F Input Capacitance	12.5 mmfd.
Oscillator Input Capacitance	6.5 mmfd.
Oscillator Output Capacitance	5 mmfd.
Mixer Output Capacitance	12.5 mmfd.
Plate Voltage	250 volts
Screen Voltage	100 volts
Anode-Grid Voltage	175 volts
Control Grid Voltage	—3 volts
Plate Current	3.3 ma.
Screen Current	3.2 ma.
Anode-Grid Current	4.0 ma.
Oscillator Grid Current	0.5 ma.
Conversion Conductance	500 micromhos.
Maximum Cathode Current	14 ma.
Control Grid Voltage for Conductance of 2 Micromhos	—45 volts

Octal Base.

6B5

Equivalent Tubes—6N6G, 6N6. Glass Tube Special Power Amplifier. Designed for power amplifier use in the output stage of a radio receiver. Can be used in push-pull for outputs as high as 20 watts in small power amplifiers or modulators. Due to the gain within the double triode tube, the input grid does not need to be driven beyond Class A, and a 76 tube will drive a pair of 6B5 tubes to 20 watts output.

Unusual Characteristics: An internal grid of the power output triode is direct-coupled to an internal cathode. No external connections are necessary, and the small triode drives the large triode in Class AB.



6B5 MODULATOR OR DRIVER STAGE

Characteristics:

Heater Voltage	6.3 volts
Heater Current	0.8 amps.
Plate Supply	300 volts
Input Plate Current	6 ma.
Output Plate Current	45 ma.
Plate Resistance	24100 ohms
Load Resistance	7000 ohms
Power Output	4 watts
Amplification Factor	58
Mutual Conductance	2400 micromhos.
Grid Bias Voltage	0
Base	medium, 7 pin

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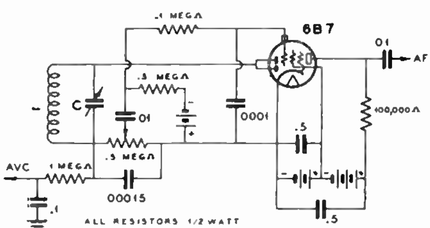
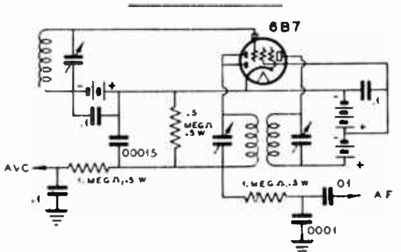
6B7

Duplex-Diode Pentode, combined detector, amplifier and automatic volume control tube for superheterodyne receivers. Pentode portion is used as RF or AF amplifier.



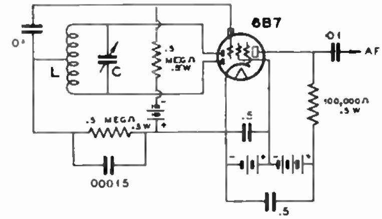
HALFWAVE DET. & A.V.C., FIXED BIAS AMPLIFIER



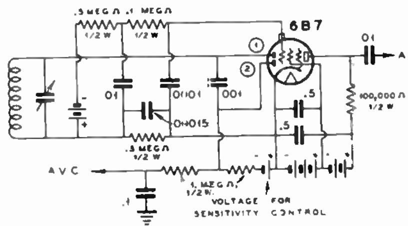
HALF WAVE DET., FIXED-BIAS HF AMPLIFIER

Note: Due to its low grid to plate capacitance the 6B7 tube is a good RF amplifier, differing from the 6Q7 metal tube in this respect.

It has a double diode and single RF pentode.



FULL WAVE DETECTOR, FIXED BIAS AMPLIFIER



HALFWAVE DET., SEPARATE AVC., FIXED BIAS AMPLIFIER

Characteristics:

Heater Voltage	6.3 volts		
Heater Current	0.3 amps.		
Grid to Plate Capacitance	.007 mmfd.		
Grid to Cathode Capacitance	3.5 mmfd.		
Output Capacitance	9.5 mmfd.		
Plate Voltage	100	180	250 max. volts
Screen Voltage	100	75	100 volts
Grid Voltage	—3	—3	—3
Plate Current	5.8	3.4	6.0 ma.
Screen Current	1.7	0.9	1.5 ma.
Plate Resistance	3.3	1.0	0.8 megohms
Amplification Factor	285	840	800
Mutual Conductance	950	840	1000 micromhos.
Cut-off Bias (Approx.)	—17	—13	—17 volts

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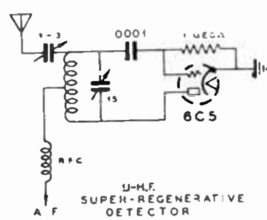
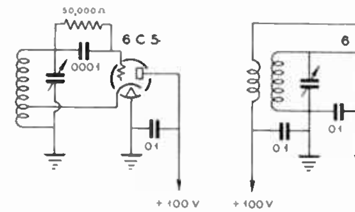
6C5

Triode for RF or audio purposes. Well suited for resistance or transformer coupled audio amplifiers. Glass tube equivalent is 76.

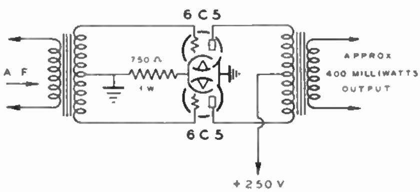


U-H.F.
SUPER-REGENERATIVE
DETECTOR

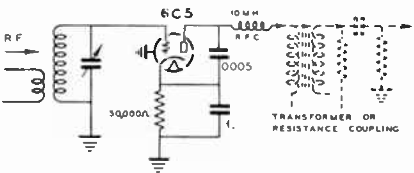
Because of its high mutual conductance the 6C5 is an effective RF oscillator in super-heterodyne receivers for wave lengths as low as 5-meters. It may be used as a super-regenerative detector in U.H.F. receivers down to 2½ meters (see U.H.F. Chapter).



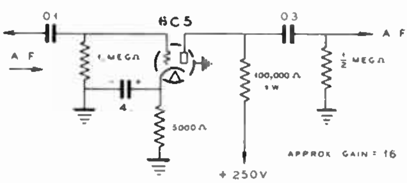
R. F., I. F. OR B. F. OSCILLATORS



PUSH-PULL AUDIO AMPLIFIER—DRIVER FOR CLASS A OR AB STAGE



BIAS DETECTOR FOR SUPERHETERODYNE RECEIVER



RESISTANCE COUPLED AUDIO AMPLIFIER

Characteristics:

Heater Voltage	6.3 volts
Heater Current	0.3 amp.
Plate Voltage	250 max. volts
Grid Voltage	—8 volts
Plate Current	8 ma.
Plate Resistance	10000 ohms
Amplification Factor, mu	20
Grid to Plate Capacitance	1.8 mmfd.
Input Capacitance	4 mmfd.
Output Capacitance	13 mmfd.

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6C6

Metal Tube Equivalent—6J7. Triple-Grid detector and audio amplifier in radio receivers and speech amplifiers. Can be used as RF amplifier for relatively low RF input signals, or as a triode audio amplifier.

Note: Refer to 6J7 for further data.

Characteristics:

Heater Voltage		6.3 volts
Heater Current		0.3 amps.
Plate Voltage	100	250 max. volts
Screen Voltage	100	100 max. volts
Grid Voltage	—3	—3 volts
Suppressor Connected to Cathode at socket.		
Plate Current	2	2 ma.
Screen Current	.5	.5 ma.
Plate Resistance	1.0	more than 1.5 megohm
Mutual Conductance	1185	1225 micromhos.
Cut-off Bias	—7	—7
Grid to Plate Capacitance (shielded).		.010 mmfd.
Input Capacitance		5.0 mmfd.
Output Capacitance		6.5 mmfd.

Triode (Screen and Suppressor Connected to Plate):

Plate Voltage	250 volts
Plate Current	7 ma.
Grid Bias	—8 volts

Can be used with resistance coupling and lower bias and less plate current.

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6D5

Glass Tube Equivalent—45. Metal Tube Triode Power Amplifier for radio receivers in single or push-pull connections. Can be used as an oscillator in 5-meter circuits.

Note: See application circuits of type 45 tube.

Characteristics:

Heater Voltage	6.3 volts
Heater Current	0.7 amp.
Plate Voltage	275 volts
Grid Voltage	—40 volts
Plate Current	31 ma.
Plate Resistance	2250 ohms
Amplification Factor	4.7
Mutual Conductance	2100 micromhos
Power Output	1.4 watts
Octal base.	

Class A B Amplifier:

Maximum Plate Voltage	300 volts
Grid Voltage	—50 volts
Plate Current Per Tube	23 ma.
Plate Load	5300 ohms.
Power Output	5 watts

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6D6

Metal Tube Equivalent—6K7, see 6K7 data for further information. Triple-Grid Super Control RF amplifier in radio receivers. Adaptable to RF and IF stages in receivers with AVC. Can be used as a mixer in super-heterodyne receivers with approx. —10 volt grid bias.

Characteristics:

Heater Voltage		6.3 volts
Heater Current		0.3 volts
Plate Voltage	100	250 volts (max.)
Screen Voltage	100	100 volts (max.)
Grid Voltage	—3	—3 volts
Suppressor tied to Cathode at socket.		
Plate Current	8	8.2 ma.
Screen Current	2.2	2.0 ma.
Plate Resistance	.25	.8 megohm
Amplification Factor	375	1280
Mutual Conductance	1500	1600 micromhos.
Mutual Conductance (at —40v. Bias)	10	10 micromhos.
Grid to Plate Capacitance		.010 mmfd.
Input Capacitance		4.7 mmfd.
Output Capacitance		6.5 mmfd.

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6D8G

Pentagrid Converter. Detector-oscillator tube in super-heterodyne receivers where heater current requirements are low.

Characteristics:

Heater Voltage		6.3 volts
Heater Current		0.15 amps.
Plate Voltage	135	250 volts
Screen Voltage	67.5	100 volts
Anode-Grid Voltage	135	250 volts (thru 20,000 ohms)
Control Grid Voltage	—3	—3 volts
Conversion Conductance	325	500 micromhos.
Plate Resistance	.4	.32 megohms
Grid Bias for Conductance of 10.	—25	—38.5 volts
Triode Mutual Conductance....	1150	1000 micromhos.
R-F Input Capacitance		8.0 mmfd.
Mixer Output Capacitance		11.0 mmfd.
Oscillator Input Capacitance		6.0 mmfd.
Oscillator Output Capacitance		5.5 mmfd.
Oscillator Grid to Anode-Grid Capacitance		1.0 mmfd.
Control Grid to Plate Capacitance....		0.3 mmfd.

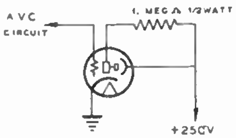
6E5-6G5

Electron-Ray Resonance Tuning Indicator for radio receivers. Visual indicator for audio volume expander circuits.

Unusual Characteristics: The target glows with a greenish light in a sector of a disk. An increase of negative DC voltage on the grid narrows the width of this segment so that the tube can be used as a visual indicator.

Note: The 6G5 Electron Ray tube is similar to the 6E5, except for "variable mu" characteristics. Its cut-off grid voltage is —22 volts.

6E5 - 6G5



CATHODE RAY TUNING INDICATOR CKT

Characteristics:

Heater Voltage	6.3 volts
Heater Current	0.3 amps.
Plate Supply Voltage	250 volts
Plate Current	0.25 ma.
Plate Resistor	1 megohm
Target Current	4.5 ma.
Grid Voltage	0 volts
"Cut-off" Voltage	—8 volts

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6E6

Duplex Triode Class A Power Amplifier for low power output automobile radio receivers.

Characteristics:

Heater Voltage	6.3 volts
Heater Current	0.6 amps.
Maximum Plate Voltage	250 volts
Maximum Plate Current	36 ma. (both sections)
Grid Bias	—27.5 volts
Amplification Factor	6
Plate Resistance	1750 ohms
Mutual Conductance	3400 micromhos.
Maximum Power Output	0.75 watts
Recommended Load Resistance	14000 ohms

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6F5

Glass Tube Equivalent — Triode Section of 75. Metal Tube, High Mu Triode for resistance-coupled audio amplifiers. Can be used in 5-meter receiver circuits as a super-regenerative detector.

Note: See 6H6 Circuit application.

Characteristics:

Heater Voltage	6.3 volts
Heater Current	0.3 amps.
Plate Voltage	250 volts
Grid Voltage	—2 volts
Plate Current	0.9 ma.
Plate Resistance	66000 ohms
Amplification Factor	100
Mutual Conductance	1500 micromhos.
Grid to Plate Capacitance	2 mmfd.
Input Capacitance	6 mmfd.
Output Capacitance	12 mmfd.

Octal base.

Application:

Plate Supply	250 volts
Grid Bias	—1.3 volts
Plate Load Resistor	0.25 to 1.0 megohms
Plate Current	0.2 to 0.4 ma.
Approximate Amplification	50 to 60
Approximate Voltage Output	15 to 25 volts (RMS)

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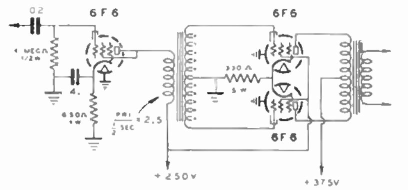
6F6

Glass Tube Equivalent—42. Metal Tube Amplifier for radio receivers and small public address systems. (See applications of 6L6 and 42.)



18 WATT AUDIO AMPLIFIER

Characteristics:

Heater Voltage	6.3 volts
Heater Current	0.7 amps.

Octal Base

Single Tube Class A Amplifier:

	Pentode Connection		Triode Connection
Plate Voltage	250	315	250 volts
Screen Voltage	250	315	...
Grid Voltage	—16.5	—22	—20 volts
Plate Current	34	42	31 ma.
Screen Current	6.8	8	...
Bias Resistor	410	440	650 ohms
Plate Resistance	80000	75000	2600 ohms
Amplification Factor	200	200	7
Mutual Conductance	2500	2650	2700 micromhos.
Load Resistance	7000	7000	4000
Harmonic Distortion	7	7	5
Power Output	3	5	0.85

Push-Pull Class AB Amplifier (Pentode)

	Fixed Bias	Self Bias
Plate Voltage	375	375 volts
Screen Voltage	250	250 volts
Grid Voltage	—26	... volts
Self Bias Resistor	...	350 ohms
Zero Signal Plate Current (per tube)	17	27 ma.
Zero Signal Screen Current (per tube)	2.5	4 ma.
Eff. Load Resistance	2500	2500 ohms
Plate to Plate Load Resistance	10000	10000 ohms
Harmonic Distortion	5	5 percent
Power Output	19	19 watts

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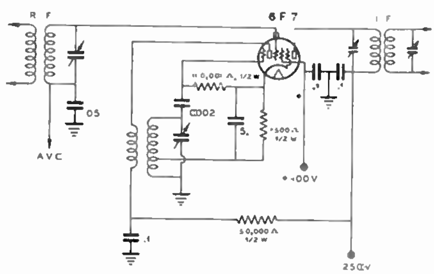
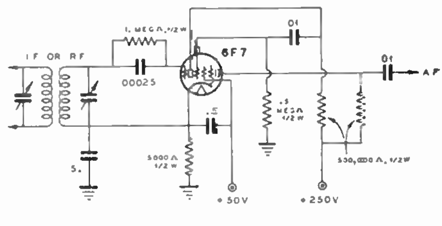
6F7

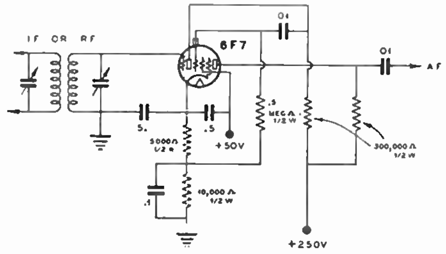
Metal Tube Equivalent — 6P7. Triode-Pentode. Mixer-oscillator in super-heterodyne receivers. Second detector and BFO or audio amplifier. U.H.F. receiver circuits.



FREQUENCY CONVERTER

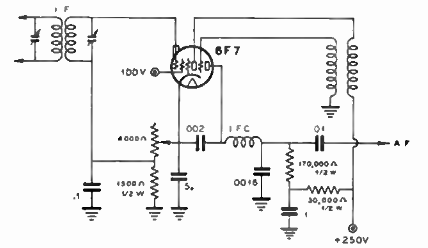


GRID LEAK TRIODE DETECTOR & PENTODE AUDIO AMPLIFIER



BIASED TRIODE DETECTOR AND PENTODE AUDIO AMPLIFIER

Characteristics:
Heater Voltage ....6.3 volts
Heater Current ....0.3 amps.
Direct Interelectrode Capacitances:
Triode Unit—
Grid to Plate Capacitance ....2.0 mmfd.
Grid to Cathode Capacitance....................2.5 mmfd.
Plate to Cathode Capacitance....................3.0 mmfd.
Pentode Unit—
Grid to Plate Capacitance................ .008 mmfd. max.
Input Capacitance ....3.2 mmfd.
Output Capacitance ....12.5 mmfd.



PENTODE I F AMPLIFIER AND BIASED TRIODE 2ND DETECTOR

Converter Service:

	Oscillator Triode Unit	Pentode Unit
Plate Voltage	100	250 volts
Screen Voltage	...	100
Grid Bias	grid leak	—10
Plate Resistance	...	2 megohms
Conversion Conductance	...	300 micromhos.
D.C. Plate Current	2.4	2.8 ma.
D.C. Grid Current	0.15	0 ma.
Screen Current	...	0.6 ma.
Oscillator Peak R-F Voltage Input	...	7 volts

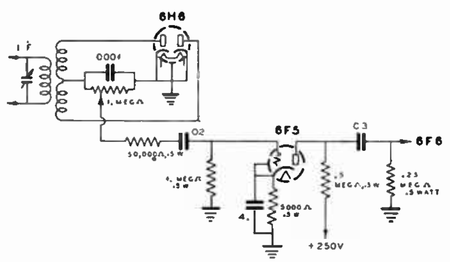
Amplifier Service:

	Triode Unit	Pentode Unit	
Plate Voltage	100 max.	100	250 max. volts
Screen Voltage	...	100	100 max. volts
Grid Voltage	—3	—3	—3 min. volts
Plate Current	3.5	6.3	6.5 ma.
Screen Current	...	1.6	1.5 ma.
Amplification Factor	8	300	900
Mutual Conductance	500	1050	1100 micromhos
Mutual Conductance at —35 Volt Bias	...	9	10
Plate Resistance	16000	290000	850000 ohms

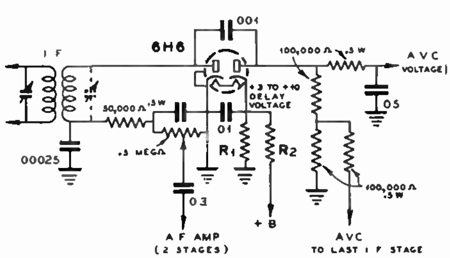
6H6

Twin Diode Metal Tube for radio receiver detector and Automatic Volume Control systems.

Unusual Characteristics: Separate cathode for each diode plate.



FULL-WAVE RECTIFIER-DETECTOR & HIGH GAIN AUDIO STAGE



DELAYED AVC & SECOND DETECTOR CIRCUIT

Characteristics:
Heater Voltage ....6.3 volts
Heater Current ....0.3 amps.
Plate to Plate Capacitance .... .02 mmfd.
Maximum RMS Plate Voltage....................100 volts
Maximum D.C. Output Current ....4 ma.
Octal Base.

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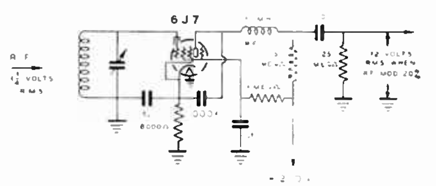
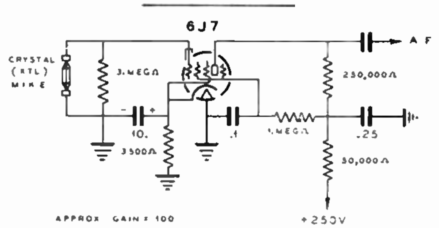
6J7

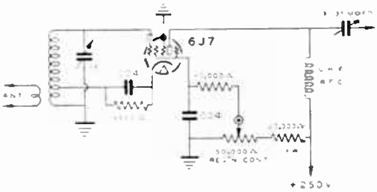
Glass Tube Equivalent—6C6.
Purpose: Triple-Grid Detector-Amplifier or biased detector in radio receivers. Other applications are high-gain audio amplifier and RF amplifier for low values of input signals where a variable mu characteristic is not necessary. Can be utilized as a regenerative RF amplifier in U.H.F. receivers up to 60 megacycles.



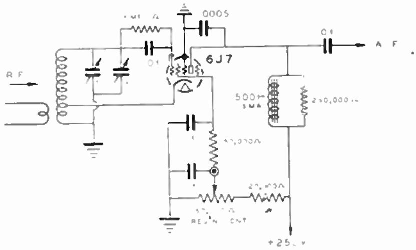
BIAS DETECTOR FOR SUPERHETERODYNE RECEIVERS



RESISTANCE COUPLED A F AMPLIFIER



5 OR 10 METER REGENERATIVE R F AMPLIFIER FOR U H F RECEIVERS



SHORT WAVE REGENERATIVE GRID LEAK DETECTOR

Characteristics:

Heater Voltage		6.3 volts
Heater Current		0.3 amps.
Plate Voltage	100	250 volts
Screen Voltage (No. 2)	100	100 volts
Suppressor Voltage (No. 3)	connect to cathode	
Control Grid Voltage (No. 1)	—3	—3 volts
Plate Current	2	2 ma.
Screen Current	0.5	0.5 ma.
Plate Resistance	1.0	1.5 megohms
Amplification Factor	1185	1500 or more
Mutual Conductance	1185	1225 micromhos.
Grid Voltage for Cut-Off	—7	—7 volts
Grid to Plate Capacitance		.005 mmfd.
Input Capacitance		7 mmfd.
Output Capacitance		12 mmfd.

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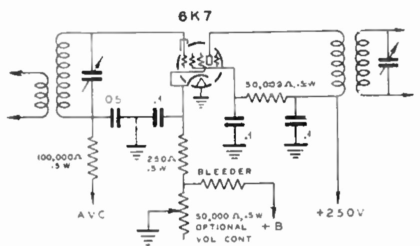
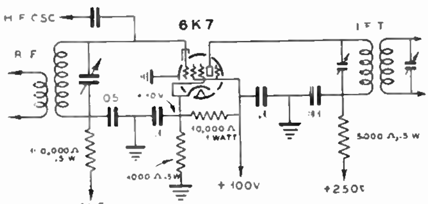
6K7

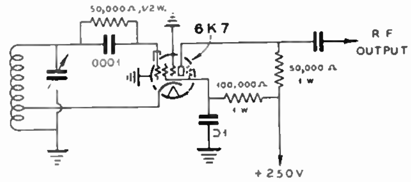
Glass Equivalent—78.
Triple-Grid R-F or I-F amplifier in radio receivers. Oscillator for super heterodyne receivers. Mixer-detector in super-heterodyne receivers.



TYPICAL RF OR IF AMPLIFIER



MIXER OR 1ST DETECTOR IN A SUPERHETERODYNE RECEIVER. APPROX. GAIN FROM 30-60.



ELECTRON COUPLED H F OSCILLATOR OR B F OSCILLATOR

Characteristics:

Heater Voltage		6.3 volts
Heater Current		.3 amps.
Plate Voltage	180	250 volts
Screen (No. 2) Voltage	75	125 volts
Grid (No. 1) Voltage	—3	—3 volts
Suppressor (No. 3)		connect to cathode
Plate Current	4.0	10.5 ma.
Screen Current	1.0	2.6 ma.
Plate Resistance	1.0	.6 megohms
Amplification Factor	1100	990
Mutual Conductance	1100	1650 micromhos.
Grid Voltage at G2	—32.5	52.5
Grid-Plate Capacitance		.005 mmfd.
Input Capacitance		7 mmfd.
Output Capacitance		12 mmfd.
Octal Base.		

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6L5G

General purpose triode similar to 6C5G, but with low heater current drain.

Characteristics:

Heater Voltage		6.3 volts
Heater Current		0.15 amps.
Plate Voltage	135	250 volts
Grid Voltage	—5	—9 volts
Plate Current	3.5	8.0 ma.
Plate Resistance	11300	9000 ohms
Amplification Factor	17	17
Mutual Conductance	1500	1900 micromhos.
Grid to Plate Capacitance		2.7 mmfd.
Grid to Cathode Capacitance		3.0 mmfd.
Plate to Cathode Capacitance		5.0 mmfd.

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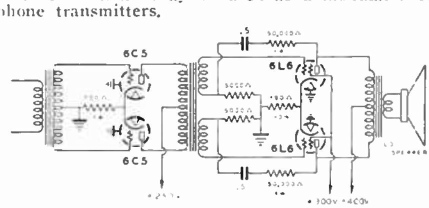
6L6

Glass Equivalent—6L6G.
Purpose: Designed primarily for push-pull amplifier in radio receivers but also widely used in crystal oscillator and RF amplifiers for radio transmitters.

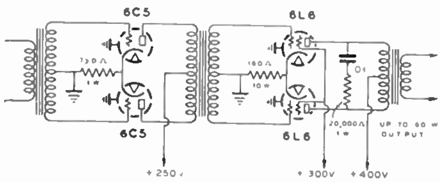
Unusual Characteristic: Has two beam-forming plates internally connected to the cathode. Has no physical suppressor grid. The beam action suppresses secondary emission and results in a more ideal pentode operation.

Precautionary Measures: Good air ventilation is desirable because the tube shell becomes very hot under normal operation. In push-pull circuits, balanced tubes are necessary, as well as balanced transformers if second harmonic elimination is desired.

Audio Amplifier Application: If not over 34 watts of audio output is required, a single 6C5 audio amplifier or power detector will drive a pair of 6L6 tubes in push-pull. A 1-to-2, or 1-to-3 step-up interstage transformer is suitable. For outputs of over 34 watts, push-pull 6C5 tubes are suitable for drivers, with a 1-to-½ primary-to-½-secondary ratio interstage transformer. The output transformer should be of large size in order to handle up to 60 watts of audio power without core saturation. May be used as a modulator for phone transmitters.

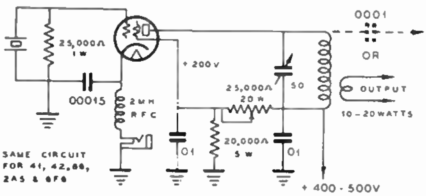


REVERSED FEEDBACK AUDIO AMPLIFIER FOR HIGH QUALITY RECEIVERS



PUSH-PULL AUDIO AMPLIFIER FOR RECEIVERS, PUBLIC ADDRESS OR MODULATOR SERVICE.

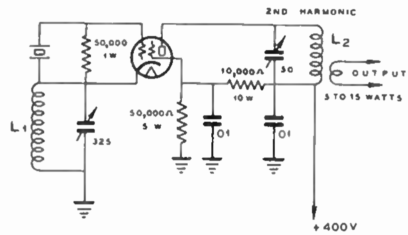
Feed-back Amplifier Application: Reverse feed-back operation in a receiver amplifier will damp-out low-frequency loudspeaker resonance. The result is similar in action to a triode, but the DC efficiency of a pentode is retained without much sacrifice in power sensitivity. Part of the output is fed back to the grid circuits in reverse phase in order to produce the effect of lower plate impedance.



6L6 CRYSTAL OSCILLATOR WITH CATHODE REGENERATION

This Circuit Can Also Be Used with 41, 42, 2A5, 89 and 6F6 Tubes

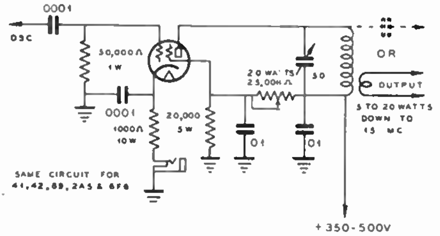
Crystal Oscillator Application: The crystal RF current is very low due to the high power sensitivity of this tube. Outputs of from 5 to 15 watts can be obtained as a crystal oscillator without exceeding tube ratings.



6L6 TRITET OR DOW CRYSTAL OSCILLATOR

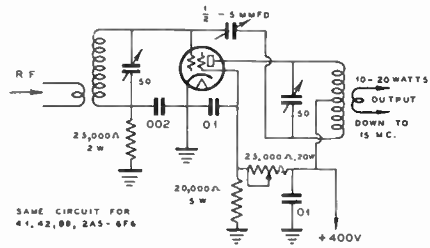
The Same Circuit Is Also Suitable for 41, 42, 2A5, 89 and 6F6 Tubes

RF Applications: The 6L6 is suitable for a low power frequency doubler in transmitters. Due to high sensitivity and harmonic output, only a small amount of power is required to drive the grid as a doubler for outputs of 20 watts and more for frequencies as high as 15 mc.



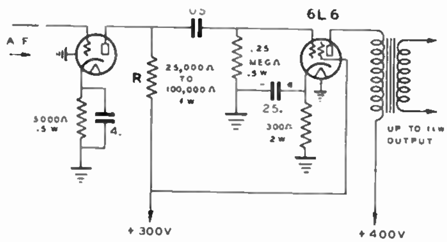
6L6 REGENERATIVE R F DOUBLER

Suitable Circuit for Other Tubes, Such as 41, 42, 2A5, 89 and 6F6



6L6 NEUTRALIZED R F BUFFER OR DOUBLER

41, 42, 2A5, 89 or 6F6 Tubes Can Be Used in Same Circuit



6L6 Audio Amplifier with 6F5 Driver. Low Values of "R" Tend to Generate Out-of-Phase 2nd Harmonic Which Cancels Distortion of 6L6 as Single-Tube Audio Amplifier

Characteristics:

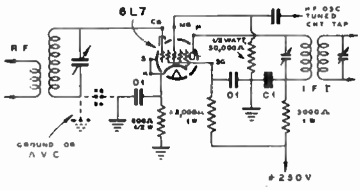
Heater Voltage	6.3 volts
Heater Current	0.9 amps.
Amplification Factor	135
Plate Resistance	22500 ohms
Mutual Conductance	6000 micromhos.

Operation Characteristics:

	Single Tube		Push Pull Tubes			
Plate Voltage	250	375	250	400	400	
Screen Voltage	250	250	250	300	300	
Control Grid Voltage	—14	—17.5	—16	—25	—25	
Zero Signal Plate Current	72	57	60	50	50	
Full Signal Plate Current	79	67	70	76	114	
Zero Signal Screen Current	5	2.5	5	2.5	2.5	per tube
Full Signal Screen Current	7.3	6	8	8.5	9.5	
Signal-Peak Volts	14	17.5	16	25	42.5	
Load in Ohms	2500	4000	5000	6600	3800	plate to plate
Power Output—Watts	6.5	11.5	14.5	34	60	
Total Distortion	10.	14.5	2.	2.	2.	
2nd Harmonic	9.7	11.5	...	...	...	
3rd Harmonic	2.5	4.2	2.	2.	2	
Peak Grid Driving Power	...	...	...	0	400	

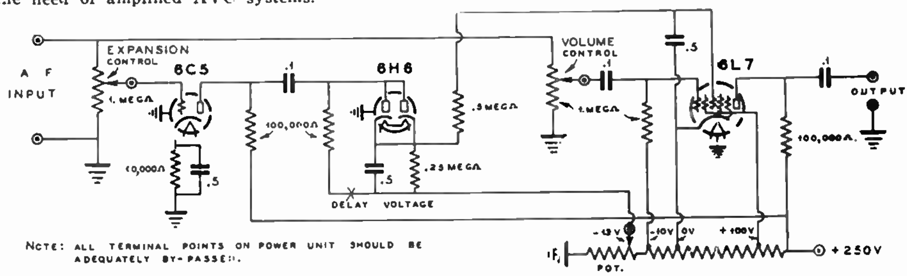
6L7

Glass Tube Equivalent—6L7G. Pentagrid Mixer Amplifier Metal Tube, designed primarily for mixer use in all-wave super-heterodyne receivers. Gives more gain at high-frequencies than other types of mixer tubes or circuit combinations. Suitable for RF or IF amplifier service and in audio volume expander circuits.



MIXER CIRCUIT FOR 6L7 TUBE

Amplifier Notes: AVC characteristic similar to sharp cut-off RF amplifiers, but without cross-modulation effects. Easy tuning in AVC receiver circuits can be obtained by substituting 6L7 for 6K7 tubes with proper circuit changes, eliminating the need of amplified AVC systems.



NOTE: ALL TERMINAL POINTS ON POWER UNIT SHOULD BE ADEQUATELY BY-PASSED.

Volume Expander Circuit for Radio or Phonograph Amplifier

Unusual Characteristics: The additional grid (No. 3) allows a mixing action with higher plate resistance and less loading effect on the first IF tuned circuit. This results in better selectivity and gain. At signal frequencies of from 10 to 60 megacycles, the conversion gain is several times as great as can be obtained from a 6A8 mixer-oscillator tube. The 6L7 requires an external oscillator, such as 6C5, 6K7, or 955 tube.

Characteristics:

Heater Voltage	6.3 volts
Heater Current	0.3 amps.

Interelectrode Capacities:

No. 1 Grid to No. 3	0.12 mmfd.
No. 1 Grid to Plate	.0005 mmfd.
No. 3 Grid to Plate	0.25 mmfd.
No. 1 Grid to all other Electrodes	8.6 mmfd.
No. 3 Grid to all Other Electrodes	11.5 mmfd.
Plate to all other Electrodes	12.5 mmfd.

Octal Base.

Application as Mixer or First Detector:

Plate Voltage	250 volts
Screen Voltage (No. 2 and No. 4)	150 volts
Signal Grid (No. 1)	—6 volts
Oscillator Gride (No. 3)	—15 volts
Peak Oscillator Voltage on No. 3 Grid	18 volts
Plate Current	3.3 ma.
Screen Current	8.3 ma.
Plate Resistance	over 1 megohm
Conversion Conductance	350 micromhos.
No. 1 Grid Voltage for 5 Micromho Conductance	—45 volts

Application as an Amplifier:

Plate Voltage	250 volts
Screen Voltage	100 volts
Control Grid (No. 1)	—3 volts
Control Grid (No. 3)	—3 volts
Plate Current	5.3 ma.
Screen Current	5.5 ma.
Plate Resistance	0.8 megohm
Mutual Conductance	1100 micromhos.
Mutual Conductance —15 volts on Grids No. 1 and No. 3	5 micromhos.

6N5

Cathode Ray tuning indicator for automobile receivers or other receivers requiring low current drain.

Characteristics:

Heater Voltage	6.3 volts
Heater Current	0.15 amps.
Plate Supply	135 volts (max.)
Target Voltage	135 volt (max.)
Triode-Plate Series Resistor	0.25 megohms
Triode-Grid Voltage at 90 Shadow	0 volts
Triode-Grid Voltage at Zero Shadow	12 volts

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6Q6G

Duplex tube with diode for detector-AVC applications and a high mu triode for audio.

Note: Low heater current requirements.

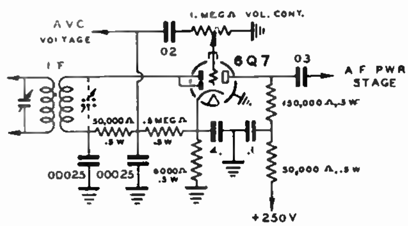
Characteristics:

Heater Voltage		6.3 volts
Heater Current		0.15 amps.
Plate Voltage	135	250 volts
Grid Voltage	—1.5	—3.0 volts
Plate Current	0.9	1.2 ma.
Amplification Factor	65	65
Mutual Conductance	1000	1050 micromhos

Octal base.

6Q7

Glass Equivalent—75. Duplex-Diode High Mu Triode Metal Tube, Combined detector, audio amplifier and automatic volume control tube in radio receivers. Normally used with resistance coupling to an audio power output tube.



TYPICAL 2ND DET-AVC CIRCUIT FOR 6Q7 TUBE

Characteristics:

Heater Voltage	6.3 volts
Heater Current	0.3 amp.
Plate Voltage	250 volts
Grid Voltage	—3 volts
Amplification Factor	70
Plate Resistance	58000 ohms
Mutual Conductance	1200 micromhos
Plate Current	1.1 ma.
Grid to Plate Capacitance	1.5 mmfd.
Grid to Cathode Capacitance	5.5 mmfd.
Plate to Cathode Capacitance	5 mmfd.

Two diode plates and triode have a common cathode.
Octal base.

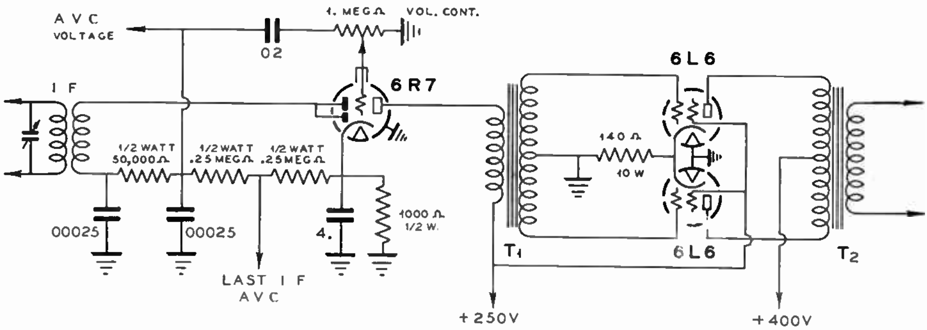
6R7

Glass Equivalent—85. Duplex-Diode Metal Tube Triode. Applications same as 6Q7. Can be transformer-coupled to Class A or low power Class AB power stage.

Characteristics:

Heater Voltage	6.3 volts
Heater Current	0.3 amp.
Plate Voltage	250 volts
Grid Voltage	—9 volts
Plate Current	9.5 ma.
Plate Resistance	8500 ohms
Amplification Factor	16
Mutual Conductance	1900 micromhos
Power Output	280 milliwatts
Grid to Plate Capacitance	2.5 mmfd.
Grid to Cathode Capacitance	5.5 mmfd.
Plate to Cathode Capacity	4.0 mmfd.

Octal base.



6R7 Automatic Volume Control Circuit

6S7G

R-F or A-F amplifier for circuits where low heater current drain is important.

Characteristics:

Heater Voltage		6.3 volts
Heater Current		0.15 amps.
Plate Voltage	135	250 volts
Screen Voltage	67.5	100 volts
Grid Voltage	—3	—3 volts
Suppressor tied to cathode at socket.		
Plate Current	3.7	8.5 ma.
Screen Current	0.9	2.0 ma.
Amplification Factor	850	1100
Mutual Conductance	1250	1750 micromhos
Grid-Bias for Cond. of 10	—25	—38.5 volts
Grid to Plate Capacitance		.007 mmfd.
Input Capacitance		4.6 mmfd.
Output Capacitance		7.8 mmfd.

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12A5

Pentode power amplifier for radio receivers. The heater connections allow series operation for "transformerless" receivers.

Characteristics:

Heater Voltage	6.3	or	12.6 volts
Heater Current	0.6	or	0.3 amps.
Plate Voltage	100		180 volts
Screen Voltage	100		180 volts
Grid Voltage	—15		—27 volts
Plate Current	17		38 ma.
Screen Current	...		8 ma.
Plate Resistance	...		390,000 ohms
Amplification Factor	...		90
Mutual Conductance	1700		2300 micromhos
Load Resistance	4500		3800 ohms
Power Output	0.65		2.6 watts

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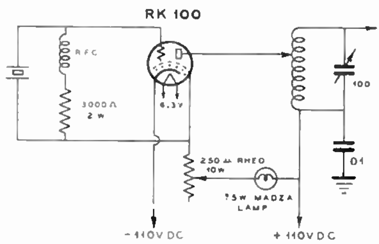
RK-100

Raytheon Gaseous Discharge Amplifier Tube with cathanode element and very low plate resistance. Operates similar to a high vacuum triode tube of very low plate resistance and high mutual conductance.

Uses: As an audio amplifier for 110 volt DC operation. Crystal oscillator. Class C amplifier. UHF oscillator.

Note: Designed primarily for operation on 110 volt DC supply lines.



CRYSTAL OSCILLATOR WITH GASEOUS-DISCHARGE TUBE

Characteristics:

Heater Voltage	6.3 volts
Heater Current	0.9 amp.
Amplification Constant	44
Grid to Plate Capacitance	19 mmfd.
Grid to Cathode Capacitance	23 mmfd.
Plate to Cathode Capacitance	3 mmfd.
Maximum Plate Dissipation	15 watts
Maximum D.C. Plate Voltage	150 volts
Maximum D.C. Plate Current	250 ma.
Maximum DC. Grid Current	100 ma.
Maximum Discharge Current	250 ma.

Push-Pull Audio Amplifier (2 tubes)

D.C. Plate Voltage	110 volts
D.C. Plate Current (per tube)	60 ma.
D.C. Grid Bias	—2.5 volts
Load Resistance (Plate to Plate)	4000 ohms
Output Power	6.0 watts

Oscillator:

D.C. Plate Voltage	110 volts
Ionizing Dicharge Current	150 ma.
D.C. Plate Current	80 ma.
Grid Resistor	500 ohms
Output	3.5 watts

Class C Amplifier:

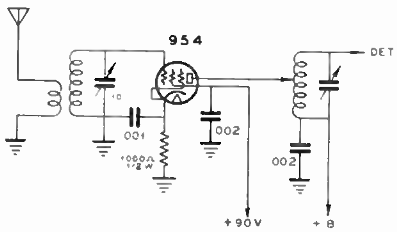
D.C. Plate Voltage	110 volts
D.C. Plate Current	250 ma.
Ionizing Discharge Current	250 ma.
Grid Resistor	500 ohms
Output	12 watts
R-F Input	3 watts

954 Acorn

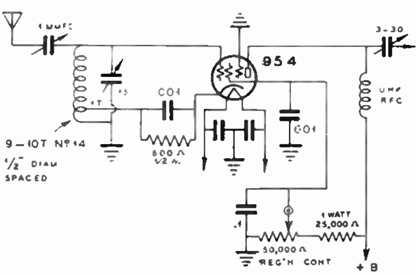
Acorn Pentode Companion tube to the 955 acorn triode for U.H.F. receivers as R-F amplifier down to less than 1 meter. A-F amplifier. Biased detector.

Note: By-pass condensers should be right at the socket in the form of ribbon leads insulated from a metal plate by mica spacers. The metal plate through which the grid end of the tube extends can have a metal collar around the hole for greater shielding effect in R-F amplifiers.

Gain: Gains of 3 at 1 meter, 10 or more at 5 meters. The input resistance at H.F. and U.H.F. is several times as great as with ordinary 6D6 R-F tubes. This allows much higher gain and better selectivity at U.H.F. This effect is noticeable even on 10 or 15 mc.



954 Acorn RF Amplifier



5-Meter Regenerative Amplifier

Characteristics:

Heater Voltage ....6.3 volts
Heater Current ....0.16 amps.
Grid to Plate Capacitance (with shield)..........007 mmfd.
Input Capacitance ....3 mmfd.
Output Capacitance ....3 mmfd.
Maximum Plate Voltage...........................250 volts
Maximum Screen Voltage..........................100 volts
Maximum Suppressor Voltage......................100 volts

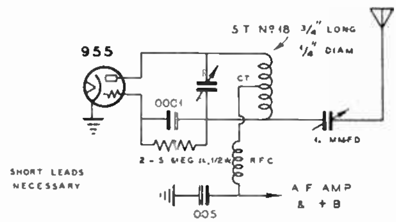
955 Acorn

Acorn Triode. The physical size of the tube elements is so small that efficient operation can be obtained down to wave lengths below one meter. Uses special socket.

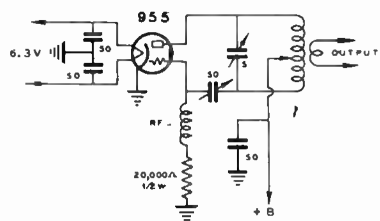
Uses: Audio amplifier in microphone pre-amplifiers. Oscillator for frequencies between 60 mc. and 600 mc. Super-regenerative detector in U.H.F. receivers. Vacuum-tube voltmeter.

Note (1): In U.H.F. circuits the by-passing condensers should be placed as close to the tube terminals as possible, such as by flat ribbon leads insulated from the mounting metal ground plate by mica spacers to form small by-pass condensers.

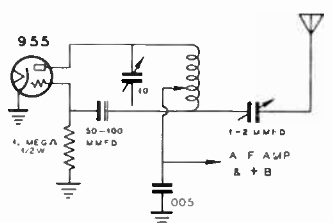
Note (2): Variation of capacity of the grid condenser in U.H.F. oscillating circuits will often allow greater R-F output and longer tube life.



1¼ METER SUPER-REGENERATIVE DETECTOR

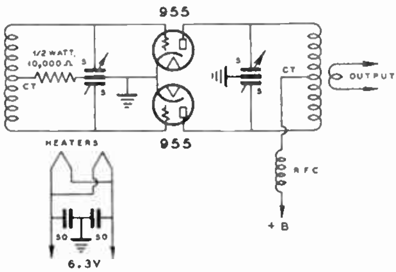


UHF OSCILLATOR FOR 955 ACORN TUBE



SUPER-REGENERATIVE DETECTOR FOR WAVELENGTHS FROM 1 TO 5 METERS

	R-F Amplifier		Biased Detector	Resistance Coupled A-F Amplifier
Plate Voltage	90	250	250	250 volts
Screen Voltage	90	100	30 to 100	50 volts
Suppressor Tied to Cathode				
Grid Bias	—3	—3	—6	—2.1 volts
Amplification Factor	1100	over 2000	...	...
Plate Resistance	1	over 1.5	...	...
Plate Current	1.2	2.0	...	0.5 ma.
Screen Current	.5	.7	...	... ma.
Plate Load	...	...	250,000	250,000 ohms
Mutual Conductance	1100	1400	...	... micromhos



PUSH-PULL OSCILLATOR FOR 955 ACORN TUBES

Characteristics:

Heater Voltage	6.3 volts
Heater Current	0.16 amp.
Amplification Factor	25
Grid to Plate Capacitance	1.4 mmfd.
Grid to Cathode Capacitance	1.0 mmfd.
Plate to Cathode Capacitance	0.6 mmfd.
Maximum D.C. Plate Current	8 ma.

Class A Amplifier:

D.C. Plate Voltage	90	135	180 volts (max.)
D.C. Grid Voltage	—2.5	—3.75	—5 volts
D.C. Plate Current	2.5	3.5	4.5 ma.
Plate Resistance	14,700	13,200	12,500 ohms
Mutual Conductance	1700	1900	2000 micromhos
Load Resistance	...	...	20,000 ohms
Power Output	...	...	135 milliwatts

Clas C R-F Amplifier or Oscillator:

D.C. Plate Voltage	180 volts
D.C. Grid Voltage	—35 volts
D.C. Plate Current	7 ma.
D.C. Grid Current	1.5 ma.
Power Output	0.5 watts at 60 mc.

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956 Acorn

RCA Acorn R F Amplifier-Pentode, remote cut-off heater-cathode type, for R-F or I-F amplifier and mixer circuits in receivers operating at wave lengths as low as 0.7 meter. The super control feature of the 956 makes the tube very effective in reducing cross-modulation and modulation distortion over the entire range of received signals. At wave lengths of one meter, the 956 is capable of giving a gain of four or more when it is used as a R-F amplifier in circuits of conventional design.

Characteristics:

Heater Voltage	6.3 volts
Heater Current	0.15 amp.
Plate Voltage	250 max. volts
Screen Voltage	100 max. volts
Grid Voltage (min.)	—3 volts
Suppressor connected to cathode at socket.	
Plate Current	5.5 ma.
Screen Current	1.8 ma.
Plate Resistance	0.8 megohm
Amplification Factor	1440
Mutual Conductance	1800 mho.
Mutual Conductance (—35 v. bias)	2 mho.
Grid to Plate Capacitance (with shield)	0.007 max. mm'd
Input Capacitance	2.7 mmfd.
Output Capacitance	3.5 mmfd.

Special Tubes

12A7

Pentode and Rectifier Combination tube for "pocket-size" AC operated radio receivers.

Characteristics—Amplifier Section:

Heater Voltage	12.6 volts
Heater Current	0.3 amp.
Plate voltage	135 volts
Screen Voltage	135 volts
Grid Voltage	—13.5 volts
Plate Current	9 ma.
Plate Resistance	100,000 ohms
Amplification Factor	100
Mutual Conductance	975 micromhos
Power Output	0.55 watts
Load Resistance	13,500 ohms

Rectifier Section:
Half-Wave Rectifier
125 volts RMS
30 ma. D.C. load (max.)

❖ ❖ ❖

25A6

Glass Tube Equivalent — 43. Power amplifier-pentode for output stages of radio receivers, particularly the "AC-DC line supply" type.

Two tubes can be used in push-pull Class A connection in order to obtain approximately twice as much output.

Due to its low maximum plate voltage rating, it it not recommended for other uses except in "Universal AC-DC" receivers.

Characteristics:

Heater Voltage			25 volts
Heater Current			0.3 amps.
Plate Voltage	95	135	180 max. volts
Screen Voltage	95	135	135 max. volts
Grid Voltage	—15	—20	—20 volts
Plate Current	20	37	38 ma.
Screen Current	4	8	7.5 ma.
Plate Resistance (ap.)	45,000	35,000	40,000 ohms
Amplification Factor	90	85	100
Mutual Conductance	2000	2450	2500 micromhos
Load Resistance	4500	4000	5000 ohms
Self-Bias Resistor	625	440	440 ohms
Power Output	0.9	2	2.75 watts
Harmonic Distortion	11	9	10%

Octal base

❖ ❖ ❖

48

Power amplifier for radio receivers designed for operation from 115 volt DC lines.

Due to its construction, its action is similar to a pentode.

Characteristics:

Heater Voltage (D.C.)		30.0 volts
Heater Current		0.4 amp.
Plate Voltage	95	125 max. v.
Screen Voltage	95	100 max. v.
Grid Voltage	—20	—22.5 volts
Plate Current	47	50 ma.
Screen Current	9	9 ma.
Plate Resistance	10,000	10,000 ap. ohms
Amplification Factor	28	28 approx.
Mutual Conductance	2800	2800 micromhos
Load Resistance	2000	2000 ohms
Power Output	1.6	2.5 watts

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RCA-1603

This tube is a pentode voltage amplifier designed to have low noise and microphonic characteristics for use in very low level preamplifiers. Its electrical characteristics are practically identical with the 6C6 which it can directly replace in suitable circuits.

Rectifiers

1V

Half wave, high vacuum, heater cathode type rectifier designed for automobile radio receivers.

Characteristics:

Heater Voltage	6.3 volts
Heater Current	0.3 amp.
A.C. Plate Voltage (RMS)	350 volts (max.)
Peak Inverse Voltage	1000 volts (max.)
D.C. Output Current	50 ma. max.)

❖ ❖ ❖

80

High vacuum type full-wave rectifier for radio receivers. Either choke or condenser input to filter is satisfactory.

Characteristics:

Filament Voltage	5 volts	
Filament Current	2 amps	
A.C. Voltage Per Plate (RMS)	350 volts (max.) or	400 volts (max.)
D.C. Output Current	125 ma.	110 ma.

81

Half-wave Rectifier. In a full-wave rectifier circuit with 2 tubes, twice as much DC output current can be obtained.

Uses: DC power supplies operating from AC supply lines.

Note. Either choke or condenser input to filter is satisfactory.

Characteristics:
Filament Voltage ....7.5 volts
Filament Current ....1.25 amps.
A.C. Plate Voltage (RMS)....................700 volts (max.)
D.C. Output Current ....85 ma. (max.)

❖ ❖ ❖

82

Full-wave, mercury vapor type rectifier tube for radio receivers or C bias supplies requiring excellent voltage regulation.

Note: Use choke input to filter.

Characteristics:
Filament Voltage ....2.5 volts
Filament Current ....3 amps.
A.C. Voltage Per Plate (RMS)....................500 volts. (max.)
Peak Inverse Voltage....................1400 volts (max.)
D.C. Output Current....................125 ma. (max.)
Peak Plate Current....................400 ma. (max.)
Approx. Tube Drop....................15 volts

❖ ❖ ❖

83

Heavy duty, mercury vapor, full-wave rectifier tube for radio receivers or Class B audio amplifiers requiring excellent voltage supply regulation.

Note: Use choke input to filter.

Characteristics:
Filament Voltage ....5 volts
Filament Current ....3 amps
A.C. Voltage Per Plate (RMS)....................500 volts (max.)
Peak Inverse Voltage ....1400 volts (max.)
D.C. Output Current....................250 ma. max.)
Peak Plate Current....................800 ma. (max)
Tube Voltage Drop (Approx.)....................15 volts

❖ ❖ ❖

83V

High vacuum type heavy duty full-wave rectifier for radio receivers requiring excellent voltage supply regulation.

Note: Condenser input to filter can be used for higher output voltage, but with inferior voltage regulation.

Characteristics:
Heater Voltage ....5 volts
Heater Current ....2.0 amps.
A.C. Voltage Per Plate (RMS)....................500 volts (max.)
D.C. Output Current ....250 ma. (max.)

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5W4

All-metal tube of filament type for use as a rectifier in radio receivers with low plate current requirements.

Characteristics:
Filament Voltage ....5 volts
Filament Current ....1.5 amps.
A.C. Plate Voltage Per Plate (RMS)....................350 volts (max.)
Peak Inverse Voltage....................1000 volts (max.)
D.C. Output Current....................110 ma. (max.)
Octal base

❖ ❖ ❖

5Z3

Heavy duty high vacuum type full-wave rectifier for radio receivers. Either condenser or choke input to filter is satisfactory.

Characteristics:
Filament Voltage ....5 volts
Filament Current ....3 amps.
A.C. Voltage Per Plate (RMS)....................500 volts (max.)
D.C. Output Current....................250 ma. (max.)

5Z4

Glass Tube Equivalent—80. High vacuum full wave rectifier to obtain DC plate supply from AC line supply for radio receivers. Either condenser or choke input type of filter may be used.

Characteristics:
Heater Voltage ....5.0 volts
Heater Current ....2.0 amps.
A.C. Voltage Per Plate (RMS)....................400 max. volts
Peak Inverse Voltage....................1100 max. volts
D.C. Output Current....................125 max. ma.
Octal base

❖ ❖ ❖

6X5

Glass Tube Equivalent—6Z4 and 84. Full wave high vacuum metal rectifier for automobile or AC operated radio receivers. Maximum voltage between heater and cathode 400 volts.

Characteristics:
Heater Voltage ....6.3 volts
Heater Current ....0.6 amp.
A.C. Voltage Per Plate (RMS)....................350 max. volts
Peak Inverse Voltage....................1250 max. volts
D.C. Output Current....................75 max. ma.
Octal base

❖ ❖ ❖

6Z4 or 84

High vacuum, heater cathode type, full-wave rectifier for supplying rectified power to automobile radio receivers.

Characteristics:
Heater Voltage ....6.3 volts
Heater Current ....0.5 amp.
A.C. Voltage Per Plate (RMS)....................350 volts (max.)
Peak Inverse Voltage....................1000 volts (max.)
D.C. Output Curent....................50 ma. (max.)

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12Z3

Half-wave, high vacuum heater-cathode type rectifier for radio receivers of the "transformerless" type. Suitable for series heater connection in such receivers.

Characteristics:
Heater Voltage ....12.6 volts
Heater Current ....0.3 amp.
A.C. Plate Voltage (RMS)....................250 volts (max.)
Peak Inverse Voltage....................700 volts (max.)
D.C. Output Current....................60 ma. (max.)

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25Z6

Glass Tube Equivalent—25Z5. Rectifier-Doubler designed to supply DC power from an AC power line in "transformerless" radio receivers. In "universal" receivers it may be operated as a half-wave rectifier, and in AC receivers as a voltage doubler to obtain about twice as high DC plate supply as in a half wave rectifier.

Characteristics:
Heater Voltage ....25 volts
Heater Current ....0.3 amp.
Full wave, high vacuum type rectifier.

Voltage Doubler:
A.C. Voltage Per Plate (RMS)....................125 max. volts
Peak Plate Current....................500 max. ma.
DC. Output Current....................85 max. ma.

Half Wave Rectifier:
AC. Voltage Per Plate (RMS)....................125 max. volts
Peak Current Per Plate....................500 max. ma.
D.C. Output Current Per Plate....................85 max. ma.
Octal base

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0Z4

Metal tube. Full-wave gas filled rectifier, primarily for vibrator type "B" Supply Units for automobile radio receivers.

Unusual Characteristics: Gas-filled rectifier with no heater. Has an ionic heated cathode.

Note: Generated R-F noise can be eliminated by proper filtering and grounding of the metal shell.

Characteristics:
No heater
D.C. Voltage Output....................300 max. volts
D.C. Output Current....................30 min. ma.; 75 max. ma.
Peak Plate Current ....200 max. ma.
Starting Voltage ....300 min. volts
Voltage Drop ....24 avg. volts
Octal Base.

Notes On New Receiver Tubes

Chapter 8

C.W. Transmitter Theory

● The analysis of the circuit and component parts of so complex a device as a radio transmitter is not an easy task, but the development of the subject material can be made plain so that the beginner as well as the advanced amateur can develop as well as widen their scope of the subject.

Definition

● A radio transmitter consists of some form of a high-frequency oscillator, and buffer amplifier stages which serve the dual purpose of amplifying the relatively weak output of the oscillator, and isolating the oscillator from the keying or modulation surges usually applied to the final amplifier.

In addition to the above, certain types of frequency stabilizing equipment (such as piezo-crystal stabilization) are employed to maintain the frequency at one value. The use of buffer amplifiers may be necessary when doubling the frequency generated by a crystal oscillator; doublers are required because mechanical limitations prevent the stable operation of piezo-crystals at frequencies higher than about 8 megacycles, whereas the final amplifier may be required to operate on much higher frequencies. The various buffers and doublers drive the grid or grids of the tubes used in the final amplifier stage. The final stage functions as a converter of direct-current plate current into radio-frequency alternating current, which is supplied to the radiating portion of the antenna system through some form of coupling device.

The Oscillator

● The function of each portion of the parts in a transmitter, and the effect of varying the

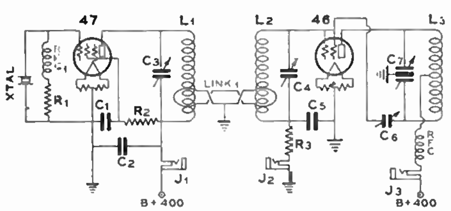


FIG. 1

Pentode crystal oscillator, link coupled to buffer stage.

characteristics follow in a step-by-step analysis. Figure 1 shows the fundamental circuit of a typical transmitter using a 47 crystal oscillator and a 46 buffer-doubler.

The first component, from left to right, is the piezo-crystal. It usually consists of a thin, flat quartz plate whose physical dimensions permit it to resonate mechanically at the frequency of the oscillator. The crystal is mounted between two flat metal plates which rest very lightly on the crystal in order to avoid the dampening effect of any pressure which would tend to retard and make difficult mechanical oscillation. Some of the better type of crystal holders have an air gap between the top plate and crystal to minimize any dampening effects. The two metal plates are lapped perfectly flat, and the flat piece of quartz functions as the dielectric. When the crystal is set into a state of mechanical vibration an alternating-current voltage is developed across the condenser which is impressed across the grid circuit. The crystal will continue to vibrate so long as there is some kind of electrical vibrating stimulus applied to it. Hence, this stimuli can come from a separate source, such as an oscillator and tube circuit in which a small portion of energy is taken from the tuned plate circuit and fed back to the crystal circuit to sustain its oscillation.

When the crystal is maintained in oscillation, it acts as a very sharply tuned series resonant circuit, consisting of high inductance, low capacity and low resistance. The actual frequency is slightly higher or lower than exact resonance so as to give an inductive or capacitive reactance depending on the character of the oscillating circuit. A crystal oscillator circuit has a very high "Q," which is an index of its resistance to changes in resonant frequency with variation in external constants. In this manner, the crystal acts as a tuned grid circuit whose resonant frequency is quite free from changes caused by load or voltage variations. However, the frequency may vary slightly with changes in the temperature of the plate, but in amateur practice the temperature effect need not be seriously considered (at least for the present).

The low-frequency crystals which operate upwards to 4000 KC usually start easier and develop more output energy than the higher frequency types, which are more fragile and rather difficult to handle.

The Radio-Frequency Choke

● The next components in the oscillator circuit are the radio-frequency choke, RFC1, and the resistor, R1, which are connected in series and shunted across the crystal. The purpose of the resistor is to provide a DC return for the grid of the ocillator tube. In addition to the DC bias on the grid of the tube, there is also present an AC voltage which is caused by the plate-to-grid feedback in the tube. This AC voltage exceeds the DC bias and causes the grid to periodically go slightly positive with respect to the filament. When the grid is positive it attracts some of the electrons emitted by the filament which are rectified into a uni-directional current (half-wave rectifier). This small rectified DC current flows back through resistor R1 to the filament; during this flow a voltage drop occurs across R1 which is impressed on the grid and therefore becomes the source of DC bias voltage. The purpose of choke RFC1 is to impede the flow of AC current while at the same time offering little or no resistance to the passage of DC to ground through R1.

In general, lowering the ohmic value of R1 down to about 10,000 ohms will increase the RF output from the oscillator, although the use of high resistive values up to about 50,000 ohms will permit the crystal to start easier. It has been found that the better made crystals start with a 10,000 ohm resistor, while poorer or inferior makes require higher ohmages.

In crystal oscillator circuits where harmonic generation is utilized in the crystal stage itself, such as in the "Tri-tet," "Dow Crystal Doubler," and in the "Jones All-Band Exciter," a high value of grid leak is used for an altogether different purpose. The distortion in the output of a vacuum-tube amplifier increases as the bias is increased, and it is the harmonic distortion which produces the second or fourth harmonic selected by the output tank circuit.

Center-tapped Resistor

● These are used to divide the DC and RF currents equally across both halves of the filament. If these returns were connected to only one-half or to one side of the filament the 60 cycle AC hum would increase in the output, because one-half of the filament heating voltage is periodically added to and subtracted from the grid voltage, which effectively modulates it with the hum frequency.

Oscillator Tube

● The oscillator tube requires little mention. Vacuum tube theory and operation are completely covered elsewhere (see Index). The ideal crystal oscillator tube should have a high amplification factor, medium-to-low plate resistance, as well as low inter-electrode capacities. The screening need not be perfect as some feed-back is necessary for self-oscillation, but it must be kept at a very low value to keep the RF current at a minimum. In some transmitting pentodes, such as the RK20 and 802, the screening is so perfect that a small external capacity must be used to provide the necessary feedback. This is advantageous in that it allows some adjustment of the feedback so that the best possible compromise between power output and RF current through the crystal can be obtained.

By-pass Condensers

● At all points where radio-frequency energy is by-passed in an amateur transmitter, non-inductive condensers of the mica dielectric type should be used.

Resistor R2

● This resistance drops the plate voltage for the screen circuit to approximately 100 volts. The value of R2 can be between 25,000 and 50,000 ohms because the screen current varies enough to offset variation in this resistor, thus varying the drop through the resistor so that the screen voltage is normal.

The Buffer Doubler

● The grid circuit is ALWAYS tuned to the same frequency to which the plate tank circuit which feeds it energy is tuned, even if the stage operates as a frequency multiplier, because frequency multiplication manifests itself in a plate circuit. The resistor R3 acts as the grid leak for the 46 stage and places a DC bias on the grid, due to the rectified current which flows through it causing the usual voltage drop. Whether the stage is to operate as a straight buffer amplifier, as a frequency multiplier, or doubler, are also factors which determine the value of R3. If the available excitation is low (less than 10 milliamperes of DC grid current, measured at J2) the grid leak can be eliminated and the lower end of L2 connected directly to ground. In this case, condenser C5 would also be eliminated. However, more excitation than 10 milliamperes is generally available and thus the grid leak is desirable. Its value is not critical up to 2,000 ohms, and values as high as 5,000 ohms are sometimes desirable for best doubling efficiency.

The grid by-pass condenser C5 provides a path for the RF return so that the grid circuit is completed back to the filament. In other words, the DC grid path goes to ground through R3, while the RF grid path to ground flows through C5 and not through R3.

In the first buffer stage maximum power amplification is desired, not maximum plate efficiency.

Neutralizing

● As was previously shown in the oscillator stage, the plate and grid of an ordinary vacuum tube act as two plates of a small condenser, so that a measurable amount of RF voltage present in the plate circuit is by-passed back to the grid circuit, where it adds to the voltages already present in that circuit in again increasing the amplitude of the RF voltage in the plate circuit. Thus there is a cumulative rise in the AC plate and grid voltages which continues and rises even after the excitation voltage from the oscillator is removed. This condition is called *Self-oscillation;* it is the frequency at which oscillation is not controlled by the quartz crystal. This state of oscillation is avoided by the process of neutralization.

The fundamentals of resonant circuits shows that the voltages at the opposite ends of a parallel resonant tank circuit are equal, though opposite in polarity at any given instant, when the center of the coil is the reference point. In the case of the plate tank coil L3 and the condenser C7, the reference point is established at the center of the coil and in the condenser by grounding the split-stator rotor. So if the capacity of C6 is equal to the plate-to-grid capacity of the 46 tube, the voltage drop across this condenser will be equal to the voltage drop across the small condenser consisting of the tube, thereby balancing out the AC voltage. If this voltage was not neutralized, the tube would go into a state of self-oscillation.

Neutralization to prevent self-oscillation is necessary only when the stage is operated as a straight buffer-amplifier. When the stage is employed to function as a doubler, there is little tendency for self-oscillation, because of the plate tank circuit being tuned to a different frequency than that of the grid tank. However, the neutralizing circuit becomes a regeneration circuit and actually aids in doubling by increasing the grid drive at the output frequency due to capacity C6. In a doubling circuit this capacity should be greater than the capacity necessary to properly neutralize a stage which operates as a straight amplifier.

The RF power in L3 can be employed to excite an antenna by means of any of the diverse antenna coupling methods, or to excite another RF amplifier stage by means of a coupling link, similar to link 1 between the oscillator and the 46 stage.

Shunt-Feed and Series-Feed Tank Circuits

● Two methods are employed to supply plate power to the transmitting tube; one of these is known as "Shunt-Feed," which delivers the DC from the power supply directly to the plate of the tube. This method prohibits the passage of any radio-frequency voltage present on the plate of the tube from being bypassed back to ground through the power supply. The RF currents are retarded from seeking this path by the inclusion of a RF choke shunted directly across the plate tank coil. Thus a good test for a radio-frequency choke is to connect it across the tank condenser and depress the key. If the presence of the RF choke across the tank condenser materially detunes the circuit from resonance, the choke was functioning inefficiently. Few RF chokes can withstand this test. One of the disadvantages of shunt-feed is that no choke has infinite impedance, and therefore a finite amount of RF power is lost to ground. It is difficult to design and build a RF choke that is effective when used on more than one of the amateur bands. These bands are even harmonics of the lowest frequency band, whereas RF chokes operate best on the odd harmonics of the lowest frequency for which they are designed; hence, a multiband choke is only a compromise on all bands and is theoretically perfect on none.

The only advantage of shunt-feeding plate voltage through an RF choke is that it allows the plate tank coil and condenser to operate at ground potential with respect to the DC plate voltage. This condition is sometimes desirable in the design of transmitters in which the connecting leads must be kept at a minimum to permit quick band changing.

Series-feed applies the DC voltage at the bottom, or low potential end (middle of the coil in a split-tank circuit) of the plate tank coil; no radio-frequency difference voltages exist between this point and ground, and practically no RF finds its way back into the power supply. In some cases where the grounding of the transmitter is somewhat uncertain it is advisable to use an RF choke at the ground end of the coil to prevent the passage of any small RF potential differences from one part of the transmitter to another. The choke has very little work to do and can be small in size.

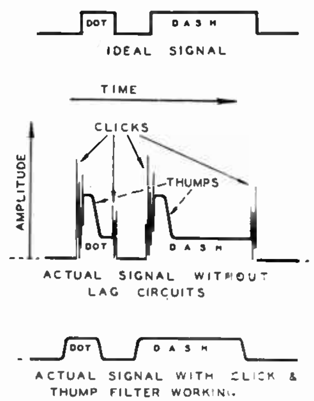
Eliminating Key Clicks

● The transmission of intelligence by means of radio-telegraphy involves the variation of the RF carrier output between the full "on" and the full "off" position. "Mark" and "Space" are defined by the presence and absence of radiated output, respectively. The carrier wave is usually cut "on" and "off" during the keying process by opening and closing the supply circuit which delivers plate power to one or more stages in the transmitter. If the change from the "no output" condition to the "full output" condition occurs too quickly, an undesired key click will be produced. This click will be radiated over a very wide range of frequencies on each side of the carrier frequency, causing a particularly annoying form of interference to other radio services. Key clicks are often audible within a 100 mile radius, but usually cause aggravating interference to radio reception nearby.

There are two distinct types of key clicks; the most common occur at the start of an impulse, or when the key is closed. If the voltage builds up too rapidly, a discontinuous wave will be produced, and its amplitude may be several hundred times the amplitude of the signal wave. This type of click is usually damped-out by providing some form of time-lag in the circuit which forces the DC current to build up relatively slowly. By "slowly" is meant that the time required for the current from the power supply to go from zero to maximum be about one-one-hundredth second. If the time is less than approximately one-five-hundredth second, annoying clicks will be produced.

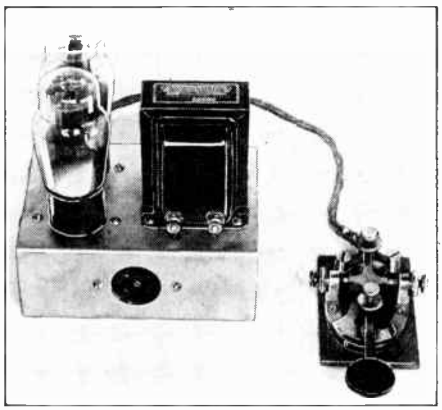
The most common form of lag circuit is one that uses a variable series inductance in series with the key, or keying relay. Often no variable inductance is available, but the inductance of any choke coil can be readily varied by connecting a variable resistor across it, as shown in Figure 4. The required value of the inductance depends on several factors, such as the amount of current flowing, the plate voltage, the voltage regulation of the source of supply, the characteristics of the filter on the supply, etc. Thus, no definite value can be specified in advance. Eliminating keying interference resolves itself into trying every known remedial measure until a satisfactory one is found.

The second type of key click is that which occurs at the end of each impulse when the key is opened. This click is a combination of the spark produced at the key contacts and the sudden change in voltage applied to the RF amplifier. The use of a series inductance increases this type of key click due to the large inductive back EMF when the circuit is opened, and the spark across the key contacts. Ordinarily, the click produced when the key is opened is considerably less bothersome than that produced when the keying contact is closed. However, a series inductance can often eliminate the "make" click at the expense of doubling or tripling the amplitude of the "break" click. The latter type of click is best eliminated by connecting a condenser in series with a variable resistor across the keying contacts. The condenser-resistor circuit represents a compromise between a minimum of clicks and good keying characteristics. The value of the condenser is not critical, it may be between ½ and 2 microfarads. However, the resistor must be carefully adjusted for best results. If the value of the resistor is too large, it will put "tails" on the dots, making the signal difficult to read. If the ohmic value is too low, the plate voltage will



How the three types of c-w signals appear on the screen of an oscilloscope.

diminish too rapidly and clicks will be produced. A time-constant of approximately one-one-hundredth second will, in most cases, allow satisfactory keying without bothersome clicks, although a fast operator who manipulates an automatic key may find that the dots are accentuated to a higher degree if the time constant is reduced to 70-to-80-thousandths second.



Vacuum tube keying unit.

To minimize the effects of the above compromise, it is desirable to key in some circuit that draws negligible power. The grid-block method of keying is useful because the key is required to open a circuit that carries no current at that instant. When keying the oscillator stage to obtain perfect break-in operation, the screen can be employed; on the other hand, the center-tap method of keying the stage is also satisfactory. Most of the high-powered commercial transmitters

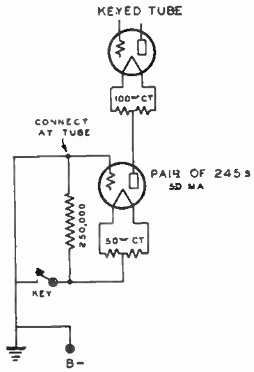


FIG. 2

Vacuum Tube Keying. This circuit shows one of the more simple vacuum tube keying circuits. Some current flows through the key and this system sometimes produces clicks when the key is opened. Both filament transformers must be insulated from each other and also from ground. This circuit will not completely cut off the plate current to the keyed stage, but will reduce it to a very small value.

that key many kilowatts of power at speeds up to 500 words per minute use some variation of the vacuum-tube keying system of which representative examples are given in Figures 2, 3, 4 and 5.

A click at the "make" means that some form of series inductance must be added in the plate or grid circuit of one or more of the amplifiers. A click at the "break" indicates that a condenser is required across the keyed circuit to enable the voltage to diminish slowly and evenly. The adjustment of the series resistor is by far the most important in eliminating clicks.

Key Thumps and their Prevention

● The deep keying thump which causes considerable interference is largely due to the plate voltage power supply building up when the key is open, thereby causing a sudden surge of output at the instant the key is closed. The transient may rise to several times the average amplitude of the steady carrier. The thump may be eliminated by improving the voltage regulation so that it is not over 15 per cent higher when the key is open than when it is closed, during which times a power demand is being made. The best way to improve the voltage regulation is to connect a bleeder resistor across the output of the filter; the bleeder should draw enough power to sustain the voltage when the key is up. The exact value of the bleeder can best be determined by experiment because the regulation of most power supplies varies quite widely.

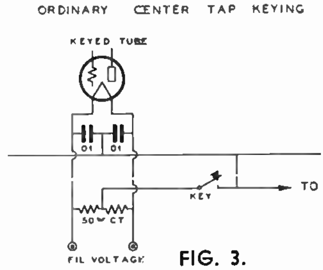


FIG. 3.

Ordinary center-tap keying. The center-tap of the filament transformer must not be grounded. As a general rule, the filament transformer which supplies the keyed stage will not be used to supply any of the other stages. The B minus lead from the power supply should be grounded.

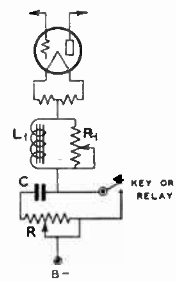


FIG. 4.

Conventional center-tap keying with an adjustable key-click filter. This system gives very good results. The actual amount of inductance and capacity in the circuit depends on the amount of current being keyed, and also on the voltage regulation of the plate power supply. L1 should be of a value between 1 and 5 henrys; R1, 20,000 ohms; C, between 1/4 and 2 mfds.; R, 2,000 ohms.

To design a scheme for the prevention of key thumps and clicks, it is only necessary to place a sufficient amount of inductance in series with the key to prevent too-sudden building-up of oscillations. By selecting the proper value of inductance the desired degree of "lag" can be introduced. The effect of the inductance in the circuit is satisfactory when the key is closed, but when the contact is broken, an arc occurs, which has the tendency to burn the contacts. To offset this effect, it is only necessary to connect a condenser across the contacts of the key to absorb the "inductive kick-back." Now, when the key is again closed, the condenser gives up its charge, causing a spot-welding effect on the key contacts, which gives rise to parasitic interference from impact excitation of associated circuits. To remedy this condition, a resistor is placed in series with the condenser to prevent sudden discharge. Unfortunately, the resistor impairs the ability of the condenser to take on a sudden charge, absorbing the self-induced voltage of the

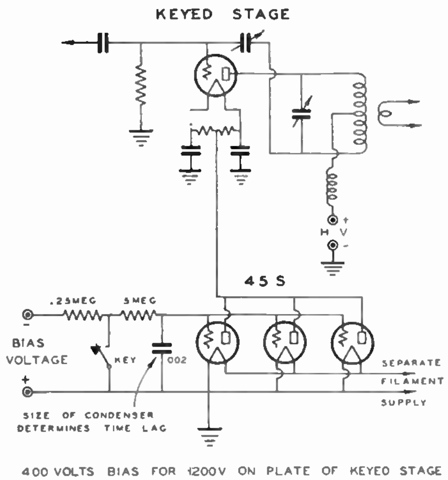


FIG. 5

High speed commercial vacuum-tube keying system.

inductance at the opening of the key and to some extent defeats the original purpose of the condenser. To compromise between the small arc occurring at the opening of the key and the small welding effect on the contacts at the closing of the key necessitates some sort of ingenious remedial measure; Figure 6 shows a scheme of great practicability. There, L1 and L2 are in series with the key and provide the necessary "lag." The "kick" from L1 is cushioned by C2. In turn, L2 prevents C2 from spot-welding the contacts on discharge. Similarly, the self-induced voltage in L2 at the opening of the circuit is taken care of by C1 and L1 and prevents a sudden discharge of C1. The correct values of L and C can be determined experimentally. The combined capacity of C1 plus C2 should be 1 microfarad or less. The value of the chokes are similar to those used in power packs.

Primary Keying

● This is a type of keying which permits a grid-leak bias to be used on the keyed stages.

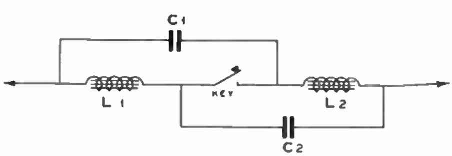


FIG. 6

Key thump filter.

This method prevents clicks and safeguards the filter condensers in the keyed stages, and in addition, does away with the necessity of using a high-voltage bleeder and eliminates back wave 100%, if more than one stage is keyed.

The disadvantages of primary keying are:

(a) requires a heavy current relay that can break an inductive AC circuit.

(b) Tends to blink the lights when used on high power.

(c) Sometimes creates band thumps in BCL sets on the same line, caused by 60 cycle surges.

(d) makes perfect keying at high speeds difficult due to the tendency of the filter condensers to add "tails" to the dots in some cases.

Center-Tap Keying

● This is another widely used method of keying which allows the use of grid-leak bias on the keyed stage, but separate bias must be used on all succeeding stages.

The advantages of center-tap keying are:

(a) will follow an automatic key ("bug") perfectly.

(b) improves the readability of received signals.

(c) permits the use of high voltage DC relays which are relatively modest in price.

The disadvantages of this system of keying are: causes bad clicks unless a well-designed click filter is used. Thumping is increased if a heavy bleeder is not placed across the high voltage; in addition, the bleeder is a necessary accessory to protect the filter condensers from failure when the key is open.

Keying the Oscillator

● This is not a type of keying but a place to key. It justifies special mention because it seems to give best results at the present time.

The outstanding features of this keying arrangement permit complete break-in and completely eliminate back-wave; also, practically eliminate clicks and thumps, and will key at high speed. Unfortunately, the plan requires that a fixed bias be supplied to all the amplifier stages; also, the keying may give rise to a "chirping effect" unless the screen voltage for the crystal oscillator tube is taken from a voltage divider, rather than from a series resistor.

Blocked-Grid Keying

● This method can be satisfactorily used to eliminate key clicks in low or medium power transmitters. In Fig. 7, R1 is the usual grid leak; fixed bias is applied through the 100,-000 ohm resistor R2 in order to block the grid current. As a general rule, 200 to 400

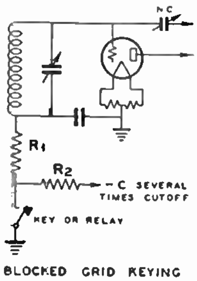


FIG. 7.

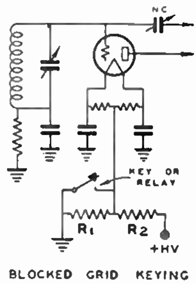


FIG. 8.

volts of bias from a small C bias supply will reduce the output to zero. In Fig. 8, the value of R1 is from two to three times as high in value as R2, the combination being connected across the high voltage supply. The keying relay shorts out the additional bias obtained in this manner when transmitting.

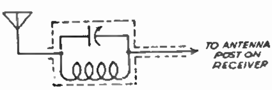


FIG. 9. Wave trap.

Interference Elimination by Wave Trap

● Interference caused by amateur transmitters in the neighborhood of broadcast receivers is usually due to the fact that the *first RF stage* in the set does not possess sufficient selectivity. Thus the high-frequency signal from the amateur transmitter rides through into the grid of the first tube in the receiver. Usually no amount of selectivity beyond this point will eliminate the interference. The amateur signal causes detection and cross modulation in the first tube. One method of reducing this type of interference is to place a tuned wave-trap in series with the antenna lead to the broadcast receiver. The trap is tuned for the weakest response to the interfering signal; the device should be placed as close as possible to the antenna post on the set. It is also essential that the receiver be provided with a short low-resistance connection to ground to prevent the AC power line from bringing in the interfering signal, in spite of the wave-trap.

Eliminating the Chirps when Keying the Crystals

● In the conventional pentode crystal oscillator circuit, the screen voltage is obtained from the plate power supply by means of a series dropping resistor. When an attempt is made to key in the center-tap of such a circuit, a bothersome and spurious-like chirp is manifested in the signal tone. When the key is up, the screen voltage rises to the same value as the plate voltage, which is from 350 to 450 volts. With the key open, no space current flows through the tube because there is no current through the screen dropping resistor; hence, there is no voltage drop, and the high voltage is thus applied to the screen. When the key is closed, and space current starts to flow in the tube, the screen current causes a voltage drop across the usual series dropping resistor and the screen voltage then drops back to its normal 100 volts. However, it does not drop back instantaneously; during the time the screen voltage is dropping there is often a very noticeable change in the frequency,

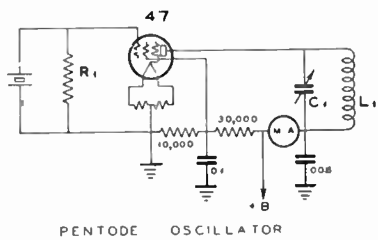


FIG. 10. Key chirp eliminator.

which causes the chirp. This effect can be eliminated by keeping the screen voltage approximately constant, whether the key is open or closed. The remedial measure requires the use of a voltage divider, instead of a series droppiug resistor as a source of screen voltage, as shown in the circuit above. The value of the resistance R should be chosen so that the voltage on the screen, when the key is closed, is 100 volts when measured by a high resistance voltmeter.

Miscellaneous Notes on Transmitter Adjustments

● A transmitter for either phone or c-w requires a proper adjustment of all the circuit components for the attainment of satisfactory operation. The following are a few practical notes which are of inestimable value in making transmitter adjustments.

Crystal Oscillators

● In oscillatory circuits employing pentode tubes such as the 47, 2A5, 42, or 59, the plate circuit should have a low ratio of tuning capacity to inductance since the plate circuit is tuned for maximum output consistent with stability. Condenser C1, of Figure 11, is tuned for a dip in plate current and then re-adjusted for slightly greater capacity for maintaining stability. A 6.3 volt pilot lamp connected in series with a turn of wire and coupled in the proximity of the oscillator coil makes a good oscillation indicator. Another type of indicator consists of taking a small neon tube and touching the tip connection to the stator plates of C1, a pink glow indicates oscillation. The plate current of the crystal oscillator will be between 10 and 30 MA, depending upon the applied plate voltage. Potentials below 350 volts will exert less strain on the crystal and will tend to prevent it from fracturing, in addition, will tend to minimize the heating effect, which is one of the causes of frequency drift. The screen voltage should seldom be over 125 volts. The value of the grid resistor R1, in Figure 11, will vary with different crystals; generally, 10,000 to 50,000 ohms sufficing—the stability increases and the output decreases for higher resistive values.

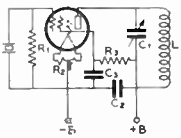


FIG. 11. Pentode oscillator.

With ordinary low-mu tubes in the oscillatory circuit, such as a 27, 56 or 10 type tubes, the procedure is the same. Plate voltage must never exceed 250 volts maximum for this type of oscillator tube.

In the Tritet or Dow oscillators, oscillation occurs by cathode regeneration at the frequency control, hence, harmonics of this frequency may be selected from the plate circuit by means of a tuned circuit C2L2 in Figure 12. The cathode coil and condenser are not tuned to resonance with the crystal, but to a frequency approximately twice as high. This circuit scheme exerts less strain on the crystal with high C than for low C in the cathode circuit, so at least 100 mmfd. of operating capacity is needed. The coils must be of such dimensions to allow operation with at least 100 mmfds. Oscillation will take place over a rather wide range of cathode tuning; certain settings, however, will give greatest power output. The plate circuit must have low C and high inductance at the harmonic chosen. When tuning to the second harmonic, the resonance condition is indicated by a decrease in plate current; the decrease will be less pronounced as the load is increased by the succeeding stage. A lamp indicator used here is adaptable to making

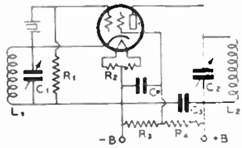


FIG. 12. Tritet oscillator.

the best output adjustments comparable with oscillator stability. If a thermo-galvanometer is placed in series with the crystal, it will be found in many cases that the Tritet oscillator has more crystal current than the pentode oscillator; high current means increased heating of the crystal and frequency creepage.

In a few cases, the above oscillator is used with vacuum-tubes having large screen-grids such as the RK20 or 803 pentodes. Here the cathode coil consists of a double winding wound in series with the filament. The tuning procedure is exactly as described for the smaller Tritet oscillator.

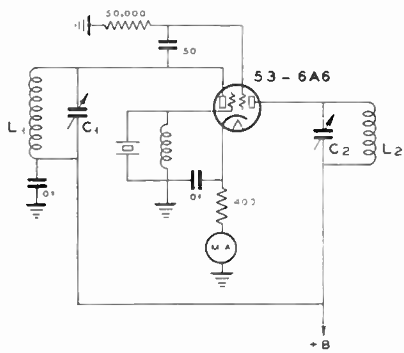


FIG. 13. Jones 53-6A6 oscillator-doubler with cathode bias resistor.

Oscillator Doublers

● The 53 or 6A6 oscillator-doubler circuit shown in Figures 13 is adjusted as follows: C1 is tuned to the crystal frequency and its capacity increased until the circuit approaches the point where oscillation is about to cease; this point is indicated by maximum output; the total plate current or cathode current will be between 50 and 75 MA, depending upon the plate voltage. The second triode acts as a doubler, and C2L2 are tuned to the harmonic as in a Tritet oscillator. The plate current will dip at resonance and a lamp indicator will glow to indicate maximum RF output. The adjustment of C1 for greatest output gives about 20 per cent less cathode current than the maximum obtainable while tuning C1 through oscillation. With cathode bias, the plate current will drop off to 20 or 30 MA. when the tube is not oscillating.

A crystal oscillator normally drives a buffer or doubler stage for greater output or frequency multiplication. In Figure 14 is shown a very simple form of frequency doubler to operate in the 40-meter band with an 80-meter crystal. The grid bias, due to the grid current flowing through the grid leak, should be higher than for a buffer stage, since the doubler is functioning as a distorting device.

A well-designed oscillator-doubler circuit is shown in Figure 15, operating as either a neutralized buffer or regenerative doubler stage. As a buffer it is neutralized in the conventional way, but as a doubler, a small coil is used together with a larger capacity value in C2. If the preceding tuning circuit is of very low C, its impedance to the second harmonic will be high, so C2 acts as a re-

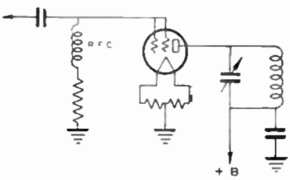


FIG. 14.

Simple 46 doubler circuit.

generation condenser feeding back second harmonic power to the grid circuit. If C2 is too large the tube will oscillate at the plate circuit resonant frequency, but if properly adjusted, the output is from 50 to 100 per cent higher than in a non-regenerative doubler. A RF indicator, such as a test lamp, will glow when adjusting C1 and C2 for maximum output without actual oscillation. No oscillations should be detectable without the crystal oscillator functioning.

In any low powered doubler stage, a fixed C bias from C batteries or C bias supply is more desirable than that of grid-leak bias. The bias voltage should nearly be 3½ times the cut-off bias (plate voltage divided by the mu of the tube) as a minimum value, and practically no DC grid current need flow. If greater RF exciation if available, higher C bias can be applied with greater output and efficiency. The reason for low

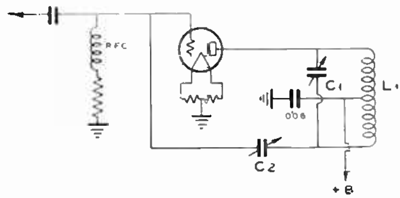


FIG. 15.

Regenerative doubler or neutralized buffer.

grid current is that the doubler tube only gives a surge of power to the tuned plate circuit every other cycle, since the frequency of the latter is twice as high as that of the grid circuit driving power. When grid current is flowing, the plate circuit receives a surge of power with an actual loss in efficiency; with grid leak bias, some grid current must flow in order to create the polarizing voltage on the grid, in this case the loss must be tolerated.

Figure 16 shows a popular doubler circuit which gives a surge of power or "push" every cycle to the second harmonic tuned plate circuit. The efficiency of this circuit is as high as some amplifier circuits and is easily adjusted. The grid circuit is tuned to the fundamental frequency with link coupling to the preceding stage and the plate circuit to twice that frequency. The C bias is made at least 3½ times cut-off and the RF excitation sufficient to allow some grid current to flow. A 53 or 6A6 tube makes an excellent "push-push" doubler, or a pair of tubes such as the high-mu type 46s, 59s, or 42s can be used. A split-stator grid condenser is needed to provide capacitive reactance to the second harmonic which prevents spurious oscillation in the doubler circuit, that is, similar to a TNT oscillator. A single tuning condenser with a bypass condenser from the center of the grid coil to the ground, allows half of the grid coil to act as an

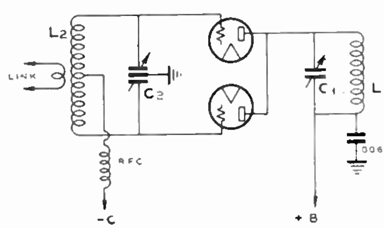


FIG. 16.

Push-push doubler.

untuned grid coil of a TNT oscillator. This same circuit is also applicable for high-powered output doubler on 10 or 20 meters; with efficiencies from 60 to 70 per cent.

Figure 17 shows another form of regenerative doubler which works effectively at high frequencies such as 14 or 28MC. Here, the cathode circuit is by-passed with only a small condenser which causes it to have an impedance common to both grid and plate circuits. If this impedance is made very high, such as by placing an RF choke in the cathode circuit. the tube will oscillate. With the values shown, the circuit will regenerate on 14 or 28MC when the grid is excited with 7 or 14MC of power. In all these doubler circuits, the DC grid bias must always be as high as can be used for the available amount of RF excitation. The plate circuit can be loaded fairly heavily by the following stage and the highest allowable potential applied to the plate for a given plate-heating effect.

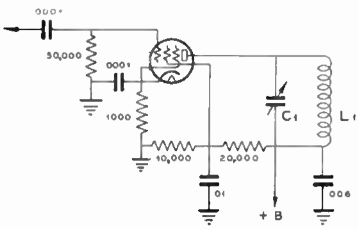


FIG. 17.

Regenerative doubler.

The circuit of Figure 15 is a popular form of buffer or amplifier stage. It can be capacitively or link coupled to the preceding stage and either fixed bias, grid-leak bias or combination of both can be applied. The C bias is made at least twice cut-off value for class C operation, but often this can not be used in practice. Quite frequently a buffer stage is employed for maximum power gain rather than for maximum efficiency. Class B operation with cut-off bias will give the greatest power gain; but, unless a large tube is used, the low plate efficiency will cause excessive plate heating. Generally, a compromise between class B and class C operation will give the greatest output for driving the following stage. In a high powered transmitter this means balancing the cost of several low power tube class C intermediate stages against fewer large tube class B to C stages. For example, a single 211 tube buffer stage might be more economical than two stages of 800s or 801s in push-pull.

Figure 18 shows a grid neutralized buffer or final amplifier stage; plate or grid neutralization being optional, though the former, as shown in Figure 19, has certain advantages. This form with a split-stator plate tuning condenser will remain in neutralization for multi-band operation provided the coils are designed to permit operation of the split-stator condenser at a medium high scale setting. This is much more important for phone operation than for C.W.

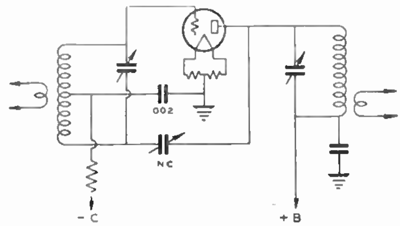


FIG. 18.

Grid neutralized stage.

Neutralizing in either case may be accomplished as follows: The plate voltage is disconnected and the grid circuit tuned for maximum grid current as indicated by a DC grid milliammeter, or neon lamp. Then the plate circuit is tuned for maximum RF excitation as indicated by means of a neon or flash-light lamp, or by a thermo-galvanometer with a turn of wire. The neutralizing condenser Nc is adjusted to the point of minimum RF current in the amplifier plate circuit, keeping the grid and plate circuit tuned to resonance. At neutralization, the effect of tuning the plate circuit through resonance will be negligible on the grid circuit DC milliameter. If the circuit is improperly neutralized, there will be a sharp deflection of the meter pointer.

Neutralizing High-Power Stages

● In high power stages where the grid driving power is 50 watts or more, the plate RF current cannot always be brought to zero on account of the presence of RF in the plate circuit caused by inter-circuit flow of high-frequency currents through the Nc condenser and through the tube element capacities. Radio-frequency current will

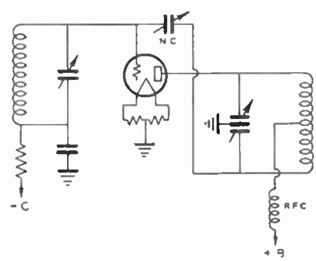


FIG. 19.

Plate neutralized stage.

always be detected by the RF indicator unless it is coupled to the exact nodal point or center of the plate coil. The DC grid meter is the most reliable RF indicator for neutralization; the measurements are always made with the plate voltage disconnected. After neutralizing, the voltage is applied and the plate circuit tuned for minimum plate current, preferably at reduced power. This stage is then loaded for the desired output and plate current at full plate voltage.

Push-pull amplifiers of the type shown in Figure 20 are neutralized by adjusting both Nc condensers as nearly simultaneously as possible. In this circuit the tube leads must be very short to prevent parasitic oscillation at ultra-high frequencies. Sometimes grid suppressors are needed for either push-pull or parallel operation of tubes; they are made by winding about 10 turns of No. 14 wire on a form one-half inch in diameter, the coil form is then extracted from the core and the coil shunted with a 200 ohm carbon resistor having a 1 or 2 watt dissipation rating. When suppressors are required, they are connected in series with the grid lead as near as possible to the grid terminal of the tube.

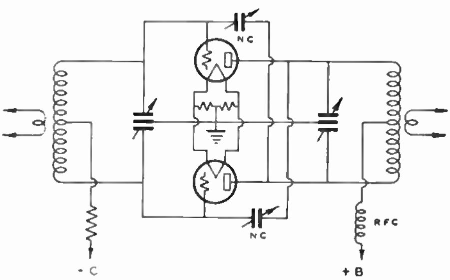


FIG. 20.

Push-pull stage.

Tuning the final amplifier stage of a C.W. transmitter is similar to that of a buffer stage except that sufficient RF excitation must be available to allow the stage to operate class C; that is, with at least twice cut-off grid bias. The plate load is then increased so that normal plate current is drawn. The antenna adjustments are covered in the section on "Antennas." These adjustments must always be made for maximum power into the actual antenna (not the dummy antenna) for a given value of plate current or tube heating effect.

For phone operation, the modulated stage must be exactly neutralized and the plate circuit shielded from the grid or any preceding stages. The latter also applies to screen-grid tube stages in either phone or C.W. transmitters. The grid excitation for a modulated phone stage is about twice that actually needed for C.W. operation unless the latter happen to have an excess of excitation. This can be checked by means of a V.T. voltmeter, linear rectifier or an oscilloscope for studying both positive and

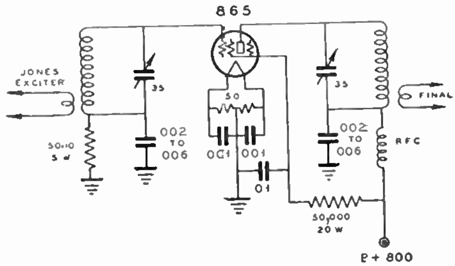


FIG. 22. Single 865 buffer or doubler circuit.

negative values of modulated waves. Another check is to draw a curve of the output RF current versus the plate voltage, since there must be a constant increase for similar increases of plate voltage; too little excitation will cause a droop in this curve. The plate load on a modulated stage must be constant and of the proper value to allow good modulation. An oscilloscope and sine wave audio oscillator are necessary instruments for adjusting all classes of phone transmitters. The section on "Electrical and Radio Measurements" cover this subject. The grid bias, grid excitation, plate load on the modulator, plate RF load, overmodulation, tube ageing and other variables are made visual for quantitative analysis by means of the cathode-ray oscilloscope.

Test for High-RF Efficiency

● To test the high efficiency of an RF stage apply some excitation to the grid circuit and apply the plate voltage to the plate (after neutralizing). A grid leak bias is used temporarily. Now, with no load coupled to the plate tank, the plate current should drop below 15% of normal. The plate current in an efficient stage reads about one-tenth of the normal operating plate current, when no load is connected. If the current does not fall, it is an indication that the tube is not functioning correctly or that there is an undesired loss somewhere in the stage. A high plate current reading with the stage unloaded may be indicative of a high-resistance connection in either the grid or plate tank circuits. It may also be due to the use of inferior materials for the grid and plate coil forms. As soon as the plate tank is detuned from resonance (unloaded) the plate current suddenly rises to a point high above the normal operating plate current. In other words, the most efficient stage will show the greatest dip in plate current as the plate tank is tuned through resonance with no load coupled to the plate circuit.

Grid Circuit Excitation

● Sufficient grid excitation can be secured when the proper circuits are chosen. If the RF amplifier can be equally well driven with less grid current, it is obvious that there will be a decided saving in buffer power, or the possible elimination of a buffer stage. Two circuits are here shown, Fig. 1A and Fig. 1B, both plate-neutralized. One is easier to drive than the other.

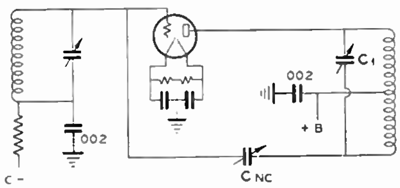


FIG. 1A

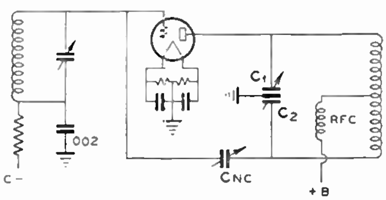


FIG. 1B

The circuit in Fig. 1A is easier to drive than the one in Fig. 1B. Fig. 1A will produce far greater output when used as a frequency doubler than the circuit in Fig. 1B, but the latter can be made into a very effective doubler by connecting a bypass condenser from ground to the center of the plate coil.

Tubes that have a very high mutual conductance, such as the 300T, cannot be used with the circuit in Fig. 1A because difficulty will be encountered from oscillation, even though neutralization would appear to be perfect. Regeneration is produced in the circuit in Fig. 1A, making it unsatisfactory for *phone* operation on *any* band with *any* tube, except for operation on 160 meters or higher wavelengths. This same circuit will also introduce excessive regeneration on 10 meters with nearly any type of tube, yet it performs with entire satisfaction for c.w. operation on wavelengths *above* 20 meters. The advantages of the circuit in Fig. 1A are numerous; it is almost twice as easy to drive as the circuit in Fig. 1B, and the grid current is from one-and-one-half to two times greater. This means that the output is increased, with a consequent saving in buffer stages. Coil changes can be made for different bands without re-neutralizing the circuit, by simple inserting a small condenser of a few micro-microfarads between the plate coil side of the neutralizing condenser (CNC) and ground. A small aluminum plate, bent-up near the rotor endplate, will increase the capacity to ground. The circuit in Fig. 1A, therefore, is ideal for c.w. operation on wavelengths *above* 20 meters, or as a *doubler* for either phone or c.w. on any band, or as a final amplifier for phone operation on 160 meters or higher wavelengths.

Use of the 45 and 46 Tube in Low-Powered R. F. Amplifiers

● The 45 tube provides better "buffing" action than a 46 when functioning as a buffer to isolate the final amplifier from the oscillator. Even slight changes in plate voltage or plate load cause a noticeable change in the grid impedance of a 46. With a 45, changes in the output circuit react but little upon the grid impedance. As an RF amplifier, the 45 eclipses the 46 in performance. The two tubes can be compared further; thus, while the 45 has a somewhat lower wattage filament, it also has a higher mutual conductance (measured at zero bias) than the 46 (grids tied together and considered as a single grid). The lower mutual conductance of the 46 is largely due to the greater "shadow" effect of the grids, which becomes quite appreciable in multiple-grid tubes. Because of its higher mutual conductance, the 45 actually requires fewer watts excitation than a 46 to drive it *to a given output with a given efficiency*. Though it takes more *voltage swing*, it can be said that the 45 is the easier to excite, because driving *power*, not voltage, is the criterion of ease of excitation.

The plate impedance of the 46 is several times that of the 45. Thus, for a given efficiency in the output circuit (ratio of load impedance to plate impedance), much looser coupling must be used to the plate tank of the 46 (raise the load impedance). Then, to regain the output, the plate voltage must be increased beyond a safe operating limit. Although the inter-electrode spacing and the spacing of the plate lead coming through the stem is much greater in the 46, it will not stand any more plate voltage than a 45. The gas content, not the spacing, limits the plate voltage that can be safely applied to a 46. Paradoxically, the residual gas in many 46s will ionize at a given plate voltage and input quicker than a 45 of the same make operated under the same conditions! The 45 permits *greater effi-*

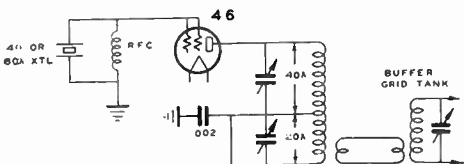
ciency than is possible with a 46, both adjusted to a given output at a given plate voltage.

Because of its high grid impedance the 45 can be more advantageously capacitively coupled to the preceding stage than a 46 (presuming it is desired to connect from the high-potential end of the plate tank of the preceding stage to avoid parasitics). The 46, with its very low grid impedance, requires an extremely small coupling capacity to give the preceding stage a sufficiently high load impedance, and most of the excitation is being wasted. The grid impedance of a 45 offers a very respectable load for most tubes, and the grid of a 45 can be capacitively coupled on the lower frequency bands with almost as much efficiency and as great a transfer of energy as can be obtained with link coupling.

The optimum ohmic value for the grid resistor is very high (between 50,000 and 75,000 ohms for a single tube); hence, it is permissible to dispense with the grid choke in capacity-coupled circuit using a 45. The only precaution necessary is that the grid resistor be either of the carbon or metallized types, these being non-inductive.

Frequency Multiplication

● Quartz-crystal oscillators have, unfortunately, a vibratory limit of about 8 megacycles; hence, to operate on a frequency higher than this value, one or more stages of frequency multiplying amplification must be added between the crystal oscillator and final amplifier. In almost every vacuum-tube amplifier there is a certain amount of distortion which represents the generation of new frequencies that are integral multiples of the exciting grid frequency. By tuning the plate circuit to the frequency of the designed harmonic, the fundamental and all undesired frequencies are by-passed to ground, while the selected harmonic (usually the second, third, or fourth) is transferred to the succeeding grid circuit.



Low-power Doubler.

Two-band operation from a single crystal is secured by tapping the plate coil and tuning each section of the coil with a separate condenser. Moderate power output is obtained.

For efficient doubling, it is essential that the doubler amplifier be carefully adjusted. For every tube there is one particular value of grid excitation and grid bias that will give maximum output; thus, a means must be provided to smoothly adjust these factors. It will be found that more bias is necessary for plate doubling than for straight class-C operation. Pentodes and high-mu triodes such as the 53, 46, 59, 841, 203A, RK21 and 838 function well as doublers, although there is some question as to whether or not high-mu tubes are better than those having medium-mu, such as the 210, 211, 852, 50T, 354, and 150T, all with regeneration. The latter can be applied to any single-ended doubler stage by using any of the conventional neutralizing circuits. When the plate is tuned to a harmonic of the grid circuit, the neutralizing circuit becomes a feedback circuit.

Push-Pull Doubling

● The push-pull circuit in Figure 2 differs from most doubler circuits in that doubling is not dependent on distortion, but on the fact that each RF impulse applied to the grid circuit results in two plate current impulses being applied to the plate tank circuit. This is because the grids are excited in push-pull and the plates excite the plate tank in parallel; thus, there are twice as many current impulses in the plate circuit as there are cycles in the grid circuit—in other words, the frequency of the plate tank is twice that of the grid tank.

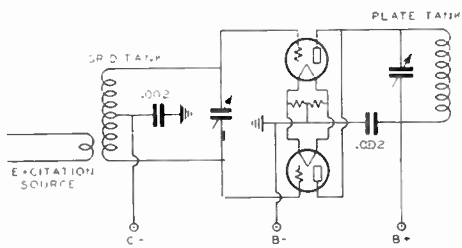


FIG. 1

Wrong way.

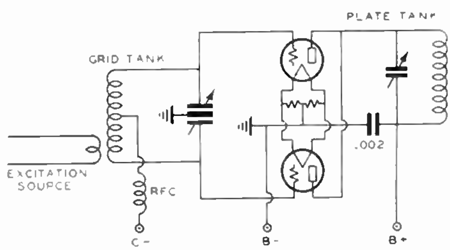


FIG. 2

Right way.

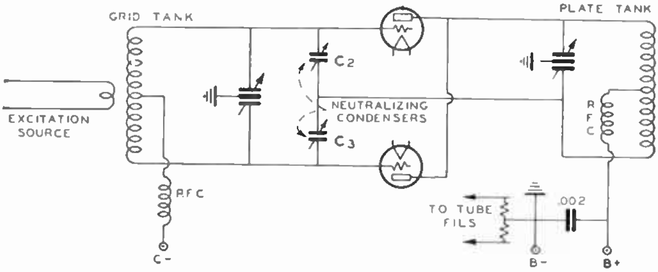


FIG. 3

The simpler forms of the push-pull doubler sometimes show a marked tendency to oscillate. The circuit in Figure 1 is particularly noted for this: the better circuits appear in Figure 2, particularly if a shielding baffle is provided between the grid and plate tanks. When using the higher-C tubes as push-pull doublers, it is often desirable to utilize the KH type of doubler shown in Figure 3. Here, oscillation is effectively prevented by separately neutralizing each tube. High grid bias is necessary for efficient operation.

The circuits shown in Figures 2 and 3 should be neutralized while connected as regular push-pull amplifiers, after which no further changes are necessary. To increase the frequency by a factor of two, requires changing the tank coil of the final amplifier to one that will tune to twice the frequency of the grid circuit. The circuit is then tested with reduced voltage while no load is coupled to the final during which times the tank condenser is varied until a pronounced dip in the plate current is found. The final is now ready for operation with a load.

Neutralizing the R. F. Amplifier

● Neutralization of a radio-frequency power amplifier is necessary to prevent self-oscillation. The latter occurs in a power amplifier because of the electrostatic energy fed back through the plate-to-grid capacity of the tube. The energy in the plate circuit is many times that in the grid circuit and self-oscillation results when only a small fraction of the plate circuit energy is applied to the grid circuit. The capacity feedback through the tube is neutralized by dividing the plate or grid tank circuit so that the voltages at each end of whichever coil is divided are equal, but opposite in polarity with respect to the center of the split tank, which is at ground potential. Both ends of the split tank circuit are then connected to the high-potential end of the other tank circuit. In other words, when using plate neutralization both ends of the plate tank are connected to the grid of the tube (one through the tube capacity and the other through an external neutralizing capacity which is equal to the internal tube capacity). See Figure 1. Thus, two feedback voltages are applied to the grid, but because they are equal and opposing, the net voltage is always zero, so the effective grid voltage (AC) is independent of the RF voltages in the plate circuit.

In the grid neutralized amplifier (Figures 2 and 3) the grid coil is split, the plate coil being continuous. Thus the RF plate voltage (AC) is applied simultaneously to both ends of the grid tank. For this reason there can be no potential difference between the two ends of the grid tank, caused by feed-

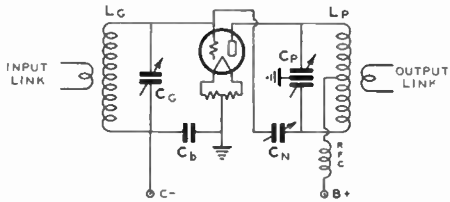
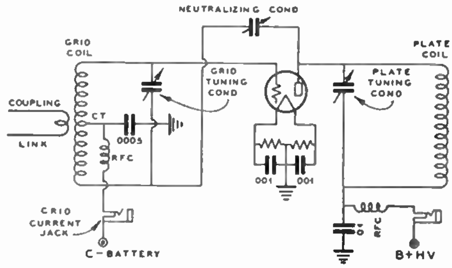
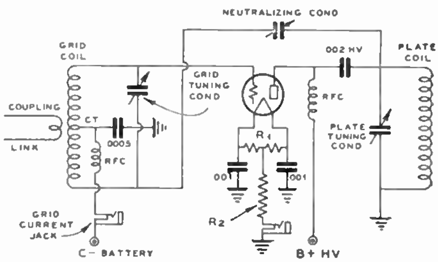


FIG. 1

Plate, or Hazeltine neutralization.



Grid neutralizing with series feed.
FIG. 2.



Grid neutralizing with parallel feed
FIG. 3.

back from the plate tank, and the effective net grid voltage is again independent of that in the plate circuit. It will be seen that the two capacities which feedback the RF plate voltage to the grid must be exactly equal, if the two voltages are to exactly neutralize each other. For proper neutralization, the capacity of the neutralizing condenser must almost exactly equal the plate-to-grid capacity of the tube.

Grid neutralization may be preferable betwen stages that are joined by link coupling so that inexpensive plate tank and neutralizing condensers can be used: on the other hand, plate neutralization is more desirable with stages capacitively coupled.

How to Neutralize

● In a perfectly neutralized RF amplifier there is no coupling from the plate circuit to the grid circuit. By the same token, there is no coupling from the grid circuit to the plate circuit. This characteristic is used in adjusting the neutralizing condenser during the neutralizing process.

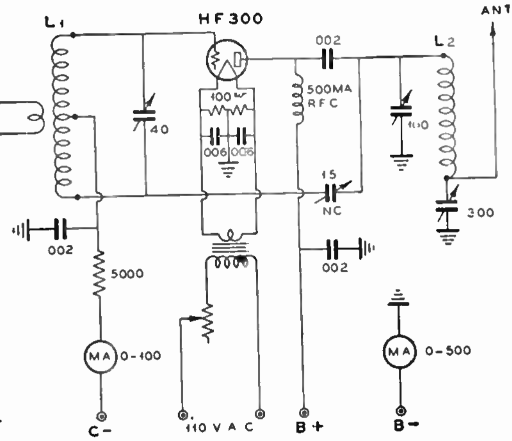
Technique

● *With the plate voltage removed from the stage being neutralized,* RF excitation is applied to the grid circuit. Some form of RF indicator, such as a thermo-galvanometer, neon bulb or flashlight globe with a single loop of wire, should then be coupled to the plate circuit. If the amplifier is *not* neutralized, there will be an indication of RF in the plate tank circuit, when it is tuned to resonance. The neutralizing condenser should be slowly varied until *all* indications of RF in the plate tank circuit disappear. After each variation of the neutralizing condenser, it will be necessary to return the grid and plate tank circuits in order to restore resonance in both these circuits.

The successfulness of the above procedure will depend upon the sensitivity of the RF indicator in the plate tank; incidentally, a neon bulb or flashlight globe is not particularly sensitive.

A better and very sensitive neutralizing indicator can be made by taking an 0-25 DC milliammeter and inserting it in the DC grid return of the stage being neutralized. Next, sufficient RF grid excitation must be applied to give a good current reading after tuning the grid circuit for maximum grid current.

If the amplifier stage is not perfectly neutralizing condenser should be varied rent will be noted when the plate tank condenser is swung through resonance. The neutralizing condenser should be varied slowly until no variation in DC grid current is shown by the milliammeter (in the grid circuit) as the plate tank condenser is tuned through resonance.



Grid-neutralized circuit.

Shunt feed, as used in this amplifier, calls for an efficient RF choke which has no resonant dip near any of the bands on which the amplifier is operated. Many types of RF chokes fail in service when used on 80 meters, but stand up satisfactorily when used on 40 and 20 meters. If the RF choke becomes quite warm after a few minutes of operation, it is proof that power is being lost in the choke and replacement should be made with a more suitable type. The plate-blocking condenser should be mounted at least one-inch from the metal panel in order to minimize the capacity to ground.

If the amplifier which is being neutralized is NOT the final amplifier, another procedure can be followed: A DC grid current meter is placed in the grid circuit of the stage following the buffer stage which is being neutralized. Now, with no plate voltage on either stage, tune the stage being neutralized through resonance, then tune the next stage to resonance. A small grid current reading will be obtained as long as the buffer stage is not neutralized, but when it is in a neutralized state, the grid current on the following stage will entirely disappear. Note: The grid current of the stage which follows the one being neutralized acts as a diode vacuum-tube voltmeter and is a very sensitive indicator of RF which is present in the plate tank of the stage being neutralized.

Neutralization of a Push-Pull Stage

● Push-pull RF amplifiers are neutralized by employing the same procedure as was used in neutralizing the single-ended amplifier. The neutralizing condensers are varied in small steps until all indication of RF disappears from the plate tank, or else there is no variation in DC grid current when the plate tank is tuned through resonance. Both neutralizing condensers should be varied simultaneously in the same direction; ganging the condensers will simplify the adjustment.

Most neutralizing troubles are caused by the RF return from the grid and plate tanks to ground. It is necessary that the low potential end of each tank coil (center of a split coil) have a short and direct RF path to the filament center-tap of the tube, or tubes. If a split-stator tank condenser is used, the rotor must be tied to the center-tap of the filament. If a single-section condenser is used with a split coil, the center of the coil must be by-passed back to the filament through a mica condenser of from .001 to .006 mfds., the value depending upon the frequency — low frequencies require higher capacities, in addition, high inter-electrode capacities require high capacities in the plate and grid returns.

It is an established fact that the lower-C tubes (such as the 808, WE304A, 50T, 852, 150T, 354 and 300T) are materially easier to neutralize, particularly at the higher frequencies, than those tubes which have higher inter-electrode capacities.

Neutralizing with Field Strength Meter

● A field strength meter is a sensitive RF indicator for neutralizing transmitter stages. The sensitivity to small RF powers is much greater than that of most RF galvanometers on the market. A small antenna with one end connected to the field strength meter, and the free end wrapped around the plate coil, will give sufficient pick-up for neutralizing low-power buffer stages. A certain amount of cut-and-try will indicate the degree of coupling needed to provide a degree of deflection in the milliammeter while neutralizing. Neutralization is obtained at minimum RF indication, just as in any other method.

Collins Inductive Neutralizing System

● Neutralization can be secured by a variation of mutual induction, as shown in Figs. 1 and 2.

This simple *Collins* system calls for a small degree of coupling between coils L1 and L2 in Fig. 1. The voltage induced back into the grid circuit is out of phase (neutralized) with the RF voltage fed back through the plate-to-grid tube capacity.

Two separate coils are used in Fig. 2 in order to allow an impedance match between a pentode plate circuit and a triode grid circuit, as well as providing a means of neutralizing. Coil L1 is coupled to the

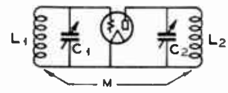


FIG. 1

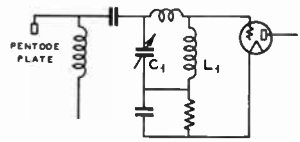


FIG. 2

Collins inductive neutralizing system.

triode plate coil for neutralizing the plate-to-grid capacity feedback. The coils must be wound in the correct direction for reversed feedback. Numerous difficulties encountered in the operation of this neutralizing system limit its application to frequencies below 20 or 30 megacycles.

New Neutralizing System

● A new system of neutralization is shown in Figs. 1 and 2. It operates on the principle of a perfect *Wheatstone Bridge* of capacities, as shown in Fig. 2, and once neutralized it remains permanently adjusted for all-band operation.

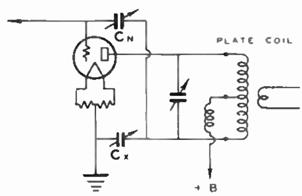
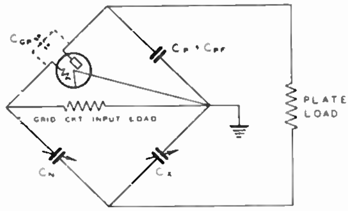


Fig. 1.

It does not call for a split-stator plate tuning condenser, yet the circuit is as thoroughly neutralized as when such a condenser is used. Single-ended amplifiers can be successfully operated on 5 or 10 meters with this circuit because they can be perfectly balanced. Fig. 1 shows a circuit for a single-ended amplifier operating on 5 or 10 meters. The plate-to-filament, and stray plate-to-ground capacities must be balanced with an additional variable condenser, Cx, in order to obtain neutralization with CN.

It can be seen from the *Wheatstone Bridge* circuit in Fig. 2 that it is a more perfectly balanced amplifier than one in which a split-stator tuning condenser is used. The capacity of condenser CN is equal to the grid-to-plate capacity of the tube, and the capacity of Cx is equal to the *total* plate-to-filament capacity of the circuit. The plate load is across two arms of the *Bridge*, the grid



NEUTRALIZING CIRCUIT

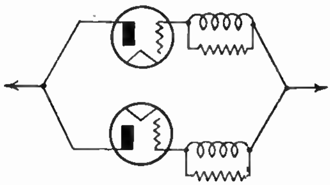
FIG. 2

tuning circuit across the other two arms, consequently there is no reaction or unbalance when coils are changed. The plate coil center-tap must not be bypassed, otherwise the *Bridge* would become unbalanced. Antenna coupling, or coupling into a high power final amplifier, must be made with a balanced circuit, such as link-coupling around the center of the plate coil.

The grid current drops when plate voltage is applied to this system; the drop is from two-thirds to one-half in value when full load and plate voltage is applied, just as with a split-stator tuning condenser circuit.

Operating Tubes in Parallel

● Parasitic oscillations are sometimes introduced when operating vacuum-tubes in parallel at both audio and radio-frequencies.



Grid chokes and resistors for parallel operation of tubes.

The most common type of parasitics occurring from parallel operation can be prevented by inserting small RF chokes, shunted with 50 to 200 ohm carbon resistors, in series with each grid lead. The choke need only consist of from 5 to 10 turns of No. 22 enameled wire wound on a form of about one-half inch diameter. Winding the chokes on the resistor will simplify the job as well as provide a convenient method of mounting.

Grid Bias

● The conditions under which practically all radio-frequency power amplifiers operate are such that plate current flows in the form of short, peaked impulses which last for less than one-half of the alternating current cycle. This means that plate current is "cut-off" during most of the RF cycle which makes for high efficiency and high power output from small tubes. To keep the plate current at zero during most of the RF cycle, it is necessary that the control grid of the amplifier tube be kept quite negative with respect to the filament by means of a DC voltage which is termed "negative bias." The AC grid excitation voltage, which usually comes from the plate circuit of the preceding amplifier stage, periodically overcomes the grid bias voltage and makes the grid slightly positive with respect to the filament, causing a short impulse of plate current to flow.

If no grid bias were used, the tube would draw plate current all of the time. This would result in very inefficient operation because the plate would never have the opportunity to cool off.

Cut-Off Bias

● Any value of grid bias which is just sufficient to reduce the plate current to zero is called the *"cut-off bias."* By taking a reading from a milliammeter inserted in the plate circuit, with different varying values of negative bias on the control grid, it will be found that the plate current will decrease as the negative bias is increased. At a certain point the plate current will be reduced to zero, and any further increase in negative grid bias has no effect on the plate current which remains at zero. Thus, the lowest value of negative grid bias which reduces the plate current to zero is termed the "cut-off bias."

It is not necessary to experiment with bias batteries and different plate voltages to determine the cut-off bias for a given set of conditions. The required values can be calculated by simply dividing the voltage applied to the plate by the amplification factor; these data may be obtained from a table of tube characteristics. When estimating the cut-off bias add 5 to 10 per cent more bias to that calculated; this is required on account of the variable-mu tendency which is characteristic of all control grids as the cut-off point is approached.

Effect of Bias on Efficiency and Output

● The amount of negative grid bias has a very definite effect on plate efficiency and power output. If the plate voltage and RF excitation voltage remain fixed, and if the bias voltage is increased beyond the cut-off point in a radio-frequency amplifier, the power output and input decline, although the plate efficiency rises. It is, therefore, necessary to make a compromise between power output and plate efficiency. The smallest amount of bias that allows the plate of the amplifier tube to run cool should be used beyond the cut-off point. This results in the maximum power output for a given tube, plate voltage, and RF excitation voltage. To increase the power output, it will be necessary to increase the plate voltage, loosen the antenna coupling, and in many cases increase the radio-frenquency excitation voltage. With this procedure, the bias must be readjusted to the lowest value that allows the plate current to remain cool. The actual value of this bias, as measured in the number of times cut-off bias, will vary from about 1.25 times cut-off in a low-efficiency high-gain buffer stage, to about 4 times cut-off bias in an extremely high efficiency low-gain amplifier, operating with very high plate voltage and RF excitation. The bias voltage and the grid driving power are closely related, such that the higher the bias the more grid driving power is necessary to reach a given power output. For tubes of similar characteristics, the one with the highest zero bias mutual conductance (see tube tables) requires the least amount of bias and grid driving power for maximum power output and plate efficiency. As an example of the effect of mutual conductance on the required bias voltage (and therefore the amount of excitation power necessary), it is found that under a given set of conditions a type 852 must be biased to 3.5 times cut-off and excited with 106 watts of grid driving power to obtain 400 watts of radio-frequency power output at 80 per cent plate efficiency. On the other hand, a type 150T, or 354, which has considerably higher mutual conductance when used under the same conditions in the same stage, requires a bias of only 2.1 times cut-off and only 29 watts of grid driving power is necessary to obtain the same 400-watt output at the same plate efficiency (80 per cent).

When a radio-frequency power amplifier is plate modulated, the negative grid bias must be equal to or greater than twice cut-off. This is necessary in order that the peak power output can increase as the square of the plate voltage, which is essential for linear modulation.

Sources of Bias

● In general, bias can be supplied from two distinct sources: (1) from within the amplifier circuit itself through a voltage drop taken across either a grid-leak resistor or cathode-bias resistor; (2), from an external source, such as batteries or a special rectified AC bias pack.

Grid-leak Bias

● Whenever the control grid of an amplifier tube becomes positive with respect to the filament (as it does in all radio-frequency power amplifiers), the positive charge on the grid attracts some of the electrons emitted from the filament. The electrons flow back to the filament through the external DC grid-return and cause a current flow in the circuit. If a resistance is placed in series with the grid-return, a voltage drop will occur across it when the current flows; the end of the resistor closest to the grid will be negative with respect to the other end closest to the filament; thus, necessarily causing the grid to become negative with respect to the filament. The voltage drop across this grid-leak resistor consists of a varying AC voltage superimposed on a constant value of DC voltage, which is proportional to the effective value of the grid current impulses. The AC component is of no concern because it is by-passed by means of a condenser directly back to the filament, and thus by measuring the DC grid current with a DC milliammeter in series with the grid-leak, the grid bias can be calculated by multiplying the grid current by the ohmic resistance of the grid-leak.

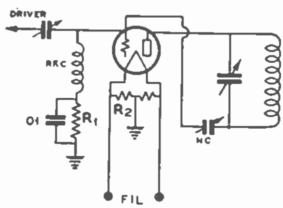
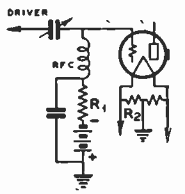


FIG. 1.

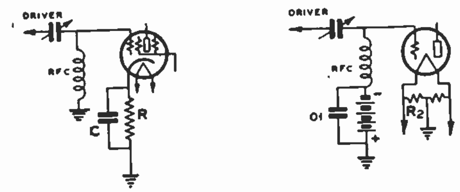
Grid-leak bias is quite flexible and more or less automatically adjusts itself with any variation in RF excitation. The value of grid-leak resistor is not particularly critical because the DC grid current usually decreases as the grid-leak resistance increases, thereby keeping the product of the two more or less constant for a given amount of RF excitation. Hence, the value of the grid-leak resistance can vary from one-half to two times the optimum value, a ratio of four to one, without materially affecting the negative DC bias voltage actually applied to the grid of the amplifier tube.

One of the disadvantages of grid-leak bias is that the bias voltage is proportional to the RF excitation, thus precluding its use in grid modulated or linear amplifiers, whose bias must be supplied from a well-regulated voltage source so that the bias voltage is independent of grid current. When grid-leak bias is used alone, it is evident that the bias disappears when the excitation fails, thereby allowing dangerously-high values of plate current to flow, with a consequent damage to the tube. It is always desirable



COMBINATION BATTERY & GRID LEAK BIAS

FIG. 2.



CATHODE BIAS

BATTERY BIAS

FIG. 3.

to augment the grid-leak bias with either cathode or separate bias supplies to keep the plate current within safe limits whenever the excitation fails. The amount of the bias supplied in addition to the grid-leak bias should usually approximate cut-off bias so that the plate current will drop to zero if the crystal stage stops oscillating, or the tuning elements are improperly adjusted in any of the other stages.

Cathode Bias

● This form of bias utilizes the voltage drop across a resistor in the B-minus lead from the high-voltage power supply. Because the B-minus lead of most high-voltage power supplies is directly grounded, the bias resistor must be placed in the negative side of the DC plate circuit of the tube itself. The negative side of the DC plate circuit of a vacuum-tube amplifier is between the filament center-tap and ground, and a resistor placed between these two points will have the total plate current flowing through it. The voltage drop across the resistor will be equal to the product of the plate current in amperes, times the resistance in ohms. The grounded end of a cathode-bias resistor is more negative than the filament end by the amount of voltage drop across the resistor; hence, if the DC grid return is brought to the ground end of this resistor, the grid of the amplifier will be more negative with respect to the filament.

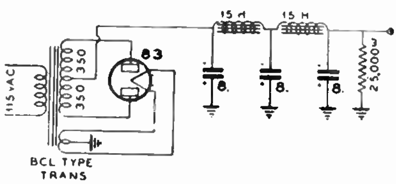
Cathode bias is probably the safest bias supply known, because the negative bias voltage is a function of the plate current and is largely independent of the RF grid excitation. With this type of bias the plate current can never reach a dangerously-high value if the excitation fails. Unfortunately, cathode-bias is generally unsuitable for class B linear amplifiers, although its use is essential in the newer class BC linear or grid-modulated amplifiers.

Cathode bias can be used in a plate-modulated class C amplifier provided a large audio by-pass condenser is connected across the bias resistor in addition to the usual mica radio-frequency by-pass condenser. The principal disadvantage of cathode bias is that the bias voltage must be subtracted from the total power supply in order to obtain the net plate voltage across the amplifier tube. In a high efficiency amplifier stage using a low-mu tube and biased to perhaps 3 times cut-off, it may require a 1600-volt power supply to actually realize 1000 volts on the plate of the amplifier tube, because 600 volts is deducted for negative bias. Cathode bias is sometimes called automatic bias because variations in plate current automatically change the bias to compensate for these variations.

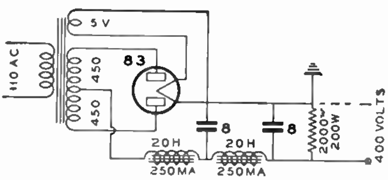
Separate Bias Supplies

● Negative grid bias may be supplied from any source of voltage external to the amplifier circuit itself, such as dry batteries or B eliminators. B batteries rarely fail without giving considerable warning to the operator and they represent one of the safest sources of negative bias. However, these batteries wear out rather rapidly due to the charging effect of the DC grid current which causes the voltage as well as the internal resistance of the batteries to rise. After a few months of service, the batteries often become noisy, especially when used for phone work. When charged-up they bulge and leak. It is not unusual to find a 45-volt battery which measures 60-volts after only a month or two of service in the grid circuit of a class C amplifier. This would be of no particular disadvantage if the 60 volts remained constant, but it often wavers and fluctuates, causing the signal tone to be impaired.

Another form of separate bias supply consists of some form of rectifier and filter system whose positive terminal is grounded and whose negative terminal connects to the DC grid return of the amplifier stage. This bias supply often consists of an old B eliminator and is quite satisfactory if certain precautions are observed. If a high-power class C amplifier is biased by a B eliminator, some form of relay should be used and controlled by the bias supply so that the plate voltage to the amplifier is cut off if the bias supply fails. Most of the older B eliminators, and many of the newer types, have very poor voltage regulation which becomes troublesome when the eliminator is used to bias two or more separate amplifier stages. Poor voltage regulation merely means high internal resistance in the B eliminator. Any variation in grid current in any one of the amplifier stages will vary the voltage drop across this internal resistance and thereby affect the bias supplied to the other stages of the transmitter. If a B eliminator, or rectified AC bias supply furnishes bias to a class B or class BC linear or grid-modulated amplifier, it is essential that the DC bias voltage remain constant and independent of the DC grid current. This means that the bias supply must have extremely good voltage regulation. Low resistance transformers and filter chokes as well as a mercury-vapor rectifier tube and a low-resistance high-current bleeder should be used to minimize variation in output bias voltage with changes in grid current which normally occur in these types of amplifiers. To adjust the DC voltage output from a bias power supply, tap the primary of the transformer, or an auto-transformer can be connected across the line to vary the voltage supplied to the bias transformer.



Here is a Bias Pack which uses a medium-to-high resistance bleeder. Voltage regulation is usually unimportant in biasing a class C amplifier and only enough bleeder is used to protect the filter condensers.



In the Bias Pack shown above, a low-resistance bleeder is used to provide a heavy, continuous current drain in order to stabilize the voltage output. A Bias Pack of this type is suitable for class B audio or class BC Linear Amplifier operation. The ungrounded side is the negative terminal.

More than one of the above supplies can be placed in series to bias a class C amplifier. In fact, it is recommended that a grid-leak be used to augment the cut-off value of bias which is best supplied by either cathode bias resistor, batteries or a separate bias pack.

A grid-leak common to more than one class C stage should be avoided, due to tremendous interaction caused by the two different grid currents in the respective stages.

To compute the wattage rating of the resistor, either as a grid-leak or to give cathode bias, multiply the square of the current in amperes flowing through the resistor by the resistance in ohms.

R. F. Impedances in Circuit Coupling

● The difference between the DC plate input and the AC power output is the plate loss, and must be dissipated in the form of heat. Because the tube cost is almost related to plate dissipation, it pays to obtain high plate efficiency as it is then possible to secure high power output from small tubes. A vacuum-tube AC generator has a definite internal resistance to the flow of current. It varies with the applied voltage and the grid excitation.

Given a constant voltage generator, the generator efficiency increases as the ratio of the impedance mis-match increases—but the power output is maximum when the load impedance is matched to the internal impedance of the generator.

The Class C RF Amplifier

● The most important application for impedance mis-matching is found in the class C radio-frequency amplifier occupying the place of a final-amplifier in an amateur transmitter.

The greatest mis-match can be obtained from a tube with the lowest dynamic plate impedance, and with the highest voltage that the tube insulation and gas content will allow. The high plate voltage greatly reduces the internal impedance. The circuit should be adjusted so that the plate tank has a high L and low C. The antenna coupling is loosened as much as possible without reducing the input below that desired, and the bias is adjusted to several times cut-off. The excitation, as measured by the DC grid current, should be between 15 and 25 per cent of the DC plate current, and will vary for different types of tubes. In general the higher the mutual conductance of the amplifier tube, the less excitation power is needed for a given load impedance.

Advantages of Link Coupling Over Other Types

(1) Effectively establishes correct impedance relations between grid and plate circuits.

(2) Permits more efficient operation of circuits wherein low-mu tubes work

into, or out of high-mu tubes, and vice-versa.

(3) Provides a flexible feed-line of several feet in length resulting in efficient operation between stages in "rack type" transmitters in which the stages are spaced quite far apart.

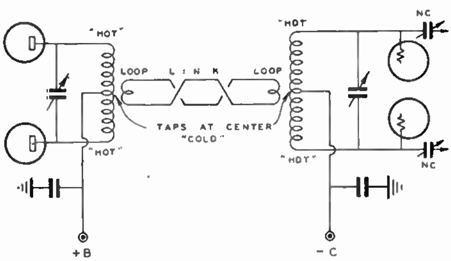
(4) Permits the use of series-feed in both grid and plate circuits.

(5) Makes possible maximum power output and minimizes oscillation difficultes.

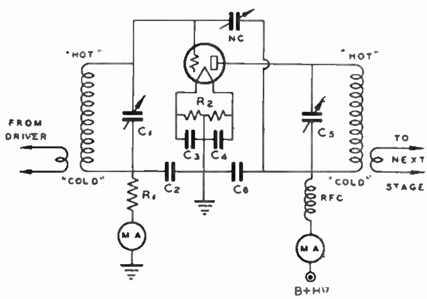
(6) For a given amount of excitation on the grid of the first buffer, link coupling reduces plate current in the crystal oscillator stage and therefore reduces the RF current through the crystal itself.

(7) Eliminates the use of taps on coils, with their attendant losses.

(8) Because of the lack of capacitive coupling effect, neutralization is made easier.



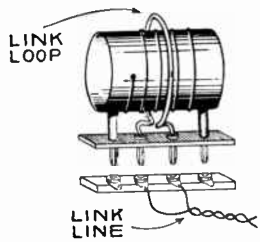
Link coupling between push-pull stages.



Link coupling between single-ended stages.

Link coupling provides a low impedance transmission line to transfer energy between two isolated tank coils, one of which is in the plate tank of the driver stage and the other the grid tank of the driven stage. This low impedance transmission line provides coupling of purely inductive nature, the capacitive loading effect of the coupling loop being negligible. Feed lines, consisting of twisted pairs can be several feet in length. The wires can be of ordinary rubber-covered No. 18 to 14 wire.

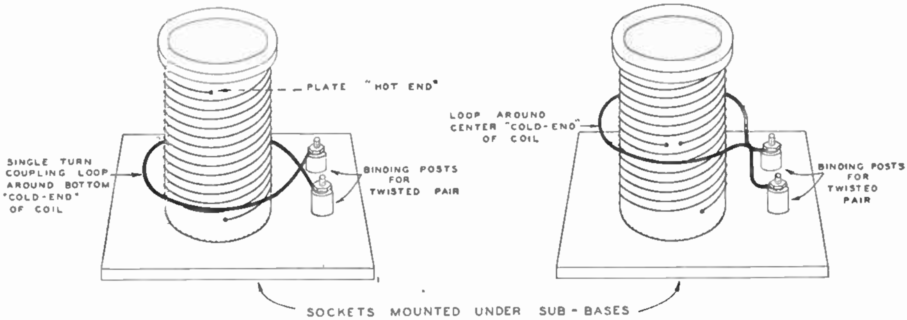
A reference to the illustrations shows some of the mechanical arrangements suitable for link coupling. For low power stages one of the fixed-coupling-loop systems is recommended. One of the coil forms ideally suitable for the fixed coupling loop is the isolantite vertical plug-in type. This coupling scheme is shown in the illustrations as well as the system using the coupling loop adjustable from the baseboard.



Coupling loop arrangement for large plug-in coil.

Link coupling can often be used between stages in a transmitter in a form which will give greater grid swing in each succeeding stage. Some tubes which have a high-mu, of the screen-grid type, have an extremely low grid impedance, especially under plate loaded condition. In such cases, it is difficult to obtain maximum grid swing or reasonable driver plate load with the usual form of one or two turns in the link coupling loop at each end of the link. To eliminate this difficulty, use one or two turns in the link coupling loop on the driver plate coil and two to six, or even seven turns at the grid coil when the driven tube is a high-mu or screen-grid type. The coupling between the grid coil and the link coil should be as close as possible, such as one winding directly over the other, or interwound. The latter is important for proper impedance matching.

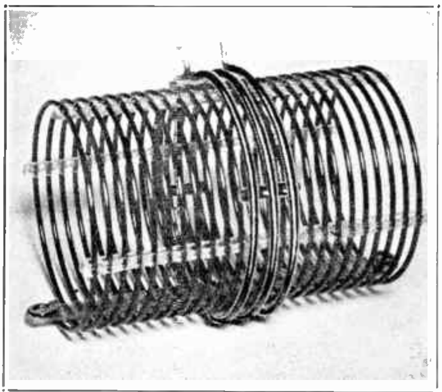
Link coupling will give a certain amount of automatic impedance matching. This can be proved by noting that about 50 per cent or more grid swing can be obtained with the usual link coupling over the old form of capacitive coupling between a pair of type 210 tubes. Only a small part of this loss in capacitive coupling is due to the grid RF choke, since the latter can be made very effective, the loss is in the impedance mis-match when the grid of the following tube is across the entire tuned circuit. Link coupling gives an impedance matching effect because the coupling is usually less than



The link coupling loop is wound around the lower end of the coil when this end is by-passed to ground.

The link coupling loop is wound around the center of the coil when the coil is center-tapped.

unity or maximum obtainable. The impedance reflected each way is not entirely dependent upon the ratio of tuned coil turns to link coil turns, since the effective coil coupling is relatively loose and resonant

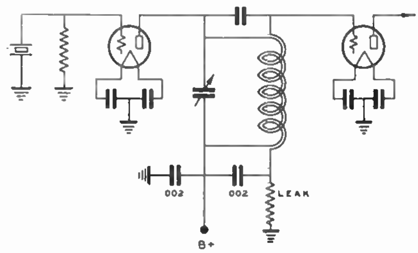


Wire-wound tank coil with variable coupling loops for connection to twisted-pair feed line.

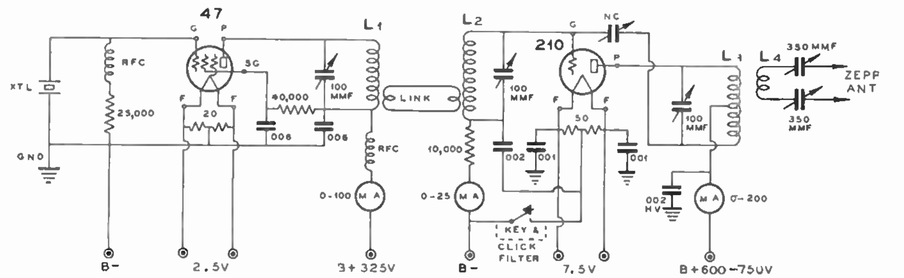
circuits are being used. Because the coupling is not unity between the coils, impedance matching takes place, if the ratio of impedances are not too great. When the impedances are greatly different, one being several times that of the other, then the low impedance circuit end should have more turns on the link coil and these two coils should be very closely coupled.

Unity Coupling

● Unity coupling between stages of a transmitter can be used as an aid to eliminate



Unity coupling between crystal oscillator and buffer stages.



Complete Circuit Diagram of 47 Oscillator link coupled to 210 amplifier stage. One or two turns of wire are wound around coils L1 and L2 to form the coupling loop. The two loops are connected through a twisted-pair feed line, made with hook-up wire.

RF choke troubles. This coupling is not as effective as link coupling, yet it does not require an additional tuned circuit. Unity coupling can be used advantageously in transmitters where space is lacking for link coupling. Care should be taken to see that the grid coil interwound turns are spaced sufficiently from the plate coil turns to prevent DC voltage flashovers. For low power operation, the grid coil is often wound inside of a copper tubing plate coil; wire used for this purpose must be well insulated.

Final Amplifier Tuning Adjustment

● The plate tuning of the amplifier should be set for a point at which minimum plate current occurs, rather than the point at which maximum grid current flows. Varying the plate tuning under operating conditions changes the plate impedance of the amplifier. The point of maximum plate impedance does not necessarily have to occur at the point of minimum grid impedance, as far as the DC current readings are concerned.

Grid Saturation

● An excess of grid excitation will not increase the power output and may shorten tube life, due to overheating of the grid. The grid will become white hot when overloaded. In some tubes this will release gas retained in the metal and ruin the tube. Too little grid excitation will cause excessive plate heating and low output. More grid excitation is required as the plate voltage is increased, it also requires more grid excitation for closer antenna coupling than when the antenna is loosely coupled.

Parallel vs. Push-Pull Operation

● The recent development of the low-C tubes practically eliminates the former difficulties encountered from parasitics and instability which accompany parallel operation of vacuum tubes. Parasitics are largely caused by the stray inductance and the capacity in the tubes themselves, as well as in the connecting leads between the tubes and the associated plate tank circuits. Parasitics are not confined to tubes in parallel, but are in fact nearly as common in push-pull circuits because the inductance of the leads when connected through the tank tuning condensers can form an ultra-high frequency tuned-plate-tuned-grid oscillator. This causes oscillations at a frequency other than that desired, with consequent low efficiency and reduced power output, as well as resulting in a poor note.

Parallel operation has many advantages over push-pull operation, even at the higher frequencies, provided low-C tubes are used. The plate tuning condenser can be one of a cheaper variety for a given tuning capacity and one neutralizing condenser is eliminated for parallel operation. Tubes are easier to drive to a given output when in parallel, due to the higher transconductance of the parallel circuit. The amplification factor is the same for a parallel connection as it is for one tube, whereas the plate resistance is cut in half.

High-C tubes, such as the **45, 2A3, 10,** 211, 203A and 204A work best in push-pull below 40 meters because the high capacity shunted across the plate tank, when high-C tubes are used in parallel, makes the use of a low-C, low-loss tank circuit impossible.

R. F. Chokes

● There are several varieties of Pie-wound RF chokes. Those who prefer to wind their own should choose the solenoid winding types. A RF choke designed for maximum impedance in one amateur band is not satisfactory for operation in other bands because of the effect of its distributed capacity and inductance. This choke would be satisfactory on three times the fundamental frequency, but worthless on twice that frequency.

The coil should be wound so that its fundamental operating frequency is about midway betwen its lowest and highest impedance. On even harmonic operation, therefore, the reactance will be fairly high. If the RF choke is to be used only on one band, it can be wound for resonance, as its effect across a tank circuit, when being tested, is negligible at that frequency. If, for example, it is to be used on both 80 and 40 meters, more or less turns are needed in order to keep the second harmonic impedance high. In all such cases the lower end of the RFC should be bypassed back to ground because some RF current will flow through it.

If the length of the solenoid is not great in comparison to its diameter, its fundamental resonance can be calculated from C in mmfd. = .24d, where d = diameter in inches, and C, the distributed capacity. The inductance can be obtained from L in micro-henrys:

$$L = \frac{a\,n}{9a + 10b}$$

where a, is the radius of the coil in inches; n, the number of turns; b, the length of the coil in inches.

$$f = \frac{1000}{2\pi\sqrt{LC}} \text{ in megacycles.}$$

The formulae give a starting point.

Actual construction for short wavelengths, such as 5 to 40 meters, can well be made on small diameter rods or tubing with a long winding several times its diameter. The wire should be large enough to safely carry the DC plate or grid current, as well as an appreciable amount of RF current.

In high power circuits, RF chokes should be placed at points of low-RF potential, if possible, because even the pie-wound chokes, contrary to popular belief, are not efficient on all amateur bands. Care must also be taken to prevent a tuned-grid tuned-plate oscillation between the grid and plate RF chokes at the fundamental frequency of the RF chokes. If possible, the grid choke must have an inductance at least 10 to 20 times that of the plate choke.

Tank Circuits

● The plate tank circuit of any transmitting radio frequency amplifier consists of a parallel resonant tuned circuit. The shunt impedance of any resonant tank circuit is the resultant of two factors: (1) the resistance of the tank circuit itself, and (2) the reflected resistance caused by coupling a load, such as an antenna, to the tank circuit. The output power dissipated in the resistance of the tank itself is entirely lost, so that for high output and efficiency it is desirable to make the tank losses as low as possible. The test for any tank circuit is to disconnect the load (antenna, etc.) and measure the DC plate curernt at normal plate voltage, bias, excitation, etc. This unloaded plate current should be approximately 10 per cent of the normal loaded DC plate current in most circuits.

Tank "Q"

● The "Q" of a transmitting tank circuit is of importance only when determining the optimum ratio of L to C for a given frequency and load resistance. In general, a phone requires twice as much C as for a similar CW amplifier. In the plate tank of a self-excited oscillator, the C is required to be about three times greater than that for a given CW amplifier. Comparatively, the minimum "Q" of a single-ended amplifier should be kept about 10 for CW, 20 for phone, and approximately 30 for a self-excited oscillator.

The accompanying table gives approximations of the optimum tank capacity for a single-ended CW amplifier at different plate voltages, power and frequencies. Variations from the indicated values of capacity up to 20 per cent will not materially affect the operation of the amplifier. Larger capacities will increase the "Q" somewhat, but with an increase in the tank losses due to the increased circulating tank current, which reduces power output and efficiency. The use of less C than that shown will reduce the "Q" and may again reduce the efficiency and power output if minimum plate current does not coincide with maximum output current; that is, at the same point when the tank condenser is tuned. The capacities shown are those which should actually be applied, not just the maximum capacity of the tuning condenser.

The table shows most of the common combinations encountered in practice. However, for widely different frequencies or power inputs, the following formula will enable the approximate tank capacity to be directly determined. The following formula applies to a single-ended grid-neutralized (unsplit tank) amplifier for CW ("Q" of 5); for phone, ("Q" of 10) multiply the indicated capacity by 2.

For split-tank coils divide the indicated capacity by 4.

$$C = \frac{3{,}200{,}000}{fR_b}$$

for Q of 10

Where C equals the tank capacity in mmf.; f, the frequency in megacycles; R_b, the DC resistance in ohms, of the plate to filament path of the amplifier (DC plate voltage divided by DC plate current, in amperes).

The optimum AC load impedance into which a Class C amplifier will work most efficiently under average conditions of grid drive and AC plate current is when the angle of flow is betwen .45 and .55 with an average of .5 times the DC load resistance.

$$Q = \omega CZ = \frac{\omega CR_p}{2} \text{ approx.}$$

$$C = \frac{Q}{\pi R_p f}.$$

Since $\omega = 2\pi f$.

It will be seen that there will be relatively little difference between the cost of the tank condenser used with either grid or plate neutralization. With grid neutralization, the plate tank capacity must be four times as large as the capacity required in a plate neutralized amplifier. However, the condensers in the plate neutralized tank circuit will have twice the peak RF voltage across them as well as twice the spacing as the condensers which are used in grid neutralized amplifiers.

The flywheel effect of the tuned circuit is important in Class C amplifiers and often the value of $\frac{VA}{Watts}$ is used in circuit design.

The "VA" represents the volt amperes of the oscillating LC circuit and "watts" represents the actual power transferred to the antenna load, or power output. VA can be computed

from $VA = \frac{(E_{p\ rms})^2}{X_c}$ where $X_c = \frac{1}{2\pi fc}$

and $E_{p\ rms}$ is the rms of RF plate voltage.

Several computations of actual Class C amplifiers have indicated that for all practical purposes $Q = \frac{VA}{Watts}$ within a limit of 10%.

Characteristics of Plate Tank Circuits

● There are eight different arrangements of plate tank circuits for radio-frequency amplifiers. Fundamentally, there are two basic circuits: these are, (a) the split-tank with plate neutralization, shown in Figures 3, 4, 5, and 7; and (b), the unsplit-tank with grid neutralization, shown in Figures 1 and 2. Of course, the push-pull circuits, shown in Figures 6 and 8, also have a split plate-tank as well as a split grid-tank, because the neutralization of a push-pull stage may be considered to be both grid and plate neutralization.

From the standpoint of the optimum ratio between inductance and capacity in the plate tank circuit of a RF amplifier the circuit arrangement affects the required tuning capacity for a given tube, plate voltage, power output and frequency.

For a given set of conditions, the impedance in ohms, measured across the ends of a split tank coil, will be exactly four times the impedance across the unsplit plate tank coil. In the grid neutralized tank circuit shown in Figure 1 the plate circuit of the amplifier tube is connected across the entire circuit so that the required reflected load impedance appears across the entire tank circuit. When the same amplifier is changed to plate neutralization with either the split coil circuit shown in Figure 3, or the split-stator condenser circuit shown in Figure 4, the plate circuit of the tube is then tapped across only half of the tank circuit. Thus the impedance measured across either half of the plate tank must be the same in order that the tube will operate under exactly similar conditions as encountered in the grid neutralized circuit. Because this is an autotransformer arrangement, the impedances across part or all of the inductance will vary as the square of the turns ratio; and since there are twice as many turns across the

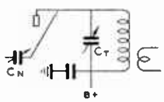


FIG 1

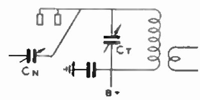


FIG 2

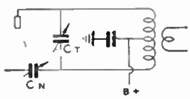


FIG 3

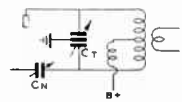


FIG 4

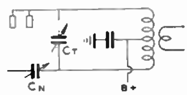


FIG 5

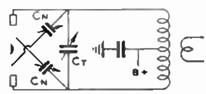


FIG 6

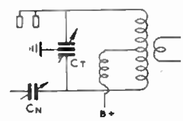


FIG 7

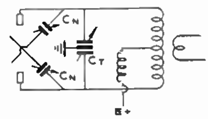


FIG 8

entire tank coil as there are across either half, the impedance across the entire tank will be two squared, or four times the impedance that one-half of the tank reflects back into the tube. For a given power, tube and plate voltage, there is twice the peak RF voltage across the split tank as there is across an unsplit tank. This higher RF voltage means that dielectric losses in the plate tank circuit are four times as high in the split circuit as in the unsplit arrangement, but because the circulating RF current is twice as high in the unsplit tank the resistance losses in that circuit are four times as large.

In a single-ended grid neutralized high efficiency amplifier operating at less than 4000 volts DC plate voltage, the circulating current losses can be minimized by tapping the plate down on the plate coil in order to reduce the amount of C necessary for a given "Q" (see Figure 1A). This technique is more desirable than employing plate neutralization; furthermore, it allows the use of a single-section condenser.

Parallel Operation

● The circuit shown in Figure 2 is exactly the same as that in Figure 1, with the exception that the two tubes are in parallel in Figure 2. If the two paralleled tubes draw

Table Showing Proper Values of Tuning Capacities for a Single-Ended Plate Neutralized Class C Amplifier, at Various Frequencies

Tube DC Impedance $Z_{DC} = \frac{Ep}{Ip}$	Operating Frequency 1,750 KC	Operating Frequency 3,500 KC	Operating Frequency 7,000 KC	Operating Frequency 14,000 KC
2,000 ohms	228 mmfd.	114 mmfd.	57 mmfd.	28.5 mmfd.
3,000 ohms	152 mmfd.	76 mmfd.	38 mmfd.	19 mmfd.
4,000 ohms	114 mmfd.	57 mmfd.	28.5 mmfd.	14 mmfd.
5,000 ohms	92	46 mmfd.	23 mmfd.	11.5 mmfd.
6,000 ohms	76	38 mmfd.	19 mmfd.	9.5 mmfd.
7,500 ohms	60	30 mmfd.	15 mmfd.	7.5 mmfd.
10,000 ohms	46	23 mmfd.	11.5 mmfd.	6 mmfd.
15,000 ohms	30	15 mmfd.	7.5 mmfd.	4 mmfd.
20,000 ohms	22	11 mmfd.	5.5 mmfd.	3 mmfd.
25,000 ohms	18	9 mmfd.	4.5 mmfd.	2 mmfd.
30,000 ohms	15	7.5 mmfd.	4 mmfd.	2 mmfd.

Determination of Proper Tank Capacity:

- The DC plate voltage and DC plate current, under full load, must be known in order to determine the proper tank circuit capacity. The first column to the left in the Table lists a number of values of DC Plate Impedances. This value is secured by dividing the DC plate voltage by the DC plate current, as shown in the following example:

A type 801 tube, operating at 600 volts and 80 milliamperes has a DC Plate Resistance or Impedance of—

$$\frac{600}{.08} = 7{,}500 \text{ ohms.}$$

By referring to the first column in the Table above (Tube DC Impedance) it can be seen that 7,500 ohms Impedance (first column) calls for 60 mmfd. capacity (second column), for operation at 1,750 KC in order that the circuit can function properly for c.w. telegraphy. However, this value of capacity, 60 mmfd., consists of the tube and neutralizing capacities, **combined** with the actual capacity of the plate tuning condenser. Therefore the actual value of capacity of the plate tuning condenser should be set to approximately 10% **less** than 60 mmfd., or 54 mmfd. because the miscellaneous circuit capacities which are effectively across the tuning condenser amount to approximately 10 mmfd., and in some cases this value is even higher than 10%. Proceeding now to the third column in the Table above (3500 KC Operation column), it is seen that the capacity **decreases** as the frequency **increases.** This reduction in capacity is inversely proportional to the frequency, and for 3,500 KC operation a capacity of only 30 mmfd. is required—just half as much as is needed for 1,750 KC operation. This capacity of 30 mmfd. can be obtained from a split-stator condenser with 50 mmfd. per section, set at near maximum capacity, because the miscellaneous shunt capacities will increase the value of this tuning condenser to the required 30 mmfd. Two 50 mmfd. sections in series give the same capacity as a single condenser of 25 mmfd.

If the value of Tube DC Impedance falls between those listed in the first column in the Table, the tuning capacities will likewise fall between the two nearest values shown in succeeding columns.

- For Grid Neutralization, multiply above values of capacity by 4.
- For Phone Operation, multiply all values of capacity by 2.
- Parallel tubes are considered as one tube at twice as much plate current, resulting in lower DC Load Resistance.
- For Push-Pull tubes, divide DC load Resistance by 2. Neutralizing and inter-electrode capacities can be subtracted from above values.

the same plate current under the same conditions of operation as the one-tube circuit of Figure 1, then the load impedance across the two tank circuits will be equal, and the same tuning capacity will give the same circuit "Q"; but, if a second tube is added to an already existing amplifier to double the output, the bias must remain unchanged, even though the DC grid current will double. The neutralizing capacity must be doubled, and the antenna coupling must also be increased in order to make the amplifier draw twice the plate current as it did before. In addition, it will be found that the tank tuning capacity must be doubled to preserve the same circuit "Q."

Push-Pull

● All push-pull circuits, such as those shown in Figures 6 and 8, have split tank coils. In these circuits there are no unbalances due to plate-to-ground capacities; the arrangement shown in Figure 8 is preferable to others, incidentally, the total plate tuning capacity is the same in either Figure 6 or 8.

With reference to Figure 8, if the two tubes together draw the same plate current as the one tube circuit in Figure 4 (assuming identical operating parameters), the load impedance across the entire circuit will be the same in both cases, and the required condenser capacities will be equal in value.

The push-pull circuit makes possible the use of a lower value of "Q" for the same circuit merit; the "Q" of a push-pull circuit need only be approximately 60 per cent of the "Q" of an equivalent single-ended amplifier. The purpose of "Q" in any tank circuit is to preserve the waveform of the alternating current. Thus, the particular advantage of the push-pull circuit is that it produces very few even harmonics and thus preserves the shape of the wave better than a single-ended circuit of the same "Q." The presence of harmonics in the distorted wave output of a low "Q" amplifier is precisely the reason why a high C (meaning high "Q") tank circuit minimizes the radiation of undesirable radio-frequency harmonics.

Tank Circuit Relationships

● The impedance across any tuned circuit is related to the series resistance of the tank. The higher the series resistance, the lower the shunt resistance. (Resistance and impedance are identical at resonance). The shunt resistance is always "Q" squared, times the series resistance.

The reactance of either the coil or condenser of any resonant circuit is always equal to "Q" times the series resistance, or the shunt resistance divided by the "Q". Thus a tank loaded so that it has a shunt resistance of 5000 ohms at resonance would be said to have a series resistance of 50 ohms if the LC ratio were such that the circuit "Q" were 10. In order to have a "Q" of 10, the coil and the condenser reactance would have to be "Q" times the series resistance, or 10 times 50, or 500 ohms. The reactance is also shunt resistance divided by "Q", or 5000/10 = 500. The capacity required to equal a 50 ohm reactance can be calculated if the operating frequency is known by the following formula:

$$X_c = \frac{1,000,000}{2 \times \pi \times f \times C}$$

where X_c equals the reactance in ohms; f, the frequency in cycles per second; and C, the capacity in microfarads.

Antenna Tank Circuits

● The use of link-coupling between the plate tank of the final amplifier and a separate antanna tank circuit to which the antenna or feeders are coupled has been universally popular. This type of coupling reduces harmonic radiation, preserves better balance on a push-pull stage, prevents the feeder radiation from altering stability of the various amplifiers in the transmitter, and tends to improve the effective "Q" of the plate tank circuit of the final amplifier.

The higher the "Q" of the antenna tank the more the harmonic radiation will be reduced. The "Q" of the antenna tank should not be less than 5 but preferably higher. The "Q" is calculated or estimated in exactly the same manner as that of the plate tank.

One of the simplest antenna tank arrangements appears in the schematic of Figure 9. If the tank is feeding an off-center Hertz antenna the shunt impedance across the tank will be the same as the characteristic impedance of the feeder, which is in the neighborhood of 600 ohms (Note: see the "ANTENNA" section for other details). Thus, to obtain a "Q" of 5, the condenser reactance at the operating frequency would be 120 ohms. At 7000 KC this would require a condenser capacity of 190 mmfds. At 3500 KC, twice this capacity would be necessary. The values of capacity are larger than can be conveniently handled and therefore the arrangement shown in Figure 10 reduces the required capacity to one-fourth, although the RF voltage (for any given power output) is doubled; consequently the twice spacing must be provided. The feeder is tapped across one-half of the total turns, making the impedance across the entire tank four times the impedance from feeder to ground, or 2400

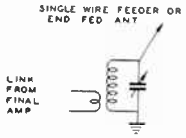


FIG 9

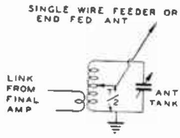


FIG 10

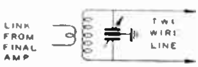


FIG 11

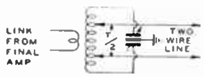


FIG 12

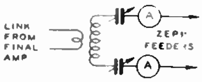


FIG 13

Various methods for coupling final amplifier to the antenna are here shown.

ohms across the tank for a 600 ohm feeder. The condenser reactance for a "Q" of 5 is 480 ohms; therefore only 48 mmfds. of capacity is necessary at 7 MC. The capacity is independent of the power output of the transmitter, which is a point of difference between the antenna tank and a plate tank, because the power output of a transmitting tube is very closely related with the reflected load impedance into which the tube works. Therefore a 1 KW transmitter would require no more capacity in a given antenna tank than a 5 watt transmitter, but the voltage spacing would have to be much greater. The effective RF voltage across any tuned circuit is always equal to the square-root of the product of the power in watts, times the shunt impedance, in ohms; or writing

$$E = \sqrt{PZ}$$

where E equals the volts; P, watts; and Z, ohms.

Thus 1 KW of power across a 600 ohm feeder represents an effective voltage of 775 volts. The voltage across 2400 ohms for the same power is twice this value, or 1550 volts. The peak voltage can be about twice the effective voltage, particularly if harmonics are present or if the carrier output is voice modulated, and thus the antenna tank tuning condenser must be rated at from two to three times the peak voltage which is present.

If it is desired to use a still smaller condenser to tune the antenna tank, the feeder can be tapped father down the tank coil. This steps-up the impedance across the entire tank circuit, according to the law of impedance transformation, wherein the impedance ratio is equal to the square of the turns ratio.

If an end-fed antenna is tapped directly to the antenna tank coil, the circuit of Figure 9 should be used, as it is not advisable to tap down on the coil. Figures 11 and 12 show split antenna tanks for feeding two-wire non-resonant transmission lines. Figure 13 describes how a Zepp antenna can be fed by means of a link from the final amplifier.

Power Transfer

● In all transmitters, care must be taken to properly transfer the power into each succeeding stage; otherwise the output from the final stage will be low. The coupling link must be adjusted so that maximum grid current is obtained in the driven stage.

With capacity coupling between stages, the grid coupling condensers must have sufficient capacity to provide a normal load or the preceding tube with maximum grid current. Lower frequencies, such as 3,500 KC, require a .00025 grid condenser between the doubler circuit and the buffer grid (for an 801 tube) for the same loading effect on the doubler plate (6A6 in this example). With low impedance tubes, such as 6A6 or 53 types, the input to a buffer stage may be capacitively coupled with nearly as much grid drive as with link coupling, provided a high or medium grid impedance is offered. A low-mu tube offers a higher grid impedance load than does a high-mu tube, such as a 203A or 46. Capacity coupling between an 801 and 50T, both medium-mu tubes, gives only a little more than half as much grid current as is obtained with link-coupling. These important points must be carefully weighed when a transmitter is to be put into operation on 10 or 20 meters, as the margin of available grid excitation is much less than on 40 or 80 meters. Probably 90 per cent of the trouble with 20-meter transmitters is lack of sufficient excitation on one or more grid stages.

Filament By-passing

● Each side of the filament must be by-passed with a .002 mfd. condenser to its particular RF stage ground-bus to provide low impedance paths for neutralizing purposes. Too low-C in the final tank circuit makes neutralization difficult, and does not give any more output on the fundamental frequency.

Self-Excited Oscillators

● The self-excited oscillator (SEO) is one of the outstanding developments in the progress of radio transmitting apparatus. When properly designed, it is one of the best forms of frequency generation, for its use permits any desired frequency to be obtained with

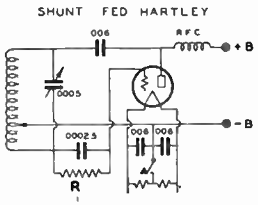


FIG. 1

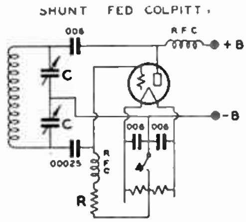


FIG. 2

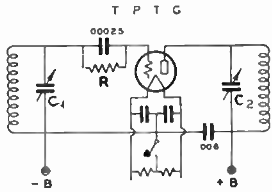


FIG. 3

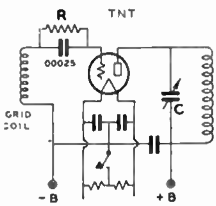


FIG. 4

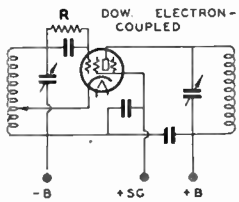


FIG. 5

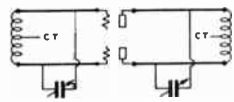


FIG. 6

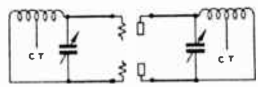


FIG. 7

few adjustments. In amateur band operation this advantage results in selecting "clear spots" in which to operate. But it is a rather dangerous circuit for beginners to design. Few amateurs, especially the novice, have wavemeters and frequency meters to check the desired frequency with a self-excited oscillator. With these precepts, it is suggested that the SEO circuits be set aside until one has become well-grounded in radio knowledge and in practice.

Good design of the SEO necessitates a choice of good parts, solid connections, freedom from vibration, and a power supply with excellent voltage regulation.

Types of SEO Circuits

● The common types are: The Hartley—Figure 1; the Colpitts—Figure 2; the tuned-plate tuned grid (TPTG)—Figure 3; the TNT—Figure 4, and the electron-coupled—Figure 5. These circuits need little explanation with possibly a reference to the TNT. Its name is correct: it is TNT in the hands of beginners and, therefore, is not a circuit for any newcomer to use.

SEO circuits can be single tube or two tube (push-pull) affairs. They can be shunt or series fed.

Design and Technique

● The push-pull circuit is to be recommended over the singled ended circuits, for there is a greater voltage swing, and the even harmonics are eliminated by circuit action. The rule to observe in construction of push-pull sets is symmetry—both mechanical and electrical. Exact electrical and mechanical symmetry cannot be obtained until left-handed and right-handed tubes are manufactured, because the grid and plate prongs of the tubes are reversed on the left-handed tubes. However, with the exception of the filament leads, a high degree of symmetry is obtainable. It is required that the leads to each inductance from each grid and plate socket be of the same length. The condensers can be connected to these leads in almost any manner without disturbing the constants. In many instances in which inductances are mounted on top of the condensers, unequal length of leads may result, even though they appear to be correct to the eye. Figure 7 illustrates the fact even though the grid and plate leads to the condensers are both of equal length, the condenser frame makes one of the leads longer than the other. To overcome this difficulty, mount the coils separately with their equal length connection to the sockets, and then connect the condensers to the leads. This might slightly throw off the balance, but odd length condenser leads still constitute capacity—and not inductance, if the leads are short and close together. This is illustrated in Figure 6. Note: Keep the condensers at least a coils' diameter away from the coil.

Piezo Quartz Crystals

● Quartz and tourmaline plates are minerals having a crystalline structure which, when cut and ground on certain crystallographic (optical) axes, possess piezo-electric properties in the influence of an oscillating electrical field. The mechanical activity or frequency of a piezo-electric element depends upon its physical dimensions (the frequency being inversely proportional to the thickness). The stability of the oscillatory properties depends mainly upon the optical cut and the crystal-temperature coefficient.

Piezo-electric Oscillator (after the U.S.N. Conference in 1929): A circuit containing a resonator (crystal) and possessing too little regeneration to oscillate itself, but which oscillates through the reaction of the crystal when the latter is vibrating near one of its normal frequencies with energy derived from the circuit. Such a circuit is often called a "crystal controlled" or "piezo-oscillator."

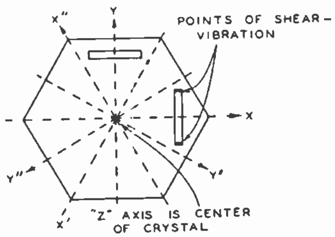


Fig. 1.

A quartz crystal plate (as used in amateur transmitters) is cut from the edges of a quartz crystal parallel to the optical axes known as X, Y and Z, see Figure 1. In general, crystals are cut with their faces either parallel or perpendicular to the Z or electric axis of the crystal. An X-cut is one that is parallel to the X-axis, while a Y-cut is parallel to the Y-axis. Y-cuts are sometimes referred to as 30-degree cuts. The thickness dimensions of the plate are parallel to the X- and Y-axes, respectively, while the rectangular length or elongation of the plate is perpendicular to the optical or Z-axis. An X-cut crystal vibrates in the direction of the Y-axis, and the chief mode of vibration for a Y-cut is that of a shearing vibrational-strain taking place about the Z-axis; with this latter cut, the crystal actually becomes elastic and waves are produced parallel to the Y-axis. A crystal cannot oscillate along the Z-axis, as the forces which hold the atoms of the crystal together are so great that there is relatively little expansion along this axis.

In general, quartz plates are most widely used for controlling frequencies below 10 megacycles, because of their relative cheapness as compared to tourmaline plates. On the higher frequencies, tourmaline is to be preferred for fundamental control, as quartz plates oscillating above 7 megacycles have a slight tendency toward side-tone oscillation. Tourmaline crystals are mechanically stronger than quartz, and are also easier to grind on account of their smaller diameter and greater thickness for a given frequency.

In amateur practice, X-cut crystals are sometimes ground with trick contours to boost the power output, but if the process is carried beyond a certain stage, the crystal will oscillate at more than one frequency unless special precautions are taken with the oscillator to prevent it. The temperature coefficient of a Y-cut plate is twice that of an X-cut (and in the opposite or negative direction), but if the oscillator is run underloaded, the drift will be negligible with either cut. Because of the temperature characteristics, X-cut crystals have a negative temperature coefficient, and Y-cuts postive; for these reasons, an X-cut plate is preferable for use just inside the HF edge of a band, and a Y-cut for the low-frequency edge.

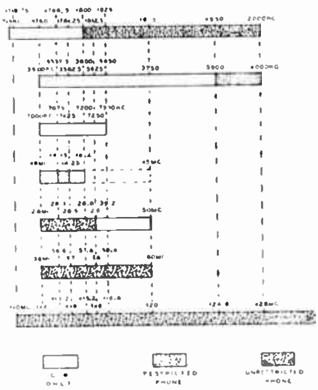
Frequency Drift and "Twin-Peaks"

● Crystals that oscillate at more than one frequency are commonly known as crystals with "twin peaks." The dual vibrational tendency is more pronounced with Y-cuts, and to a certain degree is exhibited by many X-cuts. The use of a well-designed, space wound, low "C" tank coil in an oscillator will prohibit the crystal from oscillating at two frequencies, and in addition will increase the output. Experiments have shown that the frequency stability is not improved by large tank capacities, which only tend to augment the double frequency phenomenon.

Y-cut crystals having perfectly parallel sides, lapped to a high precision, are the worst offenders in regard to twin frequencies, sometimes making it necessary to resort to a special form of clamp holder in addition to an extremely low capacity tank to confine the oscillations to one peak.

An X-cut crystal that has been accurately ground, with both sides absolutely flat and parallel, will oscillate at only one peak, provided the edges are free from imperfections or nicks. Good output from an X-cut crystal can only be obtained when the top electrode of the crystal-holder does not press too heavily against the crystal. By grinding a special contour into the crystal, a medium output is obtainable that under certain conditions may suffice; however, a crystal ground in this manner will have its output appreciably reduced by heavy electrode pressure. In grinding, if the convexity is carried too far, the crystal will have two oscillating peaks.

Twin frequencies appear in several ways: sometimes the crystal will have two frequencies several hundred cycles apart, oscillating on both frequencies at the same time, and producing an acoustically audible beat note. Other crystals will suddenly "jump" frequency as the tank tuning condenser is varied past a certain setting. Operation with the tank condenser adjusted near the point where the frequency shifts



Bliley frequency chart of Amateur Bands and harmonic relationship.

is very unstable, the crystal sometimes going into oscillation on one frequency and sometimes on the other as the plate voltage is cut "on" and "off." Still other crystals will jump frequency only when the temperature is varied over a certain range. And some plates will jump frequency with a change in either tank tuning or temperature, and produce an audible beat tone at the same time, showing actually two pairs of frequencies!

Crystals are often cut with their axes between the X and Y points, to reduce the temperature coefficient. Since X- and Y-cut plates have a frequency drift in opposite directions with increase in temperature, a plate cut between the two axes will have a negligible or near-zero drift.

Use and Care of Crystals

● When operating close to the edge of one band, it is advisable to make sure that the crystal will respond to but one frequency in the holder and oscillator in which it is functioning; for a crystal with two peaks can suddenly leave a band and operate on another without giving any indications of the change on the meter readings of the transmitter. If the transmitter frequency is such that the operation takes place on the edge of the band at all times, under all conditions of room temperature, some form of temperature control will be required for the crystal. When working close to the edges of the 14 megacycle band it is essential that the crystal temperature be kept at a fairly constant value; the frequency shift in kilocycles per degree Centigrade increases in direct proportion to the operating frequency, regardless of whether the fundamental or harmonic is used. When a crystal shifts its frequency by two kilocycles, its second harmonic has shifted 4 kilocycles. Amateurs not operating on the edge of a band need not concern themselves about frequency drift due to changes in room temperature. If a pentode tube is used for the crystal oscillator having a plate potential of approximately 300 volts, the temperature of the crystal will not increase appreciably to cause any noticeable drift at even 14 kilocycles. When a crystal oscillator is keyed on 3.5 or 1.7 megacycles, the frequency drift is not of any consequence, even with much higher values of plate input, because of the keying and of the fact that the drift is not multiplied as it would be with harmonic operation of a final amplifier.

Crystal holders have a large effect on the frequency; for example, the frequency of an 80 meter crystal can vary as much as 3 kilocycles in different holders. Even greater variations are possible on account of the uneveness of some electrodes in various types of manufactured holders. Warped electrodes touching a crystal in two or three spots form, in effect, a sort of air-gap holder. Holders having a spring to provide tension on the top electrode appreciably affect the frequency, and their use is to be discouraged.

Periodic or weekly crystal cleaning done by rubbing the top electrode around on the crystal surface to dislodge dust particles that may have worked in between the electrode and crystal will, after a year or longer, increase the frequency of the crystal. CAUTION: Do not rub the crystal or electrodes; disassemble the holder and clean the parts with alcohol, ether, or carbon-tetrachloride (carbona). With polished crystals there is less tendency of wear; however, as a safety measure, all crystals should be placed in dust-proof holders.

40 Meter Crystals

● A 40 meter crystal can be used in the conventional 47 crystal oscillator circuit and link coupled to an 841 doubler running at about 700 volts to excite a 210 full output with high efficiency on 20 meters, provided the 841 is also link coupled to the 210. On the higher frequencies there is a worthwhile increase in efficiency and output when using the link form of inductive coupling, rather than capacitive coupling. Capacitive coupling is justified at the higher frequencies only for the sake of simplicity where reduction in efficiency can be tolerated.

Special precaution must be taken with 40 meter crystals, and more care given to the circuit details than with lower-frequency crystals. Here, a suitable crystal-holder is of prime importance, as many 40 meter crystals refuse to oscillate in any holder except the particular type in which the crystal was designed to operate. Because a holder works well with an 80- or 160-meter plate does not indicate that a 40-meter crystal will function likewise.

A 40-meter crystal requires a very light top electrode with no additional pressure spring for maximum output; spring pressure is not necessary for stability unless the transmitter is subject to severe vibration. The faces of a 40-meter crystal are practically flat, and if the surfaces of the holder electrodes are truly plane, the top electrode will not tend to "rock" on the crystal and cause frequency instability.

Before placing a 40-meter crystal in its holder, the edges of the crystal should be carefully examined for nicks and imperfections. A nick almost invisible to the naked eye will sometimes have an appreciable effect on the output. If the edges show that they have been chipped, the crystal should be returned to the manufacturer for refinishing.

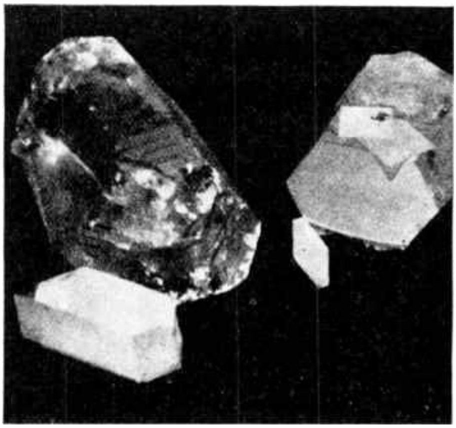
Grinding Quartz-Crystals

● Amateurs who have had no previous grinding experience should first attempt grinding a Y-cut 80- or 160-meter crystal. Although it requires a much longer time to grind an X-cut after one has become proficient, X-cuts must be finished with a greater degree of precision and are therefore best avoided by the novice for the first attempt.

The necessary material and equipment required for grinding with a minimum of labor and difficulty are: a micrometer, several pieces of heavy plate glass, an oil can filled with water, a pan of clean water, several clean towels, a bottle of India ink, a test oscillator, and a frequency measuring device such as a calibrated receiver, and lastly, small quantities of No. 150, No. 280 and No. 400 carborundum. The latter grain is used only in finishing X-cut plates, and need not be procured if only Y-cuts are to be ground. Water is used in preference to kerosene, because it is necessary to remove all oily traces each time the crystal is tested in the oscillator. A one-half inch micrometer, reading to ten-thousandths, is best adapted for thickness measurements, but a one-inch instrument, reading to thousandths, will measure close enough for Y-cut plates by estimating to ten-thousandths and with care can even be used for the lower-frequency X-cuts if nothing better is available. It is advantageous to grind down the movable face of the micrometer on a wheel so that the tip resembles a cone with a rounded point, rather than the end of a cylinder. This enables one to measure a point on a crystal instead of a section of the crystal.

The test oscillator must be equipped with a plate milliammeter, a dummy load which can be cut out of the circuit, and plug-in inductances so that either low or high "C" can be used in the tank for test purposes. An RF meter in series with the crystal is optional.

Assuming that one has the necessary materials and a 160 or 80-meter Y-cut blank which it is desired to convert into a good finished crystal, it is first necessary to finish one side flat, to use as the reference side (some blanks already have the reference side finished and marked). This can be done by rubbing one side around with even pressure on a piece of plate glass that has been smeared with No. 150 carborundum grain and water until India ink marks which have been placed on the tip of each corner disappear. The crystal is then rinsed in the pan of water and rubbed on another piece of plate glass smeared with No. 280 carborundum and water for half a minute or longer—care being taken to see that the pressure is fairly even all over the crystal and that the grinding is being done on the same side. The crystal is then washed and dried, and one corner of the finished side marked with India ink. All subsequent grinding is done on the other side. Using



A piece of raw quartz and several unfinished slabs from which oscillating crystal blanks are cut. The best quartz is mined in Brazil.

a finer grain of abrasive for finishing Y-cut crystals is not advisable, because it does not increase the output, but only aggravates the tendency toward twin-frequency peaks. By using a medium grain of carborundum for finishing and by giving the right contour to the side that is not yet finished, the second peak can be eliminated.

The crystal should now be roughened down with No. 150 grain carborundum until it is .002 or .003 inch thicker than the calculated finished thickness, which will be very close to .022 for 3500 KC and .0435 for 1750 KC. The finished thickness of a crystal of either cut can be predetermined for a given frequency within fairly close limits by applying the following formula:

$$\text{X-cut } T = \frac{112.6}{F}$$

$$\text{Y-cut } T = \frac{77}{F}$$

Where T is the thickness in inches, and F, the frequency in kilocycles.

The next step is to finish the crystal down with No. 280 abrasive to about .0004 inch greater than the calculated thickness (.001 for a 160 meter plate), frequent micrometer readings being taken to prevent any high or low spots from appearing. The crystal is then put in the oscillator. If its surfaces are reasonably parallel, it should now oscillate. If it oscillates at but one frequency as the tank tuning condenser is varied, it is a most unusual Y-cut crystal and is not acting in characteristic fashion. Making certain that it is oscillating at the low-frequency peak, the frequency should be checked to ascertain how closely it is agreeing with the formula.

The second peak, which is the highest in frequency, can be eliminated by giving the face now being ground a convex contour. The degree of convexity necessary to give one-frequency operation will vary with different crystals, but in every case the second peak will disappear before the process is carried far enough to affect the output to any great extent. In fact, a moderate curvature will actually increase the output silghtly over that of a Y-cut crystal that has been ground with both sides perfectly flat.

At this point the corners should be slightly rounded and the edges finished up. It is best to finish these before putting the final touches on the crystal as a preliminary to grinding the crystal to an exact frequency, because grinding on the edges will sometimes affect the characteristics of the plate. Grinding on the edges has a minor effect on the frequency, and also will sometimes cause a crystal that checks at one frequency to develop a second peak.

The optimum amount of convexity can only be determined for each particular crystal by trial, but it is not critical as long as no spot is higher than the center of the crystal. A contour that has been found suitable for most 80 meter crystals *of the Y-cut type is as follows:*

Edges between corner .0001 inch lower than center; corners .0003 to .0005 inch lower than center. For 160 meter crystals the convexity can be slightly greater if necessary to eliminate twin peaks. A piece of glass that has been slightly worn down facilitates grinding a uniform convex contour, but until one has used a piece of glass for roughing-down several crystals it will not be hollowed out sufficiently for the requirements. If the glass is nearly flat, pressure on each of the edges and corners—one at a time—will be necessary to get the desired curvature.

A final check for twin peaks is made by using a tank coil in the test oscillator which requires slightly more capacity to tune to resonance than will ordinarily be required in the transmitter oscillator. No attempt should be made to keep the crystal from oscillating at two frequencies with an extremely high-C tank, because almost any crystal will show a second peak if the oscillator is made very high-C. If the "medium-C" tank shows two frequencies, it will be necessary to grind down the tips and the corners until the second one disappears. A soldering iron should then be held near the crystal as the beat note is monitored in the receiver, until the crystal frequency creeps 10 or 15 kilocycles. The shift should occur gradually without sudden "jumps." The tank is then tuned through resonance for only one frequency: if two appear, the tips of the corners of the plate must be ground further. Very few plates will be found to require such drastic treatment, the slight convexity usually being sufficient.

To test for output and freedom of oscillation, the original low-C tank coil is employed. It is helpful to have a crystal that is known to be a good oscillator for comparative purposes. A low value of minimum plate current is the criterion for freedom of oscillation. A low minimum plate current means nothing, however, if the crystal becomes unstable or goes out of oscillation the moment a load is coupled to the tank. The oscillator must stand a reasonable amount of loading without going out of oscillation; in addition, must be stable when loaded.

If the finished crystal gives good output and has only one frequency response, one is then justified in attempting to grind an X-cut plate.

Grinding an X-cut Plate

● The reference side of an X-cut blank is ground down with No. 150 and No. 280 carborundum grain in the same manner as a Y-cut blank. It is then rubbed around in a circular motion for a half minute on a new piece of glass which is covered with No. 400 abrasive and water. It is imperative to use a *new* piece of glass for finishing the reference side of an X-cut blank, because maximum output will not be obtained if either side has the slightest amount of a convex curvature. One exception can be made: some manufacturers grind their X-cut plates with a special contour which calls for sections of the crystal being very slightly convex, but an amateur inexperienced in grinding will do well to keep away from such special trick contours. The output of an X-cut plate can be boosted by merely grinding it slightly concave on the finishing side. Paradoxically, while Y-cut plates have twin frequencies when the curvature is not great enough, X-cut plates exhibit double frequencies only when the curvature is too great. It is necessary, however, to remove a large section out of the center of an X-cut crystal before the second frequency appears, unless a very high-C tank is used in the oscillator. Grinding the center of an 80 meter X-cut plate .0001 or .0002 inch low will boost the output without encouraging a second frequency.

After inking the reference side, the blank is roughed down to about .03 inch over the calculated finished thickness with No. 150 carborundum, and then down a little further with No. 280 grain. The final grinding is done on a little-used piece of glass, covered with No. 400 grain and water. Enough pressure is exerted in the center of the crystal with one finger to bring the center .0001 or .0002 inch lower than the edges and corners. No spot should be lower than the center, otherwise the output will be disappointing. A new piece of glass should be used for finishing each X-cut crystal. The glass is then suitable for grinding Y-cut plates or roughing-down X-cut plates. Because 160 meter X-cut crystals are too thick to be hollowed out easily by exerting pressure in the center, even if new pieces of plate grass are used, it is necessary to finish them on a special piece of convex glass.

Finishing the edges on X-cut plates is of greater importance than on Y-cuts. An X-cut plate with unfinished edges may even refuse to oscillate unless the edges and corners do not vary over .0001 inch, or unless about .0005 inch has been hollowed out of the center (which is sufficient to cause double response frequencies). A crystal with variations greater than .0001 inch between the different corners and edges may give full output after the edges are finished. It is important that every minute imperfection be removed from the edges when finishing X-cut plates. X-cut crystals that refuse to give full output can sometimes be made to oscillate more freely by grinding the edges so that the cross-section of the crystal is reduced: that is, to grind so that the dimensions of the crystal along the other axes are changed.

To finish the edges of crystals of either cut, all nicks are first ground out by using the same grade of abrasive as used to finish the faces, but applying less water. To complete the work, the corner and edges are then slightly rounded off.

The India ink reference mark can be removed with a moistened, soft rubber eraser. The plate should be washed with soap and warm water to remove any rubber gum which may adhere to the unpolished surfaces. X-cut crystals can be polished to high transparency with rouge; however, the output will not be increased over that which is obtained by grinding with a high grade abrasive.

Mechanical Design and Construction

● The factors entering into the mechanical design and construction of an amateur transmitter are those which govern the efficiency and the results obtainable from a circuit specification. It is important, therefore, that a great deal of consideration be given to the constructional details. Practical notes are given herewith.

Before constructing a transmitter, all of the various parts should be laid out on a board (commonly called a "breadboard") or chassis and moved about until all of the RF leads are as short and direct as it is possible to make them. It is not necessary to strive for a symmetrical layout in order to improve the appearance to an onlooker: short and direct leads are important if the transmitter is to operate efficiently.

It matters little what type of base the apparatus is mounted on. A metal chassis is preferred by some constructors, while others prefer wood; however, the metal is a little more difficult to work. If the chassis is of metal, aluminum or copper should be used, especially if radio-frequencies are present. Cadmium or copper plating on steel is often satisfactory.

Boards have certain losses on account of most soft woods being poor dielectrics, which absorb energy in strong electro-static fields, such as those surrounding a transmitter stage. The losses may be minimized by selecting dry hardwood for the base.

An excellent breadboard base can be made of ordinary white pine covered with a thin sheet of No. 20 or 30 gauge aluminum, the sheet being neatly fastened by bending over the edges and tacking the underside down with small wire brads. This type of base allows condensers and coils to be mounted with ordinary wood screws. The metal acts as a shield and also keeps the capacity-to-ground constant from the various parts of the transmitter. Shielding is a necessary requirement, although it represents a small loss. Natural shielding; that is, the greatest permissible space between stages, is better than metal shields.

Since link coupling has been universally accepted as being a superior method for interlinking stages, there is now no valid reason for placing more than one stage on a single breadboard, as coupling links can be lengthened upward to ten feet. If transmitter stages closely adjoin each other, it is necessary to resort to interstage shielding to prevent feedback. Complete shielding, as is specified in receiver construction, is not a necessary requirement in transmitter design; a double baffle separated by at least one-fourth inch and six inches high will suffice in practically all cases. The plates must not touch except where they are supported to the common ground connection, or screwed to the metal chassis.

Recently a movement has been introduced to more or less standardize the size of breadboards and chassis. This practice ought to be encouraged by all amateurs, as it facilitates the quick exchange and re-placement of component parts. In general, chassis sizes more or less follow the standard rack construction specifications originally adopted by the Bell System. The front panel of a standard rack is 19 inches wide and is some even multiple of one and three-quarter inches high. Three common sizes are: seven, eight and three-quarters, and ten and one-half inches high.

The breadboards or chassis that are mounted on or behind these front panels cannot be wider than 17 inches, due to the clearance limits between the side members of the standard rack. Most chassis are eight and one-half to twelve inches deep. No movement toward standardizing the depth has been started on account of the limitations in the strength of the supporting structure.

A neat way to lay out a transmitter is to obtain several pieces of five-ply veneer, eight and one-half inches square, and then covering these pieces with No. 28 gauge aluminum. Such breadboards are of the correct size for a single low-power stage, and each can be quickly removed from the completed transmitter when rebuilding or when changes are necessary. For standard rack mounting two of these small breadboards may be mounted behind each panel. A plug and jack arrangement conveniently allows almost any stage to be taken out and replaced with another, especially in transmitters having a 47 oscillator, Jones Exciter, or electron-coupled oscillator stage. Here the buffer and doubler stages are identical and use type 210 tubes; hence, a 50 watt stage may replace any of the push-pull 210s.

Nothing in the transmitter should be nailed down. Each coil, condenser, etc., need only be fastened firmly to some support; however, it is a prerequisite that all the apparatus be placed in such a manner as to permit quick replacement should any part burn out or fail.

Not even a radio engineer can lay out a radio transmitter with the hopes of expecting it to operate perfectly the first time it is tested. Often it is found that there is insufficient excitation to some particular stage, requiring, of course, the addition of another buffer stage; this is a relatively simple problem if each stage is mounted on its own little board. Difficulty experienced from parasitic oscillation can be more easily corrected when individual breadboards are used.

When laying out a stage on a broadboard or chassis, the grid coil must be placed as far from the plate coil as possible—at least five times the diameter of the plate coil away from it. If the two coils are in close proximity, difficulties may be encountered in neutralizing the stage. In some cases, especially in high-power stages, it is desirable to orient the coils so that they are at right angles to each other so that the fields around the two coils will have the minimum of interaction between them.

Tank coils for low power stages may be wound on receiving-type plug-in coil forms, providing that they are made of ceramic or Isolantite insulating materials. Most amateurs prefer five prong plug-in coils to simplify coil change and exchange between stages.

Isolantite sockets for tubes and coil forms are desirable. Some of the newer wafer-type sockets are satisfactory for stages operating with less than 500 volts plate voltage. The latest type midget condensers give splendid results when used in the grid and plate circuit of low power stages. Good practice dictates that a closed-circuit jack be placed in every grid and plate circuit, even though some meters may always be in the circuit. When the stage is removed from the transmitter for test or rebuilding, it is always convenient to be able to quickly check the grid and plate current while the stage is being tested on the workbench.

C.W. Tone Quality on 5 and 10 Meters

● The rough notes emitted by 5 and 10 meter c-w transmitters can usually be traced to insufficient plate supply filter in the crystal oscillator stage. The pure DC note obtained when monitoring an 80 meter crystal oscillator may sound anything but pure DC when several frequency multiplier stages are added to obtain output on 5 or 10 meters. Each frequency multiplier doubles not only the RF frequency, but also the percentage of AC ripple modulation, so that this effect often becomes quite noticeable in the ultra-high frequency range. The cure lies in the use of two or more sections of filter in the plate supply to the crystal oscillator, this filter consisting of at least two large filter chokes and several condensers.

Coil Winding Charts for Copper Tubing Tank Coils

THE values given are a close approximation to your particular requirements in each case, but exact accuracy depends on the circuit arrangement and the length of the leads in the plate circuit of the tube to be used. The two factors mentioned become more important as the frequency increases. Long leads necessitate fewer turns on the coil, but the leads should be long enough to keep the tank condenser separated from the coil by at least the coil diameter.

All the values in the table are for the tubes specified when used as single-ended amplifiers with the neutralization tap near the center of the coil. If placed in the center of the coil, this tap will automatically give fixed neutralization on all bands. For push-pull amplifiers, decrease the number of turns by 25% for any given tube. The reason for this decrease will be apparent upon close comparison of single-ended and push-pull circuits. Just twice as much tube capacity is shunted across the tank in push-pull circuits as when single-ended circuits are used.

In low-C tanks, such as these, the voltage rating of the condenser should be equal to four times the plate voltage on the tube for single-section types, and twice the plate voltage (each section) for split-stator models.

CHART NO 1. For Coils Tuned With Split-Stator Condenser and Used in Circuits Employing Low-C Tubes, such as 150T, 50T, 354, 852, 800, 825, RK18.

BAND	2" Dia. Coil	3" Dia. Coil	4" Dia. Coil	5" Dia. Coil	6" Dia. Coil	Size of Tuning Condenser
160	N.S.	N.S.	N.S.	N.S.	80 Turns 36" Long ⅜" Tubing	250 Mmf. Each Section for Full Band Coverage.
80	N.S.	N.S.	60 Turns 20" Long ¼" Tubing	50 Turns 18" Long ¼" Tubing	40 Turns 18" Long ⅜" Tubing	100 Mmf. Each Section for Full Band Coverage.
40	N.S.	46 Turns 16" Long ¼" Tubing	34 Turns 12" Long ¼" Tubing	28 Turns 12" Long ¼" Tubing	22 Turns 12" Long ¼" Tubing	35 Mmf. Each Section.
20	32 Turns 15" Long ¼" Tubing	20 Turns 12" Long ¼" Tubing	16 Turns 12" Long ¼" Tubing	14 Turns 12" Long ¼" Tubing	10 Turns 12" Long ¼" Tubing	35 Mmf. Each Section.
10	8 Turns 4" Long ¼" Tubing	6 Turns 4" Long ¼" Tubing	4 Turns 4" Long ¼" Tubing	4 Turns 4" Long ¼" Tubing	3 Turns 4" Long ¼" Tubing	35 Mmf. Each Section. N.S. Indicates: NOT SATISFACTORY

CHART NO 2. For Coils Tuned With Single-Section Condenser and Used in Circuits Employing Low-C Tubes, such as 150T, 50T, 354, 852, 800, 825, RK18.

BAND	2" Dia. Coil	3" Dia. Coil	4" Dia. Coil	5" Dia. Coil	6" Dia. Coil	Size of Tuning Condenser
160	N.S.	N.S.	N.S.	N.S.	60 Turns 36" Long ⅜" Tubing	100 Mmf.
80	N.S.	N.S.	50 Turns 20" Long ¼" Tubing	40 Turns 18" Long ¼" Tubing	30 Turns 18" Long ⅜" Tubing	100 Mmf. For Full Band Coverage.
40	N.S.	36 Turns 14" Long ¼" Tubing	24 Turns 12" Long ¼" Tubing	20 Turns 12" Long ¼" Tubing	16 Turns 12" Long ¼" Tubing	35 Mmf.
20	22 Turns 12" Long ¼" Tubing	16 Turns 12" Long ¼" Tubing	12 Turns 12" Long ¼" Tubing	10 Turns 12" Long ¼" Tubing	8 Turns 12" Long ¼" Tubing	35 Mmf.
10	6 Turns 5" Long ¼" Tubing	4 Turns 5" Long ¼" Tubing	4 Turns 5" Long ¼" Tubing	4 Turns 5" Long ¼" Tubing	2 Turns 5" Long ¼" Tubing	35 Mmf.

CHART NO. 3. For Coils Tuned With Split-Stator Condenser and Used in Circuits Employing High-C Tubes, Such as 50 Watters, 210, 204A, 849, 212D, 830, 46, RK20.

BAND	2" Dia. Coil	3" Dia. Coil	4" Dia. Coil	5" Dia. Coil	6" Dia. Coil	Size of Tuning Condenser
160	N.S.	N.S.	N.S.	N.S.	72 Turns 36" Long ⅜" Tubing	250 Mmf. Each Section for Full Band Coverage.
80	N.S.	N.S.	54 Turns 16" Long ¼" Tubing	46 Turns 18" Long ¼" Tubing	36 Turns 18" Long ⅜" Tubing	100 Mmf. Each Section for Full Band Coverage.
40	N.S.	36 Turns 14" Long ¼" Tubing	24 Turns 10" Long ¼" Tubing	20 Turns 10" Long ¼" Tubing	16 Turns 10" Long ¼" Tubing	35 Mmf. Each Section.
20	24 Turns 10" Long ¼" Tubing	16 Turns 10" Long ¼" Tubing	12 Turns 10" Long ¼" Tubing	10 Turns 10" Long ¼" Tubing	8 Turns 10" Long ¼" Tubing	35 Mmf. Each Section.
10	8 Turns 5" Long ¼" Tubing	6 Turns 5" Long ¼" Tubing	4 Turns 5" Long ¼" Tubing	4 Turns 5" Long ¼" Tubing	3 Turns 5" Long ¼" Tubing	35 Mmf. Each Section.

Copper Tubing Coil Charts

CHART NO. 4. For Coils Tuned With Single-Section Condenser and Used in Circuits Employing High-C Tubes, Such as 50 Watters, 210, 204A, 849, 212D, 830, 46, RK20.

BAND	2" Dia. Coil	3" Dia. Coil	4" Dia. Coil	5" Dia. Coil	6" Dia. Coil	Size of Tuning Condenser
160	N.S.	N.S.	N.S.	N.S.	60 Turns 36" Long ¾" Tubing	100 Mmf.
80	N.S.	N.S.	50 Turns 20" Long ¼" Tubing	40 Turns 18" Long ¼" Tubing	30 Turns 18" Long ¾" Tubing	100 Mmf. For Full Band Coverage.
40	N.S.	32 Turns 14" Long ¼" Tubing	22 Turns 12" Long ¼" Tubing	18 Turns 12" Long ¼" Tubing	14 Turns 12" Long ¼" Tubing	35 Mmf.
20	18 Turns 10" Long ¼" Tubing	14 Turns 10" Long ¼" Tubing	10 Turns 10" Long ¼" Tubing	8 Turns 10" Long ¼" Tubing	6 Turns 10" Long ¼" Tubing	35 Mmf.
10	4 Turns 5" Long ¼" Tubing	4 Turns 5" Long ¼" Tubing	4 Turns 5" Long ¼" Tubing	4 Turns 5" Long ¼" Tubing	2 Turns 5" Long ¼" Tubing	35 Mmf.

Coil Chart for 1½-in. and 2½-in. Dia. Coil Forms.

BAND	1½" Dia. Coil Form	Size of Tuning Condenser	BAND	2½" dia. Coil Form	Size of Tuning Condenser	REMARKS
160	Not Satisfactory		160	46 Turns No. 16 DCC. Close wound	100 MMF. or larger	The winding data shown here is for coils that are tuned with single-section variable condensers. See Chart below for coil winding data when split-stator variable condensers are used.
80	35 Turns No. 22 DCC. Close wound	100 MMF.	80	23 Turns No. 16 DCC. Spaced one dia.	100 MMF.	
40	19 to 21 Turns No. 16 DCC. Spaced one dia.	100 MMF.	40	16 Turns No. 16 DCC. Spaced one dia.	25-35 MMF.	
20	11 to 13 Turns No. 16 DCC. Spaced one dia.	25-35 MMF.	20	8 to 10 Turns No. 16 DCC. Spaced one dia.	25-35 MMF.	
10	5 to 6 Turns No. 16 DCC. Spaced one dia.	25-35 MMF.	10	5 Turns No. 16 DCC. Spaced one dia.	25-35 MMF.	

Coil Winding Chart for 1½-in. and 2½-in. Dia. Coil Forms and Split-Stator V.C.

BAND	1½" Dia. Coil Form	Size of Tuning Condenser	BAND	2½" dia. Coil Form	Size of Tuning Condenser	
160	Not Satisfactory		160	59 Turns No. 16 Enameled Close wound. Tap at center.	250 MMF. Each Section (smaller condenser can be used).	The standard Hammarlund 35 mmf. Each section split-stator double-spaced midget variable condensers are satisfactory. The Cardwell Trim-Air 100 mmf midgets can also be used by merely removing alternate plates from rotor and stator sections and ganging two of these condensers together. The capacity will then be 25 mmf. per section.
80	Not Satisfactory		80	55 to 57 Turns No. 16 DCC. Close wound. Tap at center.	35 MMF. Each Section	
40	35 Turns No. 16 DCC. Close wound. Tap at center.	35 MMF. Each Section	40	29 Turns No. 14 Enameled Space wound. To cover 3 inches.	35 MMF. Each Section	
20	19 Turns No. 16 DCC. Spaced one dia. Tap at center.	35 MMF. Each Section	20	15 Turns No. 14 Enameled Spaced one dia. Tap at center.	35 MMF. Each Section	

NOTES

Chapter 9

TRANSMITTER FREQUENCY CONTROL

● All radio transmitters operate on assigned frequencies, or within certain bands of frequencies. For this reason some method must be provided for accurately controlling the frequency of operation. The most practical method for securing frequency control is by means of quartz crystal oscillators because the frequency of oscillation is accurately determined by the physical size of the quartz plate.

An *exciter* can be defined as a crystal controlled oscillator combined with such frequency multipliers as are needed to generate the desired operating frequency. Many vacuum tube combinations can be used for this purpose: the numerous block diagrams in the pages that follow show practically all of the modern tube circuit arrangements for the radio-frequency portion of short-wave transmitters.

In this *Chapter* the reader will find, for the first time, a number of new exciter circuits which have proved more versatile and efficient than others previously shown. Of particular interest is the new *Jones Multi-Band Crystal Oscillator,* which operates on two or more bands from a single crystal, and with only one tuning circuit.

Exciter Problems

● The essential requirements of crystal oscillators and frequency multipliers are: (1) stability of oscillation: (2) ample power output; (3) proper degree of frequency control. Good stability cannot be expected from some types of circuits, particularly when the oscillator is keyed for c.w. telegraphy. Some exciters provide too little or too much power output; frequency drift is excessive in some oscillators because of temperature change. Frequency drift is also caused by RF overload of the quartz crystal in such circuits where poor design does not permit of sufficient output without exceeding the safe recommended plate voltages for the tubes. A certain amount of grid drive is needed for correct operation of frequency doublers or low power buffer stages, yet it would be poor practice to operate a stage with more drive than is needed. Conversely, if the oscillator or exciter does not deliver a sufficient amount of grid driving power, poor design is again in evidence.

A crystal exciter usually consists of the crystal oscillator and its associated low-power buffer or frequency doubler stages. These stages can be grouped into a common unit so that the exciter will be an integral part of any transmitter.

If a transmitter is to be operated on one band only, such as 160 meters, there is no need for an elaborate exciter; on the other hand, multi-band operation calls for an exciter with the proper number of frequency doubler stages.

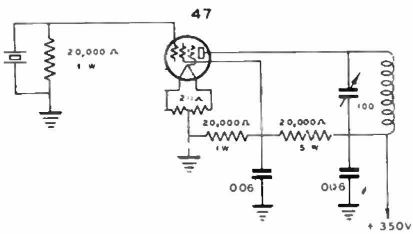


FIG. 1.

47 Pentode Crystal Oscillator, Widely Used in One-Band Transmitters.

An exciter for a single-band transmitter differs from one which operates on several bands, where the output from the oscillator and also from each succeeding frequency doubler stage should be effectively the same in value. Effective value means that the DC grid current and bias voltage should be the same on all bands of the stage that is driven by the exciter. Thus it is seen that an exciter must often deliver more output on 10 and 20 meters than on 40 or 80 meters, in order to compensate for the tuned circuit losses at the higher frequencies corresponding to 10 and 20 meters. A low power crystal oscillator is adequate for a one-band transmitter because the required output can then be secured from a buffer or power-gaining doubler. Typical examples of such exciters are the *RK-25-35 Exciter,* or the *6L6G - Oscillator-6L6G-Push-Push-Doubler,* described elsewhere in this *Chapter.*

A generous variety of entirely new crystal oscillators and exciters is shown for the first time in these pages. Those who have experienced difficulty with the 6L6 tube will find new circuits here which have been especially designed to overcome those difficulties. The new exciters with three 6A6 tubes, or three 6L6G tubes, are ideal for all-band operation because they will not be obsoleted when changes are made in the transmitter. These exciters deliver output on three bands without coil changing and the coils are easier to construct than those previously shown.

The increasing interest in 5 and 10 meter operation has brought with it the development of a special Jones 5 Meter Exciter with a 42 oscillator and three 6A6 frequency doubler stages. An 80 meter crystal in the oscillator stage of this exciter will furnish outputs on 80, 40, 20 and 10 meters; likewise, a 40 meter crystal will give good output on 5 meters. A complete description of the new device is found in the pages that follow.

Protection of Quartz Crystals

● Quartz crystals will fracture if they are subjected to excessive RF current. The crystal RF current is very high in some circuits, particularly when relatively high plate potential is applied. Some tubes also provide more crystal current than others. Circuits within circuits often produce parasitic or surge voltages which may fracture the quartz plate. Excessive current in regenerative crystal oscillator circuits can be eliminated by connecting a small resistance in series with the crystal. A 6.3 volt pilot lamp, such as those used for illuminating radio receiver dials, makes a satisfactory resistance and further provides a visual indication of excessive current.

An experimental 6L6 crystal oscillator produced a sudden rise in crystal current when the plate tuning capacities were increased beyond the point of normal oscillation. The plate circuit power output was negligible at this setting, because the crystal oscillator circuit consisted of a network of capacities which caused the crystal current to rise above 100 milliamperes. In this same oscillator the crystal current was less than 50 milliamperes at the point of normal oscillation and the highest plate circuit output. The problem was solved by connecting a 6.3 volt lamp in series with the crystal, which had the effect of damping-out the parasitic oscillation. This series resistance can have a value as high as 100 ohms without materially reducing the efficiency of most types of crystal oscillator circuits.

The 53-2A3 Exciter

● The type 53 tube has long been popular in crystal oscillator circuits because of its simplicity and relatively high output. The 6A6 tube, which is the 6.3 volt equivalent of the 53, is a somewhat better tube than the 53 because the 6A6 has a better heater construction and is less subject to tube failure. These tubes are suitable for oscillator, doublers or push-pull circuits. Fig. 2 shows a 6A6 (or 53 in a conventional push-pull oscillator circuit with an output of from 5 to 10 watts.

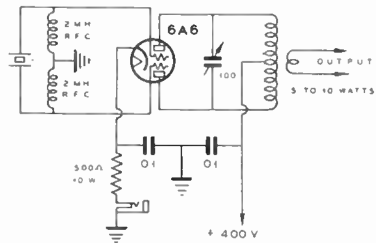
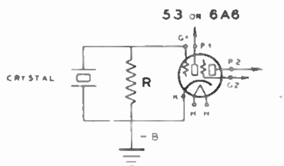


FIG. 2.
6A6 (or 53) Push-Pull Oscillator

The 53 or 6A6 first found application as an oscillator in the "*Siamese Exciter.*"



CONVENTIONAL LOW OUTPUT TRIODE OR TWIN TRIODE CRYSTAL OSCILLATOR WITH GRIDLEAK BIAS RESISTOR

FIG. 3.

The grid-leak bias resistor *R* (Fig. 3) provides a rather unsatisfactory means for supplying bias to the crystal circuit because the crystal RF current is very high and the tube had a pronounced tendency to "run wild" when the plate voltage was increased. The resulting output was quite low, and the circuit is not widely used because of these disadvantages.

It was later found by *Jones* that the 53 or 6A6 could be made to function with entire satisfaction in a crystal oscillator and doubler circuit. The apparent disadvantages of the "*Siamese Exciter*" were overcome by using cathode bias and a small RF choke across the quartz crystal. The circuit is shown in Fig. 4. *R* is the cathode resistor (400 ohms). The RF choke is a conventional small receiver type short-wave choke.

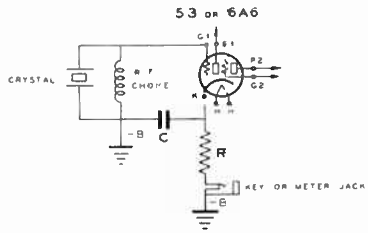
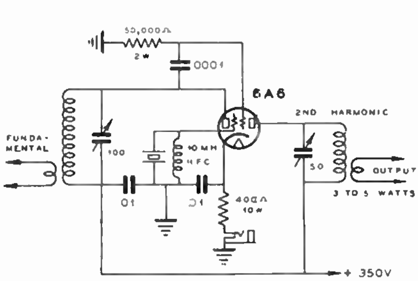


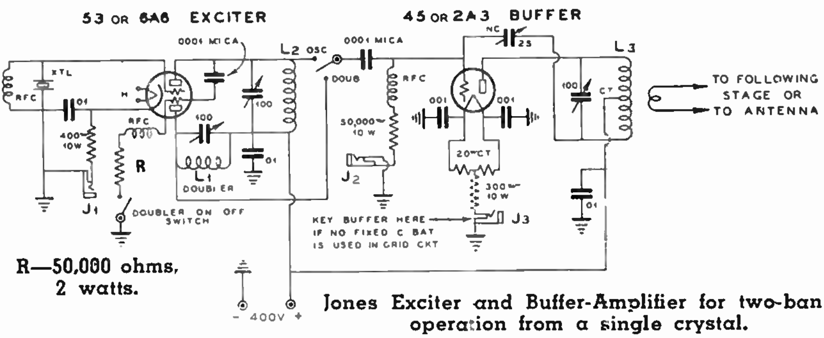
FIG. 4.
Bias Circuit of the Original Jones 53-6A6 Harmonic Oscillator, or Exciter. High Output. Low Crystal R-F Current.



JONES CRYSTAL OSCILLATOR-DOUBLER

FIG. 5.

Fig. 5 shows the complete circuit of the widely-used *Jones 53 Harmonic Oscillator.* One triode section of the 53 (or 6A6) acts as a crystal oscillator with cathode bias, which automatically holds the crystal RF current to a moderately low value for plate



R—50,000 ohms, 2 watts.

Jones Exciter and Buffer-Amplifier for two-band operation from a single crystal.

FIG. 6—53 (6A6)—2A3 Exciter.

potentials as high as 375 volts. The second section of the 53 or 6A6 acts as a frequency doubler, with high bias on the grid developed across a 50,000 ohm grid-leak and a 400 ohm cathode resistor. The two sections of the 53 or 6A6 are capacitively coupled. The output from the oscillator or doubler circuit can be delivered to a succeeding stage by means of either capacitive or link coupling.

A complete exciter unit with 53 or 6A6 oscillator, capacitively coupled to a 2A3 buffer or amplifier stage, is shown in Fig. 6.

The output from the 2A3 stage is between 20 and 25 watts. External battery bias (-135 volts) can be connected in series with the 2A3 grid leak if the oscillator circuit is to be keyed; the circuit in Fig. 6 has a 400 ohm cathode resistor, which provides fixed bias.

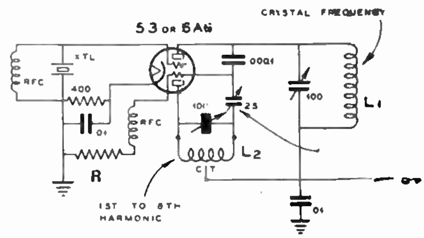


FIG. 7.
Jones Regenerative Exciter for all-band operation. R-50,000 ohms.

The 53 or 6A6 oscillator can be operated as a regenerative frequency doubler, tripler or quadrupler. See Fig. 7. The output from this regenerative quadrupler is sufficient to drive a 45 or 2A3 buffer stage, if care is taken when tuning adjustments are made. The crystal oscillator section of the 53 or 6A6 should always control the frequency and there must not be too much regeneration in the frequency multiplier section.

The simplest test or adjustment of this circuit is to use a single turn of wire and a 6-volt pilot-light as an oscillation indicator. The oscillator stage is first adjusted and tuned to approximately the mid-point of its oscillating range and the doubler section is tuned to peak output. When the oscillator is not functioning, the cathode current will be approximately 20 ma.; but in a state of oscillation this current will rise to between 50 and 110 ma. If the doubler section is not employed, its grid-leak may be opened to remove the load from the oscillator section. The grid-leak increases the bias of the harmonic producing triode to a great many times cut-off bias. The 400-ohm cathode resistor provides a fixed bias to both the triode sections, and also stabilizes it for use on plate voltages of over 300 volts.

CAUTION

•Type 53 tubes must be operated at their full rated heater voltage, otherwise the oscillator output will be greatly decreased; erratic operation and short tube life will also result. The heater voltage should be measured at the tube socket with the aid of an AC voltmeter. Heavy wire should be used for carrying the heater current, particularly when several type 53 tubes are operated in a multi-band exciter. It is better practice to operate the tube heaters with just a trifle more voltage than recommended; never use less than 2.5 volts. 6A6 tubes (6.3 volt heater) draw only 0.8 amp., as against 2 amps. for the type 53, resulting in lower current drain from the filament transformer.

Note: Other than type 2A3 or 45 type tubes can be used in the buffer stage of a Jones Exciter. The following table is of value in determining the type of tube and method of coupling to give the best results.

Single 45 or 2A3.......Capacitive coupling
Single 46 ....Link coupling
Single 841 ....Link coupling
Single 210 ....Link coupling

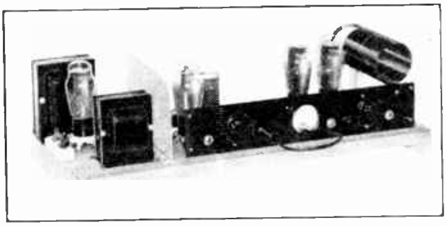


FIG. 8.

Jones 53 Exciter and Low Power Amplifier with two 2A3s or 45s, parallel connected.

Single 801 ....Link coupling
Single 865......Capacitive or Link coupling
Single 53 Push-Push Doubler.Link coupling
Single 59 Regenerative Doubler........
...................Capacitive coupling
Two 45s in Parallel or Push-Pull......
............Capacitive or Link coupling
Single 802 ....Capacitive coupling

Any of the above combinations will provide sufficient excitation for one or two type 211 tubes, or two 50Ts, or single 150T or T55, HF100, HF200, HK154 or HK354, for *grid modulation*. With CW transmitters having a very high power input to the final amplifier, an additional buffer stage should be used. Final amplifiers having two type 211 tubes are best driven by a pair of 210s or 801s operating with a plate voltage of at least 700 volts. A single 210 or 801 operating with 700 volts on the plate will give sufficient drive for CW when the final amplifier tubes are of types 150T, HK354, T814 or HF200.

Coil-Winding Table for Jones 53-2A3 Exciter

NOTE—5-Prong 1½-in. Dia. Coil Forms Used Throughout.

Band	Oscillator Coil	Doubler Plate Coil	Buffer Plate Coil
160 Meter	68 turns, No. 22 DSC, close wound on 1½-in. dia. form. Winding space occupies 2 1/16-in.	NONE	78 turns, No. 22 DSC, close wound on 1½-in. dia. form. Winding space occupies 2½-in. tap to be taken at center of winding.
80 Meter	27 turns, No. 22 DSC on 1½-in. dia. form. Space wound to cover 1½-in. winding space.	Same coil as 80 meter oscillator coil for doubling to 80 meters from 160 meter oscillator.	45 turns, No. 22 DSC, close wound on 1½-in. dia. form, center-tapped. Winding space occupies 1⅞-in.
40 Meter	13 turns, No. 18 DCC on 1½-in. dia. form. Space wound to cover winding space of 1½-in.	Same coil as 40 meter oscillator coil for doubling to 40 meters from 80 meter oscillator.	22 turns, No. 18 DCC on 1½-in. dia. form, center-tapped. Winding space occupies 1¾-in.
20 Meter	Use 40 meter oscillator coil.	7 turns, No. 18 DCC on 1½-in. dia. form. Space wound to cover a winding space of 1⅜-in.	12 turns, No. 18 DCC on 1½-in. dia. form, center-tapped. Winding space occupies 1¾-in.

The New Jones MULTI-BAND Oscillator

Fundamental and Harmonic Operation From a Single Tuned Circuit

This Oscillator operates on two bands (or more) from a single crystal, by merely changing the oscillator plate coil.

● Heretofore it has not been possible to operate a crystal oscillator on any but its fundamental frequency without additional tuned circuits. This new *Jones Oscillator* uses a single crystal, a 6L6 metal tube, an untuned regenerative cathode circuit and a plate coil tuned to the desired frequency of operation. Briefly, it will deliver output on 80 meters, for example, with an 80 meter plate coil and an 80 meter crystal; likewise, 40 meter operation is secured by simply plugging a 40 meter plate coil into the circuit in place of the 80 meter coil. The same crystal operates on both bands. The only change in the circuit adjustment is in tuning of the plate condenser to resonate the circuit at the desired output frequency. See Fig. 9.

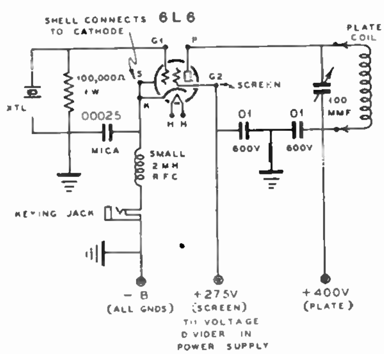


FIG. 9.
The New Jones Multi-Band Oscillator.

Outputs of from 15 to 25 watts can be obtained on 80 meters, and 15 to 20 watts on 40 meters, depending upon the value of screen and plate voltages (without exceeding normal tube ratings). From 3 to 5 watts can be obtained on 20 meters when the tube acts as a quadrupler, and nearly one-half watt is delivered on the eighth harmonic. *This oscillator circuit functions most effectively with 160 or 80 meter crystals.* A 40 meter crystal, however, will deliver between 5 and 10 watts on 20 meters, more than ample power for driving another 6L6 doubler or quadrupler stage.

From the foregoing it is seen that this oscillator eliminates one doubler stage. There are no critical values of bypass condensers or resistors, and the oscillator will operate with crystals which otherwise do not oscillate easily in other circuits. The crystal RF current in an 80 meter crystal, when the output circuit is delivering over 20 watts on 80 meters, will be between 20 and 50 milliamperes. The crystal RF current with the same crystal when the output circuit is delivering approximately 20 watts on 40 meters, will be less than 10 milliamperes. Most crystals are rated to carry up to 100 milliamperes without danger of fracture or frequency drift. It can thus be seen that this new oscillator places very little strain on the quartz crystals, in spite of the very high RF output.

The cathode circuit has an untuned regenerative system which consists of a .00025 mfd. mica fixed condenser and a small 2 mh. RF choke. The type of RF choke is not important, as shown from tests made with a half dozen varieties of RF chokes, there being no difference in the final result. If the bypass condenser is too small, the crystal will not maintain control of oscillation when operating at harmonics, and the crystal current will be excessive when operating on the fundamental frequency. If the bypass condenser is too large, the output on harmonics will be very low or entirely absent, and the output on the fundamental frequency will be less.

This oscillator circuit calls for the use of a *metal-type* 6L6 tube. The metal shell must be tied to the cathode at the tube socket. This provides a small amount of capacity coupling between the cathode and plate, which is necessary in this circuit. If glass 6L6G tubes are employed, a small fixed capacity of approximately 5 or 10 mmfds. should be connected between the cathode and plate.

6F6 metal tubes will also operate when used in this circuit, but the output will be only half that secured from the 6L6, without greatly exceeding the rating of the tube. Of all the various types of pentodes used in experimental work, the 6L6 has given the highest output with the least amount of effort in circuit adjustment.

This crystal oscillator with an 80 meter crystal continues to oscillate weakly at 80 meters, no matter what plate tuned circuit is employed. Oscillation can be heard in a frequency monitor, even when the plate coil is entirely removed from the circuit, or when the screen voltage is disconnected. As long as a positive potential is applied to either screen or plate, the fundamental crystal oscillator circuit continues to function. If the crystal is removed, no sign of oscillation is found, unless the cathode bypass condenser is omitted, or if it is too-low in value, such as .0001 mfd. The size of this condenser can be varied aproximately 25% without affecting the operation of the circuit. The screen of the 6L6 tube can be connected to the high voltage supply through a 5,000 ohm 10 watt resistor with a 50,000 ohm 2 watt bleeder to ground. If the screen is supplied with over 275 volts, the screen dissipation will be excessive, resulting in reduced tube life. The screen voltage can be adjusted to the desired value under load if the power supply has a bleeder resistor with a sliding tap.

The oscillator can be keyed in the cathode circuit and with a sufficient number of buffer or doubler stages the key clicks will not be bothersome. Key clicks can be minimized by shunting a 3000 to 5000 ohm resistor across the key contacts in the cathode circuit, allowing the oscillator to continue to function at greatly reduced output. The output will be too low to drive the next stage when the key is up; however, the crystal does not stop oscillating, with the result that the sudden surge which causes bad key clicks is not present.

Coil Design

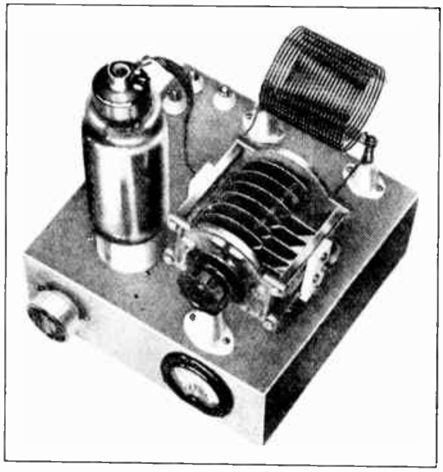
The plate coils are wound on standard 1½ inch plug-in forms. The 40 meter coil has 17 turns of No. 18 enameled wire, spaced over a length of 1¼ inches. The 80 meter coil has 35 turns of No. 16 enameled wire, slightly spaced to cover a 1½ inch winding length. The 160 meter coil has 70 turns of No. 24 DSC, close-wound.

PRECAUTIONARY MEASURES

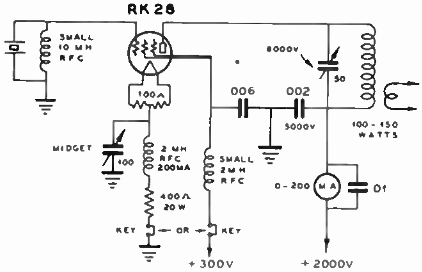
● AT—cut or low—temperature quartz crystals are recommended for the 6L6 or 6L6G oscillator in order to prevent spurious oscillation in the circuit. Crystals with two peaks of oscillation (two frequencies a few kilocycles apart) should never be used in a regenerative or harmonic crystal oscillator. The 6L6 tube's cathode bypass condenser must sometimes be as large as .0005 mfd. in value when the circuit is operated on 80 or 160 meters. Care must be taken to prevent excessive regeneration with consequent self-excited operation not controlled by the quartz crystal itself. The larger value of cathode bypass condenser is a safeguard against excessive regeneration.

High Power Crystal Oscillator

● From 100 to 150 watts of output can be obtained on 80 meters from the regenerative crystal oscillator illustrated below. Cathode bias and cathode regeneration make this high output possible, and without overloading the crystal. The crystal RF current measures only 40 milliamperes through an AT-cut crystal; this current is so low that no frequency drift is encountered. No external feed-back capacity is needed between the control grid and plate circuit in order to obtain oscillation, because the cathode or filament center-tap RF choke and variable



RK-28 Oscillator 100 to 150 Watts Output on 80 Meters.



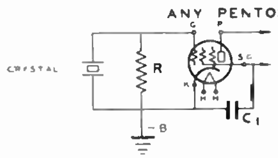
REGENERATIVE RK28 CRYSTAL OSCILLATOR

condenser arrangement produces the necessary feed-back.

This oscillator will serve as a complete one-tube transmitter, with the key in either the cathode or screen circuit. The screen and suppressor of the RK-28 are tied together and operated with approximately 300 volts on the screen. The 100 mmfd. midget variable condenser connected from center-tap to ground should be set towards maximum capacity. Too much capacity will reduce the output, and the circuit cannot be properly keyed.

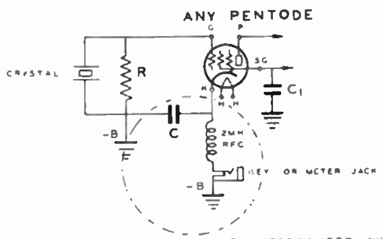
Regenerative Pentode Oscillator

● The performance of nearly any pentode crystal oscillator can be improved, oscillation can be stabilized, and up to twice as much output can be secured by means of heavier plate loading with the circuit improvement here described. Most types of pentode crystal oscillators often refuse to oscillate when they are more than lightly loaded. The circuit improvement shown in Fig. 13 overcomes this difficulty at the cost of about 50 cents for two additional parts, a small RF choke and a mica fixed condenser.



CONVENTIONAL LOW OUTPUT PENTODE CRYSTAL OSCILLATOR WITH GRIDLEAK BIAS RESISTOR

FIG. 12



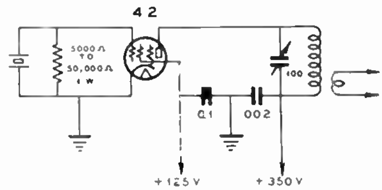
HIGH OUTPUT PENTODE CRYSTAL OSCILLATOR WITH REGENERATIVE FEATURE AS DEVELOPED BY JONES

FIG. 13

C—.0001 or .00025 mfd. (mica).
C1—Screen By-Pass Condenser.
R—Grid-Leak, 50,000 ohms.

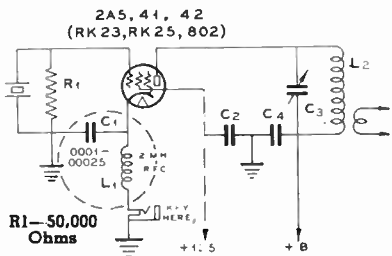
The RF choke in the cathode circuit of the tube, and the .0001 or .00025 mfd. bypass condenser shown in Fig. 13, produce a regenerative effect which can be compared to a regenerative electron-coupled circuit. This effect can only be realized in a tuned plate circuit in which a tetrode or pentode tube has its screen-grid bypassed to ground. The RF choke simply prevents a short-circuit of the "regenerative" bypass condenser for RF purposes, and its value is not at all critical. Any jumble-wound or commercial type RF choke is suitable if the winding is heavy enough to carry the cathode space current. 200 turns of No. 32 DSC wire, jumble-wound on a ½ in. diameter rod or spool, makes a satisfactory choke.

The RF crystal current is greatly reduced in this circuit, and higher plate voltages can



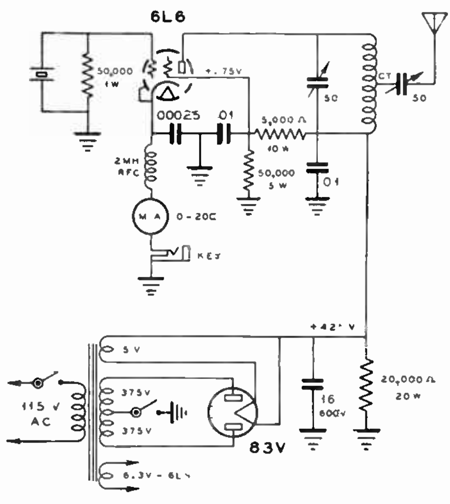
Typical Crystal Oscillator Circuit

FIG. 14



IMPROVED PENTODE CRYSTAL OSC CKT

FIG. 15



25 WATT C W TRANSMITTER

FIG. 16

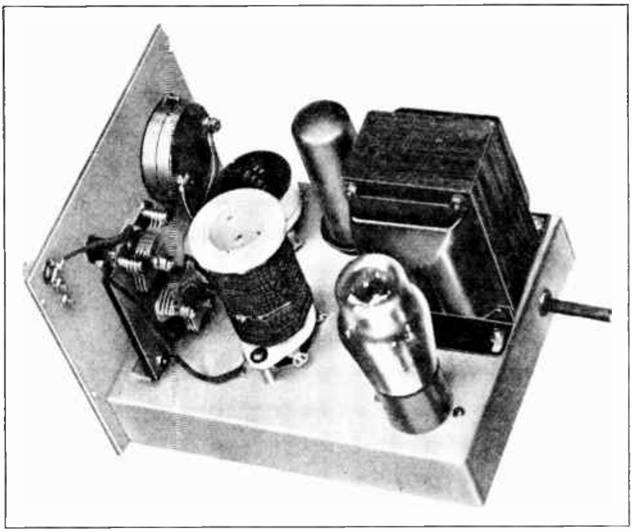


FIG. 17

Complete 25 Watt Transmitter, Using Circuit Diagram Shown in Fig. 16. This Is an Ideal Low Power Portable Set.

17. It delivers 25 watts output. The entire transmitter, including power supply, is mounted on an 8 in. x 6 in. x 1½ in. metal chassis. The regenerative system allows heavy antenna loading while keying for c.w. operation. The antenna coupling system is a novel one, in that the antenna can be a single wire of any length and thus this little transmitter would be ideal for portable operation. The oscillator coils are center-tapped. A 50 mmfd. variable condenser provides a means for varying the antenna coupling. Coil data for this transmitter is similar to that shown for the *6L6G three-band exciter* (except for the center-tap). This simple antenna coupling system will not provide a perfect impedance match with some antennas, yet this defect is offset by the convenience and simplicity of the system for portable operation.

therefore be applied. As much as 15 watts output has been obtained from a 42 crystal oscillator, and 25 watts from an RK-25. See Figs. 14 and 15.

A 47 crystal oscillator will also function in this circuit if a separate filament winding is provided. A center-tap resistor of 20 ohms, a RF choke and a midget 1000 mmfd. variable condenser from center-tap resistor to ground will provide regeneration. If the cathode bypass condenser *C* (Fig. 13) is too small, the output will be low and the crystal current will rise. If the condenser is too large, the plate cannot be sufficiently loaded when keying the oscillator under constant output conditions.

This new circuit improvement was tested in all of the conventional pentode oscillator circuits and it was found that a .00025 mfd. mica condenser for the cathode bypass was satisfactory. A smaller condenser was needed for a high power RK-28 crystal oscillator. This RK-28 high power exciter (described elsewhere in this chapter) makes an ideal one-tube transmitter because it delivers from 100 to 150 watts output on 80 meters with less than 40 ma. crystal RF current. 20 and 40 meter crystals should therefore function without overheating at outputs of approximately 100 watts. Reverting to the conventional oscillator circuit with added grid-to-plate capacity, excessive crystal RF current was evidenced with outputs of only 75 watts on 80 meters.

A complete one-tube transmitter with a 6L6 metal tube is illustrated in Figs. 16 and

6L6G Tritet Oscillator

● The 6L6G or 6L6 tube is well suited for the *Tritet* circuit and it is far more effective than a 42 or 59 in this oscillator-doubler

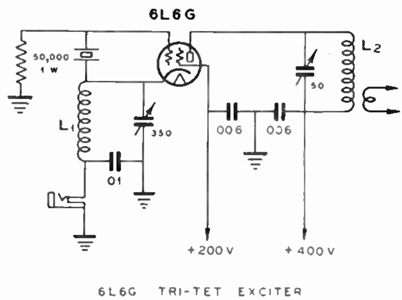


FIG. 18

L1—Cathode Coil

L2—Plate Coil.

arrangement. The actual cathode tuning capacity should be at least 200 mmfd. for high output and moderate crystal current. Too-low a value of capacity in this circuit will often result in fractured crystals.

The cathode circuit is tuned to a frequency approximately 50% higher than that of the crystal. This produces regeneration in the triode section (grid, cathode and screen grid circuit), and the system oscillates at the crystal frequency. The large cathode tuning condenser provides a cathode by-pass condenser for the second harmonic, to which the plate circuit is correctly tuned with low C-to-L ratio in its tuned circuit.

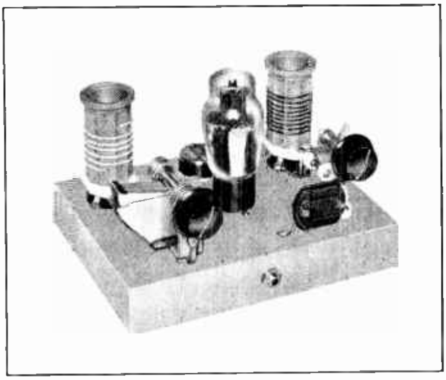


FIG. 19
6L6G Tritet Oscillator.

The table shows the values of output and crystal RF current that were secured at various values of screen voltage with 400 volts plate supply. A 40 meter crystal produced the following outputs on 20 meters:

Screen Volts	DC Cathode Current	Crystal Current	Watts Output
165	55	50	5
210	73	75	10
275	105	100	15

These values of output are somewhat lower than those obtained from a 6L6G regenerative oscillator, such as the *Three-6L6G-Exciter.* The crystal current is approximately three times as high in the *Tritet* oscillator, but this disadvantage can be offset in some cases by the reduction in number of tubes needed for output on 20 meters. The screen voltage should not be over 200 volts, if excessive crystal heating is to be avoided. Two 6L6G tubes, one oscillator and one doubler, will deliver greater output.

An RCA-802 or RK-25 can be substituted for the 6L6G tube in the Triter Exciter, or the new RCA-807 may also be used. The 807 is similar to the 6L6G, but with the plate lead through the top of the envelope. The RK-20 or RCA-804 will deliver as much as 50 watts on the fundamental frequency, and 25 or 30 watts on the second harmonic, when operated at voltages recommended for Class C RF amplifier service, as shown in the *Tube Chapter.* Lower screen voltages than those recommended may be necessary in order to prevent overheating of the crystal.

6L6G Tritet Coil Data

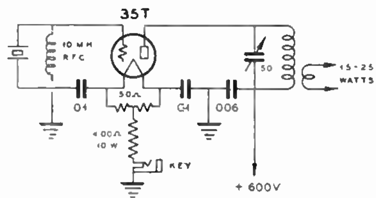
All Coils Wound on 1½ in. Diameter Forms

Wave-length	L2 Plate Coil	L1 Cathode Coil	Crystal
160	78 turns No. 24 DSC Closewound	Short-circuited	160
80	38 turns No. 18 Enam. Closewound	25 turns No. 22 DSC 1½ in. long	160
40	20 turns No. 18 Enam. 1½ in. long	12 turns No. 18 Enam. 1½ in. long	80
20	9 turns No. 18 Enam. 1¼ in. long	7 turns No. 18 Enam. 1¼ in. long	40

35T Crystal Oscillator

This oscillator is a high-power version of a 53 or 6A6 circuit. The high mutual conductance and very low inter-electrode capacities of the 35T, in conjunction with its high mu, make it a good crystal oscillator tube.

Cathode or center-tap resistor bias instead



35T CRYSTAL OSCILLATOR

FIG. 21

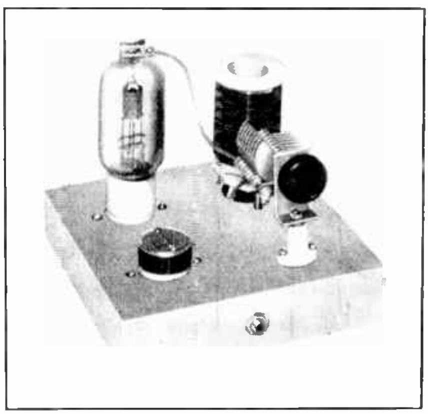


FIG. 20
35T Triode Oscillator.

of grid-leak bias keeps the crystal r-f current low and plate voltages as high as 1000 or even 1200 are satisfactory. With grid leak bias, not over 500 volts can be applied to the plate without danger to the crystal.

The following results were obtained in the Laboratory with an Eimac 35T.

Crystal Frequency	Plate Volts	Cathode Current	Crystal Current	Watts Output
3550	600	75	45	20
7050	500	68	60	12
7050	600	80	70	20

35T Oscillator Coil Data

All Coils Wound on 1¾ in. Dia. Forms.

Wave-length	Plate Coil
160	70 turns, No. 24 DSC, 2" long
80	34 turns, No. 18 Enam., 2" long
40	16 turns, No. 18 Enam., 1½" long
20	8 turns, No. 18 Enam., 1½" long

Reinartz Crystal Oscillator

● A cathode circuit tuned to half the crystal frequency will provide regeneration in a crystal oscillator, resulting in greater output and lower crystal RF current. An 802 pentode, with at least 500 volts on the plate and 150 volts on the screen, will deliver 15 to 25 watts output on the fundamental frequency of the crystal. The reactive effect produces regeneration at the harmonic frequency of the tuned cathode coil, thus increasing the operating efficiency of the oscillator without danger of uncontrollable oscillation at frequencies other than that of

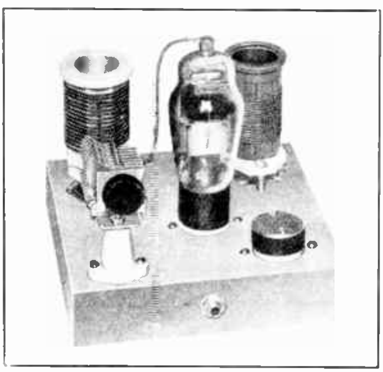


FIG. 22
Reinartz 802 Oscillator.

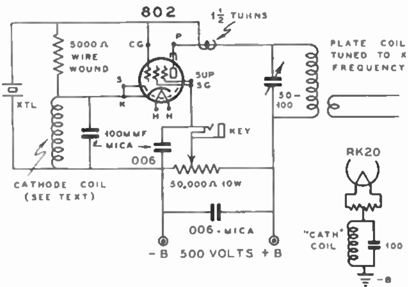


FIG. 23
Reinartz 802 Oscillator Circuit.

the crystal. Complete screening between the control grid and plate circuit of the 802 necessitates the use of a small external capacity in order to obtain stable oscillation. This capacity can consist of a piece of insulated hook-up wire connected to the control grid, with 1½ turns of its free end wrapped around the plate lead at the coil socket. The circuit is shown in Fig. 23

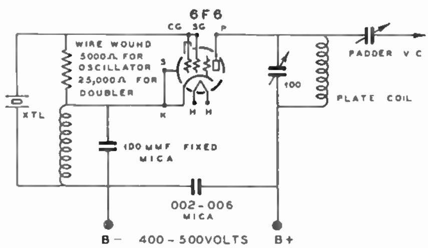


FIG. 24
Reinartz 6F6 Crystal Oscillator.

A 5,000 ohm wire-wound resistor serves as a combination RF choke and resistance across the grid circuit. Some makes of wire-wound resistors are not suitable for this purpose because they resonate at some particular frequency, which causes them to absorb RF energy. Most types of wire-wound resistors, however, are satisfactory.

The screen-grid circuit can be keyed for c-w operation. When the key is open, the circuit continues to oscillate weakly, but the power output is not sufficient to excite a buffer or doubler stage. When the key is closed, normal output is again secured, and since the crystal is maintained in oscillation at all times there is nearly a complete absence of key clicks.

An RK-20 or 803 can be substituted for the 802 in this circuit if greater power output is needed. A 100 ohm center-tapped filament resistor at the tube socket terminals will provide a means of connection to the cathode tuned circuit because neither the RK-20 or 803 has a separate cathode.

802 Reinartz Coil Data

Wave-length Meters	Plate Coil	Cathode Coil
160	70 turns No. 22 DSC 2" long 1¾" diam.	116 turns No. 26 Enam. Closewound 1½" diam.
80	34 turns No. 18 Enam. 2" long 1¾" diam.	55 turns No. 24 DSC Closewound 1½" diam.
40	16 turns No. 18 Enam. 1½" long 1¾" diam.	27 turns No. 24 DSC 1½" long 1½" diam.
20	8 turns No. 18 Enam. 1½" long 1¾" diam.	14 turns No. 24 DSC 1½" long 1½" diam.

804 Exciter

● This crystal oscillator will deliver outputs up to 50 watts without overloading the crystal because cathode regeneration greatly improves the efficiency of the circuit. It will serve as a one-tube cw transmitter or as a high powered exciter for driving a final amplifier to several hundred watts output. The total number of stages in the transmitter can thus be kept to a minimum, if such design is desirable. An RK-20 can be substituted without circuit change.

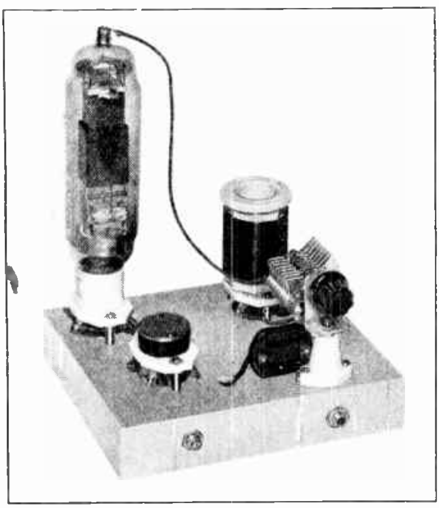
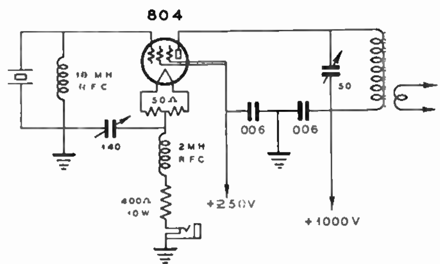


FIG. 25
50 Watt Regenerative Exciter

Cathode or center-tap bias, instead of grid leak bias, reduces the RF crystal current by approximately 50%. The RF choke shunted across the crystal provides an AC path for grid current and the grid bias is secured by means of a 400 ohm 20-watt resistor in the filament center-tap lead. Regeneration is obtained by a 100 mmfd. variable midget condenser from center-tap to common RF ground. The RF crystal current will be high and the output will be reduced if this capacity is too small. Too much capacity on the other hand will reduce the output under heavy load conditions, or when keying.



REGENERATIVE 50WATT CRYSTAL OSCILLATOR

FIG. 26

No series RF filament chokes are necessary with a separate 7½ volt filament supply transformer because more or less capacity to ground in the transformer can be compensated for by the 140 mmfd. variable condenser. The exact value of capacitance is not at all critical; a variation of 40 or 50 mmfd. is permissible. Regeneration greatly reduces the crystal current and crystal heating, with consequent heavier output loading and good oscillator stability.

804 Crystal Oscillator Coil Data

All Coils Wound on 1¾ in. Dia. Forms.

Wave-length	Plate Coil
160	66 turns, No. 22 DSC. Closewound
80	33 turns, No. 18 Enam., 2" long
40	16 turns, No. 16 Enam., 1½" long
20	7½ turns, No. 16 Enam., 1½" long

High Power 6L6G Exciter

● Three 6L6G tubes in this exciter deliver a relatively high output at double the frequency of the crystal. This output is sufficient to drive almost any final amplifiers without aid of buffer stages. A 150T, 203H, HF200, HK354, or Taylor 814 can be driven to over 400 watts output on c.w. from this exciter.

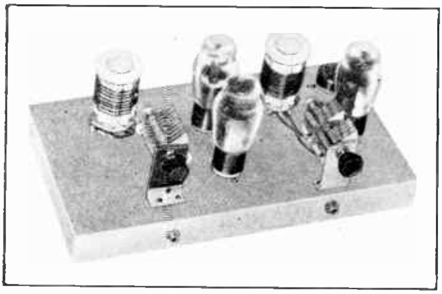


FIG. 27

30 Watt One-Band Exciter.

Coil Data for High Power 6L6G Exciter

All Coils Wound on 1¾-inch I. C. A. Ceramic Forms

160 Meter Oscillator

70 turns No. 24 DSC., with C. T., 2" long, 1¾" diameter

80 Meter Oscillator or Doubler Coil

34 turns No. 16 E., with C. T., 2" long, 1¾" diameter

40 Meter Oscillator or Doubler Coil

16 turns, No. 16 E., with C. T., 1½" long, 1¾" diameter

20 Meter Oscillator or Doubler Coil

8 turns No. 16 E., with C. T., 1½" long, 1¾" diameter

10 Meter Doubler Coil

4½ turns No. 16 E., 1½" long, 1¾" diameter

The crystal oscillator drives a pair of Raytheon 6L6G tubes in a "push-push" doubler. Output is available on any band, from 80 to 10 meters, by merely changing coils and crystals. 160 to 20 meter crystals are needed. This type of exciter will appeal to those amateurs who transmit on one band most of the time, with occasional operation on other bands.

The screen grids of the 6L6G tubes show color with more than 275 volts, although much greater output could be obtained with up to 300 volts on the screens. A safe upper limit seems to be 250 volts. The output is greatly reduced with lower screen voltage, as is the crystal RF current, and also the heating effects. Longer tube life can be expected when the screen is supplied with less than 250 volts, and not more than 400 volts on the plates. When better high-frequency tube element insulation supports are eventually incorporated in the 6L6 and 6L6G tubes, higher plate voltages can then be used. At 400 volts the exciter output is approximately 30 watts. With 600 volts on the plates the output was approximately 60 watts in laboratory tests.

The chassis is 15 in. x 8 in. x 1½ in. of plated steel. Ceramic coil forms, tube sockets and coil sockets are used, because of the high RF voltages. The tuning condensers are symmetrically mounted so that the exciter can be fitted to a standard 19 in. relay rack panel. The coil sockets, as in most exciters, are supported about one inch above the iron chassis in order to reduce tuned circuit losses.

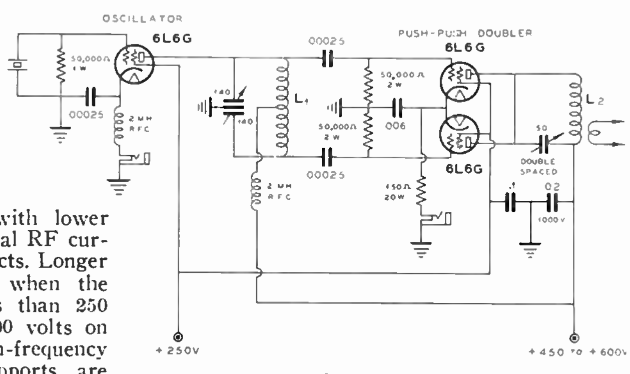


FIG. 28

Circuit for Exciter Illustrated in Fig. 27

RK-25, RK-35 Exciter

● A RK-25 regenerative pentode crystal oscillator drives a RK-35 doubler to relatively high output for exciting a medium power final amplifier in the unit here described. The RK-25 has cathode regeneration and oscillates readily with high output under heavy load, and with very low values of crystal RF current. The Ratheon RK-35 is capacitively coupled to the oscillator, heavily loading the latter. The RK-35 can be

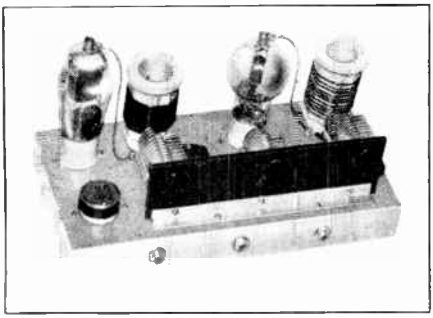


FIG. 29
RK-25, RK-35 Exciter.

neutralized for RF amplification at the crystal frequency, or the neutralizing condenser can serve as a regeneration feedback condenser for frequency doubler service.

A combination of grid-leak and fixed bias is shown for the RK-35. The grid-leak supplies the main portion of grid bias when the RK-25 is oscillating, and the C battery supplies a cut-off when the cw or phone key is open. This enables the crystal oscillator stage to be keyed in its cathode circuit for break-in operation.

This exciter will deliver approximately 35 watts output on any band. It is built on a 15 in. x 6 in. x 1½ in. chassis, with a 2½ in. x 12 in x ⅛ in. bakelite vertical subpanel. The latter supports the two tuning condensers and the neutralizing or regeneration condenser. Isolantite coil and tube sockets are recommended at these RF power outputs. For the same reason, ceramic coil forms are essential because most bakelite coil forms will blister between the base

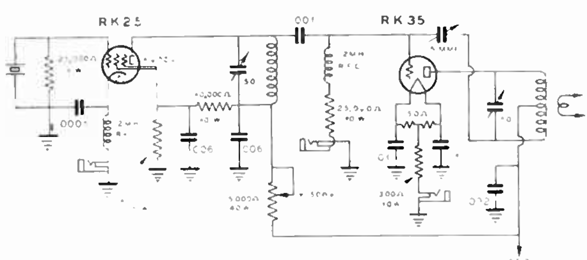


FIG. 30
Circuit for RK-25, RK-30 Exciter

prongs. Link coupling of one to two turns will couple the RK-35 plate circuit to the tuned grid circuit of a fairly-high-power final amplifier. This exciter will put out nearly 50 watts at the crystal frequency when coupled to an antenna.

RK 25-35 Exciter Coil Data
All Coils Wound on 1¾ in. Diam. Forms.

Wave-length	RK 25	RK 35	Crystal
160	70 turns No. 24 DSC 2" long	78 turns No. 22 DSC Closewound C.T.	160
80	70 turns No. 24 DSC 2" long	38 turns No. 18 Enam. 2" long C.T.	160
40	38 turns No. 18 Enam. 2" long	20 turns No. 16 Enam. 2" long C.T.	80
20	20 turns No. 16 Enam. 2" long	10 turns No. 16 Enam. 2" long C.T.	40
10	9 turns No. 16 Enam. 2" long	5 turns No. 16 Enam. 1½" long C.T.	20

6L6G Three Band Exciter

● 6L6 and 6L6G tubes are excellent crystal oscillators because high output can be obtained at moderate plate voltage with very low values of RF current through the crystals. The exciter shown in Figs. 31 and 32 will deliver approximately 20 watts output on any three bands, such as 40, 20, and 10 meters, from one crystal. The coil construction is simple; there is only a single winding on each coil, with no taps, and five coils cover the range from 160 to 10 meters.

The crystal oscillator has a regenerative cathode circuit in order to obtain as much output from the oscillator as from the doubler stages under all load conditions. The doubler stages have a combination of self-bias cathode resistors and grid leak bias, the former for the purpose of providing bias when the crystal is not oscillating (keying for cw operation).

A two-turn coupling link can be slipped over the desired coil for the chosen output frequency. Link coupling to the grid of the buffer, or to a medium power output stage, provides maximum transfer of RF power. *This exciter will supply nearly twice as much output as the 53 exciter previously described*, and it is somewhat easier to construct. Bakelite plug-in coil forms are suitable, although porcelain or ceramic forms (as illustrated) will not blister or burn between treminal prongs. Their use is recommended.

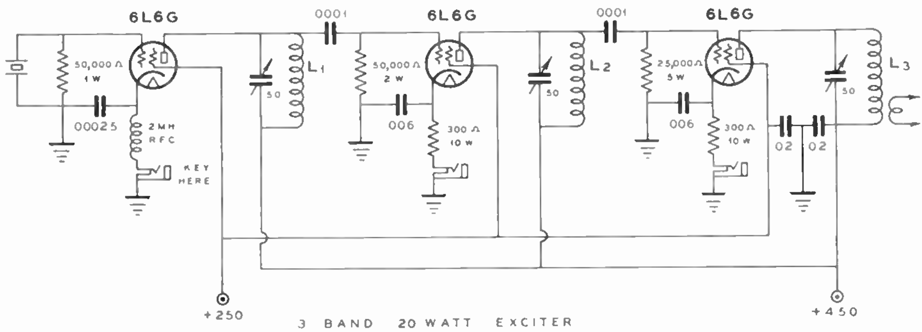


FIG. 31

Three-Band Exciter

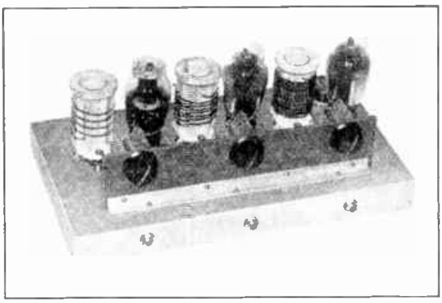


FIG. 32

6L6G Three-Band Exciter.

The chassis is 8 in. x 15 in. x 1½ in., No. 20 gauge plated steel. The tuning condensers mount on a bakelite panel, 2½ in. x 12 in. x ⅛ in. The parts are symmetrically located and the entire unit can be mounted behind a standard 19 in. x 7 in., or 19 in. x 8¾ in. relay rack panel.

Coil Data for 6L6G Three-Band Exciter

160 Meters
70 turns No. 24 DSC., 1¾" diameter, 2" winding space. Approx. inductance equals 135 mh.

80 Meters
34 turns No. 16 Enam., 1¾" diameter, 2" winding space. Approx. inductance equals 32 mh.

40 Meters
16 turns No. 16 Enam., 1¾" diameter, 1½" winding space. Approx. inductance equals 8½ mh.

20 Meters
8 turns No. 16 Enam., 1¾" diam., 1½" winding space. Approx. inductance equals 2 mh.

10 Meters
4½ turns No. 16 Enam., 1¾" diameter, 1½" winding space. Approx. inductance equals ¾ mh.

Unity Coupled Exciter

● An exciter somewhat similar to the one here shown was described in the 1936 edition of this *Handbook*. It had but three tubes, whereas this new exciter has four. Furthermore, the improved version is more versatile and its output, particularly on 10 meters, is higher than that delivered by the earlier model.

Fig. 39 shows the complete circuit diagram and Fig. 41 shows how the unity-coupled coils are wound. The oscillator is a push-pull 53 or 6A6; it places very little RF strain on the crystal, and it delivers about twice as much output as a conventional 53 oscillator-doubler. The frequency doubler stages also use 53 or 6A6 tubes, but in a push-push circuit, and at least 10 watts output can be taken from the final doubler circuit for 10 meter operation. This is sufficient output to drive a 210, RK-18 or RK-28, 803, 35T or Taylor 756 tube.

Design Specifications: The unit is built on a 10 x 17 x 2½-inch metal chassis mounted behind a 19 x 8¾-inch relay-rack panel. A built-in power supply completes this unit and renders the assembly adaptable to further additions of power stages without altering the exciter unit. A 12 x 3 x 3/16-inch bakelite or "Masonite" sub-panel supports the three midget tuning condensers which are near the coil and tube sockets. These condensers are connected through insulated couplings to the front panel tuning dials. The arrangement of the tube and coil sockets permits very short grid and plate leads. Since each stage operates on an octave higher frequency, no shielding is required. The power units are remotely mounted from the RF units so as to preclude the possibility of encountering hum problems. Only one filter-choke is shown, hence, it must be well designed and efficient.

The link-coupling circuits can be wired in series, two turns around the center of each plug-in coil. (See *Jones 6-Band Exciter.*) These two-turn coils should be large enough so that the plug-in coil-forms fit through them into the isolantite coil sockets. The links can be supported on stand-off insulators, the output terminating on another pair of through-type insulators at the rear of the chassis. In the unit shown in Fig. 38, the coupling coil is merely slipped over the coil which supplied the frequency desired for operating a separate buffer-amplifier stage.

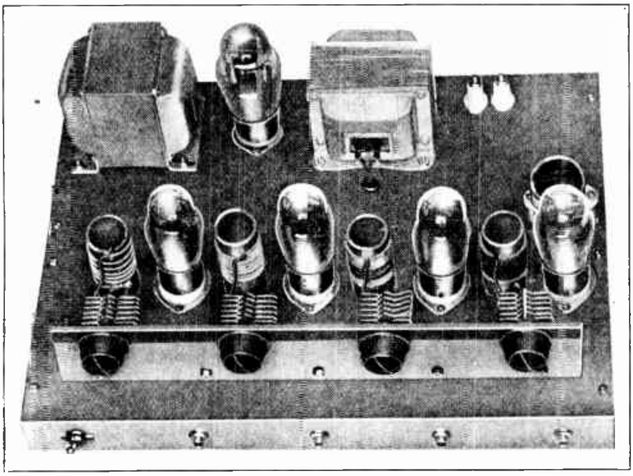


FIG. 38—Jones 4-Band Unity Coupled Exciter.

The doubler grid-circuits are connected to interwound grid coils which are closely coupled to the plate tuned-circuits. As can be seen from the coil tables, only enough grid turns are wound on each coil to drive the push-pull grids at the proper frequency. Too many turns will cause excessive regeneration at the doubler plate-circuit frequency with self-oscillation. This is due to inductive reactance in the grid circuits and, when not excessive, improves the doubler efficiency and output.

Cathode resistors and grid-leaks combine to give high grid-bias to the doubler grid circuits. Cathode bias only on the crystal stage has the effect of keeping the crystal RF current low for relatively high power output.

An open-circuit plug in any cathode circuit, automatically cuts that and the succeeding stages out of the circuit. This allows about 10 to 15 per cent greater output from the stage which is actually driving the external buffer. The cathode current varies from 50 to 75 MA per stage depending upon plate voltage and RF load. Resonance in each doubler stage is indicated by a sharp decrease in cathode current of from 20 to 50 MA, providing the preceding stage is in resonance. (Note: a single turn of wire connected in series with a flashlight lamp will function as a resonator indicating device when coupled to the stage under test.)

JONES "4 - 53, 6A6" FOUR BAND EXCITER

80 TO 10 METERS. 20 WATTS OUTPUT ON 10 METERS.
ONLY ONE CRYSTAL (80λ) REQUIRED.

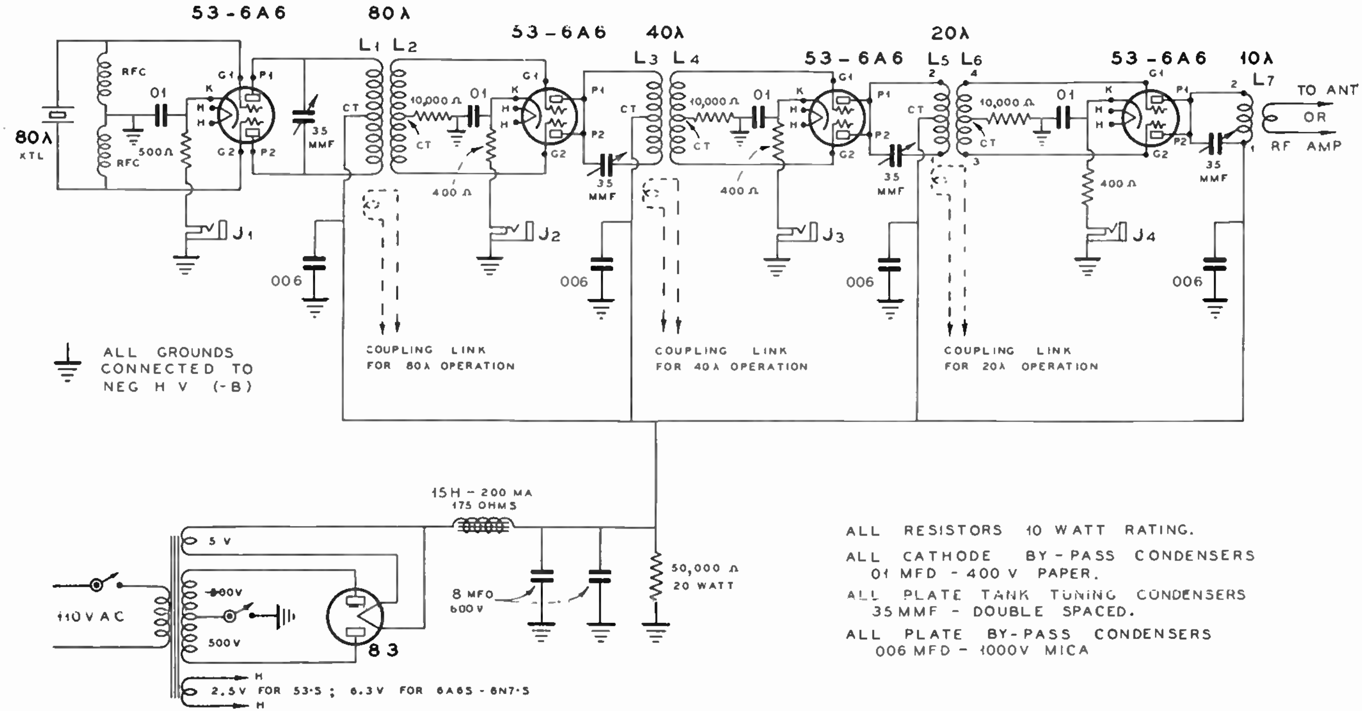


FIG. 39.

The power supply has two switches, one for the mains control and the other to apply plate voltage after the 53 or 6A6 tube heaters have attained their normal operating temperatures. The DC plate potential should be between 375 and 425 volts; higher voltages will give greater output providing the cathode current per tube does not exceed 75 or 80 MA.

The greatest output from the oscillator stage occurs at the maximum condenser setting just before the stage drops out of oscillation, or near that setting. Generally, for stability, in keying the crystal stage, this oscillator condenser has to be set back a dial degree or two towards less capacity and higher cathode current. The cathode current in any stage should not be over 20 to 30 MA when the crystal is *not* oscillating, and between 50 to 75 MA when the stage is oscillating. The circuit diagram, Fig. 39, shows 35 mmfd. plate tuning condensers throughout. Single-spaced 50 or 100 mmfd. midget variable condensers will be equally satisfactory.

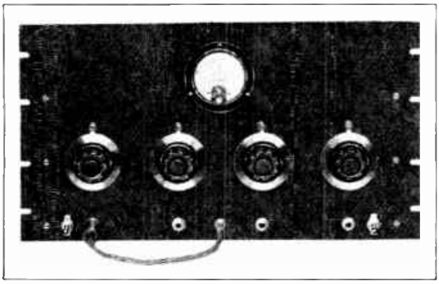
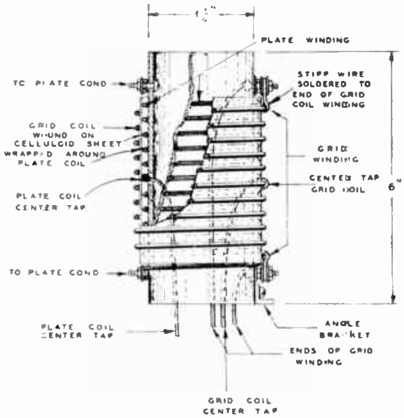


FIG. 40.
Relay-Rack Panel for Jones Exciter



COIL CONSTRUCTION FOR NEW JONES FOUR 53 – 6A6 FOUR BAND EXCITER.

FIG. 41.

Coil Winding Data for 80-to-10 Meter Unity-Coupled Exciter

All Coils Are Wound on 1¼-in. Bakelite Tubing

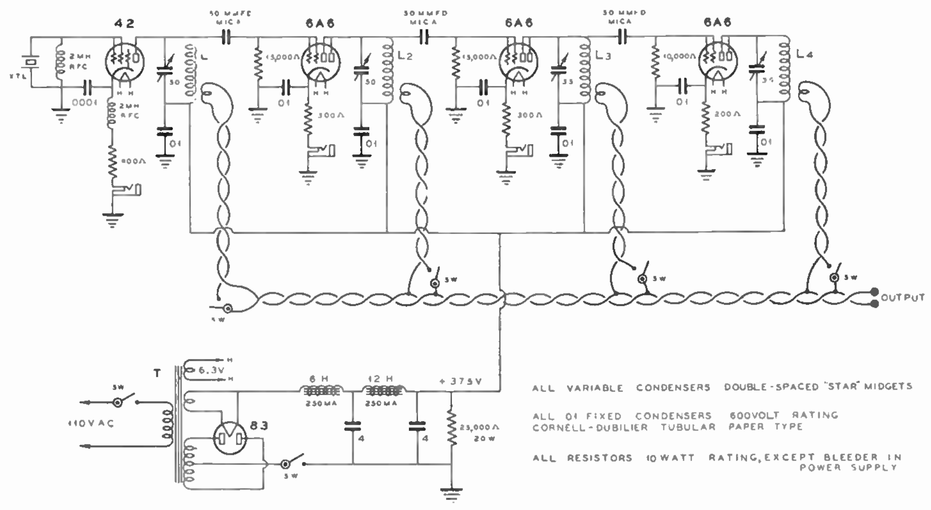
80 Meter Crystal	**80 Meter Oscillator Plate Coil** has 42 turns of No. 22 DSC wire, close wound, and center-tapped. Place a celluloid sheet over this plate winding, then wind the Grid coil on the celluloid sheet, as follows: 30 turns No. 22 DSC, close wound and center-tapped.
	40 Meter Doubler Coil. Plate winding: 22 turns No. 18 DSC, space-wound over a winding length of 1½-in., and center-tapped. **Grid Coil:** 20 turns No. 22 DSC, 1¼-in. winding length, center-tapped. Grid coil insulated from plate coil with celluloid strip, same as for Oscillator coil.
	20 Meter Doubler Coil: Plate winding: 12 turns No. 16 DCC, space wound over a winding length of 1¾-in., and center-tapped. **Grid Coil:** 10 turns No. 20 DSC, space wound over a winding length of 1½-in., center-tapped. Celluloid insulation between two coils, same as above.
	10 Meter Doubler Coil: Plate winding: 6 turns No. 16 DCC, space wound over a winding length of 1½-in. **Not** center-tapped. The 10 meter coil has only one winding, i.e., the plate winding. A link-coupling loop can be slipped over the TOP of any one of the above 4 coils for the chosen frequency of operation.

Practical 6-Band Exciter 5 to 160 Meter Operation

● One of the greatest difficulties encountered by the experimenter is the design of a crystal-controlled exciter from which several watts of output can be secured in the 5-meter band without resorting to costly and special tubes. Outputs of from 3 to 5 watts are obtained on 5 meters, and from 5 to 7 watts on 10, 20, 40, 80 and 160 meters from the simple exciter illustrated here for the first time. It was designed by Jones and first demonstrated to the radio amateurs at the 1936 Amateur Convention in Oakland, California. Its presentation aroused more interest than any exciter previously shown, because it operates on four bands from a single crystal. For example, the unit shown in the photograph operates on 40, 20, 10 and 5 meters from a 40 meter crystal. There are no neutralizing problems to cope with, inexpensive receiving tubes are used mere throw of a toggle switch. All four stages are first tuned to resonance for maximum output, after which no major retuning of any stage is necessary. Normally, the tuning dials can be left in one position at all times.

The exciter is a completely self-contained unit and it will serve as a driver for any phone or c-w transmitter because the plate supply has a two-section filter with negligible hum in the output. Furthermore, it occupies only as much space as is available for a standard 19 in. x 7 in. relay rack panel, with a chassis pan 17 in. x 11 in. x 1¾ in.

The coil design is extremely simple because each coil consists of only a single winding in the plate tuning circuit, with a two turn coupling loop wound on the same form slightly below the bottom turn of the



JONES 6 BAND EXCITER
DELIVERS 2 TO 5 WATTS OUTPUT ON 5 METERS

FIG. 33

throughout, a pair of terminals for connecting the coupling link to the exciter and single-pole toggle switches connect or disconnect the output from any stage without appreciable detuning effects. Thus it can be seen that operation on 40, 20, 10 or 5 meters can be secured without change in the coupling to the buffer stage, and the chosen frequency of operation is determined by the plate winding. The coupling to the buffer stage can be easily varied by moving the coupling turn (or turns) closer to, or farther away from, the node of the grid coil. The node of the plate coils in the exciter is at the positive B ends of the tuned plate circuits (bottom of plate coil windings). The small mica .00005 (50 mmfd.) fixed coupling condensers connected between plate coils and grids of the doubler stages are mounted above chassis between socket terminals or lugs. All tube and coil sockets are supported about ¾ in. above chassis. A large hole is punched directly under each coil and tube socket in order to facilitate wiring connections. All of the plate tuning condensers are insulated from the metal panel with fibre washers of the type that have protruding collars, so that the condenser shaft will not short-circuit the plate supply to the chassis. The rotor of each tuning condenser should connect to the positive B side of each circuit.

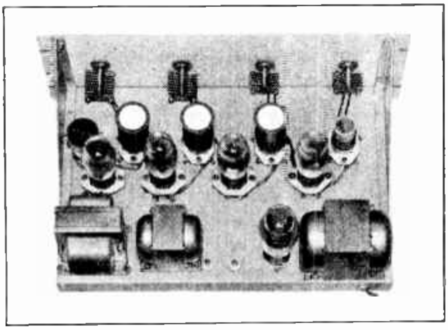


FIG. 34
Top View of 6-Band Exciter

Each stage is individually bypassed to ground, directly at the coil or tube socket, resulting in greater stability and efficiency, especially on 5 and 10 meters. These bypass condensers are 600 volt paper tubulars, mounted under the chassis. The metering

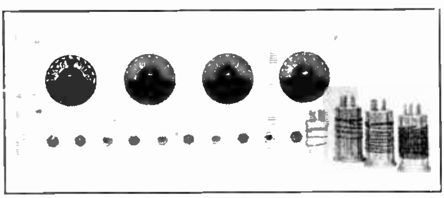


FIG. 35
Front View of Exciter and Coils

jacks are not insulated from the metal panel because the sleeves connect to ground.

An analysis of the circuit diagram shows that the doublers are straight-forward high-mu circuits with the grids and plates of the 6A6 tubes connected in parallel. Parallel operation results in approximately twice as much output as can be obtained with a single section of a 6A6, and this method of connection has proven satisfactory even on 5 meters. The grid drive from each succeeding doubler stage is sufficient to bias each stage to several times cut-off, resulting in high doubler efficiency. A combination of grid-leak and cathode bias is provided.

In order to simplify the design of the crystal oscillator, a 42 tube was selected This tube can be used as a high-mu triode in a regenerative crystal oscillator circuit. A 6A6 with grids and plates in parallel would give more oscillator output, but the crystal RF current is excessive when the plate potential is more than 300 volts. A push-pull 6A6 crystal oscillator would also require a split plate coil, and such a coil cannot be easily coupled into a single grid circuit.

Regeneration in the crystal oscillator increases the output. and with less crystal current than in any other standard circuit

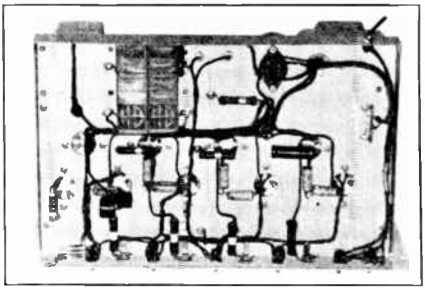
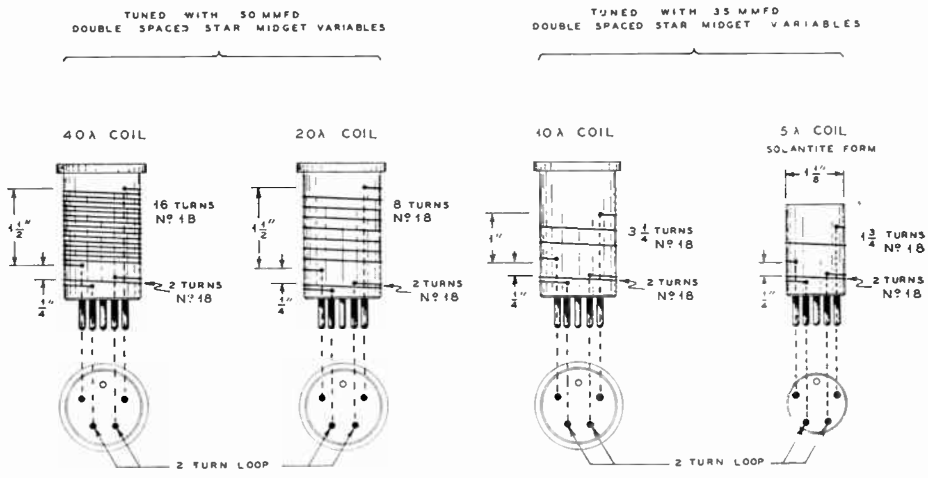


FIG. 36
Under-chassis View, Showing Placement of Resistors, Condensers, Coupling Link Line and Switches.

with the same tube. Regeneration is produced by means of a non-critical RF choke in the cathode circuit, by-passed to ground with a .0001 mfd. mica fixed condenser of the postage-stamp variety. The RF choke can be any standard small receiving type with an inductance of approximately 2 mh. The size of the cathode by-pass condenser depends upon the type of tube in the crystal oscillator circuit; for this particular circuit a .0001 mfd. mica condenser is correct. Other tubes may require a condenser as large as .00025 mfd. The tuning of the regenerative oscillator circuit is not critical and there is no self-oscillation when the crystal is removed. The circuit is tuned for maximum output. It can be loaded more heavily than a non-regenerative oscillator without loss of oscillation. The output of the crystal oscillator can be increased at least 50% with the regenerative circuit here shown.

The cathode of the crystal oscillator can be keyed for c-w or break-in operation.

Link coupling terminals are at the rear



COILS FOR 40, 20, 10 AND 5 METER OPERATION
(40λ CRYSTAL IN OSCILLATOR)

FIG. 37

of the chassis deck between the rectifier tube and swinging choke. The power supply requires a power transformer that will supply approximately 400 volts output at 250 milliamperes. A 1000 volt center-tap winding rated at 150 milliamperes RMS is satisfactory. This transformer should also have a 5 volt rectifier filament winding and a 6.3 volt heater supply for the RF tubes. Swinging-choke input gives good voltage regulation when keying the oscillator, or when one or more stages are cut out of operation by means of an open-circuit plug in the cathode jack.

The constructor is advised to build the entire unit at one time, then plug each succeeding coil into its proper place after the preceding stage has first been tuned to resonance and functions properly. The oscillator cathode current will be between 40 and 60 milliamperes, depending upon the external load and plate supply voltage. Each doubler circuit will draw between 55 and 75 milliamperes, depending upon the external load. These values should not be exceeded.

A flashlight globe and single turn of wire provides a convenient method for tuning each doubler circuit to resonance.

The band selector toggle-switching arrangement effectively places the link circuits in parallel when more than one switch is thrown to the "*ON*" position at one time. The idling stages should not be detuned. Each coupling link connects through a twisted-pair with a switch in one side, thus completing the circuit to the output standoff insulator connectors.

Coil Winding Specifications

All coils, except the 5 meter coil, are wound on standard five prong 1½ in. diameter low-loss plug-in coil forms. The 5 meter coil is wound on a 1⅛ in. diameter ceramic 5-prong plug-in form. Coils for 160, 80, 40, 20 and 10 meter operation have a 2-turn winding at the bottom of the form. This 2-turn winding is the coupling loop, and the ends of the loop are connected to two of the prongs on the coil form. The pictorial drafting (Fig. 74) shows a complete group of coils for 40, 20, 10 and 5 meter operation with a 40 meter crystal in the oscillator stage.

160 Meter Coil: 60 turns, No. 24 DSC, close-wound.

80 Meter Coil: 30 turns, No. 18 DSC, close-wound.

40 Meter Coil: 16 turns, No. 18 DSC, space-wound over a winding length of 1½ inches.

20 Meter Coil: 8 turns, No. 18 DSC, space-wound over a winding length of 1½ inches.

10 Meter Coil: 3¼ turns, No. 18 DSC, space-wound over a winding length of 1 inch.

5 Meter Coil: 1¾ to 2½ turns, No. 18 DSC, spaced approximately ⅜ in. between turns. Some readjustment of this spacing may be necessary in order to permit the plate tuning condenser to resonate the circuit.

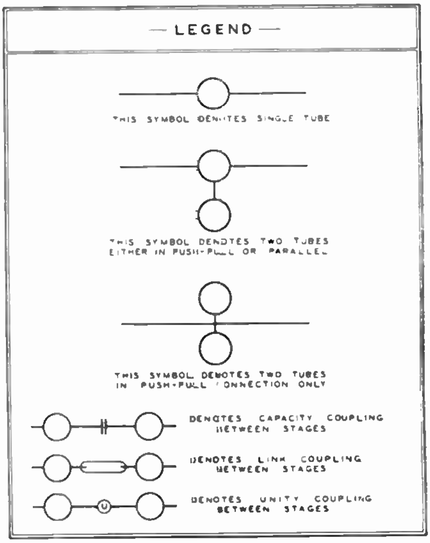
Transmitter Output, Shown By Block Diagrams

● The several pages of block diagrams in this *Chapter* will aid the reader in his choice of a suitable transmitter for almost every purpose. The diagrams are divided into three groups: (1) C-W., (2) Radiotelephony, (3) Combination C. W. and Radiotelephony. Directly above each tube symbol in each diagram is a figure which denotes the wavelength of operation of the tube. The tube type number is in the center of the tube symbol and the function of the tube, explaining whether it is an oscillator, buffer, buffer-doubler or amplifier, is indicated directly below the tube symbol. The safe operating plate voltage for each tube is also clearly shown. Beginning with the first symbol in the C. W. group, it is seen that a 6A6 tube, operating as an 80 meter oscillator, with 450 volts plate supply, will deliver an output of 10 watts for C. W. telegraphy. The next tube is a 6L6, operating as a 40 meter oscillator with 450 volts plate supply. The output is 25 watts for C. W. telegraphy. Proceeding to the next block diagram, it is seen that a 6L6 oscillator, operating on 80 meters, with 300 volts plate supply is link-coupled to a succeeding stage wherein a type 210 tube is used in a Class C RF amplifier operating on 80 meters, and with 750 volts plate supply. The output from the final tube (210) is 40 watts for C. W. telegraphy.

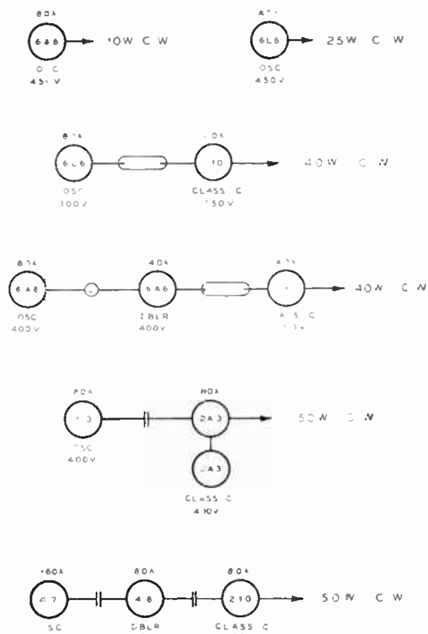
Block diagrams for Radiotelephone Transmitters and for combination Radiotelephone-C. W. transmitters, begin where the C. W. block diagrams end.

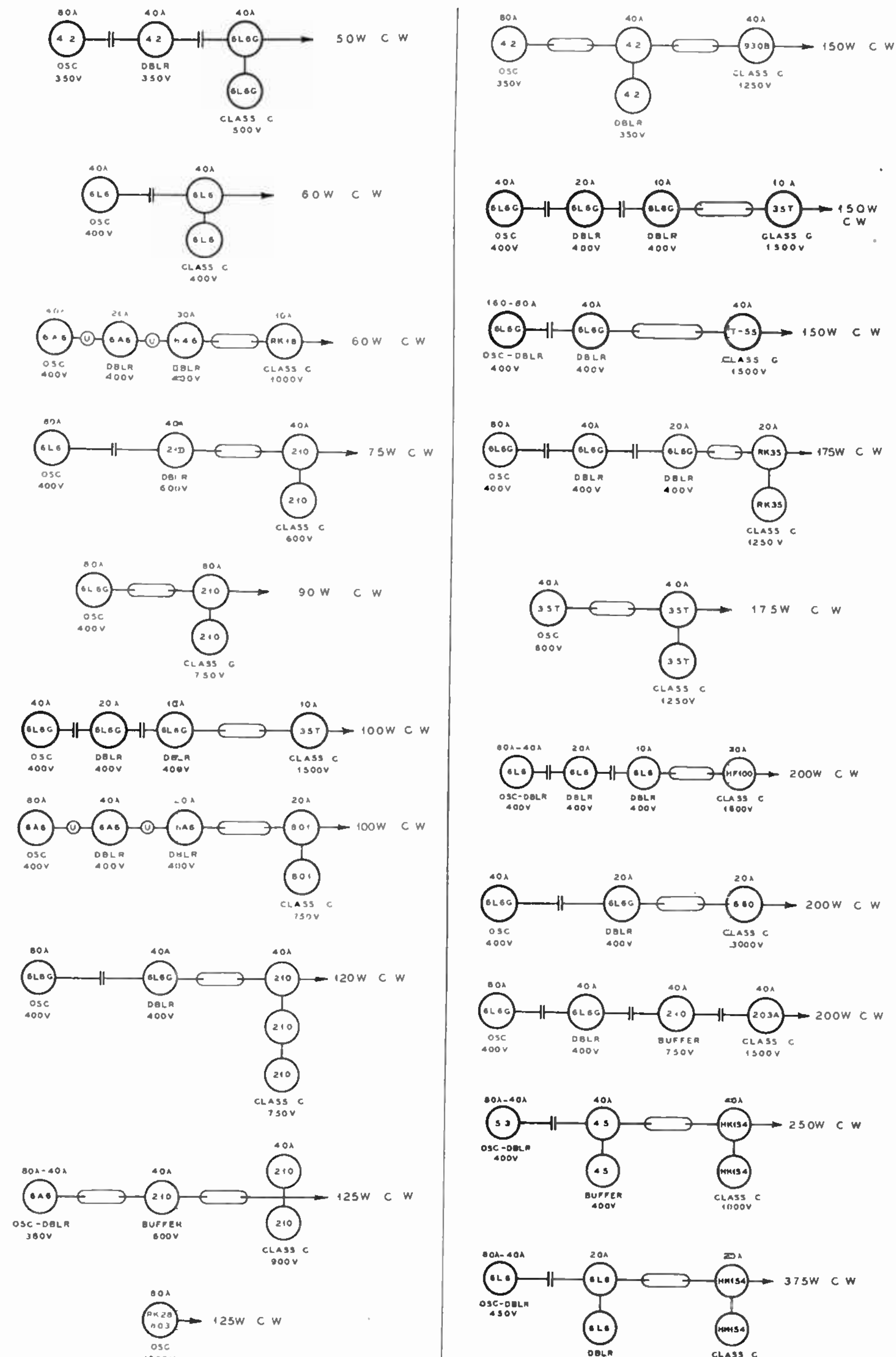
The *Legend* shows the various types of coupling between stages. *"U"* (Unity Coupling) consists of inter-winding an untuned grid circuit with a tuned plate circuit. *Capacitive Coupling* is indicated by the conventional fixed condenser symbol. *Link Coupling* is indicated by the loop symbol between tubes, denoting that a tuned plate circuit is link coupled to a tuned grid circuit. The *Legend* also indicates whether push-pull or parallel connection of tubes is suggested. Push-push doubler connections are the same as those for parallel tube connection. All such doublers are of the push-push variety.

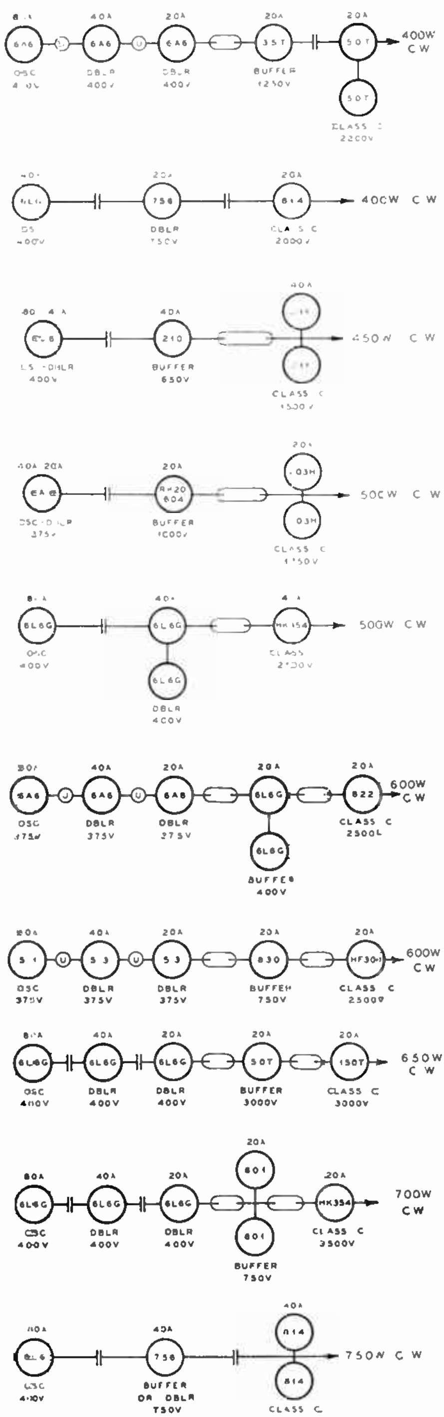
Relative power output, rather than the power input, is shown in all of the block diagrams, beginning with low power and ending with high power transmitter combinations.

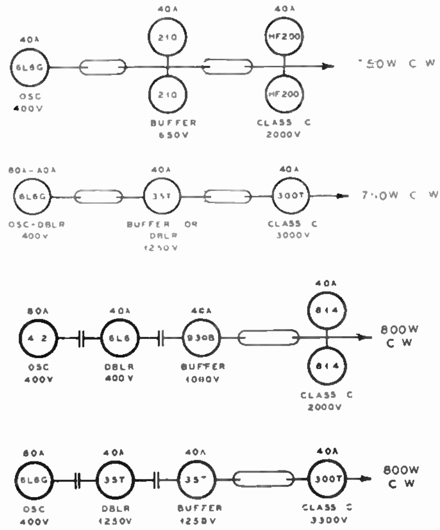


C.W.

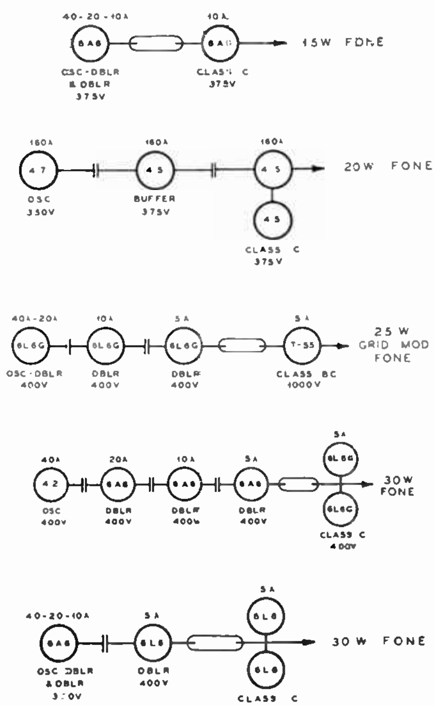


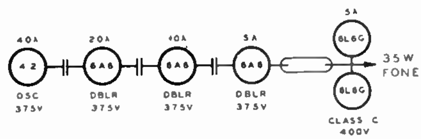

80A 42 OSC 350V
40A 42 DBLR 350V
40A 6L6G 6L6G CLASS C 500V
50W CW
40A 6L6 OSC 400V
40A 6L6 6L6 CLASS C 400V
60W CW
6A6 OSC 400V
6A6 DBLR 400V
30A 6A6 DBLR 400V
10A RK18 CLASS C 1000V
60W CW
80A 6L6 OSC 400V
40A 210 DBLR 600V
40A 210 210 CLASS C 600V
75W CW
80A 6L6G OSC 400V
80A 210 210 CLASS C 750V
90W CW
40A 6L6G OSC 400V
20A 6L6G DBLR 400V
10A 6L6G DBLR 400V
10A 35T CLASS C 1500V
100W CW
80A 6A6 OSC 400V
40A 6A6 DBLR 400V
6A6 DBLR 400V
20A 801 801 CLASS C 750V
100W CW
80A 6L6G OSC 400V
40A 6L6G DBLR 400V
40A 210 210 210 CLASS C 750V
120W CW
80A-40A 6A6 OSC-DBLR 360V
40A 210 BUFFER 600V
40A 210 210 CLASS C 900V
125W CW
80A RK28 803 OSC
125W CW
80A 42 OSC 350V
40A 42 42 DBLR 350V
40A 930B CLASS C 1250V
150W CW
40A 6L6G OSC 400V
20A 6L6G DBLR 400V
10A 6L6G DBLR 400V
10A 35T CLASS C 1500V
150W CW
160-80A 6L6G OSC-DBLR 400V
40A 6L6G DBLR 400V
40A T-55 CLASS C 1500V
150W CW
80A 6L6G OSC 400V
40A 6L6G DBLR 400V
20A 6L6G DBLR 400V
20A RK35 RK35 CLASS C 1250V
175W CW
40A 35T OSC 800V
40A 35T 35T CLASS C 1250V
175W CW
80A-40A 6L6 OSC-DBLR 400V
20A 6L6 DBLR 400V
10A 6L6 DBLR 400V
30A HF100 CLASS C 1800V
200W CW
40A 6L6G OSC 400V
20A 6L6G DBLR 400V
20A 860 CLASS C 3000V
200W CW
80A 6L6G OSC 400V
40A 6L6G DBLR 400V
40A 210 BUFFER 750V
40A 203A CLASS C 1500V
200W CW
80A-40A 53 OSC-DBLR 400V
40A 45 45 BUFFER 400V
40A HK154 HK154 CLASS C 1000V
250W CW
80A-40A 6L6 OSC-DBLR 450V
20A 6L6 6L6 DBLR 450V
20A HK154 HK154 CLASS C 1500V
375W CW





Radiotelephony Block Diagrams

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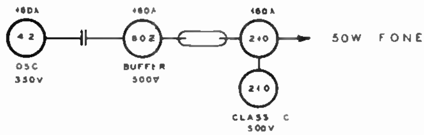
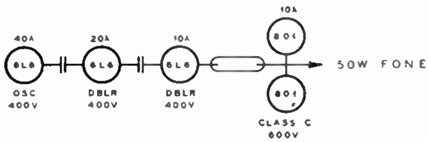
20A
10A
5A
5A
42
6A6
6A6
6A6
6L6G
6L6G
OSC 375V
DBLR 375V
DBLR 375V
DBLR 375V
CLASS C 400V
35W FONE


160A
160A
160A
42
802
210
210
OSC 350V
BUFFER 500V
CLASS C 500V
50W FONE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20A
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10A
6L6
6L6
6L6
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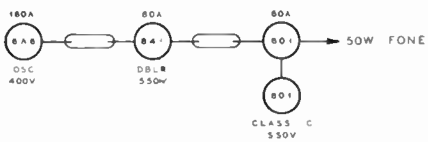
801
OSC 400V
DBLR 400V
DBLR 400V
CLASS C 600V
50W FONE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80A
80A
6A6
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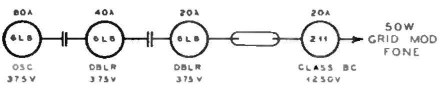
DBLR 550V
CLASS C 550V
50W FONE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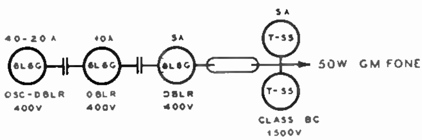
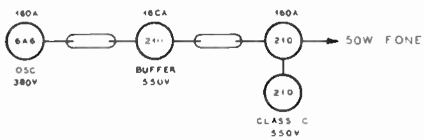
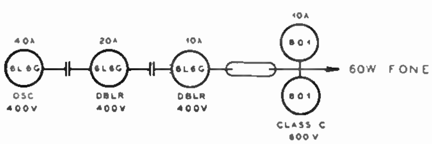
40A
20A
20A
6L6
6L6
6L6
211
OSC 375V
DBLR 375V
DBLR 375V
CLASS BC 1250V
50W GRID MOD FONE


40-20A
10A
5A
5A
6L6G
6L6G
6L6G
T-55
T-55
OSC-DBLR 400V
DBLR 400V
DBLR 400V
CLASS BC 1500V
50W GM FONE


160A
160A
160A
6A6
210
210
OSC 380V
BUFFER 550V
CLASS C 550V
50W FONE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20A
10A
10A
6L6G
6L6G
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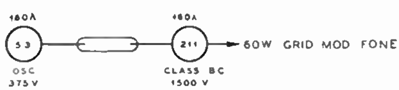
OSC 400V
DBLR 400V
DBLR 400V
CLASS C 600V
60W FONE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53
211
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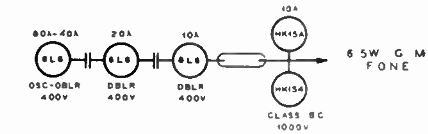
CLASS BC 1500 V
60W GRID MOD FONE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20A
10A
10A
6L6
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6L6
HK154
HK154
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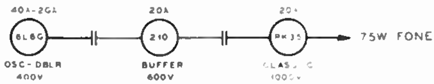
DBLR 400V
DBLR 400V
CLASS BC 1000V
65W GM FONE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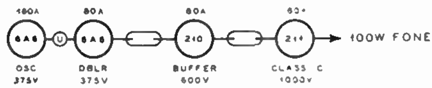
20A
6L6G
210
OSC-DBLR 400V
BUFFER 600V
75W FONE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6A6
6A6
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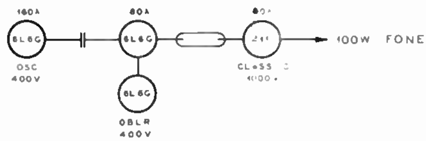
DBLR 375V
BUFFER 600V
100W FONE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6L6G
6L6G
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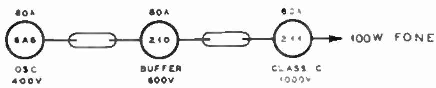
DBLR 400V
100W FONE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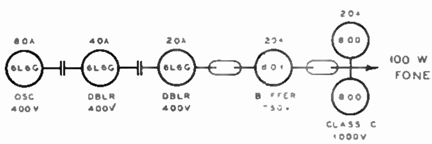
BUFFER 600V
CLASS C
100W FONE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40A
20A
20A
6L6G
6L6G
6L6G
800
800
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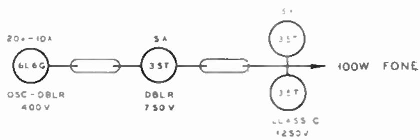
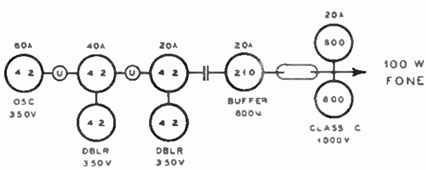
DBLR 400V
DBLR 400V
CLASS C 1000V
100 W FONE


5A
6L6G
35T
OSC-DBLR 400V
DBLR 750V
100W FONE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40A
20A
20A
20A
42
42
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42
210
800
800
OSC 350V
DBLR 350V
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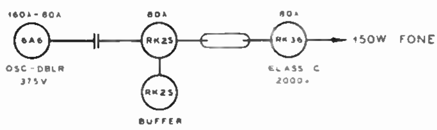
BUFFER 600V
CLASS C 1000V
100 W FONE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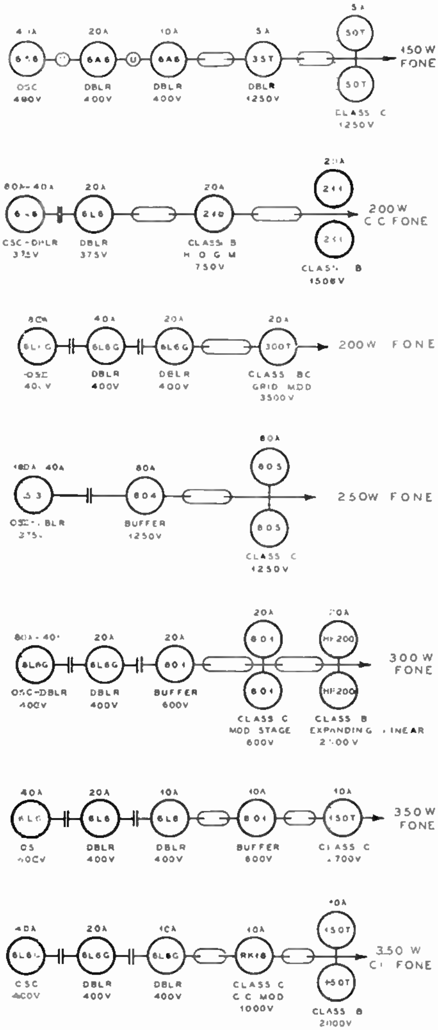
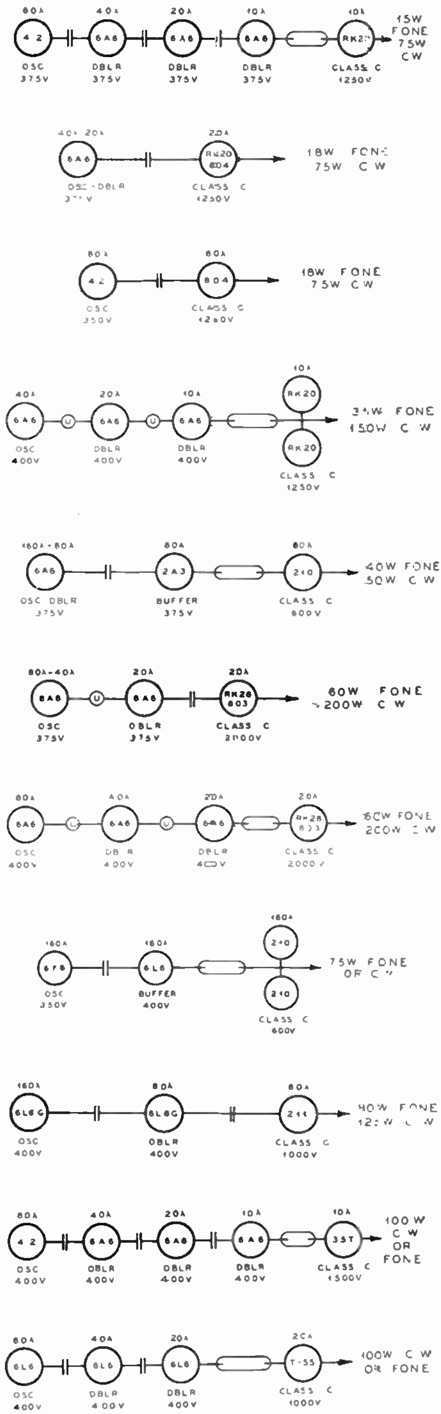
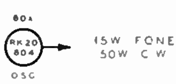
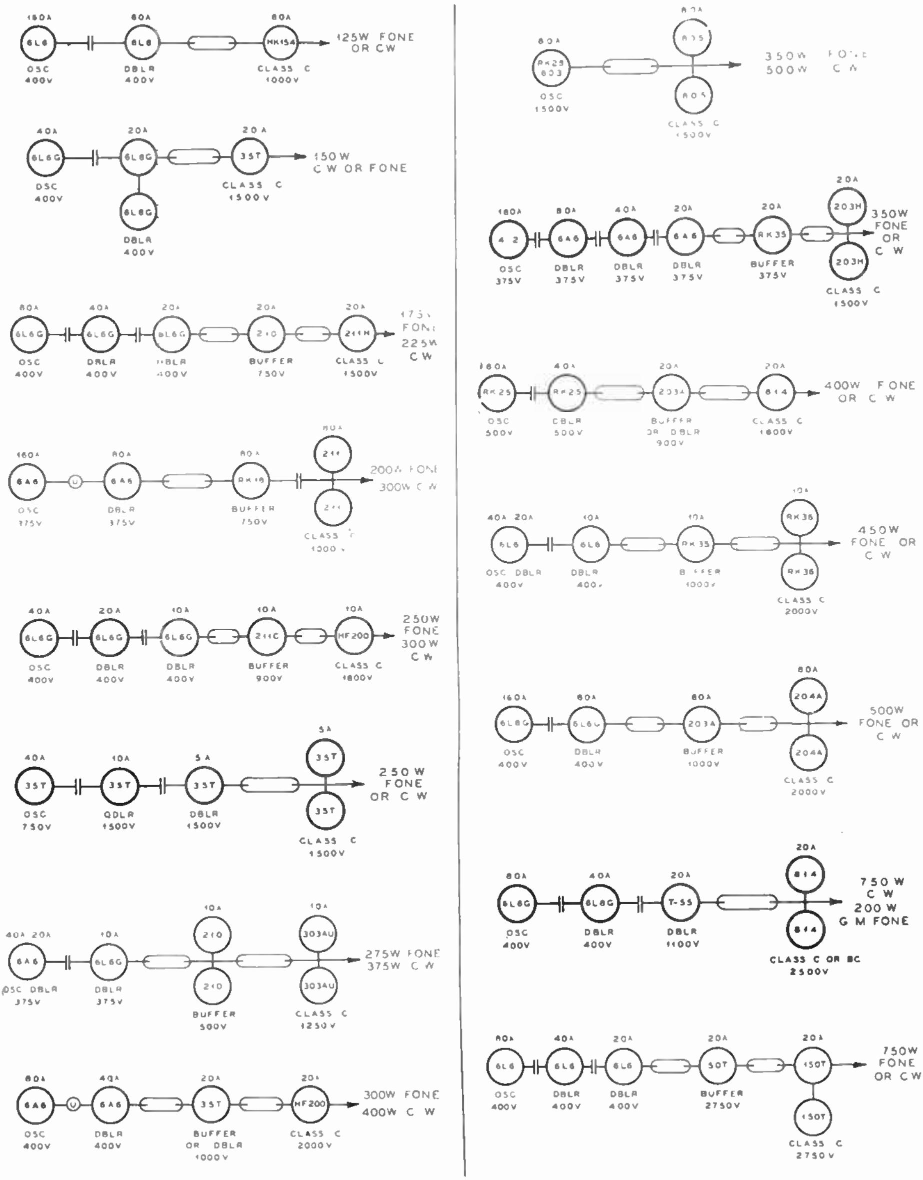
80A
80A
6A6
RK25
RK25
OSC-DBLR 375V
BUFFER 500V
150W FONE





Combination Radiotelephony and C.W. Block Diagrams





125W FONE OR CW
150 W C W OR FONE
175W FONE 225W C W
200W FONE 300W C W
250W FONE 300W C W
250 W FONE OR C W
275W FONE 375W C W
300W FONE 400W C W
350W FONE 500W C W
350W FONE OR C W
400W FONE OR C W
450W FONE OR C W
500W FONE OR C W
750 W C W 200 W G M FONE
750W FONE OR CW

Chapter 10

C. W. TRANSMITTER CONSTRUCTION

25 Watt Transmitter for Newcomers

● More power output can be secured from a simple one-tube transmitter with the new *Jones Regenerative Oscillator Circuit* and 6L6 tube than from any other one-tube oscillator circuit of previous design. The 6L6 is the new beam power pentode tube; its glass equivalent is the 6L6G, identical in characteristics. Either tube can be used in the transmitter here shown. The glass tube enables the operator to visually determine if the heater, screen and cathode are functioning properly. The accompanying photographs and circuit diagrams show the 6L6 metal tube in a 25 watt transmitter. This output is ample for the newcomer who desires to acquaint himself with amateur operating conditions. The oscillator can later be used as a driver for a higher power buffer or amplifier stage.

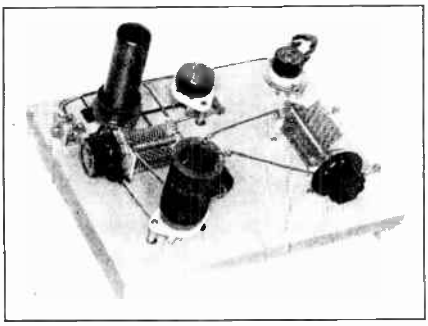


FIG. 1—Complete One-Tube 25 Watt c.w. Transmitter with 6L6 Metal Tube.

The plug-in coil form on which the plate coil is wound also holds the winding for the antenna coupling coil, the latter being wound above the plate winding, with a spacing of from ⅜ in. to ½ in. between the plate coil and the antenna coil. A midget 250 mmf. variable condenser is connected across the antenna coil for parallel tuning of Zepp feeders. The antenna tuning condenser is plainly seen in the photograph.

The laboratory model of this little transmitter successfully covered a distance of more than 1500 miles on the 80 meter band. For the sake of simplicity, both a pictorial and schematic circuit are shown. All values are given, and no substitution should be made. The new *Jones regenerative oscillator feature* results in very high output and low crystal RF current.

The tube elements are not visible in the case of a metal tube 6L6, and thus the screen voltage should be measured with a DC voltmeter.

The plate of the 6L6 is supplied with 400 volts, the screen with 200 volts. Slightly higher voltages can be used, but the builder is cautioned to carefully keep an eye on the tube so that neither the screen nor the plate show color. The screen voltage should be taken directly from a tap on the voltage divider in the power supply unit, as the circuit diagram shows. Adjust the slider on the voltage divider resistor to a point where the screen of the 6L6 is supplied with 200 volts. The 6L6G tube's screen will run red-hot if the screen voltage is too high.

The oscillator is keyed in the cathode circuit. Either a closed-circuit jack, or a pair of Fahnestock clips can be used for plugging-in or connecting the key in the cathode circuit. The plate tuning condenser is of the midget 100 mmfd. variety. The new "Star" midget 50 mmfd. double-spaced variable condenser will give more satisfactory service, although a single-spaced condenser will usually withstand the plate voltage without flash-over. The RF choke is a small 125 MA Hammarlund receiver-type. Mica fixed condensers should be used where indicated in the circuit diagram. A 5-prong socket is at the left rear of the baseboard for the power cable plug, although common connector clips could also be used.

The entire transmitter is mounted on a wood baseboard, 9 in. wide, 11 in. deep and ½-in. thick. Cleats are mounted on the bottom, front and rear, to raise the board from the table because some of the wiring is under the board.

The plate coil for 80 meter operation with an 80 meter crystal has 29 turns of No. 18 or 20 DSC or DCC wire, close-wound, on a standard 1½-in. diameter 4-prong plug-in coil form. Spaced from ⅜ in. to ½ in. from the plate coil is the winding for the antenna coil, 12 to 14 turns of No. 20 DSC or DCC wire, close wound, with the leads brought to the top of the coil form where they are secured to the rim of the form by drilling two holes, tapped to take a 6/32 machine screw, and then connecting the coil leads to these screw terminals.

A variable antenna coupling system can be made by merely sawing the plate coil form into two pieces; the upper portion (approx. 1-in. long) would then be the antenna coil, as shown in the *Regenerative Pre-selector* described in the *Receiver Chapter*.

The 250 mmfd. midget antenna tuning condenser is connected directly across the antenna coil leads. The transmitter can also be operated on 40 meters with a 40 meter crystal, but in this case the plate coil will have only 19 turns of No. 20 DSC wire, slightly space wound, and only 8 or 10 turns of wire in the antenna coil. Some slight "pruning" of coil turns will be required in order to give best results with various types and lengths of antenna feeders. When fully loaded to the antenna, the 6L6 tube should draw from 80 to 100 mills in the plate circuit. Altho these current values may seem somewhat high, the load on the tube is of an intermittent nature, there being no load when the key is up, because in this position the cathode circuit of the 6L6 is open. When the transmitter is not coupled to the antenna, the plate current of the 6L6 will take a pronounced dip to 20 milliamperes or less when the plate tuning condenser is swung through the resonance point. After coupling the antenna to the transmitter, slightly readjust the plate tuning condenser, then simultaneously adjust and readjust both the plate and antenna tuning condensers until the plate of the 6L6 draws from 80 to 100 milliamperes. A 0-200 MA DC milliammeter can be connected in the plate circuit of the 6L6 for making tests. It is difficult to properly adjust a transmitter without the aid of a milliammeter. One or more of these meters should be in every amateur station, particularly when the station is operated by a newcomer.

Two-band operation of this transmitter from a single crystal, such as 80 and 40 meter operation from an 80 meter crystal, is accomplished by merely changing the plate coil, increasing the value of the resistor (across the crystal) to 100,000 ohms, and connecting the metal shell of the 6L6 tube to cathode at the socket terminals. The newcomer is cautioned not to operate this transmitter on harmonic frequencies until he has first acquainted himself with its operation on the fundamental frequency. A frequency-meter monitor should be employed to determine the frequency of operation when the transmitter is operated on harmonics. See *Jones Two-Band Oscillator (Chapter: Transmitter Frequency Control)* for coil data and operating instructions for harmonic operation, also for data on 6L6G tube as a doubler.

No other similar one-tube transmitter will give better results than the one here described; it is the newest and most modern version of a transmitter which has been rigidly tested against many others over a period of several months. The results will surprise you.

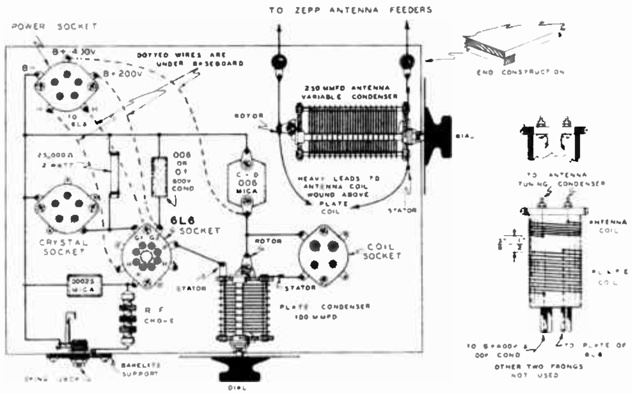


FIG. 2—Pictorial Diagram of One-Tube Transmitter and Plate Coil Construction.

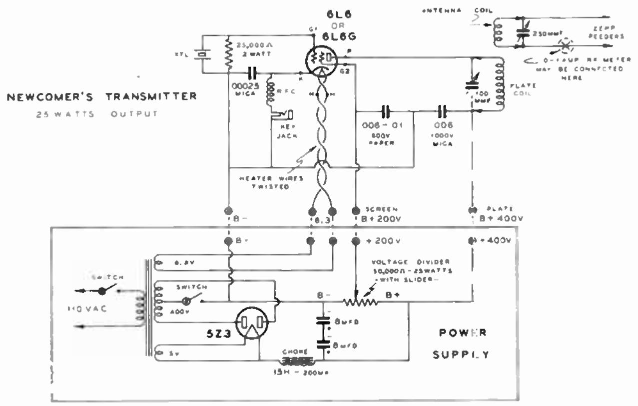


FIG. 3—Schematic Circuit Diagram of RF, Power Supply and Antenna Systems.

'47 Transmitter

● Those who prefer the older type of tubes will find the accompanying circuit diagram entirely satisfactory for a simple one-tube transmitter. It can be built on a baseboard the same size as that shown for the 6L6

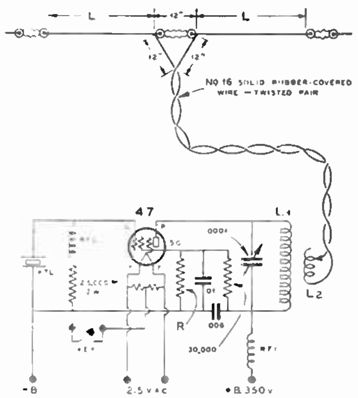


FIG. 4—Experimental single-tube transmitter with 47 pentode. The plate coil (L1) is coupled to a twisted-pair feed line. Resistor R has a value of 10,000 ohms. Refer to Chapter on Antennas for data on "L" in above diagram.

transmitter, and the same parts arrangement can be used throughout. The antenna is coupled to the plate coil in the same manner as for the 6L6 transmitter. The tuning condenser has the same value, the plate coil winding is the same, and the small by-pass condensers are identical in size and voltage rating. Approximately 10 watts output can be secured from this 1-tube '47 transmitter with a plate potential of 400 volts and 125 volts on the screen. This is less than half the power output secured from the 6L6 one-tube transmitter shown in Fig. 1.

50 Watt C.W. Transmitter

● This transmitter is simple in construction. The circuit design uses receiving type tubes. The total cost of all parts is approximately $25, including power supply and tubes. The output circuit can be loaded to 50 watts, which is ample for communication over a range of approximately 1000 miles on 80 meters c.w. The signal is clear and pure; no key-clicks are radiated when the key-click filter is connected as shown in the circuit diagram.

Technical Notes

● A 53 push-pull crystal oscillator drives a pair of 2A3 tubes in parallel on 80 meters. Smaller coils, and a 40 meter crystal can be used for 40 meter operation. The 2A3 tubes, being of the low-mu variety, have fairly high grid impedance as Class C amplifiers, and they can be capacitively coupled to the oscillator plate coil. The latter is center-tapped and by-passed to the ground bus connection in order to make grid neutralization possible. Grid neutralization allows the plate circuit to be connected into a simplified antenna matching circuit which eliminates nearly all radiation of illegal harmonics. This system is very good for working into a single-wire-fed *Hertz* antenna, as shown elsewhere in this book. The plate current is fed through a RF choke across the antenna tuning condenser. A DC blocking condenser passes the RF into the antenna and insulates it from the plus B voltage. A ¼-ampere *"Littlefuse"* should be connected in series with the RF choke in order to protect this choke and power supply in the event of an RF arc across the antenna tuning condenser, which is only single-spaced. This condenser has only a fraction of the RF peak voltage across it, because its reactance is much less than that of the lower capacity plate tuning condenser.

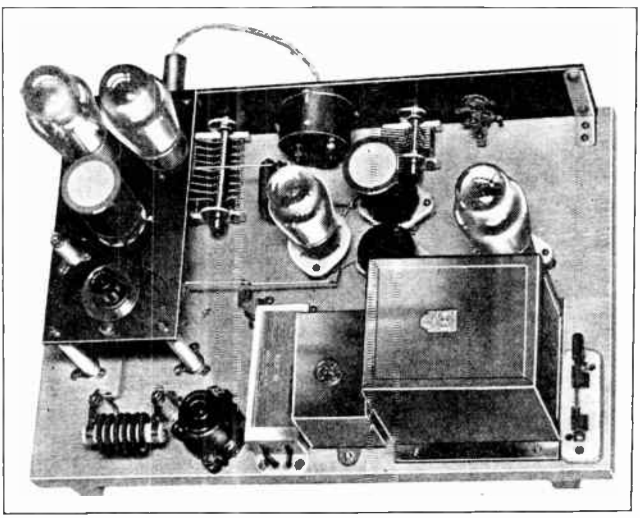


FIG. 5—Looking Down on the 53-2A3 Transmitter.

The 2A3 tubes can handle more plate dissipation than is needed, thus the output of 50 watts is limited only by the fact that the plate voltage and current are the limiting factors here. These tubes have a very high mutual conductance, consequently they are easily driven in a Class C amplifier at moderately high frequencies, such as 80 meters. On the other hand, the rather high inter-electrode capacities of the 2A3 limit its efficiency on higher frequencies, such as 20 meters.

The 53 push-pull crystal oscillator delivers nearly twice as much output as other oscillators at the same plate voltage (with the exception of the 6L6), and it places no excessive RF strain on an 80 meter crystal with the value plate voltage shown in the circuit diagram.

Center-tap keying is satisfactory if a key-click filter is wired into the circuit. A net-work consisting of a 1½-henry 60 ohm iron core choke, a ½-mfd. condenser and a 400 ohm resistor will eliminate clicks in this transmitter. Oscillator cathode keying can be used if a C battery with at least 90 volts is connected in series with the 15,000 ohm 2A3 grid leak.

The power supply should have a transformer which does not vibrate perceptibly under load, if it is mounted on the same base-board with the RF components. This transformer must supply a DC load of 250 ma, thus it should be large enough to handle this current. Choke input maintains good voltage regulation while keying the final stage. The filter shown is satisfactory for c.w. output, but it is not suitable for phone operation because there would be too much carrier hum.

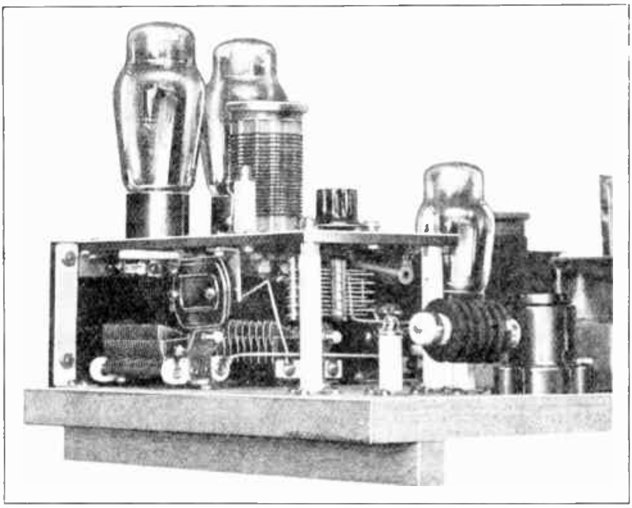


FIG. 7—Close-up of Final Amplifier and Sub-panel for Tubes, Coil and Neutralizing Condenser. The Final Plate and Antenna Tuning Condensers Are Secured to the Front Panel. See Fig. 6.

Operation at lower power could be accomplished with a smaller power transformer, such as a 700 to 800 volt center-tapped transformer, and condenser input to the filter. Two 8 mfd. electrolytic condensers in series will withstand the AC peak voltage in this case. The voltage regulation will not be good, and the circuit shown is recommended if a 1000 volt center-tapped transformer is available. The alternate filter system for the lower voltage power transformer is shown in dotted lines.

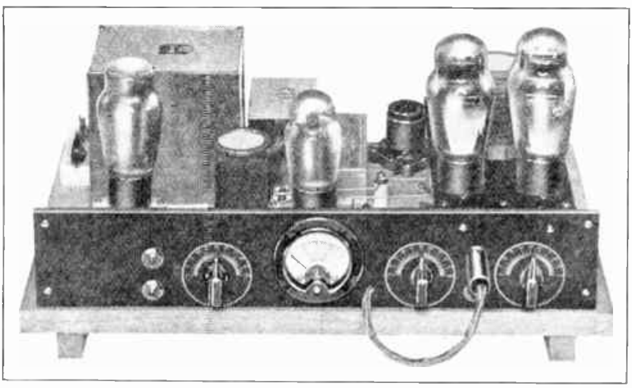


FIG. 6—Front View, showing Control Panel with Meter-Jacks and Tuning Dials.

Constructional Notes

● The complete transmitter, except for key and key-click filter, is mounted on an oak baseboard, 17 in. x 11 in. x 1 in. The baseboard is fitted with a pair of cleats, so as to leave space beneath the board for

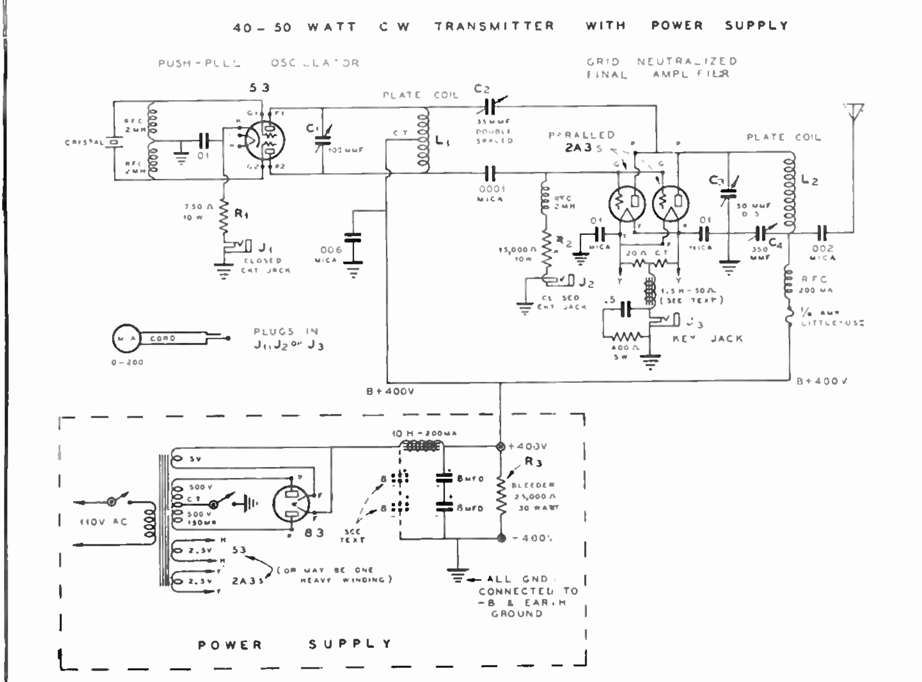


FIG. 8—Complete Circuit Diagram of 50-Watt c.w. Transmitter.

wiring, RF chokes, resistors and miscellaneous small parts.

The bakelite vertical front panel is 16 in. x 3 in. x 3/16 in. It supports the current measuring jacks, oscillator tuning condenser, 0-200 ma. meter, and the final amplifier tuning condensers. Another 7½ in. x 4 in. x 3/16 in. bakelite horizontal sub-panel supports the final plug-in tank coil, 2A3 tubes and neutralizing condenser. Front panel brackets support one end of this amplifier deck, and a pair of 3-inch standoff insulators act as rear supports.

Isolantite tube and coil sockets are used throughout because there is less RF loss and danger of flash-over than when bakelite wafer sockets are used.

The 80 meter oscillator coil consists of 44 turns of No. 18 DSC wire on a 1½-in. plug-in coil form. Coil L2 has 32 turns of No. 18 DSC wire. Different antennas may require from 25 to 35 turns of wire on this coil.

The key-click filter choke can be wound on an old AF transformer core with from 2000 to 3000 turns of No. 30 DSC or DCC wire in a jumble-winding on one leg of the core. A piece of writing paper should be slipped into the butt joint in order to take care of DC magnetization effects of the 2A3 plate currents.

Operating Notes

● The 53 tube should be operated without plate current for about 30 seconds in order to enable it to reach normal cathode temperature.

The 2A3 plate fuse should be left out of the circuit until the 53 is oscillating properly; the 2A3 stage is then neutralized. The removal of the fuse prevents application of plate voltage. The 53 cathode current will increase to between 50 and 100 ma. when it is oscillating. The oscillator tuning condenser C1 should be set toward the highest capacity setting at which oscillation persists, and where output is greatest. The cathode current should be between 50 and 75 ma. for this setting, and the final grid current should be at least 10 ma. when the 2A3 stage is neutralized.

A ¼-watt neon glow lamp is held against the plate lead of the 2A3 tubes when neutralizing. Without plate voltage or antenna connection to the final amplifier, the two tuning condensers should then be set for resonance, as indicated by a dip in grid-current and an increase in brilliance of the neon lamp. The neutralizing condenser is then rotated to the point of zero glow in the neon lamp (being certain that the crystal oscillator is still functioning), and to the indication of no dip in grid current as the plate tuning condenser is varied through resonance. The telegraph key should remain closed during these tests.

After neutralization, plate voltage can be applied to the amplifier and a single-wire-fed Hertz antenna connected to the output. The antenna can be about 135 feet long, fed at 18 feet either side of center, if it is to be used for 80 meters only. If all-wave operation is desired, the feeder should be connected about 22 feet off center. If a Zepp antenna is used, a coupling coil and separate feeder tuning condensers will be necessary. A twisted-pair feeder can be coupled to the lower end of the plate coil by means of 2 to 3 turns of insulated wire wrapped tightly around the coil form over the winding. In the two latter cases, the antenna condenser C4 should be set toward maximum capacity, with C3 always set for plate current dip (resonance).

In tuning a single wire fed antenna, C4 should always be set for the desired load, which will occur in the region of high capacity settings. C3 should then be rotated for minimum plate current; if the plate current is too low, reset C4 to a lower value capacity and again retune C3 to resonance. The plate current can be as high as 175 ma. into the 2A3 tubes for heavy antenna loading. Sometimes the plate coil L2 must be "pruned" by adding or removing a few turns in order to match a particular antenna. It is a good plan to connect a 50 watt Mazda lamp across the antenna and ground connections to determine the effects of different condenser settings which give greatest output at certain values of plate current. An antenna and ground can later be connected, and the condensers set to give the same values of plate current at the point of greatest dip. The oscillator tuning condenser C1 should be set to give greatest output into the 2A3s, with not more than 75 ma. of cathode current for the 53. Here again, the Mazda lamp is of value in determining the proper setting. Connect a loop of wire to the lamp (4 or 5 turns in the loop), and couple the loop to the oscillator coil when making this test.

75 Watt C.W. Transmitter

● Some of the advantages of the 6L6G beam power pentode when properly used in a crystal oscillator circuit are evidenced in the transmitter here described. The photographs show the separate units of the RF portion. The power output from the 6L6G Jones Oscillator is so high that the succeed-

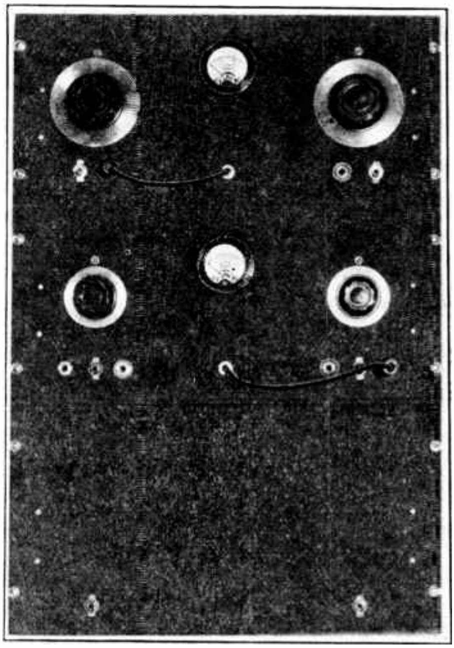


FIG. 9—Masonite Relay-Rack Construction for 75-Watt c.w. Transmitter.

ing 210 buffer or doubler stage can be driven to good efficiency in a capacitively-coupled circuit. The 210 buffer-doubler, however, is link-coupled to the push-pull 210 final amplifier. With 400 volts on the plate of the 6L6G, and 200 volts on the screen, the 210 buffer-doubler grid operates with from 8 to 10 grid mills under load, with a grid-leak resistor of from 5,000 to 10,000 ohms, plus 135 volts of *C* battery, as shown in the schematic diagram. The transmitter is keyed in the cathode circuit of the oscillator. If 8 or 10 mills of grid current cannot be secured when a 10,000 ohm resistor is used

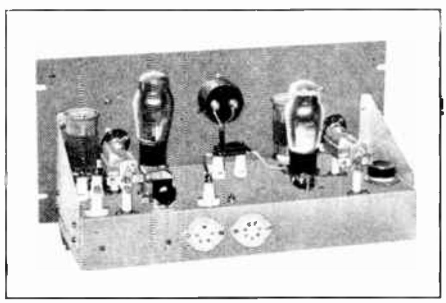


FIG. 10—6L6G Exciter and 210 Buffer-Doubler.

in the first 210 grid, reduce the value to 5,000 ohms.

The push-pull 210 final amplifier grid is driven with 25 mills, under load. One or two turns in each coupling loop will give ample excitation; first try one turn, then two.

FIG. 11—Final Amplifier with Two 210 Tubes in Push-Pull. The Tubes, Grid, Coil and Neutralizing Condensers Are Mounted on a Separate Masonite "Deck," Supported on Small Insulators.

The buffer stage is operated with approximately 600 volts on the plate. A series dropping resistor automatically reduces the voltage to the correct value. The final amplifier, on the other hand, is operated with the full 650 volts (or slightly more) on the plates.

and another for the 210 stages. The correct values of all of the power supply components are clearly shown in the circuit diagram. Double-spaced midget variable condensers are used throughout. The neutralizing condensers are 35 mmfd. double spaced *Star* midget variables. If 160 meter operation is desired, all variable condensers should have a maximum capacity of at least 100 mmfd., except the final plate condenser, which should be of the split-stator type, double spaced, 125 mmfd. per section, or more. The circuit diagram shows smaller condenser values, because this particular transmitter was designed primarily for 80, 40 and 20 meter operation.

The constructor is advised to build one stage of the transmitter at a time. First build and wire the oscillator, give it a thorough test, then proceed with the construction of the succeeding stages.

Mechanical Details

● Relay-rack construction, or common breadboard assembly can be used, as the builder prefers. Relay racks can be of metal or *Masonite*, painted black. If metal racks are chosen, make certain that the plate circuit meter jacks are *well insulated* from the panels. A suitable arrangement is to mount the jacks on a small bakelite strip, screwed to the rear of metal panel, with a ½-inch hole drilled through the panel to pass the

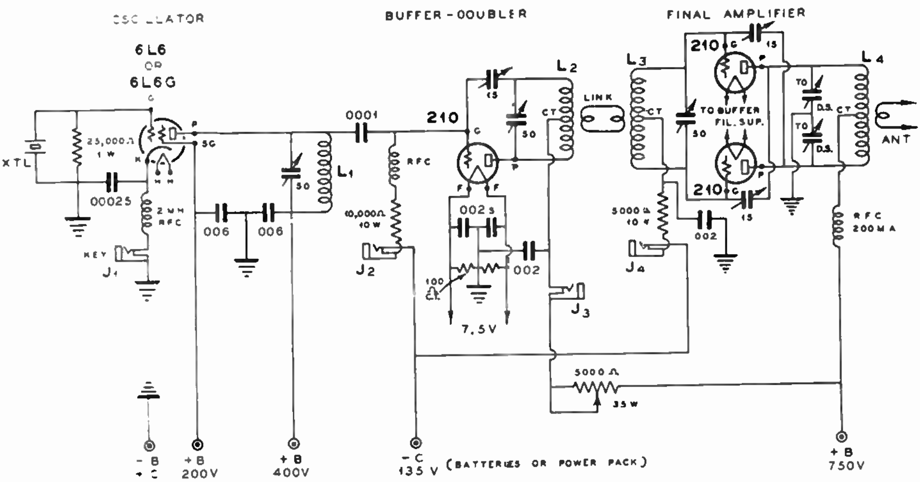


FIG. 12—Circuit Diagram of RF Portion of 75-Watt c.w. Transmitter.

The transmitter operates on 160, 80, 40 and 20 meters, depending upon the frequency of the crystal.

The power supply consists of two units on a common chassis, one for the oscillator

meter plug. One or more 0-200 MA DC milliammeters can be used. Meter jacks are provided for the oscillator cathode, oscillator plate, buffer-doubler grid, buffer-doubler plate, final grid and final plate cir-

Coil Winding Table for 75 Watt C.W. Transmitter				
Band	Oscillator Plate Coil	210 Buffer Plate Coil	Final Amp. Grid Coil	Final Amp. Plate Coil
160	60 turns No. 22 DSC close-wound.	72 turns No. 22 DSC wire, close-wound. Center-tapped.	Same as 210 Buffer Plate Coil	78 turns No. 18 DCC, 4-in. dia., 4-in. long. Center-tapped.
80	25 turns No. 18 DSC close-wound.	34 turns No. 18 DSC, close-wound. Center-tapped	48 turns No. 18 DSC. Close-wound. Center-tapped.	40 turns No. 14 Enam. 2⅝ in. dia. 4½ in. long. Center-tapped.
40	17 turns No. 18 DSC, spaced to cover 1½-in.	21 turns No. 18 DSC, spaced to cover 1½ in. Center-tapped.	24 turns No. 18 DSC, spaced to cover 1-inch. Center-tapped.	22 turns No. 14 Enam. 2⅝ in. dia. 4½ in. long. Center-tapped.
20	Use 40 meter Oscillator coil and double in Buffer plate.	14 turns No. 18 DSC, spaced two diameters. Center-tapped.	13 turns No. 18 DSC, spaced two diameters. Center-tapped.	10 turns No. 14 Enam. 2⅝ in. dia. 4-in. long. Center-tapped.

cuits. Some typical milliammeter readings for 80 meter operation are: Oscillator cathode, 60 MA; oscillator plate, 50 MA; buffer-doubler grid, 10 MA; buffer-doubler plate, 60 to 75 MA; final grid, 25 MA; final plate, 200 MA with antenna correctly coupled to final plate coil. Condenser input can be used in the 210 power supply unit if the voltage is insufficient with choke input. Two 5Z3 tubes, connected as diodes, can be substituted for the single 5Z3 shown in the circuit diagram if the transformer voltage is slightly higher than that recommended for a 5Z3 rectifier.

125 Watt Transmitter with 35T Tubes

● The Eimac 35T tube is ideally suited for use in doubler circuits because it has a high amplification constant. Its low inter-electrode capacities make operation on 5-meters practicable. Two of these Tantalum-plate tubes are shown in the transmitter pictured in Fig. 13, the circuit diagram in Fig. 14. This transmitter will put out 125 watts,

Coil Winding Table for 35T Transmitter Shown in Figs. 13 and 14		
L1	53 Osc. 40 Meters.	16 turns, No. 20 DSC on 1½-in. dia. form. Space wound to cover winding space of 1½-in.
L2	53 Doubler. 20 Meters.	8 turns, No. 20 DSC on 1½-in. dia. form. Space wound to cover winding space of 1⅜-in.
L3	2A3 Plate. 20 Meters.	10 turns, No. 20 DSC on 1½-in. dia. form. Space wound to cover winding space of 1⅜-in. This winding must be center-tapped.
L4	35T Grid, 20 Meters.	8 turns, No. 22 DSC on 1½-in. dia. form. This winding is interwound with L3.
L5	20 Meters.	12 turns, No. 12 Enameled, 2-in. dia., 2-in. long. This winding must be center-tapped.
	10 Meters.	10 turns, No. 8 wire, 1½-in. dia., 3-in. long.
L6	20 Meters.	10 turns, No. 12 Enameled, 2-in. dia., 2½-in. long.
	10 Meters.	8 turns, No. 8 wire, 1½-in. dia., 3-in. long.
L7	20 Meters.	12 turns, No. 12 Enameled, 2-in. dia., 2½-in. long. This winding must be center-tapped.
	10 Meters.	10 turns, No 8 wire, 1½-in. dia., 3-in. long. This winding must be center-tapped.

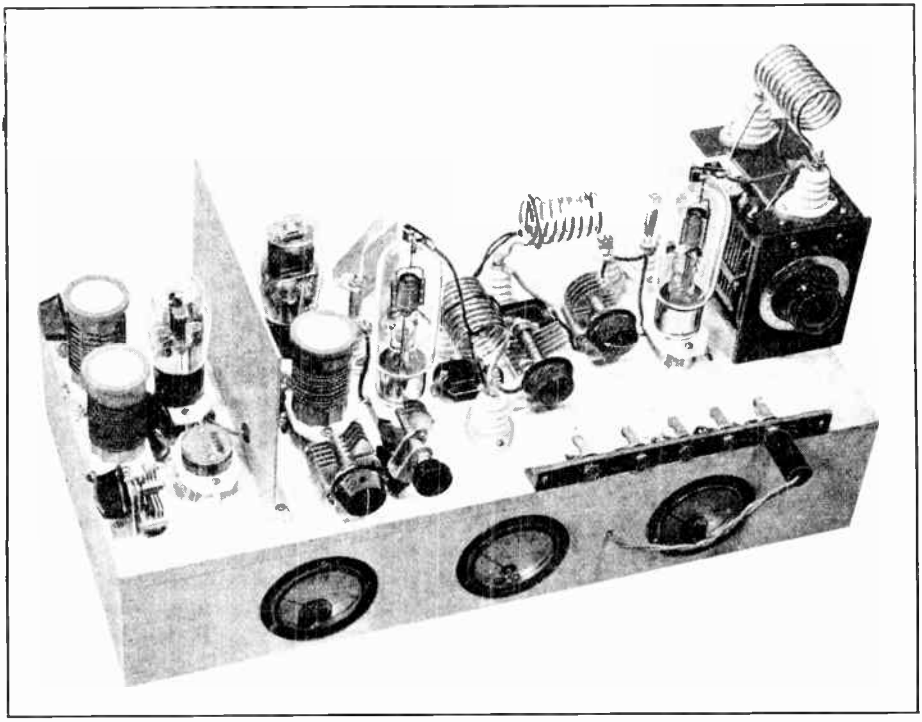


FIG. 13—The 35T Low-C Triode in a Modern c.w. Transmitter for High-Frequency Operation.

even on 10 meters, without exceeding the 35-watt plate dissipation of the tube. A pair of 35T's in the final amplifier will deliver more than ¼ k-w output.

A Jones '53 exciter drives a 2A3 buffer stage which, in turn, excites the first 35T either as a doubler or buffer. Unity coupling provides ample grid excitation from the 2A3 to the first 35T. Optimum grid excitation with respect to the 2A3 plate load can be adjusted by varying the number of turns in the grid coil L_4. The value of grid leak shown in the circuit is suitable for doubling. However, it will also function satisfactorily for buffer operation where the output efficiency is higher, and less input plate power will therefore be required. The grid leak in the final should have a value of from 1,000 to 5,000 ohms.

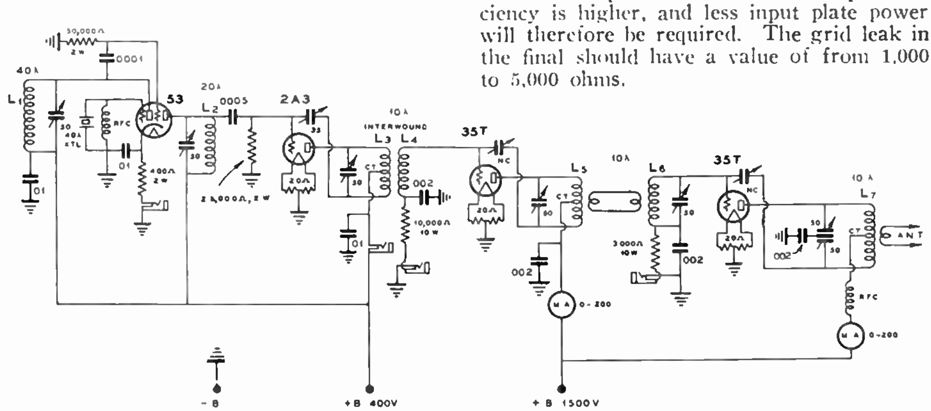


FIG. 14—Circuit Diagram Showing 35T Tubes in a Transmitter with 125 Watts Output.

35T Amplifier, 100 Watts Output, with New Neutralizing System

● An amplifier to follow the *Jones All-Band Exciter* is shown in Fig. 15. The exciter will supply from 10 to 15 watts of driving power from four 53s or 6A6s on 10, 20, 40 and 80 meters. This is sufficient power to drive the 35T amplifier in Class C operation to outputs of over 100 watts. The 35T is a high-mu triode with exceedingly low interelectrode capacities, rated at 35 watts plate dissipation, making it an ideal 100 watt output tube for all-band operation. It is also a very excellent crystal oscillator and doubler.

Outputs up to 150 watts can be realized from this amplifier when the plate potential is approximately 1800 volts, and the output circuit tuned to 10 meters. The normal maximum plate potential is rated at 1500 volts; for values between 1250 and 1500 volts, 100 watts of output can be secured with apparent ease on any band.

Technical Notes

● This amplifier has two systems of neutralization, both of the plate-circuit type. One of these systems is easier to drive for cw operation because the center-tap of the plate coil is by-passed to ground, thus introducing a certain amount of regeneration when plate voltage is applied. Another distinct advantage is that the grid current is greater. However, regeneration becomes excessive with some types of tubes and the amplifier will self-oscillate, thus making it unsuitable even for cw operation. The 35T tube functions satisfactorily when the center-tap is by-passed to ground. All regenerative frequency doublers using this type of circuit should have a by-pass in the plate coil center-tap because the output will be greatly increased, and the plate current will decrease.

The other system of neutralization operates on the principle of a perfect Wheatstone Bridge of capacities, as related in the *Transmitter Theory Chapter*. This neutralizing systems does not require a split-stator tuning condenser in the plate circuit, and it functions perfectly on 5 and 10 meters.

Condensers C_X and C_N in Fig. 16 consist of one fixed aluminum plate and two adjustable plates. The fixed plate connects to the free end of the plate coil and the variable plates connect to the grid and to chassis ground. The two movable plates can be secured to coil jacks, which act as bearings, or they can simply be made to turn on the screws of the standoff insulators. Once properly adjusted, the plates can be locked in position with the latter form of construction. The fixed plate is 3 inches high and 2½ inches wide. The grid plate of

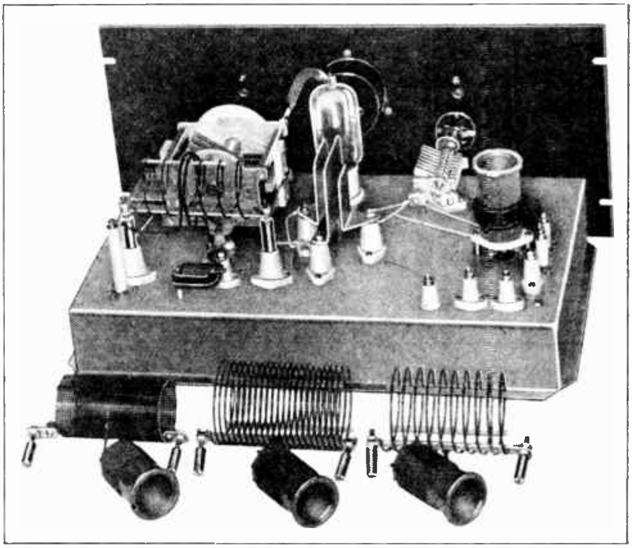


FIG. 15—35T Amplifier with New System for Neutralizing.

C_N is 1½ inches square, mounted so as to clear the fixed plate by ½-inch, and to rotate from one end, in order to allow lower values of capacity. The grounded plate is on the opposite side of the fixed plate and is 3 inches high and 2 inches wide, for the particular amplifier shown. Balance occurs with this plate about ⅜-inch, or slightly less, from the fixed plate.

Operating Notes

● A small neon lamp and a grid milliammeter are needed in order to properly neutralize and balance this amplifier. Several neutralizing settings are possible for different settings of C_X, but only one is really correct. With the plate by-pass disconnected, and no plate voltage applied, the amplifier is neutralized in the usual manner. When held on the plate lead of the 35T, the

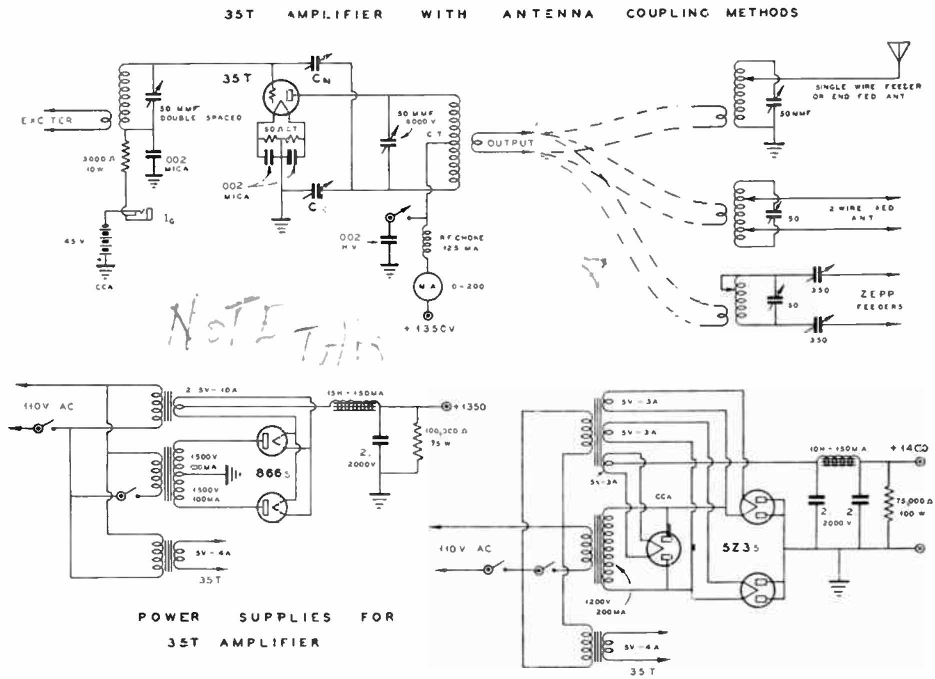


FIG. 16—RF, Antenna and Power Supplies for 125 Watt 35T Amplifier.

neon lamp should go out as neutralization is approached with Cx. Cx is set at a value which will give a setting of CN at which no grid dip is noticeable on the milliammeter when tuning through resonance with the plate tank condenser.

A second test for the proper setting of Cx occurs when plate voltage is applied. The tube will over-heat at low output if Cx is not set roughly to its proper value. Checking in this manner for different settings of condenser Cx and CN, with and without plate voltage, will soon enable anyone to acquaint himself with this neutralizing system.

The grid current should be at least 15 ma., 20 ma. is correct for a 35T under load if high efficiency is desired. This amount of drive can be obtained from a 6A6 push-pull oscillator or a push-push doubler operated with 400 volts on the plates. With the un-bypassed neutralizing system, 15 ma. is about all that can be realized from a 6A6 driver, but up to 30 or 35 ma. can be had when the plate coil is by-passed to ground, at a sacrifice in stability.

Antenna coupling should be made with a 2-or-3-turn link to another tank coil and condenser similar to the plate tank circuit. The antenna feeder or feeders should tap on this additional tuned circuit at points which will give best indication of antenna field strength when normal plate current is drawn at resonance from the final amplifier. Resonance occurs in the plate tank at minimum point of plate current as the circuit is tuned by rotating the variable condenser rotor.

FIG. 17—Jones Exciter and 35T Amplifier. 100 to 150 Watts Output.

A twisted-pair feeder antenna can be coupled directly to the plate tank coil by wrapping from 1 to 4 turns around the center of the coil. Each band would require a different number of turns, and also a different antenna, because the twisted-pair feeder is not suited for harmonic operation.

The 35T plate operates at a cherry red when dissipating its normal amount of power. It is a "high vacuum" type of tube, designed to operate efficiently when the plate is red hot; however it should not be operated at white heat.

35T Amplifier Coil Data

Wave-length	Grid Coil 1½" Diam.	Plate Coil
10	4 turns, No. 18 DCC, 1" long.	6 turns, No. 14 Enam. Center-Tapped. 1½ turns per inch, 4" long, 2" dia.
20	9 turns, No. 18 DCC, 1½" long.	10 turns, No. 14 Enam. Center-Tapped. 2½ turns per inch, 4" long, 2¾" dia.
40	19 turns, No. 18 DCC, 1½" long.	20 turns, No. 14 Enam. Center-Tapped. 5 turns per inch, 4" long, 2¾" dia.
80	39 turns, No. 18 DCC, 2" long.	28 turns, No. 16 Enam. Center-Tapped. 12 turns per inch, 3½" long, 2" dia.

125 Watt C.W. Transmitter with HK-154 Gammatron

● The growing interest in the spectrum below 20 meters has resulted in the introduction of a number of new tubes particularly suited for very-high-frequency operation. One of these new tubes in the *HK-154 Tantalum Plate Gammatron*. Its plate dissipation is 50 watts, it can be operated with 1500 volts on the plate, and the grid and plate supports protrude through the sides of the tube envelope. This construction makes the tube particularly suitable for operation on wavelengths as low as 2 meters. Outputs of from 100 to 200 watts per tube can be obtained with plate potentials of from 800 to 1500 volts.

A highly satisfactory transmitter for c-w operation, with a final amplifier that uses a

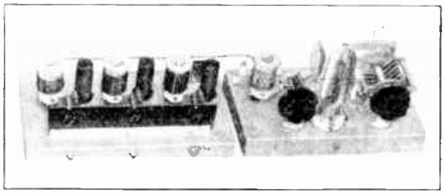


FIG. 18—New Jones 6L6 Exciter and HK-154 Amplifier.

split-coil neutralizing circuit is illustrated in the photograph and circuit diagram, Figs. 18 and 19. The exciter has three 6L6 metal tubes. It provides sufficient output on any band from 10 meters to 160 meters to drive the HK-154 for c.w. operation at plate potentials of 1000 to 1200 volts. The same exciter will also supply ample output on 5 meters to grid modulate one or two HK-154 tubes for voice communication. The crystal oscillator incorporates the new *Jones Regenerative Circuit* which delivers output on the fundamental, second, or fourth harmonic of the crystal by simply changing the plate coil in the oscillator stage. The remaining two stages in the exciter are ordinary pentode doublers the output on 5 meters is 5

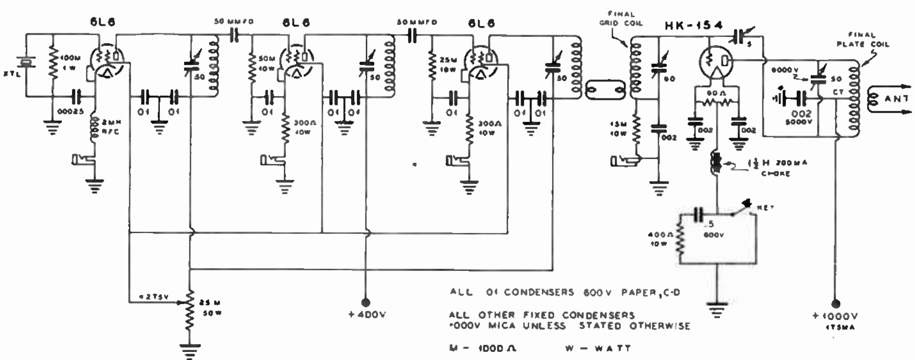


FIG. 19—125 Watt c.w. Transmitter.

watts, but 15 watts or more can be secured on the longer wavelengths. Either 160 or 80 meter crystals will give adequate output at any desired frequency.

The amplifier shown in the photograph is equipped with 20 meter coils. The final plate coil has 10 turns of No. 10 wire, 2-inches in diameter, 3 turns per inch, center-tapped and "air-supported." The final amplifier grid coil has 10 turns of No. 18 wire on a 1¾ inch diameter ceramic plug-in form; the winding length is 2 inches. The neutralizing condenser consists of two No. 12 gauge aluminum plates, 2 inches by 3 inches. One plate is mounted on a standoff insulator with a coil jack, so that the plate spacing can be varied. The other, or "stator" plate, remains stationary and is also mounted on a standoff insulator. A split-coil neutralizing circuit, rather than a split-stator arrangement, produces sufficient grid driving power under conditions of full output.

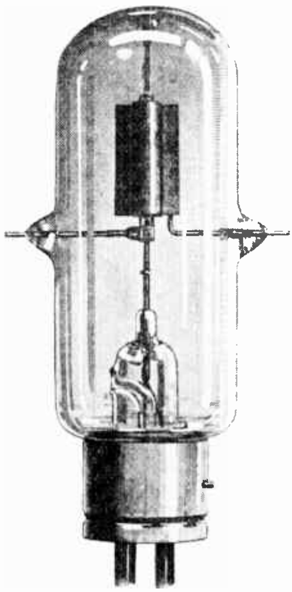


FIG. 20—The HK-154 Gammatron with Grid and Plate Leads Through Sides of Tube Envelope.

The bypass condensers and resistors are mounted under the chassis. The final amplifier chassis is 8 in. x 14 in. x 1¼ in. The exciter chassis is 8 in. x 15 in. x 1¾ in. The coils for the Exciter are wound on 1¾ in. ceramic forms.

All tuning condensers, other than the final plate condenser, are double-spaced 50 mmf.

Exciter Coil Winding Table

160 Meters: 70 turns No. 24 DSC, 2 inches of winding space.
80 Meters: 34 turns No. 16 enameled, 2 inches of winding space.
40 Meters: 16 turns No. 16 enameled, 1½ in. of winding space.
20 Meters: 8 turns No. 16 enameled, 1½ in. of winding space.
10 Meters: 4½ turns No. 16 enameled, 1½ in. of winding space.

variables. The final condenser shown in the photograph is a Hammarlund TC-50-A, 50 mmf. high voltage type.

High Power 2-Stage C.W. Transmitter

● When two 6L6 or 6L6G tubes are connected in parallel in a crystal oscillator circuit with the regenerative feature previously described, sufficient output is obtained to drive a high power final amplifier to outputs of over 400 watts. 40 or 80 meter operation is secured with either a 40 or 80 meter crystal. The crystal oscillator operates with 400 volts on the plates of the 6L6G tubes, and 250 volts on the screens. The oscillator delivers between 40 and 50 grid milliamperes,

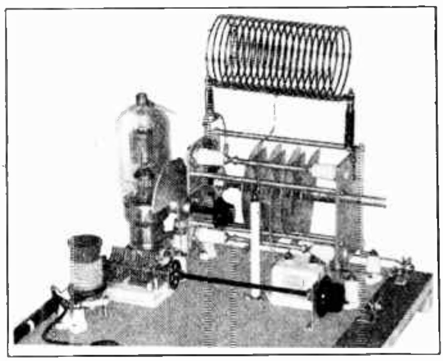


FIG. 21—Close-up of HK-354 Gammatron Amplifier, Showing Neutralizing Condenser Assembly.

through a 5000 ohm grid-leak, to the HK-54 tube. This is sufficient grid excitation for operation of the power amplifier at inputs of from 500 to 600 watts with a plate supply of 2000 volts. The split-coil in the plate circuit of the final amplifier, with by-

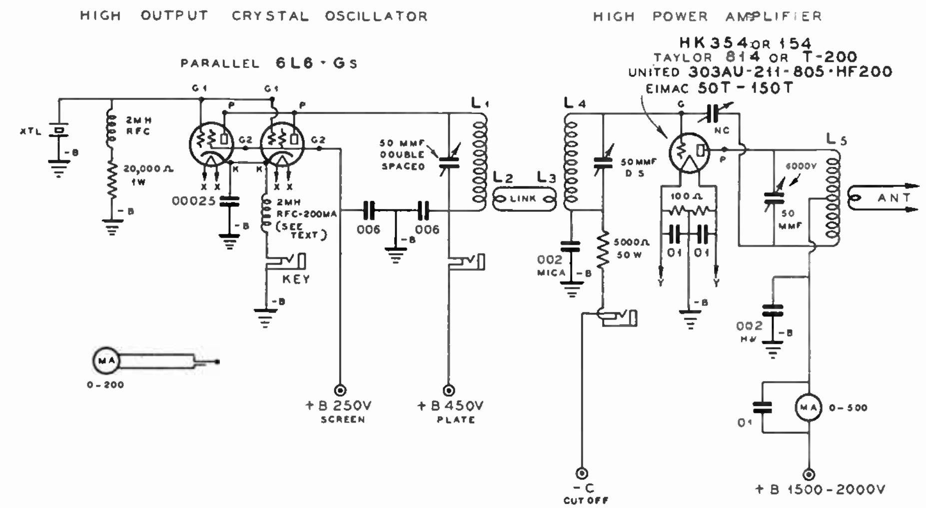


FIG. 23—One Band c.w. Transmitter-Output 300-350 Watts

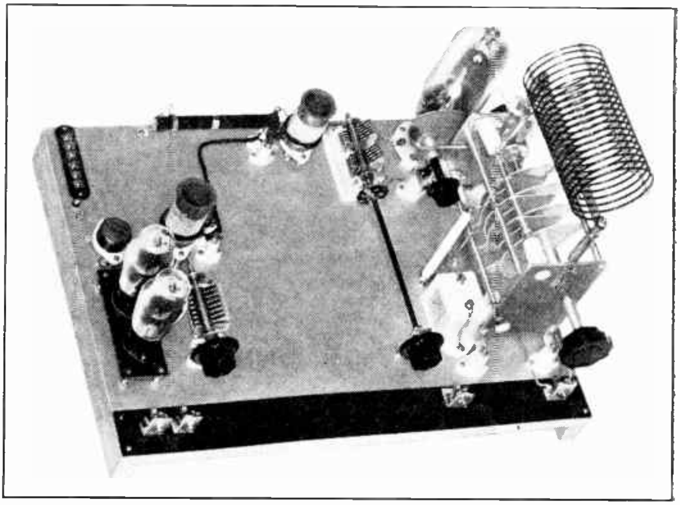


FIG. 22—2-Stage High Power Transmitter with Parallel 6L6G Oscillator.

pass to ground, provides a neutralizing circuit which has some inherent regeneration. As a result, the grid current does not drop below 40 milliamperes when the voltage is applied with the amplifier coupled to the antenna. The frame of the final plate tuning condenser acts as one side of the neutralizing condenser, another neutralizing plate (the rotor) is attached to the condenser frame with a strip of Mycalex, 1 in. x 3 in.

The entire transmitter is mounted on a large breadboard, 18 in. x 26 in. x ¾-in., covered with a thin sheet of aluminum, tacked to the under side of the board. One end of the final plate coil plugs into a sleeve attached to a Mycalex support on the rear frame of the condenser. The other jack plugs into a sleeve secured directly to the condenser frame, resulting in short leads between coil and condenser.

The oscillator is link-coupled to the grid of the final amplifier and the coupling link is supported on standoff insulators.

A more simple method would consist of two turns of wire twisted tightly around the bottom of both the oscillator plate coil and final grid coil, and the loops connected together with a conventional twisted-pair line.

The regenerative crystal oscillator circuit enables the use of very tight coupling between the two coils without tendency of pulling the oscillator out of oscillation.

The final amplifier can be keyed in the center tap if a key-click filter is connected in the keying circuit; primary keying is also satisfactory.

The screen voltage on the oscillator should be limited to 200 volts for 40 meter operation, or 250 volts for 80 meters.

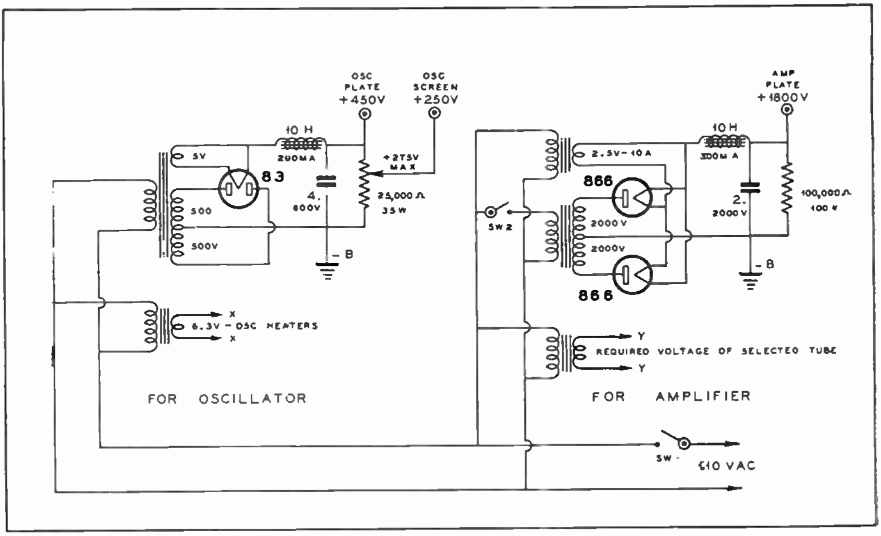


FIG. 24—Power Supply for Transmitter Circuit in Fig. 23.

Higher screen voltages will overheat the crystal and fracture it.

Laboratory tests show that this transmitter is capable of over 700 watts output with 2,800 volts plate supply. In one test, the crystal stage was operated with 600 volts on the plate and 275 volts on the screen. The grid current to the final stage was between 75 and 80 milliamperes under load, at the expense of a 40 meter crystal.

The oscillator plate coil for 40 meter operation has 17 turns of No. 16 DCC wire, spaced to cover a winding length of 1½-in. The grid coil, for 40 meters, has 19 turns of No. 16 DCC wire, spaced the same as the oscillator coil. The final amplifier plate coil for 40 meters has 20 turns of No. 10 enameled wire, 3½-in. diameter, 7 in. long, center-tapped.

Coil data for 80 meter operation is as follows: Oscillator coil, 36 turns No. 18 or 20 DSC, close wound on a 4-prong receiving type coil form. Grid coil, 32 turns No. 18 or 20 DSC, close-wound on 4-prong receiving type coil form. Final amplifier plate coil, 28 turns No. 10 enameled, 4½ in. diameter, 7½ in. long, center-tapped. 50 or 70 mmf. double-spaced midget variable condensers tune the oscillator plate and final grid coils; the final tank condenser should be of the high-voltage type, 35 or 50 mmf., single section. The one shown in the photograph is an Audio Products Co. Type WS150035. The grid tuning condenser is a double-spaced two-section 35 mmf. per section midget variable, with both sections connected in parallel to give a maximum capacity of 70 mmf.

Tuning

The grid milliamperes will usually drop when the key is pressed. Slight readjustments of the oscillator and grid tuning condensers, when the key is *down*, will tend to bring the grid current back to almost normal.

The input impedance of the amplifier changes when the key is down and when normal antenna load is applied, thus making it necessary to slightly change the degree of link coupling.

RK-35, RK-36, 500 Watt Transmitter

● This cw transmitter is built into a 30 in. x 19 in. relay-rack as a complete unit, including power supplies. The new Raytheon RK-36 low-C tantalum plate 100-watt tubes are connected in push-pull in the final amplifier. This final amplifier is driven by an RK-35 buffer stage for operation on any band by merely changing the coils. The RK-35 is a 35-watt tantalum plate tube; it supplies more output than is needed to drive the final amplifier if the buffer is operated with more than 1000 volts on the plate. The final amplifier can be operated at 2000 volts on c.w., with about 350 ma. of plate current.

The type of coupling between buffer and final stage, as shown in L2 in the circuit diagram, functions very well and requires only one tuned circuit. The grids of the final stage are tapped down toward the center of the coil to a point where the buffer stage draws only normal current (not over 100 ma.). With wire-wound coils, these taps are made by soldering ½-inch pieces of wire to the coil turns, so that connection can be made with clips. The buffer grid tuned circuit can be link-coupled to any tuned circuit of the exciter, and three-band operation is therefore made possible without changing the exciter coils or crystal. The RK-35 grid coil and condenser are mounted on the exciter deck in order to conserve space on the deck above.

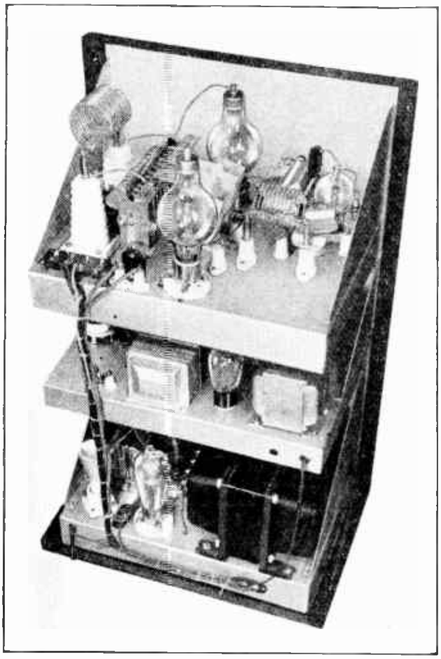


FIG. 25—Rear View of RK-35, RK-36 c.w. Transmitter.

The neutralizing condensers are made of No. 16 gauge sheet aluminum. The capacity can be varied by bending the grid section plates with a bakelite rod when neutralizing the final amplifier. These two neutralizing condensers have ½-inch spacing between adjacent plates and overlap 1-inch x 2-inches; this is sufficient capacity to neutralize either RK-36 or 50T tubes. The stationary U-shaped plates fasten directly to the stator screws of the final tuning condenser; the "moving" plates mount on standoff insulators and cross-connect to opposite grids. The RF leads are short, and high efficiency on 10 meters, as well as on other bands, is obtained. The buffer neutralizing condenser is made from two plates which overlap. Each plate is 1-inch square and the separation between plates is ¼-inch. A large Johnson coil plug and jack is ideal for the rotor plate bearing.

The rotor of final tank condenser is by-passed to ground, rather than directly connected, in order to prevent a DC arc in case of RF flash-over. RF arcs 2 inches long can be drawn from either stator plate with a lead pencil or screw-driver test prod.

The high voltage power supply also furnishes power for the buffer stage, although if more space is available a separate 900 or 1000 volt supply would be desirable. The no-load buffer plate voltage rises to nearly 2000 volts, but in spite of this voltage the transmitter keys satisfactorily in the crystal oscillator stage. Fixed bias for the buffer

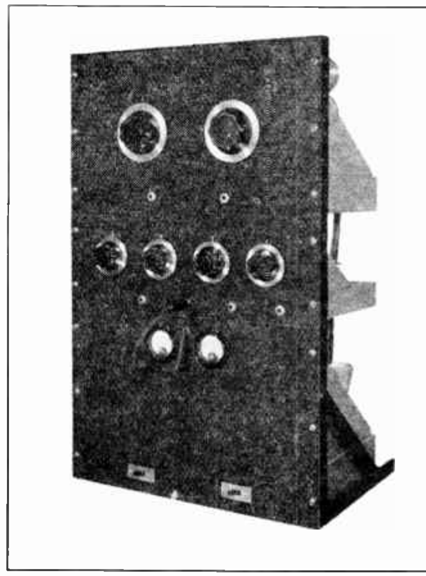


FIG. 26—The Front Panel Arrangement Is Symmetrical and Beautiful.

and final stages is obtained by floating the negative high voltage and filament supplies at +400 volts from the small power supply unit. The grids are operated at less-positive or ground potential, which in effect provides negative fixed bias to these grids. 10 ma. of grid current in the buffer is sufficient, likewise 50 to 70 ma. is satisfactory in the final amplifier grid circuit.

The exciter is similar to one described in the *Exciter Chapter*. It has three RK-6L6G tetrodes in a regenerative crystal oscillator, and standard doubler circuits. 6A6 tubes would give sufficient output to drive the RK-35, but 6L6G tubes give more lee-way, and the output can be adjusted by varying the screen voltage on the 400-volt power supply bleeder resistor. The smaller power

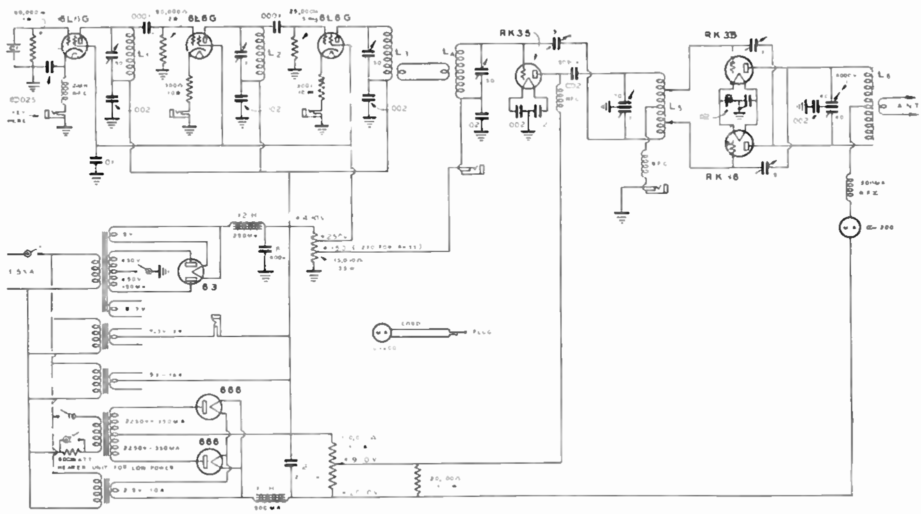


FIG. 27—Complete Circuit of Exciter, RF Portion and Power Supplies for RK-35, RK-36 c.w. Transmitter.

transformer must be capable of supplying 250 ma. DC at 400 volts, because each 6L6G tube draws approximately 75 ma. total cathode current. Cathode bias resistors supply bias to the 6L6G doubler tubes when keying the crystal oscillator cathode circuit. The exciter power supply is built on the exciter chassis, which measures 12 in. x 17 in. x 1¾ in. The other chassis are 12 in. x 17 in. x 2½ in. A 10½ in. x 19 in. panel is secured to the main power supply chassis. A 7 in. x 19 in. panel, and a 12¾ in. x 19 in. panel are secured to the exciter and main amplifier chassis respectively.

The coils are wound on ribbed 1½-in. diameter forms for the exciter and RK-35 grid coils. The final grid (or RK-35 plate) coils, and the final tank coils, are wound on various sizes of rolling-pin forms, with strips of celluloid for coil supports. The turns are cemented in place with Duco Household Cement. The forms are removed after the Duco cement has dried. Standard wire-wound coils can be used, but it should be remembered that the RK-35, RK-36 tubes are of the very low C type, and fairly large values of inductance are needed for each band.

Coil Data for RK-35, RK-36 500 Watt C.W. Transmitter

Wave-length	Exciter Coil	RK35 Grid Coil	RK35 Plate Coil	Final Tank Coil
40	18 turns No. 20 DSC 1½" long 1½" dia.	20 turns No. 20 DSC 1½" long 1½" dia.	18 turns No. 14 Center-Tapped 2½" long 2⅜" dia., tapped at 4¾ turns from ends	22 turns No. 10 Center-Tapped 3¼" long 2⅜" dia.
20	9 turns No. 20 DSC 1½" long 1½" dia.	10 turns No. 20 DSC 1½" long 1½" dia.	10 turns No. 14 Center-Tapped 2" long 2" dia., tapped at 1¾ turns from ends	11 turns No. 10 Center-Tapped 3" long 2⅜" dia.
10	5 turns No. 20 DSC 1½" long 1½" dia.	5 turns No. 20 DSC 1½" long 1½" dia.	4 turns No. 14 Center-Tapped 2" long 2" dia., tapped at ½ turn from ends	6 turns No. 10 Center-Tapped 2½" long 2½" dia.

Economical 1 K.W. Transmitter

● Most high power c.w. transmitters are designed to use several buffer and doubler stages with moderate size tubes, or relatively few stages with larger and more costly tubes and power supplies. The transmitter illustrated here is designed for operation with the new *Taylor* tubes, which work very efficiently in a three-stage transmitter for all-band operation.

Technical Notes

● A 6L6G pentode regenerative crystal oscillator drives a *Taylor* 756 buffer-doubler tube to over 40 watts output as a doubler. The buffer-doubler is then directly coupled to a pair of *Taylor* 814 200-watt tubes in a push-pull final amplifier with an input of one kilowatt. The oscillator delivers about 20 watts output to drive the doubler to over seven times cut-off, thus the latter functions at between 50% and 60% efficiency, depending upon the plate load impedance formed by the grids of final amplifier. These grids of the *Taylor* 814 tubes are tapped on the plate coil of 756 tube at points which will not cause excessive plate current in the 756 tube as a doubler or neutralized amplifier. The final amplifier operates at better than 75% efficiency, and laboratory tests with inputs of 1.6 KW showed no plate color in the tubes. These tubes are very easily excited at relatively high efficiencies and outputs.

Capacitive coupling functions satisfactorily and reduces the number of tuned circuits to three, as the schematic diagram shows. The new improved pentode oscillator circuit allows heavy plate loading, such as that which results when the oscillator is capacitively coupled into a high-mu tube grid circuit. Self bias on the 756, and fixed bias on the 814, allows keying in the crystal oscillator for break-in operation and minimizes key-click radiation.

Plate supply costs have been reduced by the system shown. The final amplifier plate supply is slightly overloaded, but c.w. intermittent service places less strain on rectifier tubes and transformers than when phone operation is used; consequently the power supply shown in the circuit diagram is entirely satisfactory for c.w. telegraphy.

Constructional Notes

● The entire RF portion is mounted on an oak baseboard, 11 in. x 30 in. x 1 in., with end cleats to make room for resistors, jacks, fixed condensers and some wiring under the board. Each plate in the neutralizing condensers for the final amplifier is 3¼ in. x 3½ in. of 16 gauge aluminum. The U-shaped construction gives four plates with ½-in. space between plates. A 1-in. tab at one end of the back of the "U" provides a means of mounting, with short connecting leads to the stators of the main tuning condenser. The other two "U" sections mount on small standoff insulators and cross-connect to opposite grids for neutralization. These capacities are made equal to the grid-to-plate capacities of the tubes by bending the "U" sections backward or forward while neutralizing. The edges of all condenser plates are rounded with a file.

The final tank coil mounts on short brass strips, with coil plugs, attached directly to the stators of the tuning condenser by means of brackets. The tuning condenser is a home-made affair, built from plates purchased from a radio salvage store. The space between adjacent rotor plates is 13/16-in., and the stator plates are approximately 4 in. x 18 in. x 16 gauge aluminum. Any manufactured split-stator tuning condenser with 35 to 50 mmfd. per section, with at least ⅜-in. spacing between rotor and stator plates is satisfactory.

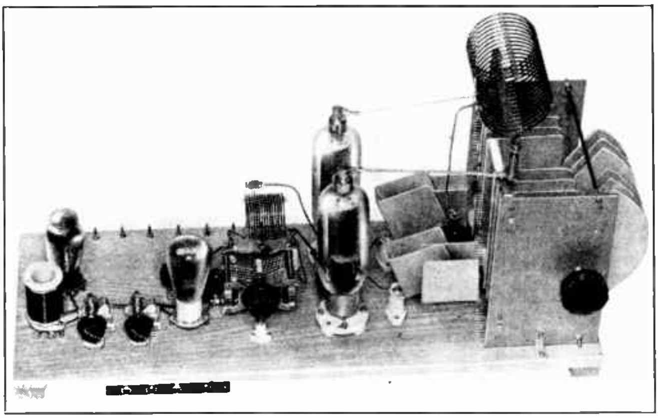


FIG. 28—1-KW Transmitter with Taylor 756 and 814 Tubes.

The buffer plate tuning condenser should be double-spaced in order to prevent flash-over. Single-spaced osciliator tuning condensers have a slight tendency to flash-over,

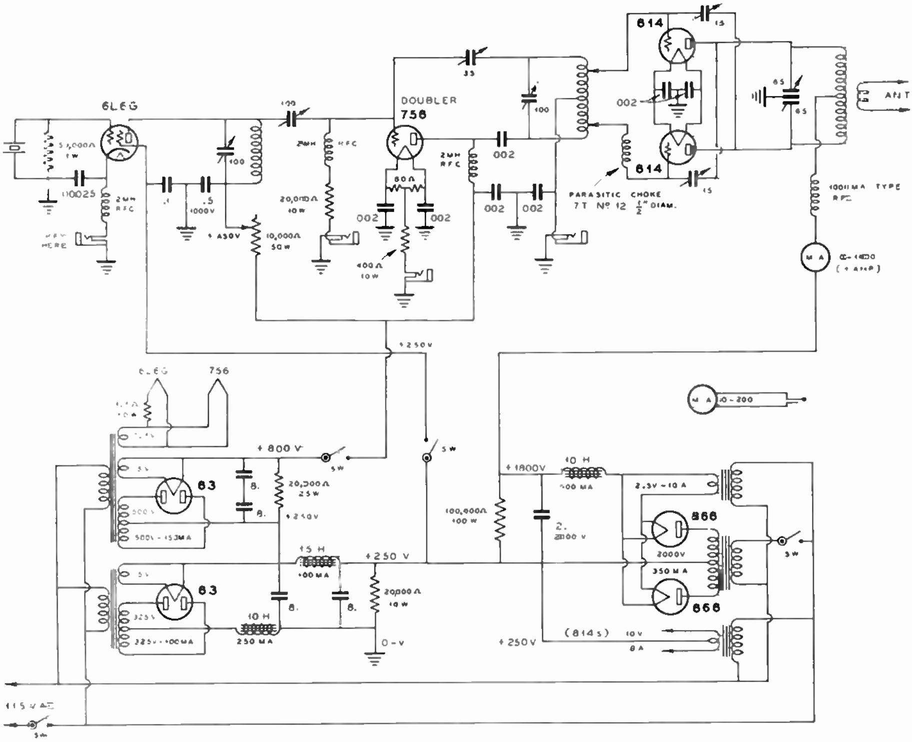


FIG. 29—Economical 1-KW c.w. Transmitter Circuit.

but they can be used if the oscillator plate supply is slightly less than 400 volts. The screen supply of 250 volts also furnishes bias for the final amplifier and boosts the 550 volt supply to approximately 800 volts.

The oscillator coil for an 80 meter crystal consists of 31 turns of No. 16 enameled wire on a 1¾ inches in diameter porcelain form, with a winding length of 2 inches. A 16-turn coil of the same dimensions is correct for a 40 meter crystal. The 40 meter buffer coil has 14 turns of No. 14 enameled wire, wound on celluloid strips, 2⅓ inches in diameter, 2 inches long. It is center-tapped and tapped at 3⅓ turns from each end with wire "lugs" for connection to the Fahnestock clips. The 40 meter final tank coil has 16 turns of No. 10 enameled wire, wound on celluloid strips to occupy a length of 5 inches, 3½ inches in diameter. Coils for 80, 20 and 10 meters can be made by consulting other coil tables in the pages.

Operation

● In the experimental transmitter, the oscillator cathode current was 75 ma., the 756 center-tap space current was 120 ma. as a doubler, and the final plate current was 550 ma. The doubler grid current measured approximately 10 ma., and the final grid current 50 ma., under full antenna load operating conditions. A small parasitic grid choke reduced a tendency for 5-meter oscillation when the plate voltage was increased to 2750 volts during special tests, with the final amplifier operating at inputs of more than 1-KW. The addition of a 2000 ohm grid leak in the final amplifier grid jack circuit is recommended if the oscillator screen supply furnishes less than 250 volts positive bias to the filament return circuit of the final amplifier. The total grid-to-filament DC bias should be at least 250 volts for Class C c.w. operation with plate voltages as shown in the schematic diagram.

Notes

Chapter 11

TRANSMITTER TUBE DATA

● This chapter contains complete data on all popular types and makes of standard and special transmitter tubes of American manufacture. More information is here given than has previously appeared in any other book. Included are typical operating conditions for class B audio amplifiers or modulators, and for R-F amplifier service. From this data the reader can tell at a glance what type of driver stage is needed, power supply requirements, the output that can be expected, and how the tube constants vary under numerous operating conditions. Where such information was not given in the *Tube Manufacturers' Data Bulletins,* separate calculations were made in order to determine the operation of all types of tubes. These calculations are given in the pages that follow.

Safe values of plate voltage and current for all transmitter tubes are given. Many amateurs and experimenters operate their transmitter tubes at higher than normal ratings, without exceeding the actual plate dissipation ratings of the tubes. This practice can be considered satisfactory only when the tube is used for c-w service, and only if the grid driving power is greatly increased so that the tubes can be operated over a lesser angle of plate current flow during each R-F cycle, resulting in operation at higher plate efficiency. The DC grid current should never exceed the maximum rated values, yet the grid bias voltage may be increased to such a value that two or four times as much grid driving power is applied to the grid, or grids, of the tube, or tubes, in the final amplifier stage. This practice results in greater *plate efficiency* (within limits), but at a sacrifice in *power gain;* in extreme cases 200 watts of grid drive may be needed to obtain 600 watts of antenna power from a final amplifier. It is obvious that the foregoing does not represent economical design, and thus the *Tube Tables* in this chapter are, in general, based on a power gain of approximately 10, with plate efficiencies of from 66% to 75%. Radiation of harmonics does not become a too-serious problem when *Class C* amplifiers operate in this range of efficiency, particularly when the proper *C-to-L* ratio of tank circuit is employed.

The values of *grid driving power* listed in the *Tables* are those actually used by the grid of the tube. The power loss in the C-bias supply or grid leak should be added to these values, and for all-band operation the circuit losses should be taken into account when designing amplifiers or buffer stages. At 10 and 20 meters, the tuned circuit losses are higher than in the lower-frequency bands, such as 80 and 160 meters. These circuit losses cannot be given in a *Tube Table:* only the grid bias loss and grid driving power can be listed. An excess of power should be available for the driving stage in order to compensate for circuit losses. Some neutralizing circuits introduce a regenerative effect, requiring less grid drive. Circuits of this type are particularly desirable for c-w operation, but they are *not* recommended for phone operation.

Crystal Oscillator Tubes

● From the amateur's viewpoint, the best tube for a crystal oscillator is the metal 6L6 beam power pentode, or its glass equivalent, 6L6G. Next in order are the types 6A6 and 53, identical in characteristics except for heater voltage and current. Other tubes suitable for crystal oscillator circuits are types 41, 42, 2A5, 59, 47, 56, 76, 6F6, 6C5, 6F5, 6N7, 30, 19 and 10. Because most oscillator tubes fall in the category of *Receiver Tubes,* the reader will not find these tubes listed in the *Transmitter Tube* chapter; refer to the chapter on *Receiver Tubes* for characteristics, circuits and applications.

Frequency Doublers

● Among receiver type tubes, the 6L6 or 6L6G again takes its place at the head of the list for most satisfactory doubler service. The 6A6 or 53 is next in line, followed by the 46. A tube for doubler service should have a high amplification constant; pentode 2A5, 42 or 59 types are therefore occasionally used. Outputs of from 2 to 15 watts can be delivered by such tubes. Greater outputs from frequency doublers are secured from tubes such as the 841, *Eimac* 35-T, *Taylor* 756. These tubes will deliver outputs of from 15 to 50 watts when driven by a 6A6 or 6L6-6L6G crystal oscillator, and they have a further advantage in that they can be easily neutralized when operating in buffer stages. The output from a doubler is almost as great as from a buffer, if the grid bias in the former is at least six times cut-off bias, and if nearly normal DC grid current is flowing.

R-F Amplifiers

● The most popular all-around inexpensive tube for amateur service has been the type 10 or 210. Two or three of these tubes, driven by a crystal exciter, will deliver outputs of more than 100 watts. More efficient and higher power tubes have recently been introduced and the popular 210 is gradually being replaced with tubes of later design.

Many of the new carbon plate tubes are easy to drive to high outputs. In general, these tubes are easier to drive than the older types of low C tantalum plate tubes at most amateur frequencies. On the other hand, tantalum plate tubes are less bulky in plate construction for a given plate dissipation, interelectrode capacities are lower, and thus these tubes are more efficient for operation at the higher frequencies, particularly in the u-h-f region. Both types can be made to operate with equal effectiveness on the amateur bands. Tantalum plate tubes are gas-free and can be operated at very high plate voltages (4,000 to 5,000 volts) for 1 K.W. input to a single tube; however, a more powerful driver is needed than for two carbon plate tubes operating at lower plate voltage with the same input.

● Tubes for transmitter, modulator and audio applications are listed in the order of their rated plate dissipation. Frequency range, interelectrode capacities, grid driving power, power output, and average operating conditions are given. The capacity of the neutralizing condenser should be equal to the grid-to-plate capacity of the tube. The power output and grid driving power requirements are listed for average conditions where Class C amplifiers operate at an angle between 120 and 140 degrees. The Class C plate efficiency will run between 66% and 75% under these conditions. If more grid drive is available, greater output and higher efficiencies are secured in some cases. The Amplification Factor (mu) determines the value of d-c grid bias needed for the particular type of amplifier circuit in which the tube operates. Vacuum Tube Theory is more thoroughly treated in Chapter 3. Receiver tubes which are also suitable for transmitter operation, such as types 45, 46, 47, 53, 59, 6A6, 6B5, 41, 42, 2A3, 2A5, 6L6, 6L6G and 6F6 are covered in Chapter 7.

RK-15

RAYTHEON 4-pin base tube, similar to 46, and designed for Class B audio amplifier or R-F doubling. Control grid at top of tube.

Characteristics:

Max. DC Plate Voltage	400 volts
Max. DC Plate Current	50 ma.
Max. Plate Dissipation	10 watts

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RK-16

RAYTHEON Triode 5-pin base, similar to 59 when triode-connected. For use as Class B driver stage. Characteristics same as RK-15.

❖ ❖ ❖

RK-17

RAYTHEON Pentode, 5-pin base. Designed primarily for crystal oscillators in standard pentode circuits. Control grid at top of tube. Characteristics same as RK-15.

❖ ❖ ❖

RK-34

RAYTHEON Twin-Triode Power Amplifier. Designed primarily for U.H.F. amplifier or oscillator service. May be used efficiently up to 240 mc., providing the plate dissipation is maintained at not over 10 watts.

Note: A fixed bias of —15 volts is desirable in case of failure of RF-excitation.

Unusual Feature: Two plate leads are brought thru the top of the tube envelope, thus reducing interelectrode capacities for U.H.F. service.

Characteristics:

Heater Voltage	6.3 volts
Heater Current	0.8 amps.
Amplification Factor	13
Grid-to-Plate Capacity	2.7 mmfd.
Input Capacity	4.2 mmfd.
Output Capacity	2.1 mmfd.
Max. Plate Dissipation	10 watts
Max. D.C. Plate Voltage	300 volts
Max. D.C. Plate Current	80 ma.
Max. D.C. Grid Current	25 ma.

Class A Amplifier (Sections in Parallel):

D.C. Plate Voltage	300 volts
D.C. Grid Voltage	—16 volts
Plate Resistance	2950 ohms.
Mutual Conductance	4400 micromhos.
Plate Current	25 ma.
Load Resistance	5000 ohms.
Power Output	0.8 watts

Class B Amplifier:

D.C. Plate Voltage	180	300 volts
D.C. Grid Voltage	—6	—15 volts
Static Plate Current	15	15 ma.
Load Resistance	6000	10,000 ohms.
Power Output	7.2	12 watts
Peak A.F. Input (grid-to-grid)	100	100 volts

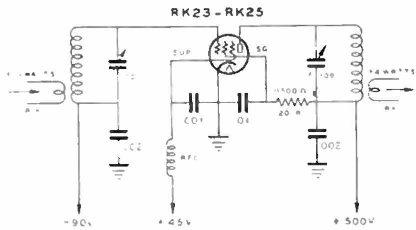
R-F Service—Class C Amplifier:

D.C. Plate Voltage	300 volts
D.C. Grid Voltage	—45 volts
D.C. Plate Current	75 ma.
D.C. Grid Current	15 ma.
Grid Driving Power	1.8 watts
Grid Bias Loss	0.67 watts
Power Input	14 watts
Approx. A.C. Load Impedance	1600 ohms

RK-23-25

RAYTHEON R-F Amplifier, Frequency Doubler, Oscillator, Suppressor, Control Grid or Plate Modulated Amplifier. As a doubler, approx. 12 watts can be obtained. This tube has large 7-pin base. Plate at top of tube.

Frequency Range: 100% ratings up to 30 mc.



Typical Low Power Buffer Circuit for RK-23, RK-25

Characteristics:	RK-23	RK-25
Heater Voltage	2.5	6.3 volts
Heater Current	2.0	0.8 amps.
Grid-Plate Cap.		0.2 mmfd.
Input Capacity		10 mmfd.
Output Capacity		10 mmfd.
Max Plate Dissipation		8 watts

R-F Service:

	Control Grid Modulation	Supp. Mod.	Class C Telegraphy	
D.C. Plate Voltage	500	500	500	500 v.
D.C Screen Voltage	200	200	200	200 v.
D.C. Suppress. Voltg.	45	—45	0	45 v.
D.C. Grid Voltage	—125	—90	—90	—90 v.
Peak RF Grid Voltage	150	135	135	135 v.
Peak AF Grid Voltage	45	75	...	...
D.C. Plate Current	34	32	50	55 ma.
D.C. Screen Current	20	40	40	35 ma.
D.C. Grid Current	1.5	6	6	6 ma.
Grid Driving Power	1.3	.8	.8	.8 watts
Grid Bias Loss	.2	.5	.5	.5 watts
Pwr. Output (approx.)	6.5	5.5	18	24 watts
Screen Resistor	20,000	7500	7500	8500 ohms.

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842

RCA Audio Frequency Amplifier and Modulator. Triode. Not as desirable as a type 2A3, which will provide more output at lower plate voltage.

Characteristics:	
Filament Voltage	7.5 volts
Filament Current	1.25 amps.
Grid-Plate Capacity	7 mmfd.
Grid-Filament Capacity	4 mmfd.
Plate-Filament Capacity	3 mmfd.
Amplification Factor	3
Max. Plate Dissipation	12 watts
Max. Plate Voltage	425 volts
Base	4-pin

Class A Audio Amplifier (1 Tube):		
Plate Voltage	350	425 volts
Grid Voltage	—72	—100 volts
Plate Current	34	28 ma.
Plate Resistance	2400	2500 ohms.
Mutual Conductance	1250	1200 micromhos.
Peak Grid AF Voltage	57	95 volts
Load Resistance	5600	8000 ohms.
Power Output	2.1	3.0 watts
Self-Bias Resistor	2120	3570 ohms.

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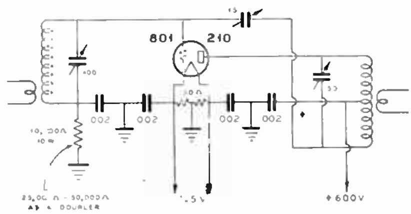
10

Triode. Class C Amplifier or Doubler. Class B Power Amplifier and Modulator for medium power transmitters. Crystal Oscillator in commercial transmitters (at 250 volts max. plate supply). Often operated at 750 to 900 volts plate supply and 75 ma. per tube in Class C Telegraphy, amateur service.

Frequency Range: Up to 15 mc. at normal ratings. May be operated on frequencies as high as 60 mc. at reduced plate voltage (400 volts) if tube is equipped with Ceramic base, or if molded bakelite bases are cross-slotted with hacksaw cut.

Characteristics:		
Filament Voltage		7.5 volts
Filament Current		1.25 amps.
Plate Voltage	350	425 max. volts
Grid Voltage	—31	—39 max. volts
Plate Current	16	18 ma.
Plate Resistance	5150	5000 oms.
Amplification Factor	8	8
Mutual Conductance	1550	1600 micromhos.
Load Resistance	11,000	10,200 oms.
Self-Bias Resistance	1950	2150 ohms.
Power Output	0.9	1.6 watts
Plate-Grid Cap.		7 mmfd.
Input Capacitance		4 mmfd.
Output Capacitance		3 mmfd.
Base		Medium 4 pin



210 or 801 Buffer-Doubler Circuit with Split Plate Coil, Requiring Minimum Grid Drive Under Load

Class C Amplifier (Telegraphy):			
D.C. Plate Voltage	400	500	600 v.
D.C. Plate Current	65	65	65 ma.
D.C. Grid Voltage	—100	—125	—150 v.
D.C. Grid Current	10	10	12 ma.
Approx. AC Load Imped.	3000	3800	4600 ohms.
Approx. Power Output	16	21	27 watts
R.F. Grid Excitation	2.7	3.0	3.8 watts
Grid Bias Loss	1.0	1.25	1.8 watts
Plate Loss	10	11.5	12 watts

Class B, A-F Amplifier:		
Plate Voltage	400	600 v.
Grid Bias	—50	—75 v.
Zero Sig. Plate Current (per tube)	4	4 ma.
Max. Sig. Plate Current (per tube)	65	65 ma.
Load Resistance (Plate to Plate)	6000	10,000 ohms.
Approx. Power Output (2 tubes)	27	45 watts

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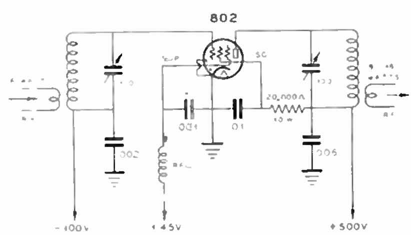
802

RCA Pentode. R-F Amplifier, Frequency Doubler, Oscillator Suppressor, Grid or Plate Modulated Amplifier. Plate at top of tube.

Frequency Range: 100% up to 30 mc., 55% at 60 mc.

Note: The internal shield should connect to cathode at the socket, in all circuits.



802 Pentode Low Power Buffer Stage

Characteristics:	
Heater Voltage	6.3 volts
Heater Current	0.8 amps.
Grid-to-Plate Capacity	0.15 mmfd.
Input Capacity	12 mmfd.
Output Capacity	8.5 mmfd.
Max. Plate Dissipation	10 watts
Max. Screen Dissipation	6 watts
Base	7 pin

802 Continued

R-F Service:

	Control Grid Modulation	Supp. Mod.	Class C Teleg.	
D.C. Plate Voltage..	500	500	500	500 volts
D.C. Screen Voltage..	200	200	200	200 volts
D.S. Suppress. Voltg.	0	—45	0	40 volts
D.C. Grid Voltage...	—130	—90	—100	—100 volts
Peak RF Grid Voltg.	145	125	155	135 volts
Peak AF Grid Voltg.	50	65	...	...
D.C. Plate Current ..	25	22	45	45 ma.
D.C. Screen Current..	8	28	22	12 ma.
D.C. Grid Current....	1	4.5	6	2 ma.
Grid Driving Power..	.8	.5	.9	.25 watts
Grid Bias Loss	.13	.4	.6	.2 watts
Pwr. Output (Approx.)	4	3.5	14	16 watts
Screen Resistor	37,500	10,700	13,700	20,000 ohms.

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WE-307A

Western Electric Pentode. Oscillator, High-Frequency Amplifier and Doubler, Suppressor-Modulated Amplifier. Designed for portable H.F. and U.H.F. transmitters.

Frequency Range: 100% ratings up to approx. 60 mc.

Unusual Feature: Quick-heating filament instead of heater for intermittent use in automobile transmitters.

Characteristics:

Filament Voltage	5.5 volts
Filament Current	1.0 amps.
Grid-to-Plate Cap	0.55 mmfd.
Input Cap.	15 mmfd.
Output Cap.	12 mmfd.
Max. Plate Dissipation	15 watts

R-F Service:

	Suppress. Mod.	Class C Teleg.
D.C. Plate Voltage	500	500 v.
D.C. Screen Voltage	200	200 v.
D.C. Suppress. Voltage..	—50	0 v.
D.C. Grid Voltage	—35	—35 v.
Peak R-F Grid Voltage	50	50 v.
Peak A.F. Grid Voltage	50	0 v.
D.C. Plate Current	40	52 ma.
D.C. Screen Current	21	18 ma.
Power Output (Approx.)	6	17 watts
Screen Resistor	14,000	14,000 ohms.

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841

RCA, Amperex, United. High-Mu ('10) Triode. Class B modulator. Class C RF amplifier or doubler. Oscillator. Resistance Coupled audio amplifier.

Frequency Range: 100% ratings up to 6 mc. New ceramic base types may be operated up to 30 mc at full ratings, which are about 50% higher than the 450 volt type listed.

Note: Grid excitation varies under different operating conditions; thus the driver stage should be capable of supplying twice as much power as listed for grid drive and bias loss.

Characteristics:

Filament Voltage	7.5 volts
Filament Current	1.25 amps.
Amplification Factor	30
Grid to Plate Capacity	7 mmfd.
Grid to Filament Capacity	4 mmfd.
Plate to Filament Capacity	3 mmfd.
Maximum Plate Dissipation	15 watts
Maximum DC Plate Voltage	450 volts
Maximum DC Plate Current	60 ma.
Maximum DC Grid Current	20 ma.
Base	UX-4-pin

Class B Modulator or AF Amplifier:

DC Plate Voltage	350	425 volts
DC Grid Voltage	—5	—5 volts
Zero Sig. Plate Current (per tube)	3.5	6.5 ma.
Maximum Sig. Plate Current (per tube)	57	60 ma.
Load Resistance (plate to plate)	5200	7000 ohms.
Power Output	21	28 watts

R-F Service

	Class C Telephony	Class C Telegraphy		Doubler
DC Plate Voltage......	350	450	600	450 volts
DC Grid Voltage.......	—36	—32	—74	—170 volts
DC Plate Current	50	50	50	28 ma.
DC Grid Current	18	12.5	12	8 ma.
Grid Driving Power (Approx.)	1.75	1.25	2.1	1.75 watts
Grid Bias Loss	.65	.4	.9	1.4 watts
Power Output (Approx.)	11.5	14	18.5	7.5 watts
Approx. A.C. Load Impedance	3500	4500	5400	8100 ohms
Mod. DC Load Resistance	7000	9000	12,000	.... ohms

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843

RCA Triode. Oscillator, AF power amplifier and R.F. Amplifier of the heater-cathode type for 2.5 volt filament supply. Not in general use.

Frequency Range: 100% ratings up to 6 mc. 50% at 30 mc.

Note: Grid driving power requirements vary over wide limits.

Characteristics:

Heater Voltage	2.5 volts
Heater Current	2.5 amps.
Amplification Factor	7.7
Grid to Plate Capacity	6 mmfd.
Grid to Cathode Capacity	5 mmfd.
Plate to Cathode Capacity	5 mmfd.
Maximum D.C. Plate Voltage	450 volts
Maximum D.C. Plate Dissipation	15 watts
Maximum D.C. Plate Current	40 ma.
Maximum D.C. Grid Current	7.5 ma.
Base	UX-5 pin

Class A Audio Amplifier:

D.C. Plate Voltage	350	425 volts
D.C. Grid Voltage (Approx.)...	—25	—35 volts
Peak Grid Swing (Approx.)....	25	35 volts
D.C. Plate Current	25	25 ma.
Plate Resistance	4700	4800 ohms.
Mutual Conductance	1700	1600 micromhos.
Load Resistance	9500	12,000 ohms.
Power Output	0.95	1.6 watts

Class C Amplifier:

	Plate Mod. Telephony		Telegraphy	
D.C. Plate Voltage..	250	350	350	450 volts
D.C. Grid Voltage..	—100	—140	—100	—149 volts
D.C. Plate Current..	30	30	30	30 ma.
D.C. Grid Current...	7	7	5	5 ma.
Grid Driving Power.	1.3	1.6	0.8	1.0 watts
Grid bias loss	0.7	1.0	0.8	1.5 watts
Power Input	7.5	10.5	10.5	13.5 watts
Power Output (Approx.)	4	6	6	8 watts

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844

RCA Screen-grid R. F. Amplifier—doubler or buffer. Oscillator. Not in general use.

Characteristics:

(Heater-Cathode Type)

Heater Voltage	2.5 volts
Heater Current	3.25 amps.
Amplification Factor	75
Grid to Plate Capacity	0.15 mmfd.
Input Capacity	9.5 mmfd.
Output Capacity	7.5 mmfd.
Maximum Plate Dissipation	15 watts
Maximum Screen Dissipation	3 watts
Maximum D.C. Plate Voltage	500 volts
Maximum D.C. Plate Current	30 ma.
Maximum D.C. Grid Current	5 ma.
Base	UX 5-pin

R-F Service

	Class B Telephony	Plate Mod. Class C	Class C Telegraphy	
D.C. Plate Voltage ...	500	500	400	500 volts
D.C. Screen Voltage...	180	150	175	175 volts
D.C. Grid Current....	—40	—100	—125	—125 volts
D.C. Plate Current ..	20	20	25	25 ma.
Power Output	3	4	6	9 watts

865

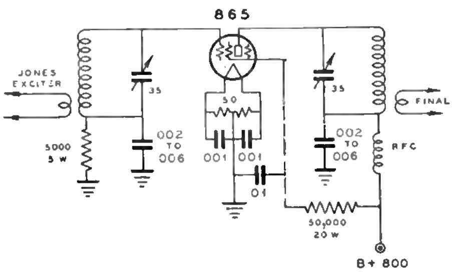
RCA Screen-Grid Tetrode. Buffer, amplifier, and frequency doublers. As a doubler about 5 to 10 watts may be obtained.

Characteristics:

Filament Voltage	7.5 volts
Filament Current	2.0 amps.
Grid to Plate Capacity	0.10 mmfd.
Input Capacity	8.5 mmfd.
Output Capacity	8.5 mmfd.
Plate Voltage	500 volts
Screen Voltage	125 volts
Grid Voltage	0 volts
Amplification Factor	130
Plate Resistance	200,000 ohms.
Mutal Conductance	750 micromhos
Plate Current	21 ma.
Maximum Plate Dissipation	15 watts
Base	4-pin. Plate through top of envelope

Class C Operation:

D.C. Plate Voltage	500	750 volts
D.C. Plate Current	50	40 ma.
D.C. Screen Voltage	125	125 volts
D.C. Grid Voltage	—80	—80 volts
D.C. Grid Current	9	5.5 ma.
Grid Driving Power (Approx.)	2.0	1.0 watts
Grid Bias Power Loss	.7	.45 watts
Plate Power Input	25	30 watts
Power Output (Approx.)	10	16 watts



Single 865 Buffer or Doubler Circuit

801

RCA, Amperex, United 310. Triode. Class C. RF amplifier for phone or cw. Class B modulators. Frequency doubler.

Caution: The values given for grid driving power and power output vary with frequency and load circuit impedance. The driving stage should have, if possible, twice as much power output as needed for grid driving power and bias supply loss.

Note: As a doubler, regeneration can be obtained at the output frequency to improve the output efficiency without requiring as high grid bias and grid drive as listed in the table.

Characteristics:

Filament Voltage	7.5 volts
Filament Current	1.25 amps.
Grid to Plate Capacity	6.0 mmfd.
Amplification Factor	8
Grid to Filament Capacity	4.5 mmfd.
Plate to Filament Capacity	1.5 mmfd.
Maximum Plate Dissipation	20 watts
Maximum D.C. Plate Voltage	600 volts
Maximum D.C. Plate Current	70 ma.
Maximum D.C. Grid Current	15 ma.
Base	UX-4 prong Isolantite

Class B Audio:

Plate Voltage	400	500	600	750 volts
Grid Voltage (Approx.)	—50	—60	—75	—90 volts
Zero Sig Plate Current (per tube)	4	5	4	6 ma.
Maximum Sig Plate Current (per tube)	65	65	65	65 ma.
Load Resistance (plate to plate)	6000	8000	10,000	12,000 ohms.
Power Output	27	36	45	60 watts

Class C Operation, Amplifier:

D.C. Plate Voltage	500	500	600	750 volts
D.C. Grid Bias	—190	—125	—150	—190 volts
D.C. Plate Current	55	65	65	65 ma.
D.C. Grid Current	15	10	15	15 ma.
Grid Driving Power (Approx.)	4.5	2.2	4	5.3 watts
Bias Supply Power Loss	2.9	1.2	2.25	2.9 watts
Power Output (Approx.)	18	16	25	35 watts
Approximate A.C. Load Resistance	4300	3600	4500	5500 ohms.
D.C. Modulator Load	9100	....	....	.... ohms.
Frequency Range	60	90	120	150 megacycles
Class C Telephony	480	360	310	2[illegible]0 volts
Class C Telegraphy	600	455	390	3[illegible]0 volts

Frequency Doubler	**No Regeneration**	**With Regeneration**
D.C. Plate Voltage	600	600 volts
D.C. Plate Current	75	75 ma.
D.C. Grid Voltage	—495	—250 volts
D.C. Grid Current	8	10 ma.
Grid Driving Power	4.75	3.5 watts
Grid Bias Supply Loss	4	2.5 watts
Power Output (Approx.)	25	25 watts
Plate Loss	20	20 watts

807

R.C.A. Beam Power Pentode Transmitter Tube. R-F buffer or doubler for frequencies up to 60 mc. at full rated input. 50% ratings at 150 mc. Also useful as crystal oscillator with external capacity connected between grid and plate. Class AB audio amplifier with 60 watts output for two tubes (see 6L6 characteristics). If care is taken in placement of parts and if shield is placed around tube and if the input circuits are shielded from the output circuits, no neutralization will be required for R-F circuits.

Characteristics:

Heater Voltage	6.3 volts
Heater Current	0.9 amps.
Grid to Plate Capacity	0.2 mmfd.
Input Capacity	11.6 mmfd.
Output Capacity	5.6 mmfd.
Maximum Plate Dissipation	21 watts
Maximum D.C. Plate Voltage	400 volts

Plate lead at top of envelope.
Standard 5-pin Ceramic base.

R-F Amplifier:

D.C. Plate Voltage	300	400 volts
D.C. Screen Voltage	250	250 volts
D.C. Grid Voltage	—50	—50 volts
Peak R-F Grid Voltage	80	80 volts
D.C. Plate Current	95	95 ma.
D.C. Screen Current	10	9 ma.
D.C. Grid Current	3	2.5 ma.
Grid Driving Power (Approx)	0.22	0.18 watts
Power Output (Approx.)	17.5	25 watts

RK-39

Raytheon Beam Power Tetrode. Designed for frequency doubling or as a crystal oscillator at higher plate voltages than can be used on 6L6 tube. This tube should be neutralized when operated as a buffer.

Characteristics:

Heater Voltage	6.3 volts
Heater Current	0.9 amps.
Grid to Plate Capacity	1.0 mmfd.
Input Capacity	12 mmfd.
Output Capacity	7.5 mmfd.
Maximum Plate Dissipation	20 watts
Maximum Screen Dissipation	3 watts
Maximum D.C. Plate Voltage	750 volts
Maximum Plate Current	80 ma.
Maximum Screen Current	10 ma.
Base	Standard 5-pin UX. Plate through top of envelope

Tetrode Crystal Oscillator:

	Tetrode Crystal Oscillator		Frequency Doubler		Class C.R.F.
D.C. Plate Voltage	500	750	500	750	750 volts
D.C. Plate Current	60	70	35	45	80 ma.
D.C. Screen Voltage	250	250	250	250	250 volts
D.C. Screen Current	6	7	10	7	10 ma.
D.C. Grid Bias	...	...	130	130	60 volts
D.C. Grid Current	...	...	2	2	4 ma.
Power Output	16	33	11	20	40 watts
Grid Driving Power	...	...	1	1	0.5 watts

250

RCA Audio Amplifier in radio receivers or as a low power modulator for transmitters.

Note: Not over 10,000 ohms resistance can be placed in the grid circuit without endangering tube operation. These tubes have been supplemented by more modern tubes, such as the 2A3 and 6L6.

Characteristics:

Filament Voltage	7.5 volts
Filament Current	1.25 amp.
Grid to Plate Capacity	9 mmfd.
Grid to Filament Capacity	5 mmfd.
Plate to Filament Capacity	3 mmfd.
Maximum Plate Dissipation	25 watts
Maximum Plate Voltage	450 volts
Base	4 pin

Class A Audio Amplifier:

Plate Voltage	350	400	450 max.	volts
Grid Voltage	—63	—70	—84	volts
Plate Current	45	55	55	milliamperes
Plate Resistance	1900	1800	1800	ohms.
Amplification Factor	3.8	3.8	3.8	
Mutual Conductance	2000	2100	2100	micromhos.
Load Resistance	4100	3670	4350	ohms.
Undistorted Power Output	2.4	3.4	4.6	watts

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WE-316A

U.H.F. oscillator or amplifier especially designed for operation at frequencies above 100 megacycles. The upper limit of oscillation as a regenerative negative grid oscillator is 750 mc.

Note: Outputs of approximately 8 watts can be obtained at ¾ meter, and 4 watts at ½ meter (600 mc.).

Characteristics:

Filament Voltage	2 volts
Filament Current	3.65 amps.
Thermionic Emission	.4 amp.
Amplification Factor	6.5
Grid to Plate Capacity	1.6 mmfd.
Grid to Filament Capacity	1.2 mmfd.
Plate to Filament Capacity	0.8 mmfd.
Maximum Plate Dissipation	30 watts
Maximum D.C. Plate Voltage	450 volts
Maximum D.C. Plate Current	80 ma.
Maximum D.C. Grid Current	10 ma.

All leads extend directly out from tube elements.

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WE-254B

Tetrode R. F. Amplifier. *Frequency Range:* 100% up to 15 mc. 66⅔% at 20 mc.

Characteristics:

Filament Voltage	7.5 volts
Filament Current	3.25 amps.
Plate to Grid Capacity	.085 mmfd.
Input Capacity	11.2 mmfd.
Output Capacity	5.4 mmfd.
Amplification Factor	100
Maximum Plate Dissipation	25 watts
Maximum Screen Dissipation	4 watts
Maximum D.C. Plate Voltage	750 volts
Maximum D.C. Plate Current	75 ma.
Maximum D.C. Grid Current	25 ma.
Base	4 prong, plate through top of envelope

R-F Service

	Class B r. f.	Class C Telegraphy	
D.C. Plate Voltage	750	500	750 volts
D.C. Screen Voltage	150	150	150 volts
D.C. Grid Voltage	—70	—125	—125 volts
D.C. Plate Current	50	75	75 ma.
Approximate Power Output	12.5	25	37.5 watts

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800

RCA or Amperex Triode. Class B Modulator. Class C RF Amplifier. Frequency doubler. U.H.F. oscillator and amplifier.

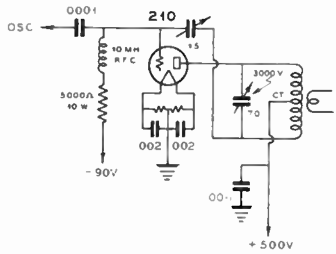
Frequency Range:	90	120	150	200 MC.
Class C plate Voltage (max)	1125	1000	875	650 Teleg.
	900	800	700	500 Telep.

Caution: Maintain at least 7.5 volts at filament terminals of tubes.

Note: Grid driving power is a function of load impedance, frequency and type of neutralizing circuit. The driver stage should be capable of supplying approximately twice as much power output as required for the listed values of grid drive and grid bias loss.

Class B RF Telephony: Plate voltage of 1000, plate current of 42, grid voltage —55, carrier power 14 watts.

Note: Regeneration at the output frequency in doubler operation will allow equivalent outputs without as high grid drive and grid bias.



DRIVER FOR PUSH-PULL CLASS C TYPE 800 TUBES

Characteristics:

Filament Voltage	7.5 volts
Filament Current	3.25 amps.
Amplification Factor	15
Maximum Plate Dissipation	35 watts
Grid to Plate Capacity	2.5 mmfd.
Grid to Filament Capacity	2.75 mmfd.
Plate to Filament Capacity	1.0 mmfd.
Maximum D.C. Plate Voltage	1250 volts
Maximum D.C. Plate Current	80 ma.
Maximum D.C. Grid Current	25 ma.
Base	4 pin

Plate and grid at top of envelope.

Class B Audio Amplifier:

D.C. Plate Voltage	750	1000	1250 volts
D.C. Grid Voltage (Approx.)	—40	—55	—70 volts
Zero Sig. Plate Current (per tube)	13	14	15 ma.
Load Resistance (plate to plate)	6400	12,500	21,000 ohms.
D.C. Plate Input	80	80	80 watts
Power Output (2 tubes)	90	100	106 watts

Class C R.-F. Amplifier (Telegraphy):

D.C. Plate Voltage	750	1000	1250 volts
D.C. Plate Current	70	70	70 ma.
D.C. Grid Voltage	—100	—135	—175 volts
D.C. Grid Current	15	15	15 ma.
Grid Driving Power	2.5	3.5	4.5 watts
Grid Bias Loss	1.5	2.0	2.6 watts
Approximate Power Output	35	50	65 watts
Power Input	52.5	70	87.5 watts
Approximate A.C. Load Impedance	5300	7100	9000 ohms.

R.-F. Frequency Doubler:

D.C. Plate Voltage	1000 volts
D.C. Plate Current	53.5 ma.
D.C. Grid Voltage	—517 volts
D.C. Grid Current	6 ma.
Grid Driving Power	3.8 watts
Grid Bias Loss	3.1 watts
Approximate Power Output	36 watts
A.C. Load Impedance (Approx.)	10,100 ohms

Class C R.F. Amplifier (Telephony):

D.C. Plate Voltage	750	1000 volts (max.)
D.C. Plate Current	70	70
D.C. Grid Voltage	—150	—200 volts
D.C. Grid Current	18	18 ma.
Grid Driving Power (Approx.)	5	6 watts
Grid Bias Loss	2.7	3.6 watts
Power Output (Approx.)	35	50 watts
A.C. Load Resistance (Approx.)	5300	7100 ohms.
Modulator D.C. Load	10,700	14,300 ohms.
Power Input	52.5	70 watts

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RK-30

Raytheon H. F. Triode. Similar to 800 in all respects. See 800 data.

Characteristics:

Filament Voltage	7.5 volts
Filament Current	3.25 amps.
Maximum Plate Dissipation	35 watts
Amplification Factor	14
Grid—Plate Capacity	2.5 mmfd.
Grid—Filament Capacity	2.75 mmfd.
Plate—Filament Capacity	2.75 mmfd.
Maximum D.C. Plate Voltage	1250 volts
Maximum D.C. Plate Current	115 ma.
Maximum D.C. Grid Current	25 ma.
Base	UX 4 pin

Plate and grid at top of envelope.

RK-20

Raytheon RF Amplifier. Frequency Doubler. Oscillator. Suppressor, Grid - or - Plate - modulated Amplifier.

Caution: Do not apply screen voltage without simultaneous application of plate voltage.

Frequency Range: 100% ratings up to 20 MC. The RK 20 has lower input and output capacitances than the 804, and may therefore be used more effectively at higher frequencies, such as 30 mc.

Characteristics:

Filament Voltage ....7.5 volts
Grid Current ....3.0 amps.
Grid to Plate Capacity....012 mmfd.
Input Capacity ....11 mmfd.
Output Capacity ....10 mmfd.
Maximum Plate Dissipation....40 watts
Maximum Screen Dissipation ....15 watts
Base ....UX 5 pin
Isolantite. Plate at top of envelope.

R-F Service

	Class B Telephony	Suppressor Modulation Telephony	Class C Telegraphy	
D.C. Plate Voltage..	1250	1250	1250	1250 volts
D.C. Screen Voltage..	300	300	300	300 volts
D.C. Suppressor Voltage	0	—45	0	45 volts
D.C. Grid Bias ...	—30	—100	—100	—100 volts
Peak R.F. Grid Volts	70	175	175	175 volts
Peak A.F. Grid Volts	..	75	...	... volts
D.C. Plate Current...	43	43	80	92 ma.
D.C. Screen Current..	15	36	37	32 ma.
D.C. Grid Current...	..	5	5	5 ma.
Grid Driving Power..	.5	.9	.9	.9 watts
Grid Bias Loss	..	.5	.5	.5 watts
Power Output (Approx.)	16	18	64	80 watts
Screen Resistor	60,000	25,000	26,000	29,000 ohms.

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804

RCA Pentode R. F. Amplifier. Frequency doubler. Oscillator. Suppressor, grid or plate modulated amplifier.

Caution: Do not apply screen voltage without simultaneous application of plate voltage.

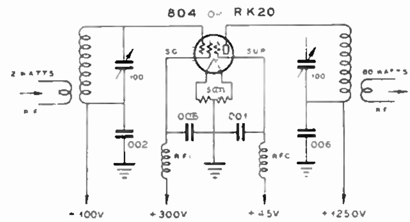
Frequency Range: 100% ratings at 15 mc. 75% at 35 mc. and 50% at 80 mc. Special attention should be given to shielding and by-passing at high frequencies.

Characteristics:

Filament Voltage ....7.5 volts
Filament Current ....3.0 amps.
Grid to Plate Capacity ....0.01 mmfd.
Input Capacity ....16 mmfd.
Output Capacity ....14.5 mmfd.
Maximum Plate Dissipation ....40 watts
Maximum Screen Dissipation ....15 watts
Mutual Conductance ....3250 micromhos.
UX-5 pin base plate at top of envelope.

R-F Service

	Class B Telephony	Suppressor Mod. Telephony		Pentode Class C Telegraphy	Tetrode Class C Telegraphy
D.C. Plate Voltage	1250	1000	1250	1250	1250 volts
D.C. Screen Voltage	300	300	300	300	180 volts
D.C. Suppressor voltage	45	—35	—50	45	180 volts
D.C. Grid Bias..	—20	—100	—100	—100	—100 volts
Peak R.F. Grid Volts	27	140	140	150	160 volts
Peak A.F. Grid Volts	..	60	70	..	... volts
D.C. Plate Current	45	45	48	92	92 ma.
D. C. Screen Current	11	33.5	35.5	27	23 ma.
D.C. Grid Current	1	5.5	7	7	8 ma.
Grid Driving Power.	.25	.7	.85	.9	1.2 watts
Grid Bias Loss...	..	.6	.7	.7	.8 watts
Power Output (Approx.)	16	16	21	80	80 watts
Screen Resistor ..	86,000	21,000	27,000	35,000	..... ohms.



Conventional Screen-Grid Buffer or Final Amplifier

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RK-35

Raytheon U.H.F. Triode. General purpose triode with tantalum plate. Class B Audio, R.F. Amplifier or oscillator.

Frequency Range: 80% of full ratings at 56 mc., 60% at 112 mc.

Note: Grid driving power requirements vary over wide limits, depending upon plate load, circuit losses and type of circuit.

Characteristics:

Filament Voltage ....7.5 volts
Filament Current ....3.25 amps.
Amplification Factor 8
Grid to Plate Capacity....2.7 mmfd.
Grid to Filament Capacity....3.5 mmfd.
Plate to Filament Capacity....0.4 mmfd.
Maximum Plate Dissipation....35 watts
Maximum D.C. Plate Voltage....1250 volts
Maximum D.C. Plate Current....100 ma.
Maximum D.C. Grid Current....20 ma.
Base......UX-4 pin. Plate at top, grid at side of envelope

R-F Service

	Class B r.f.	Grid Mod. r.f.	Class C
D.C. Plate Voltage..........	1000	1000	1000 volts
D.C. Grid Voltage..........	160	240	320 volts
D.C. Plate Current..........	52	50	96 ma.
D.C. Grid Current..........	..	..	15 ma.
Grid Driving Power..........	6	2.6	6.5 watts
Grid Bias Loss..........	..	..	5 watts
Power Input	52	50	96 watts
Power Output (Approx.)......	17	16	70 watts

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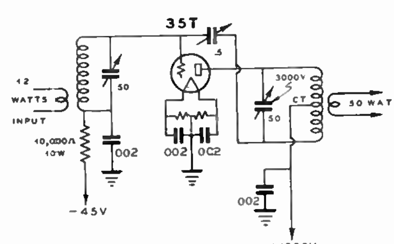
35-T

Eimac High-Mu Triode. Crystal oscillator for plate voltages up to 1200 volts. Class B modulator or AF amplifier. Class C buffer or doubler. Class C telephony. U.H.F. oscillators with quarter-wave line frequency control. U.H.F. r. f. amplifiers.

Frequency Range: 100% ratings up to 100 mc.

Note (1): For plate modulation, the values of grid bias should be increased at least 50%, and the grid drive will be approximately doubled.

Note (2): Values of grid bias and grid drive may be reduced with regenerative doubler circuits. The above values are for values of efficiencies between 58% and 68%. Lower grid bias and drive give lower efficiencies. With regeneration, the bias may be reduced to approximately ⅓ of the above values without loss of output. The bias should never be less than 3½ times cut-off bias when doubling.



REGENERATIVE FREQUENCY DOUBLER OR QUADRUPLER

Characteristics:

Filament Voltage ....5 to 5¼ volts
Filament Current ....4 amps
Amplication Factor (Average)............................30
Maximum Normal Plate Dissipation...............35 watts
Grid to Plate Capacity............................1.9 mmfd.
Maximum D.C. Plate Voltage....................1500 volts
Maximum D.C. Plate Current........................150 ma.
Maximum D.C. Grid Current........................25 ma.
Base: UX-4 pin. Plate at top of envelope.

Class B Audio Amplifier (2 tubes):

D.C. Plate Voltage.	500	750	1000	1250	1500 volts
D.C. Grid Voltage.	0	—10	—22.5	—40	—50 volts
Zero Signal D.C. Plate Current	65	50	40	20	16 ma.
Maximum Signal D.C. Plate Current	200	200	188	158	110 ma.
Load Resistance (Plate to Plate)..	4000	7000	11000	17200	23600 ohms
Driving Power	6.5	8.5	7.5	5.5	4.5 watts
Output Power	50	90	120	130	140 watts

Class C r.f. Amplifier Telegraphy (Buffer Service)

D.C. Plate Voltage........	400	750	1000	1500 volts
D.C. Grid Voltage...	—20	—38	—50	—100 volts
D.C. Plate Current.......	90	90	90	90 ma.
D.C. Grid Current........	15	18	20	20 ma.
Grid Driving Power (Approx.)	2	3.0	3.5	4.5 watts
Grid Bias Loss...........	.3	.7	1	2 watts
Power Input	36	67.5	90	135 watts
Power Output (Approx.)...	20	47.5	62	101 watts
A.C. Load Resistance......	1700	3500	5200	8400 ohms

Frequency Doubler (Without Regeneration):

D.C. Plate Voltage..........	750	1250	1500 volts
D.C. Grid Voltage...........	—115	—502	—530 volts
D.C. Plate Current..........	87	85	87 ma.
D.C. Grid Current..........	10	10	10 ma.
Grid Driving Power.........	5	6.5	6.8 watts
Grid Bias Loss	4.5	5	5.3 watts
Power Input	65	106	130 watts
Power Output	37.5	72	90 watts
A.C. Load Resistance........	4000	7600	9500 ohms

Regenerative Frequency Doubler:

D.C. Plate Voltage....................	750	1000 volts
D.C. Grid Voltage....................	—90	—150 volts
D.C. Plate Current....................	100	80 ma.
D.C. Grid Current....................	20	20 ma.
Grid Driving Power....................	4.5	5.5 watts
Grid Bias Loss.......................	1.8	3 watts
Power Input	75	80 watts
Power Output (Approx.)...............	40	50 watts

RK-18

Raytheon H. F. Triode. Class B modulator. Class C r. f. amplifier or oscillator. Buffer or doubler.

Note (1): Values of grid drive will vary with load resistance, circuit design, and losses; thus the driver stage should be capable of supplying approximately twice as much output as listed for grid drive and bias loss.

Note (2): The efficiency of a doubler at a lower value of grid bias than that listed may be improved by regeneration at the output frequency.

Frequency Range: 100% ratings up to 30 KC.

Characteristics:

Filament Voltage ....7.5 volts
Filament Current ....3.0 amps.
Amplification Factor 18
Grid to Plate Capacity..........................4.8 mmfd.
Grid to Filament Capacity......................4.6 mmfd.
Plate to Filament Capacity......................2.9 mmfd.
Maximum Plate Dissipation ....40 watts
Maximum D.C. Plate Voltage....................1000 volts
Maximum D.C. Plate Current......................85 ma.
Maximum D.C Grid Current........................25 ma.
Base ....UX-4 pin. Plate at top of envelope

Class B Modulator or A.F. Amplifier:

D. C. Plate Voltage...............	750	1000 volts
D.C. Grid Voltage................	—40	—50 volts
Peak A.F. Grid Voltage (per tube)	90	100 volts
Zero Signal D.C. Plate Current (per tube)	5	7 ma.
Maximum Signal D.C. Plate Current (per tube)...............	80	80 ma.
Load Resistance (Plate to Plate)...	10,000	12,000 ohms
Power Output (2 Tubes)...........	65	100 watts

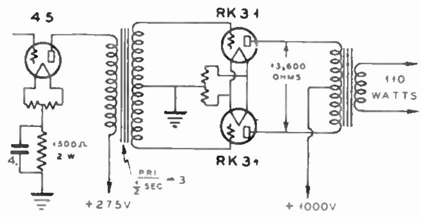
R-F Service

	Class C Telegraphy Final	Class C Telegraphy Buffer	Frequency Doubler
D.C. Plate Voltage.......	1000	1000	1000 volts
D.C. Grid Voltage.......	—122	—80	—125 volts
D.C. Plate Current......	88	80	64 ma.
D.C. Grid Current.......	22	15	10 ma.
Grid Driving Power......	6.0	2.7	5.3 watts
Grid Bias Loss..........	2.7	1.2	4.3 watts
Power Input	88	80	64 watts
Approximate Power Output	60	42	35 watts
Approximate A.C. Load Impedance	5300	5850	7000 ohms
Efficiency	68	52.5	55%

RK-31

Raytheon High Mu Triode. Primarily a Class B Audio Amplifier. May be used for R.F.

Note: R.F. grid excitation requirements vary widely, thus the driver stage should be designed with ample factor of safety for output needs.



CLASS B AUDIO AMPLIFIER OR MODULATOR

Characteristics:

Filament Voltage ....7.5 volts
Filament Current ....3.0 amps.
Amplification Factor Varies with Input...........high mu.
Maximum Plate Dissipation.......................40 watts
Maximum D.C. Plate Voltage....................1250 volts
Maximum D.C. Plate Current......................85 ma.
Base ....UX 4 pin. Plate at top of envelope

Class B Modulator or AF Amplifier:

D.C. Plate Voltage............	1000	1250 volts (max.)
D.C. Grid Voltage.............	0	0 volts
Grid Driving Power (2 tubes).	900	900 milliwatts
Zero Signal D.C. Plate Current (per tube)	12	15 ma.
Maximum Signal D.C. Plate Current (per tube)..........	80	80 ma.
Load Resistance (Plate to Plate)	13,600	17000 ohms
Power Output (2 tubes)........	110	110 watts

R-F Service

	Class C Telegraphy	Frequency Doubler
D.C. Plate Voltage................	1250	1000 volts
D.C. Grid Voltage................	—90	—300 volts
D.C. Plate Current................	85	85 ma.
D.C. Grid Current................	25	15 ma.
Grid Driving Power...............	5.25	6 watts
Grid Bias Loss....................	2.25	4.5 watts
Power Input	106	85 watts
Approximate Power Output.........	76	52 watts
Approximate A.C. Load Impedance..	7250	5100 ohms

WE-300A

Western Electric Class A audio amplifier or modulator, especially suitable for automobile transmitters.

Note: If fixed C bias is used, the plate current should be limited to not over 70 ma.

Characteristics:

Filament Voltage ....5.0 volts a.c. or d.c.
Filament Current ....1.2 amps.
Amplification Factor (Approx.)......................3.8
Grid to Plate Capacity..........................15 mmfd.
Grid to Filament Capacity........................9 mmfd.
Plate to Filament Capacity......................4.3 mmfd.
Maximum Plate Dissipation......................40 watts
Maximum D.C. Plate Voltage....................450 volts
Maximum D.C. Plate Current......................100 ma.

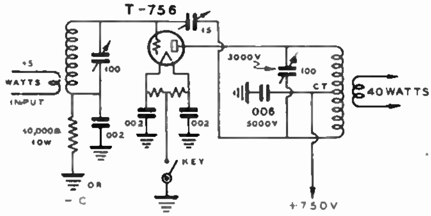
Class A (Single Tube) Modulator:

D.C. Plate Voltage....	200	250	350	450 volts
D.C. Grid Voltage....	—39	—45	—71	—97 volts
D.C. Plate Current....	40	80	80	80 ma.
Load Resistance	2500	1500	2200	3000 ohms.
Power Output	2.6	5.0	9.6	14.6 watts

756

Taylor Triode for Doubler and Class C operation. Class B audio amplifier.

Note: Grid drive requirements vary widely under different operating conditions.



R F DOUBLER OR NEUTRALIZED BUFFER

Characteristics:

Filament Voltage	7.5 volts
Filament Current	2 amps.
Amplification Factor	25
Grid to Plate Capacity	8 mmfd.
Grid to Filament Capacity	3.5 mmfd.
Plate to Filament Capacity	2.7 mmfd.
Maximum Plate Dissipation	40 watts
Maximum D.C. Plate Voltage	850 watts
Maximum D.C. Plate Current	110 ma.
Maximum D.C. Grid Current	20 ma.
Base	UX-4 pin. Isolantite.

Class B Audio Amplifier (2 Tubes):

D.C. Plate Voltage	850 volts
D.C. Grid Voltage	—30 volts
Zero Signal Plate Current	20 ma.
Maximum Signal Plate Current	225 ma.
Load Impedance (Plate to Plate)	6750 ohms.
Power Output	100 watts

Class C R.F. Amplifier:

	Plate Mod. Telephony	Telegraphy	
D.C. Plate Voltage	750	750	850 volts
D.C. Grid Voltage	—80	—75	—85 volts
D.C. Plate Current	90	110	110 ma.
D. C. Grid Current	20	16	16 ma.
Grid Driving Power (Approx.)	5	3.5	3.7 watts
Grid Bias Loss	1.6	1.2	1.4 watts
Power Input	67.5	82.5	93.5 watts
Power Output	40	50	60 watts

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825

Taylor 40 watt Triode. Intermediate between 801 and 211 tubes. Class B audio amplifier operating in the Class AB region. Class B r.f. amplifier for telephony or telegraphy in high frequency transmitters.

Note: Grid drive requirements vary widely under various current conditions.

Characteristics:

Filament Voltage	7.5 volts
Filament Current	2 amps.
Amplification Factor	8
Grid to Plate Capacity	7 mmfd.
Grid to Filament Capacity	3 mmfd.
Plate to Filament Capacity	2.7 mmfd.
Maximum Plate Dissipation	40 watts
Maximum D.C. Plate Voltage	850 volts
Maximum D.C. Plate Current	110 ma.
Maximum D.C. Grid Current	25 ma.
Base	UX-4 pin

Class B Audio Amplifier (2 Tubes):

D.C. Plate Voltage	850 volts
D.C. Grid Voltage (Approx.)	—67.5 volts
Zero Signal D.C. Plate Current	50 ma.
Maximum Signal D.C. Plate Current	170 ma.
Load Impedance (Plate to Plate)	8000 ohms.
Power Output	80 watts

Class C R-F Amplifier:

	Plate Mod. Telephony	Telegraphy	
D.C. Plate Voltage	750	750	850 volts
D.C. Grid Voltage	—235	—180	—225 volts
D.C. Plate Current	80	100	100 ma.
D.C. Grid Current	20	15	15 ma.
Grid Driving Power (Approx.)	6	4.3	4.8 watts
Grid Bias Loss	4.7	2.7	3.4 watts
Power Input	60	75	85 watts
Power Output	40	45	55 watts

930

United Electronics Co. Triode. Amperex (830). Oscillator, modulator, r.f. amplifier, generally as a neutralized r.f. amplifier or buffer stage in high frequency transmitters.

Note: Intermediate between 211 and 210 or 801 in operation.

Frequency Range: 100% ratings up to 6 MC.

Characteristics:

Filament Voltage	10 volts
Filament Current	2 amps.
Amplification Factor	8
Grid to Plate Capacity	9.9 mmfd.
Grid to Filament Capacity	4.9 mmfd.
Plate to Filament Capacity	2.2 mmfd.
Maximum Plate Dissipation	40 watts
Maximum D.C. Plate Voltage	750 volts
Maximum D.C. Plate Current	110 ma.
Maximum D.C. Grid Current	18 ma.
Base	UX 4 pin

R-F Service

	Class B Telephony	Class C Plate Mod. Telephony	Class C Telegraphy
D.C. Plate Voltage	750	600	750 max. v.
D.C. Grid Voltage	—95	—180	—180 volts
D.C. Plate Current	80	100	110 ma.
D.C. Grid Current	...	15	15 ma.
Grid Driving Power	...	5	5 watts
Grid Bias Loss	...	2.7	2.7 watts
Power Input	60	60	82.5 watts
Power Output	20	40	55 watts

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841A

Taylor H. F. Triode. Doubler or buffer stage in high power transmitters. R.F. Amplifier down to 7½ meters.

Note: Grid driving power requirements vary over wide limits under operating conditions.

Characteristics:

Filament Voltage	10 volts.
Filament Current	2 amps.
Amplification Constant	14.6
Grid to Plate Capacity	9 mmfd.
Grid to Filament Capacity	3.5 mmfd.
Plate to Filament Capacity	2.5 mmfd.
Maximum Plate Dissipation	50 watts
Maximum D.C. Plate Voltage	1250 volts
Maximum D.C. Plate Current	150 ma.
Maximum D.C. Grid Current	30 ma.
Base	UX 4 pin

Class C R-F Amplifier:

D.C. Plate Voltage	1000 volts
D.C. Grid Voltage	-180 volts
D.C. Plate Current	150 ma.
D.C. Grid Current	20 ma.
Grid Driving Power	7 watts
Grid Bias Loss	3.6 watts
Power Input	150 watts
Power Output	100 watts

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830B

RCA 830-B. United Electronics Co. 930-B. Class B modulator for outputs up to 175 watts. May be driven by a push-pull 45 or 2A3 driver stage. Also used for RF.

R.F. Frequency range: 100% ratings up to 15 mc. 75% at 30 mc. 50% at 60 mc.

Note: R. F. Grid driving power requirements vary with load impedance, circuit design and circuit losses with increase of frequency. The driver stage should be capable of supplying twice as much power output as listed for grid drive and grid bias loss.

Characteristics:

Filament Voltage	10 volts
Filament Current	2 amps.
Amplification Factor	25
Maximum Plate Dissipation	60 watts
Grid to Plate Capacity	11 mmfd.
Grid to Filament Capacity	5 mmfd.
Plate Filament Capacity	1.8 mmfd.
Max. D.C. Plate Voltage	1000 volts
Maximum D.C. Grid Current	60 ma.
Maximum D.C. Plate Current	150 ma.
Base	UX 4 pin

Plate at top of envelope.

Class B Modulator or A-F Amplifier:

D.C. Plate Voltage	800	1000 volts
D.C. Grid Voltage	—27	—35 volts
Peak Grid to Grid A-F Volts	250	270 volts
Zero Sig. D.C. Plate Current (2 tubes)	20	20 ma.
Maximum Sig. D.C. Plate Current (2 tubes)	280	280 ma.
Eff. Load Resistance (Plate to Plate)	6000	7600 ohms
Grid Driving Power	5	6 watts
Maximum Sig. Power Output	110	150 watts

R-F Service

	Class B R-F	Class C Telephony	Class C Telegraphy		Frequency Doubler
D.C. Plate Voltage	1000	800	600	1000	1000 volts
D. C. Plate Current	85	95	140	140	75 ma.
D.C. Grid Bias	—35	—150	—95	—110	—435 volts
D.C. Grid Current	6	20	30	30	15 ma.
Grid Driving Power (Approx.)	6*	5	6	7	8.5 watts
Grid Bias Loss	2	3	2.8	3.3	6.5 watts
Power Input	85	76	84	140	75 watts
Power Output (Approx.)	26	50	45	90	45 watts
Mod. D.C. Load Resist.	...	8400	...	...	... ohms
Approximate A.C. Load Impedance	...	4200	2150	3600	... ohms

*At Peak.

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834

RCA U.H.F. amplifier and oscillator. *Frequency Range:* Up to 350 megacycles.

Rated input at 100 mc.—100%
Rated input at 350 mc.— 50%

Note (1): Grid driving power varies with type of circuit used, load impedance, and frequency range (dielectric and circuit losses increase with frequency). Driver should be capable of twice as much output as listed for grid drive and bias loss, as a factor of safety in design.

Note (2): Regeneration in the frequency doubler will allow lower values of grid bias and grid drive for same output power.

Characteristics:

Filament Voltage ....7.5 volts
Filament Current ....3.25 amps.
Amplification Factor 10.5
Grid to Plate Capacity ....2.6 mmfd.
Grid to Filament Capacity ....2.2 mmfd.
Plate to Filament Capacity ....0.6 mmfd.
Maximum Plate Dissipation ....50 watts
Maximum D.C. Plate Voltage ....1250 volts
Maximum D.C. Plate Current ....100 ma.
Maximum D.C. Grid Current ....20 ma.
Base ....UX 4 pin
Plate and Grid Through Top of Tube Envelope.

R-F Amplifier

	Class C Telegraphy Amplifier	Class C Telegraphy Doubler	Class C Telephony	Class B Telephony
D.C. Plate Voltage	1250	1000	1000	1000 volts
D.C. Plate Current	95	78	90	50 ma.
D.C. Grid Current	15	10	17.5	0.5 ma.
D.C. Grid Voltage	—193	—684	—310	—90 volts
Grid Driving Power	4.8	8.4	7.5	3 watts
Grid Bias Loss	2.9	6.8	5.5	... watts
Power Input	119	78	90	50 watts
Approx. Power Output	89	45	60	16 watts
Approx. AC Load Imped.	6500	6600	5500	... ohms
Max. DC Load Imped.	...	...	11,100	... ohms

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304B

Western Electric U.H.F. oscillator or amplifier up to 300 mc.

Frequency	Class C Telegraphy Plate Volts	Oscillator Plate Volts
100 mc.	1250	1000
200 mc.	1000	800
300 mc.	750	600

Characteristics:

Filament Voltage ....7.5 volts
Filament Current ....3.25 amps.
Amplification Factor 11
Grid to Plate Capacity ....2.5 mmfd.
Grid to Filament Capacity ....2.0 mmfd.
Plate to Filament Capacity ....0.7 mmfd.
Maximum Plate Dissipation ....50 watts
Maximum D.C. Plate Voltage ....1250 volts
Maximum D.C. Plate Current ....100 ma.
Maximum D.C. Grid Current ....25 ma.
Base ....UX 4 pin
Plate and Grid at Top of Envelope.

Class B Audio Amplifier (2 tubes):

D.C. Plate Voltage	750	1000	1250 volts
D.C. Grid Voltage	—55	—85	—110 volts
Max. Sig. D.C Plate Cur.	200	200	200 ma.
Zero Sig. D.C. Plate Cur.	40	40	40 ma.
Load Res. (Plate to Plate)	7000	10,000	14,000 ohms
Power Output	85	110	140 watts
Driver Power	10	10	10 watts

Class C Service:—See 834.

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808

RCA Tantalum Plate Triode. High-Frequency Oscillator and Amplifier. 100% ratings up to 30 MC. 50% ratings at 130 MC.

Characteristics:

Filament Voltage ....7.5 volts
Filament Current ....4 amps.
Amplification Factor 47
Grid to Plate Capacity ....3 mmfd.
Grid to Filament Capacity ....5 mmfd.
Plate to Filament Capacity ....0.2 mmfd.
Standard UX-4 pin base.
Plate through top, grid through side of envelope.

Class B Audio Amplifier (2 Tubes):

D.C. Plate Voltage	1250	1500 volts
D.C. Grid Voltage	—15	—25 volts
Zero Signal D.C. Plate Current	40	30 ma.
Maximum Signal D.C. Plate Current	230	190 ma.
Load Resistance (plate-to-plate)	12700	18300 ohms
Grid Driving Power	7.8	4.8 watts
Power Output, Approximate	190	185 watts

Class C RF Amplifier:

	Plate Mod. Telephony	Class C Telegraphy	
D.C. Plate Voltage	1250	1250	1500 volts
D.C. Grid Voltage	—225	—150	—200 volts
D.C. Plate Current	100	135	125 ma.
D.C. Grid Current	32	30	30 ma.
Grid Driving Power	10.5	8	9.5 watts
Grid Bias Loss	7	4.5	6 watts
Power Output (Approximate)	105	120	140 watts

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RK-32

Raytheon U.H.F. Triode. Similar to 834 in all respects. See 834 data.

Characteristics:

Filament Voltage ....7.5 volts
Filament Current ....3.25 amps.
Amplification Factor 11
Grid to Plate Capacity ....3.0 mmfd.
Grid to Filament Capacity ....2.0 mmfd.
Plate Filament Capacity ....1.0 mmfd.
Maximum Plate Dissipation ....50 watts
Maximum D.C. Plate Voltage ....1250 volts
Maximum D.C. Plate Current ....100 ma.
Maximum D.C. Grid Current ....20 ma.
Base ....UX 4 pin
Plate and Grid at Top of Envelope.

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RK-37

Raytheon High-Mu Triode, Tantalum Plate. Oscillator or Amplifier for very high frequency operation. 100% ratings up to 30 MC. 80% ratings at 56 MC. 60% ratings at 112 MC.

Characteristics:

Filament Voltage ....7.5 volts
Filament Current ....3.25 amps.
Maximum Plate Dissipation ....35 watts
Maximum D.C. Plate Voltage ....1250 volts
Maximum D.C. Plate Current ....100 ma.
Maximum D.C. Grid Current ....25 ma.
Grid to Plate Capacity ....2.9 mmfd
Grid to Filament Capacity ....3.2 mmfd
Plate to Filament Capacity ....0.3 mmfd
Standard UX-4 pin base.
Plate through top, grid through side of envelope.

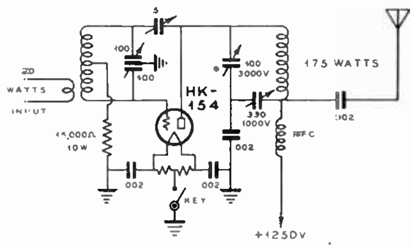
R. F. Service

	Class B R.F.	Grid Mod. Telephony	Class C
D.C. Plate Voltage	1000	1000	1000 volts
D.C. Grid Voltage	—45	—52.5	—70 volts
D.C. Plate Current	50	50	95 ma.
D.C. Grid Current	....	....	20 ma.
Peak RF Grid Power	2.3	[illegible].3	3.0 watts
Peak Audio Voltage	....	45	.. volts
Carrier Output Power	15	15	60 watts

HK-154

Heintz & Kaufman. General purpose U.H.F. and H.F. triode. Tantalum plate and grid.

Note: Grid drive requirements vary widely under different operating conditions.



GRID NEUTRALIZED FINAL AMPLIFIER

Characteristics:

Filament Voltage ....5.0 volts
Filament Current ....6.5 amps.
Amplification Factor 6.7
Grid to Plate Capacity ....5 mmfd.
Maximum Plate Dissipation ....50 watts
Maximum D.C. Plate Voltage ....1500 volts
Maximum D.C. Plate Current ....175 ma.
Maximum D.C. Grid Current ....30 ma.
Base ....UX-4 pin.
Grid and Plate Leads Through Opposite Sides of Envelope.

A-F Amplifier (2 tubes):

D.C. Plate Voltage	750	1000	1500 volts
Power Output	150	200	250 watts
Grid Driving Power (Approx.)	10	10	10 watts

R-F Service

	Class B R-F		Class C R-F		
D.C. Plate Voltage	750	1500	750	1000	1500 volts
D.C. Plate Current	80	56	175	175	175 ma.
D.C. Grid Voltage	—112	—225	—275	—350	—500 volts
D.C. Grid Current	...	...	20	20	20 ma.
Approx. Grid Driving Power	...	...	6	10	13 watts
Grid Bias Loss	...	...	5.5	7	10 watts
Approx. Power Output	18	28	85	125	200 watts

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T-55

Taylor Class C r.f. Amplifier. U.H.F. oscillator down to 2 meters wavelength.

Characteristics:

Filament Voltage ....7.5 volts
Filament Current ....3.25 amps.
Amplification Factor 20
Grid to Plate Capacity ....2.5 mmfd.
Grid to Filament Capacity ....1.7 mmfd.
Plate to Filament Capacity ....0.7 mmfd.
Maximum Plate Disipation ....55 watts
Maximum D.C. Plate Voltage ....1500 volts
Maximum D.C. Plate Current ....150 ma.
Maximum D.C. Grid Current ....40 ma.
Base ....UX-4 pin.
Plate at Top of Envelope.

Class C R-F Amplifier:

D.C. Plate Voltage ....1500 volts
D.C. Grid Voltage ....—180
D.C. Plate Current ....150 ma.
D.C. Grid Current ....30 ma.
Grid Driving Power ....10 watts
Grid Bias Loss ....5.5 watts
Power Input ....225 watts
Power Output ....170 watts

Class B Audio Amplifier (Two Tubes):

D.C. Plate Voltage	1000 volts	1500 volts
D.C. Grid Voltage (Approx.)	—45 volts	—67.5 volts
Zero D.C. Signal Plate Current	40 ma.	40 ma.
Load Resistance, Plate to Plate	10,000 ohms	12,000 ohms
Audio Output (2 tubes)	125 watts	175 watts

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WE-305A

Western Electric R.F. amplifier, oscillator or harmonic generator at ultra-high frequencies.

Frequency Range: 100% ratings up to 50 mc. 50% plate voltage rating at 100 mc.

Note: Plate, screen, and filament center-tap leads come out through rods at top of tube to enable short leads at very high frequencies. Cooling lugs of copper are needed for operation at frequencies above 50 mc.

Characteristics:

Filament Voltage ....10 volts
Filament Current ....3.1 amps.
Plate to Grid Capacity ....0.14 mmfd.
Input Capacity ....10.5 mmfd.
Output Capacity ....5.4 mmfd.
Maximum Plate Dissipation ....60 watts
Maximum Screen Dissipation ....6 watts
Maximum D.C. Plate Voltage ....1000 volts
Maximum D.C. Screen Voltage ....200 volts
Maximum D.C. Plate Current ....125 ma.
Maximum D.C. Grid Current ....40 ma.

R-F Service

	Class B R-F	Class C R-F		
D.C. Plate Voltage	1000	1000	750	500 volts
D.C. Grid Voltage	—135	—250	—175	—200 volts
D.C. Screen Voltage	200	200	200	200 volts
D.C. Plate Current	90	125	125	125 ma.
Approx. Power Output	30	85	65	42 watts

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WE-282A

Western Electric Tetrode. Screen-grid r.f. amplifier or frequency doubler.

Frequency Range: 100% ratings up to 30 mc. 50% ratings at 60 mc.

Characteristics:

Filament Voltage ....10 volts
Filament Current ....3 amps.
Amplification Factor 100
Plate to Grid Capacity ....0.2 mmfd.
Input Capacity ....12.2 mmfd.
Output Capacity ....6.8 mmfd.
Maximum Plate Dissipation ....70 watts
Maximum D.C. Plate Voltage ....1000 volts
Maximum D.C. Plate Current ....100 ma.
Maximum D.C. Grid Current ....50 ma.
Maximum Screen-Grid Dissipation ....5 watts
Base ....Standard 4 pin 50 watt

R-F Service

	Class B R-F	Class C Telegraphy	
D.C. Plate Voltage	1000	750	1000 volts
D.C. Grid Voltage	—90	—150	—150 volts
D.C. Screen Grid Voltage	150	150	150 volts
D.C. Plate Current	100	100	100 ma.
Plate Power Input	100	75	100 watts
Approximate Power Output	33	50	67 watts

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HF-100

Amperex Triode. H.F. and U.H.F. amplifier or oscillator down to 2 meters in wavelength.

Note: Similar to 830-B, except for lower interelectrode capacities and ability to operate efficiently in U.H.F. applications.

Characteristics:

Filament Voltage ....10 to 10.5 volts
Filament Current ....2 amp.
Amplification Factor 23
Grid to Plate Capacity ....4.5 mmfd.
Grid to Filament Capacity ....3.5 mmfd.
Plate to Filament Capacity ....1.4 mmfd.
Maximum Plate Dissipation ....75 watts
Maximum D.C. Plate Voltage ....1500 volts
Maximum D.C. Plate Current ....150 ma.
Maximum DC. Grid Current ....30 ma.
Base ....Standard 4 prong base (UX)
Plate Out Top, Grid Out Side of Envelope Carbon plate.

Class C R-F Service:

	30 mc. or Lower	120 mc.
D.C. Plate Voltage	1500	1000 volts
D.C. Grid Voltage	—200	—110 volts
D.C. Plate Current	150	120 ma.
D.C. Grid Current	20	20 ma.
Grid Drive (Approx.)	7	6 watts
Grid Bias Loss	4	2.2 watts
Power Output (Approx.)	170	70 watts
Maximum Plate Dissipation	75	50 watts

50T

Eimac general purpose H.F. and U.H.F. triode. Tantalum plate and grid. The low inter-electrode capacitances and small physical size make this tube very effective for ultra-high frequency amplification.

Frequency Range: 100% ratings up to 80 mc.

Note: Values of grid excitation vary considerably with load impedance, circuit design, and losses at higher frequencies; thus the driver should be designed to furnish approximately twice as much output as listed for grid drive and bias loss.

Characteristics:

Filament Voltage	5 to 5.25 volts
Filament Current	6 amps.
Amplification Factor (Avg.)	11
Grid to Plate Capacity	2 mmfd.
Grid to Filament Capacity	2 mmfd.
Plate to Filament Capacity	0.4 mmfd.
Maximum Plate Dissipation	75 watts
Maximum Plate Voltage	3000 volts
Maximum Plate Current	125 ma.
Maximum Grid Current	30 ma.
Base	UX-4 pin.

Plate at top, grid at side of envelope.

Class B Audio Amplifier (2 tubes):

DC plate voltage	1000	1500	2000	2500	3000 volts
D.C. Grid Voltage (Approx.)	—80	—135	—180	—225	—275 volts
Zero Sig. D.C. Plate Current (Approx.)	20	20	20	20	20 ma.
Max. Sig. D.C. Plate Current	250	230	200	180	160 ma.
Load Resistance (Plate to Plate)	5000	12,000	20,000	30,000	45,000 ohms
Driving Power	7	7	7	7	7 watts
Output Power	106	200	250	300	350 watts

R-F Service

	Plate Mod. Telephony		Class C Telegraphy			Frequency Doubler
D.C. Plate Voltage	1500	2500	1000	2000	3000	2000 volts
D.C. Grid Voltage	—350	—600	—200	—400	—600	—810 volts
D.C. Plate Current	100	100	125	125	125	100 ma.
D.C. Grid Current	25	25	25	25	25	15 ma.
Grid Driving Power (Ap.)	12.5	19	9	14	19	14 watts
Grid Bias Loss	9	15	5	10	15	12 watts
Power Input	150	250	125	250	375	200 watts
Power Output (Approx.)	105	185	90	197	300	132 watts
A.C. Load Resistance	8000	13,000	4000	8500	13,000	18,000 ohms
Mod D.C. Load	15,000	25,000	...	...	...	... ohms

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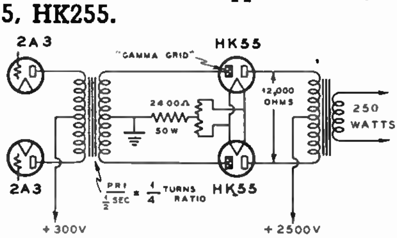
H-K Heintz and Kaufman Gridless Gammatrons, Types HK55, HK 155, HK255.



HIGH OUTPUT CLASS A AUDIO AMPLIFIER

Characteristics:

	Type 55	Type 155	Type 255
Filament Voltage	6.0	5	14 volts
Filament Current	3	10	30 amps.
Normal Plate Dissipation	75	150	500 watts
Amplification Factor	3.5	2	3
Maximum D.C. Plate Current	150	300	1000 ma.
Maximum D.C. Plate Voltage	1250	3000	5000 volts
Plate Impedance	1200	1100	1000 ohms.

Unusual Features:

Control element is a gamma plate of tantalum.

Filament is between regular plate and gamma plate.

Uses: Oscillators, audio and radio frequency amplifiers. Nearly complete plate current variation may be secured without driving the control (gamma plate) element positive.

Type 255. Inter-Electrode Capacity:

Gamma Plate to Power Plate	5 mmfd.
Filament to Gamma Plate	12 mmfd.
Filament to Power Plate	7 mmfd.

Type 255 Class A Audio Amplifier (Single Tube with no Grid (Gamma) Current):

D.C. Plate Voltage	1500	2000	2500	3000 volts
D.C. Grid Voltage	—350	—570	—800	—1000 volts
D.C. Plate Current	.34	.25	.20	.17 amps.
Load Resistance	5000	6000	8000	20000 ohms
Output Power	60	125	175	180 watts
Efficiency	12	25	35	36%
Harmonic Distortion (Approx.)	5	5	5	5%

Type 255 Class B Audio Amplifier (2 Tubes, "Grids" Swing to Zero and Draw no Current):

D.C. Plate Voltage	2000	3000	5000	8000 volts
D.C. Grid Voltage	—800	—1200	—2100	—3300 volts
D.C. Plate Current	.60	.83	.90	.75 amps.
Power Output	450	1100	2500	4000 watts
Plate Efficiency	38	44	56	67%
Load Resistance (Plate to Plate)	4000	5000	10000	23000 ohms.
Plate Loss	750	1400	2000	2000 watts

Type 255 Class B R-F Amplifier (Single Tube, no "Grid" Current):

D.C. Plate Voltage	2000	3000	5000	8000 volts
D.C. Grid Voltage	—800	—1200	—2100	—3300 volts
D.C. Plate Current	120	155	142	97 ma.
Load Resistance	1500	2000	4500	12000 ohms.
Plate Loss	188	347	490	500 watts
Power Input	240	465	710	775 watts
Power Output	52	118	220	275 watts
Efficiency	21.5	25	31	36%

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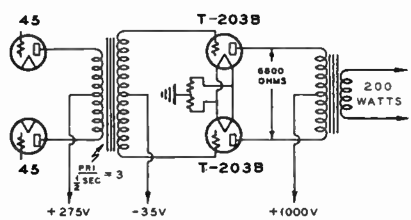
203-B

Taylor High Mu Triode. Designed primarily for class B audio amplifiers.

Driver: 2A3s in push-pull with $\frac{\text{Primary}}{\frac{1}{2}\text{ sec.}} = 1.6$ ratio input transformer.



ECONOMICAL CLASS B MODULATOR

Characteristics:

Filament Voltage	10 volts
Filament Current	3.85 Amps.
Amplification Factor	25
Maximum Plate Dissipation	100 watts
Maximum D.C. Plate Voltage	1000 volts
Maximum D.C. Plate Current	75 ma. (in R-F circuits)
Grid to Plate Capacity	14 mmfd.
Grid to Filament Capacity	6 mmfd.
Plate to Filament Capacity	5 mmfd.
Base	Standard 4 pin. 50 watt

Class B Audio Amplifier (2 Tubes):

D.C. Plate Voltage	1000 volts
D.C. Grid Voltage (Approx.)	—35 volts
Zero Signal D.C. Plate Current (per tube)	20 ma.
Maximum Signal D.C. Plate Current (2 tubes)	330 ma.
Load Impedance (plate to plate)	6800 ohms.
Power Output	200 watts
Driving Power	10 watts

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WE-242A

Western Electric Triode. R.F. Amplifier or oscillator. Audio amplifier in modulators.

Frequency Range: 100% up to 6 mc. 50% of plate voltage ratings at 30 mc.

Characteristics:

Filament Voltage	10 volts
Filament Current	3.25 amps.
Amplification Factor	12.5
Grid to Plate Capacity	13.0 mmfd.
Grid to Filament Capacity	6.5 mmfd.
Plate to Filament Capacity	4.0 mmfd.
Maximum Plate Dissipation	85 watts
Maximum D.C. Plate Voltage	1250 volts
Maximum D.C. Plate Current	150 ma.
Maximum D.C. Grid Current	50 ma.
Base	4 pin, 50 watt

Class B Audio Amplifier (2 Tubes):

D.C. Plate Voltage	1000	1250 volts
D.C. Grid Voltage	—55	—80 volts
Maximum Signal D.C. Plate Current	300	300 ma.
Zero Signal D.C. Plate Current	60	60 ma.
Load Resistance (plate to plate)	6000	8000 ohms.
Power Output	165	200 watts
Driver Power	25	25 watts

R-F Service

	Class B R-F	Class C Telephony	Class C Telegraphy
D.C. Plate Voltage	1250	1000	1250 volts (max.)
D.C. Grid Voltage	—90	—175	—200 volts
D.C. Plate Current	106	150	150 ma.
D.C. Grid Current	...	30	30 ma.
Grid Driving Power	...	10	11 watts
Grid Bias Loss	...	5	6 watts
Power Input	132.5	150	187.5 watts
Power Output	44	100	125 watts

RK-36

Raytheon R.F. amplifier or oscillator for H.F. and U.H.F. applications.

Frequency Range: 100% ratings up to 56 mc.

Note: Grid drive may vary widely under different operating conditions.

Characteristics:

Filament Voltage	5.0 volts
Filament Current	8.0 amps.
Amplification Factor	11
Grid to Plate Capacity	5 mmfd.
Grid to Filament Capacity	4.5 mmfd.
Plate to Filament Capacity	1.0 mmfd.
Maximum Plate Dissipation	100 watts
Maximum D.C. Plate Voltage	3000 volts
Maximum D.C. Plate Current	165 ma.
Maximum D.C. Grid Current	35 ma.

4 prong med. base. Plate out top and grid out side of envelope. Tantalum plate.

R-F Service

	Class B	Grid Mod.	Class C
D.C. Plate Voltage	2000	2000	2000 volts
D.C. Grid Voltage	—180	—270	—360 volts
D.C. Plate Current	75	72	150 ma.
D.C. Grid Current	...	...	30 ma.
Grid Driving Power (Approx.)	10*	3.5*	15 watts
Grid Bias Loss	...	...	5.4 watts
Power Output (Approx.)	50	42	200 watts

*(Peak).

RK-38

Raytheon High-Mu Triode. Tantalum Plate. Designed for Class B Audio Amplifier, RF Amplifier or Oscillator Service. 100% ratings up to 56 MC.

Characteristics:

Filament Voltage	5.0 volts
Filament Current	8 amps.
Grid to Plate Capacity	4.5 mmfd.
Grid to Filament Capacity	3.9 mmfd.
Plate to Filament Capacity	1.0 mmfd.
Maximum Plate Dissipation	100 watts
Maximum D.C. Plate Voltage	3000 volts
Maximum D.C. Plate Current	165 ma.
Maximum D.C. Grid Current	40 ma.

Standard 4 pin-UX base. Plate through top, grid through side of envelope.

RF Service

	Class B RF	Grid Mod. Telephony	Class C
D.C. Plate Voltage	2000	2000	2000 volts
D.C. Grid Voltage	—100	—150	—200 volts
D.C. Plate Current	75	80	150 ma.
D.C. Grid Current	...	....	30 ma.
Peak RF Grid Power	7	4	11.5 watts
Peak Audio Voltage	...	100	... volts
Carrier Power Output	55	60	225 watts

211

Class B modulator. Class B and C r.f. amplifier for telephony or telegraphy. Occasionally used as a frequency doubler.

Frequency Range: Full ratings up to 6 megacycles. 50% ratings at 30 mc.

Note (1): Grid driving requirements vary with load impedance, frequency of operation (due to losses), and type of circuit; thus the driver stage should be capable of supplying twice as much power output as listed for grid drive and bias loss.

Note (2): The W. E. 242A is similar in characteristics and operation to the 211. The 211D is similar to the 211 but it also has slightly lower inter-electrode capacities.

Characteristics:

Filament Voltage	10.0 volts
Filament Current	3.25 amps.
Amplification Factor	12
Grid-Plate Capacity	14.5 mmfd.
Grid-Filament Capacity	6 mmfd.
Plate-Filament Capacity	5.5 mmfd.
Maximum Plate Dissipation	100 watts
Base	4 pin, 50 watt

Class B Modulator (A-F):

D.C. Plate Voltage	1000	1250 volts
Zero Signal Plate Current (per tube)	10	10 ma.
Zero Grid Bias	—77	—100 volts
Maximum Signal Plate Current (per tube)	160	160 ma.
Load Resistance (plate to plate)	6900	9000 ohms.
Power Output (2 tubes)	200	260 watts

R-F Amplifier Service:

	Class B Telephony	Class C Telephony	Class C Telegraphy	Doubler
D.C. Plate Voltage	1250	1000	1250	1250 volts
D.C. Plate Current	106	150	165	145 ma.
D.C. Grid Bias	—100	—260	—215	—712 volt
D. C. Grid Current	Approx. zero	35	20	30 ma.
Grid Driving Power (Approx.)	. .	14	7.3	26 watts
Grid Bias Loss	...	9	4.3	21 watts
Power Input	133	150	208	180 watts
Approx. Power Output	42.5	100	150	120 watts
Approx. A.C. Load Impedance	...	3300	3800	4870 ohms.
Modulator D.C. Load Resistance	...	6666	...	.... ohms.

203A

Class B audio service and as an RF Amplifier.

Frequency Range: 100% ratings up to 6 mc. 50% at 30 mc.

Note: The grid drive requirements vary with load impedance, circuit design, and high frequency circuit losses; thus the driver should be able to deliver twice as much power as listed for grid drive and bias loss.

Characteristics:

Filament Voltage	10 volts
Filament Current	3.25 amps.
Amplification Factor	25
Maximum Plate Dissipation	100 watts
Grid-Plate Capacity	14.5 mmfd.
Grid-Filament Capacity	6.5 mmfd.
Plate-Filament Capacity	5.5 mmfd.
Base	4 pin, 50 watt

Class B Modulator or A-F Amplifier (2 Tubes):

D.C. Plate Voltage	1000	1250 volts
D.C. Grid Bias	—35	—45 volts
Zero Signal D.C. Plate Current (per tube)	13	13 ma.
Maximum Signal D.C. Plate Current (per tube)	160	160 ma.
Load Resistance (plate to plate)	6900	9000 ohms
Power Output	200	260 watts

R-F Service

	Class B R-F	Class C Telephony	Class C Telegraphy	Frequency Doubler
D.C. Plate Voltage	1250	1000	1250	1000 volts
D.C. Plate Current	106	150	160	126 ma.
D.C. Grid Bias	—45	—135	—130	—495 volts
D.C. Grid Current	...	50	25	20 ma.
Grid Driving Power (Approx.)	...	7	7	13 watts
Grid Bias Loss	...	6.8	3.3	5 watts
Power Input	133	150	200	126 watts
Approx. Power Output	42.5	90	125	80 watts
Approx. A.C. Load Impedance	...	3300	3900	4200 ohms.
Modulator D.C. Load Resistance	. .	6666	...	.... ohms.

838

Most used as Class B modulator due to its zero bias characteristic.

R.F. Frequency Range: 100% ratings up to 30 mc. 65% at 60 mc. 50% at 90 mc.

Note (1): Push-pull 2A3 tubes in Class A will serve as a driver for Class B 838 tubes. The Class B input transformer should have a turns ratio of $\frac{\text{Prim.}}{\frac{1}{2}\text{ sec.}} = 3.2$ if fixed bias is used on the 2A3s. A little greater ratio of stepdown is desirable if the 2A3 drivers are self biased.

Note (2): For R.F. the driver should have approx. twice as much output as listed in the table in order to compensate for variations of load impedance, circuit design and range of frequency of operation.

Characteristics:

Filament Voltage	10 volts
Filament Current	3.25 amps.
Amplification Factor	varies with amplitude of signal
Maximum Plate Dissipation	100 watts
Grid-Plate Capacity	8 mmfd.
Grid-Filament Capacity	6.5 mmfd.
Plate-Filament Capacity	5 mmfd.
Maximum D.C. Plate Voltage	1250 volts
Maximum D.C. Plate Current	175 ma.
Maximum D.C. Grid Current	70 ma.
Base	4 pin, 50 watt

Class B Modulator:

D.C. Plate Voltage	1000	1250 volts
D.C. Grid Voltage	0	0 volts
Approx. Peak A-F Grid Input Voltage	90	90 volts
Zero Signal D.C. Plate Current (per tube)	53	74 ma.
Maximum Signal D.C. Plate Current (per tube)	160	160 ma.
Load Resistance (plate to plate)	7600	11200 ohms.
Maximum Power Output (2 tubes)	200	260 watts
Peak Driving Power (Approx.)	5	5 watts

R-F Service

	Class B R-F	Class C Telephony	Class C Telegraphy	Frequency Doubler
D.C. Plate Voltage	1250	1000	1250	1000 volts
D.C. Plate Current	106	150	155	157 ma.
D.C. Grid Bias	0	—135	—90	—465 volts
D.C. Grid Current	60*	60	30	20 ma.
Grid Driving power (Approx.)	10*	17.5	6	12.3 watts
Grid Bias Loss	...	8	2.7	9.3 watts
Power Input	133	150	195	157 watts
Approx. Power Output	42.5	100	140	100 watts
Approx. A.C. Load Impedance	...	3300	4070	5360 ohms.
Modulator D.C. Load Resistance	...	6666	...	... ohms.

*(At Peak).

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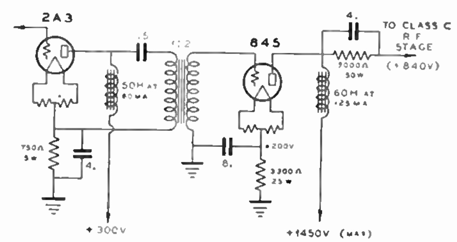
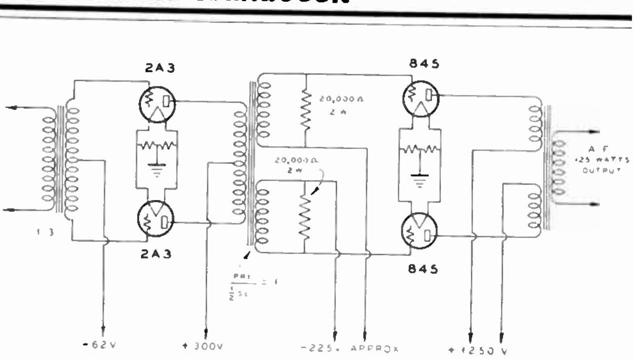
845

Triode. Class A or AB audio amplifier in public address systems, or as modulator in radio transmitters. Seldom used in R.F. amplifiers.



Single 845 Modulator for 50 Watt Radiophone



125 Watt Output Modulator with 845s in Push-Pull

Characteristics:

Filament Voltage	10 volts
Filament Current	3.25 amps.
Amplification Factor (average)	5
Grid to Plate Capacity	13.5 mmfd.
Grid to Filament Capacity	6.0 mmfd.
Plate to Filament Capacity	6.5 mmfd.
Maximum Plate Loss	100 watts
Maximum Plate Voltage	1250 volts
Maximum Plate Current	175 ma.
Base	4 pin, 50 watt

Class A Audio Amplifier (1 Tube):

D.C. Plate Voltage	750	1000	1250 volts
D.C. Grid Voltage	—98	—155	—209 volts
D.C. Plate Current	95	65	52 ma.
Peak Grid A-F Voltage	93	150	201 volts
Load Resistance	3400	9000	16000 ohms
Power Output	15	21	24 watts

Class AB Audio Amplifier (2 Tubes):

D.C. Plate Voltage	1250 volts
D.C. Grid Voltage	—225 volts
Zero Signal D.C. Plate Current	45 ma.
Power Output	125 watts
Load Impedance, Plate-to-Plate	12,000 ohms.

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850

RCA screen-grid r.f. amplifier of the 100 watt type.

Frequency Range: 100% ratings up to 13 mc. 50% at 30 mc.

Note: Grid drive varies widely under various load impedances.

Characteristics:

Filament Voltage	10 volts
Filament Current	3.25 amps.
Amplification Factor	550
Grid to Plate Capacity	0.25 mmfd.
Input Capacity	17 mmfd.
Output Capacity	25 mmfd.
Maximum Plate Dissipation	100 watts
Maximum D.C. Plate Voltage	1250 volts
Maximum D.C. Plate Current	175 ma.
Maximum D.C. Grid Current	40 ma.
Maximum Screen Dissipation	10 watts

R-F Service

	Class B Telephony	Class C Telegraphy		
D.C. Plate Voltage	1250	750	1000	1250 volts
D.C. Screen Voltage	175	175	175	175 volts
D.C. Grid Voltage	—13	—150	—150	—150 volts
D.C. Plate Current	110	160	160	160 ma.
D.C. Grid Current	...	35	35	35 ma.
Grid Driving Power (Approx.)	...	10	10	10 watts
Grid Bias Loss	...	5	5	5 watts
Plate Power Input	137.5	120	160	200 watts
Power Output	40	55	100	130 watts
Screen Series Resistor	...	15000	25000	40000 ohms.

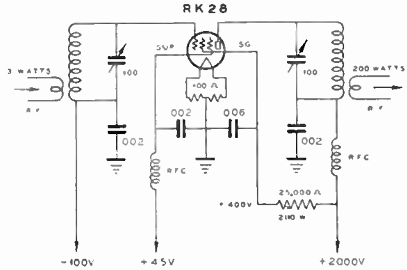
RK-28

Raytheon screen-grid tube for Suppressor Modulated telephony. Buffer or final amplifier in radio transmitters. Since it is a screen grid tube, no neutralization is needed. May be used as a crystal oscillator or doubler at reduced inputs and outputs of approx. 60%.

Precaution: Input and output circuits should be shielded and all circuits carefully by-passed for r.f. Screen voltage should only be applied when plate voltage is connected.

Frequency Range: 100% ratings up to 20 mc. The RK 28 has a lower output capacitance than the 803, so can be operated more effectively at higher frequencies, such as 14 and 30 mc.

Note: Combined plate and screen modulation may be applied for a carrier output of 100 watts with a maximum plate supply of 1500 volts. With 400 volts DC on screen, 300 volts peak AF on it, and 1500 peak volts on the plate will provide 100% modulation.



RK-28 C-W Radio-Frequency Amplifier

Characteristics:

Filament Voltage ....10 volts
Filament Current ....5 amps.
Grid to Plate Capacity ....0.02 mmfd.
Input Capacity ....15.5 mmfd.
Output Capacity ....5.5 mmfd.
Maximum Plate Dissipation ....100 watts
Maximum Screen Dissipation ....35 watts
Base ....5 pin, 50 watt. Plate at top of envelope

R-F Service

	Class B Telephony	Suppressor Modulation Telephony	Class C Telegraphy	
D.C. Plate Voltage ..	2000	2000	2000	2000 volts
D.C. Screen Voltage..	400	400	400	400 volts
D.C. Suppressor Voltage	0	—50	0	45 volts
D.C. Grid Bias Voltage	—38	—100	—100	—100 volts
Peak R-F Grid Voltage	90	180	180	180 volts
Peak A-F Grid Voltage	...	90	...	... volts
D.C. Plate Current....	75	80	120	140 ma.
D.C. Screen Current..	30	85	75	60 ma.
D.C. Grid Current	...	11	10	10 ma.
Grid Driving Power..	.9	2.7	1.8	1.8 watts
Grid Bias Loss........	...	1.1	1.0	1.0 watts
Power Output (Approx.)	50	60	160	200 watts
Screen Resistor	55000	20000	21000	26000 ohms.

852

Triode. RCA. Amperex. United. U.H.F. Oscillator. H.F. Amplifier or Class B modulator.

Frequency Range: 100% ratings up to 30 mc. 80% at 60 mc. 50% at 120 mc. and 40% at 150 mc. (2 meters).

Characteristics:

Filament Voltage ....10 volts
Filament Current ....3.25 amps.
Amplification Factor 12
Grid to Plate Capacity ....2.6 mmfd.
Grid to Filament Capacity.....................1.9 mmfd.
Plate to Filament Capacity....................1.0 mmfd.
Maximum plate Dissipation ....100 watts
Maximum D.C. Plate Voltage ....2500 volts
Maximum D.C. Plate Current...................150 ma.
Maximum D.C Grid Current.......................40 ma.
Base ....Small 4 pin. UX Grid at top. plate through side of envelope.

Class B Modulator or R-F Amplifier:

D.C. Plate Voltage	2000	3000 volts
D.C. Grid Voltage	—155	—250 volts
Zero Signal Plate Current (per tube).	11	7 ma.
Maximum Signal Plate Current (per tube)	90	80 ma.
Load Resistance (plate to plate)......	22000	36000 ohms.
Power Output	220	360 watts

R-F Service

	Class B Telephony	Plate Modulation Telephony	Class C Telegraphy	
D.C. Plate Voltage....	3000	2000*	3000	3500 volts
D.C. Grid Voltage	—250	—500	—600	—950 volts
D.C. Plate Current....	43	67	85	100 ma.
D.C. Grid Voltage....	...	30	25	35 ma.
Grid Driving Power (Approx.)	...	23	20	44 watts
Grid Bias Loss	...	15	15	33 watts
Power Output (Approx.)	40	75	180	270 watts
Power input	129	134	255	350 watts
Approx. A C. Load Impedance	...	15000	17000	15000 ohms.
Modulator D.C. Load Resistance	...	30000	...	... ohms.

*(Max.)

860

Screen-Grid Tetrode. (RCA). R.F. Amplifier for high frequencies.

Frequency Range: 100% ratings up to 30 mc. 80% at 40 mc.

Note (1): When plate modulated, the screen should be modulated simultaneously.

A small r.f. by-pass condenser from screen to filament, and a series 100,000 ohm resistor to the r.f. plate return, will allow simultaneous screen and plate modulation.

Note (2): The grid excitation will vary with load impedance and circuit losses, thus the driver should have an available output of approximately twice that listed for grid drive and bias loss.

Caution: Do not turn off filament without first removing plate voltage. Do not apply screen voltage without plate voltage.

Characteristics:

Filament Voltage ....10 volts
Filament Current ....3.25 amps.
Amplification Factor 200
Grid-Plate Capacity ....08 mmfd.
Input Capacity ....7.75 mmfd.
Output Capacity ....7.5 mmfd.
Maximum Plate Dissipation ....100 watts
Maximum Screen Dissipation ....10 watt
Base ....4 pin

R-F Service

	Class B Telephony	Plate Mod. Class C Telephony	Class C Telegraphy	
D.C. Plate Voltage....	3000	2000*	2000	3000 volts
D.C. Screen Voltage...	300	300	300	300 volts
D.C. Grid Voltage......	—50	—225	—150	—150 volts
D.C. Plate Current.....	43	67	90	85 ma.
D.C. Grid Current.....	...	30	15	15 ma.
Grid Driving Power....	...	15	7	7 watts
Grid Bias Loss........	...	6.7	2.25	2.25 watts
Power Output (Ap.)....	40	75	100	165 watts

*Maximum.

100T

Eimac High-Mu and Low-Mu Triodes having amplification factors of approximately 30 and 10, respectively. Tantalum Plates and Grids. Especially designed for UHF operation.

Tentative Characteristics:

Filament Voltage ....5.0 volts
Filament Current ....6 amps.
Grid to Plate Capacity ....2 mmfd.
Normal Plate Dissipation ....100 watts
Maximum Plate Dissipation ....150 watts
Maximum D.C. Plate Voltage ....3000 volts
Maximum D.C. Plate Current...................225 ma.
Maximum Grid Current ....30 ma.
Base: Standard UX-4-pin. Plate through top. grid through side of envelope.

211C

The 211C tubes of various manufacturers (Amperex, Taylor, United) are similar to 211 tubes in operation, except for lower grid to plate capacitance. They are somewhat more effective at the higher frequencies down towards the U.H.F. region. *See 217 tube data.*

Note: The W.E. 261A and WE 276A are somewhat similar to the 211C in characteristics and operation.

Characteristics:

Filament Voltage	10 volts
Filament Current	3.25 amps.
Maximum Plate Dissipation	100 to 120 watts
Maximum D.C. Plate Voltage	1350 volts
Maximum D.C. Plate Current	180 ma.
Maximum D.C. Grid Current	50 ma.
Grid to Plate Capacity	7 to 9 mmfd.
Grid to Filament Capacity	5.5 mmfd.
Plate to Filament Capacity	5 mmfd.
Base	standard 4 pin 50 watt

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211H

Amperex R.F. amplifier for radio transmitters.

Note (1): The grid input and plate output powers will vary greatly with different values of load impedance and frequency. The values listed are typical operating conditions.

Note (2): At high frequencies, circuit and dielectric losses increase and thus the grid driver should have available approximately twice as much output as shown in the table below for grid drive and bias supply power loss.

Note (3): This tube has the plate lead out through the top of the envelope and thus it will operate more efficiently at higher frequencies than a standard type 211 tube.

Characteristics:

Filament Voltage	10 volts
Filament Current	3.25 amps.
Grid to Plate Capacity	8.0 mmfd.
Grid to Filament Capacity	5.5 mmfd.
Plate to Filament Capacity	2.0 mmfd.
Amplification factor	12
Mutual Conductance at 100 ma. I_b	4000 micromhos
Maximum Allowable Plate Dissipation	120 watts
Base	standard 4 pin 50 watt

Class C Amplifier

	Single Tube at 60 mc.	Less Than 20 mc.	Telegraphy
D.C. Plate Voltage	1200*	1500*	2000 volts
D.C. Plate Current	175	175	180 ma.
D.C. Grid Bias	—200	—300	—300
D.C. Grid Current	30	30	50 ma.
Grid Driving Power (Ap.)	11	14	20 watts
Grid Bias Supply Loss	6	9	15 watts
Power Output (Approx.)	100	190	250 watts
Power Input	216	263	360 watts
Plate Loss	116	73	110 watts
Approx. A.C. Load Imped.	3500	4300	5500 ohms
Modulator D.C. Load	6850	8500	11,100 ohms

*Maximum

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203H

Amperex R.F. Amplifier or Oscillator, especially at high frequencies.

Note (1): The grid r.f. excitation requirements vary with efficiency, plate load and circuit design; thus the driver must be designed to allow for these factors.

Note (2): The plate lead is through the top of the tube; thus it will stand higher plate voltages and operate more efficiently at high frequencies than a regular type 203-A.

Characteristics:

Filament Voltage	10 volts
Filament Current	3.25 amps.
Grid to Plate Capacity	9 mmfd.
Grid to Filament Capacity	6 mmfd.
Plate to Filament Capacity	1.8 mmfd.
Maximum Plate Dissipation	120 watts
Maximum Plate Voltage	1500 volts
Maximum Plate Current	180 ma.
Maximum Grid Current	50 ma.
Amplification Factor	25
Base	standard 50 watt

Class C Amplifier

	At 60 mc.	Less Than 20 mc.
D.C. Plate Voltage	1200	1500 volts
D.C. Grid Voltage	—150	—180 volts
D.C. Plate Current	175	175 ma.
D.C. Grid Current	40	40 ma.
Grid Driving Power	14	17 watts
Grid Bias Loss	6	7.3 watts
Power Input	210	263 watts
Power Output (Approx.)	100	180 watts

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805

RCA High-mu type tube for Class B audio service. May also be used for r.f. service.

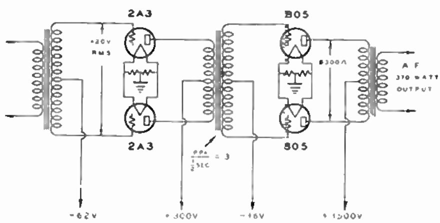
Note (1): Plate lead out top of tube reduces flash-over danger.

Frequency Range: 100% ratings up to 30 mc. 75% at 45 mc. and 50% at 85 mc.

Note (2): The Class B input transformer between push-pull 2A3s (fixed bias) and Class B 805 tubes should have a turns-ratio of

$$\frac{\text{primary}}{\frac{1}{2}\text{ Sec.}} = 3.0$$

Note (3): The grid excitation and bias may vary widely for Class C operation. It is desirable that the driver be capable of supplying approximately twice as much output as listed for grid drive and bias loss.



805 High Power Class B Modulator and Driver

Characteristics:

Filament Voltage	10 volts
Filament Current	3.25 amps.
Amplification Factor Varies with Input Signal.	
Grid to Plate Capacity	6.5 mmfd.
Grid to Filament Capacity	8.5 mmfd.
Plate to Filament Capacity	10.5 mmfd.
Maximum Plate Dissipation	125 watts
Maximum D.C. Plate Voltage	1500 volts
Maximum D.C. Plate Current	210 ma.
Maximum D.C. Grid Current	70 ma.
Base	standard 4 pin 50 watt

Plate at top of envelope.

Class B Modulator or A-F Amplifier:

D.C. Plate Voltage	1250	1500 volts
D.C. Grid Bias	0	—16 volt
Peak A-F Grid to Grid Voltage	235	280 volts
Zero Signal D.C. Plate Current (per tube)	74	42 ma.
Max. Sig. D.C. Plate Current (per tube)	200	200 ma.
Load Resistance (Plate to Plate)	6700	8200 ohms
Maximum Signal Driving Power	6	7 watts
Maximum Signal Power Output	300	370 watts

R-F Service

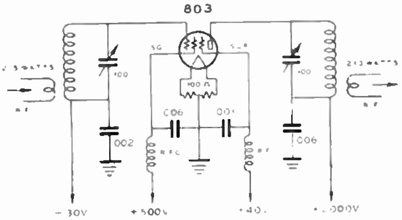
	Class B Telephony	Plate Mod. Telephony	Class C Telegraphy	Frequency Doubler
D.C. Plate Voltage	1250	1250	1500	1250 volts
D.C. Grid Voltage	0	—160	—100	—400 volts
Peak R-F Grid Voltage	75	300	230	625 volts
D.C. Plate Current	135	160	200	135 ma.
D.C. Grid Current	15	60	40	25 ma.
Grid Driving Power (Approx.)	11	16	9.2	12.5 watts
Grid Bias Loss	...	9.6	4	10 watts
Power Input	169	200	300	169 watts
Approx. Power Output	55	140	215	85 watts
Ap. A-C Load Imped.	...	3900	3600	3800 ohms
Mod. D.C. Load Resist.	...	7800	...	...

803

RCA. Suppressor Modulated telephony. Buffer or final amplifier in radio transmitters. Since it is a screen grid tube, no neutralization is needed. May be used as a crystal oscillator or doubler at approximately 60% output.

Frequency Range: 100% ratings up to 20 mc. High interelectrode capacities also tend to reduce output circuit efficiencies at higher frequencies such as 30 mc.

Precaution: Input and output circuits should be shielded and all circuits carefully by-passed for R.F. Screen voltage should not be applied unless plate voltage is connected.



Medium Power 803 Final Amplifier

Characteristics:

Filament Voltage	10 volts
Filament Current	3.25 amps.
Mutual Conductance at I_b=55	4000 micromhos
Grid to Plate Capacity	0.15 mmfd.
Input Capacity	15.5 mmfd.
Output Capacity	28.5 mmfd.
Maximum Plate Dissipation	125 watts
Maximum Screen Dissipation	30 watts
Base	5 pin 50 watt

Plate at top of envelope.

R-F Service

	Class B Telephony	Suppressor Mod.	Telephony	Class C Telegraphy	
D.C. Plate Voltage	2000	1500	2000	1250	2000 volts
D.C. Screen Voltage	600	500	500	500	500 volts
D.C. Suppressor Voltage	40	—110	—135	40	40 volts
D.C. Grid Bias Voltage	—40	—50	—50	—30	—30 volts
Peak R-F Grid Voltage	55	120	120	150	150 volts
Peak A-F Grid Voltage	...	150	175	...	...
D.C. Plate Current	80	80	80	160	160 ma.
D.C. Screen Current	15	55	55	45	42 ma.
D.C. Grid Current	3	15	15	18	16 ma.
Grid Driving Power (Approx.)	1.5	1.6	1.6	1.8	1.6 watts
Grid Bias Loss	.1	.75	.75	.5	.5 watts
Power Output (Approx.)	53	40	53	130	210 watts
Screen Resistor	100,000	18,000	27,000	17,000	36,000 ohms

HD-203C
HD-211C

Taylor U.H.F. and H.F. oscillator for diathermy machines.

Characteristics:

Filament Voltage	10 volt
Filament Current	4 amps.
Amplification Factor	20 and 12
Grid to Plate Capacity	9 mmfd.
Plate to Filament Capacity	4 mmfd.
Maximum Plate Dissipation	150 watts
Maximum DC Plate Voltage	2000 volts
Maximum D.C. Plate Current	250 ma.
Maximum D.C. Grid Current	60 ma.
Base	standard 4 pin 50 watt

Plate at top of envelope.

Class C R-F Amplifier:

D.C. Plate Voltage	1500	1750 volts
D.C. Grid Voltage	—150	—180 volts
D.C. Plate Current	250	250 ma.
D.C. Grid Current	50	50 ma.
Grid Driving Power	15	19 watts
Grid Bias Loss	7.5	9 watts
Power Input	375	433 watts
Power Output	250	300 watts

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HD-203A

Taylor heavy duty 203A tube, intermediate between 204A and 203A. Class B audio amplifier or modulator. Class C r.f. amplifier.

Note: Grid driving power requirements vary over wide limits.

A. F. Driver. 2A3s in push-pull with fixed grid bias input transformer ratio of $\frac{\text{primary}}{\frac{1}{2}\text{ sec.}} = 1.6$.

Characteristics:

Filament Voltage	10 volts
Filament Current	4 amps.
Amplification Factor	25
Grid to Plate Capacity	12 mmfd.
Grid to Filament Capacity	7 mmfd.
Plate to Filament Capacity	5 mmfd.
Maximum Plate Dissipation	150 watts
Maximum D.C. Plate Voltage	2000 volts
Maximum D.C. Plate Current	250 ma.
Maximum D.C. Grid Current	60
Base	standard 4 pin 50 watt

Plate out top of envelope

Class B Audio Amplifier (2 tubes):

D.C. Plate Voltage	1500	1750 volts
D.C. Grid Voltage	—45	—67.5 volts
Load Resistance (Plate to Plate)	8000	9000 ohms
Static Plate Current (Per Tube)	18	18 ma.
Maximum D.C. Plate Current (2 Tubes)	425	425 ma.
Power Output	400	500 watts
Driver Power	18	18 watts

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T-200

Taylor U.H.F. Triode, suitable for Oscillator or Amplifier service. Similar to HF-300.

Note: Grid driving requirements vary widely under different operating conditions.

Characteristics:

Filament Voltage	10 to 11 volts
Filament Current	4 amp.
Amplification Factor	16.6
Grid to Plate Capacity	7 mmfd.
Grid to Filament Capacity	5 mmfd.
Plate to Filament Capacity	3 mmfd.
Maximum Plate Dissipation	200 watts
Maximum D.C. Plate Voltage	2500 volts
Maximum D.C. Plate Current	350 ma.
Maximum D.C. Grid Current	80 ma.
Base	standard 4 pin 50 watt

Plate at top, grid at side of envelope.

Class C R-F Amplifier:

D.C. Plate Voltage	2500 volts
D.C. Grid Voltage	—300 volts
D.C. Plate Current	300 ma.
D.C. Grid Current	50 ma.
Grid Driving Power (Approx.)	24 watts
Grid Bias Loss	15 watts
Power Input	750 watts
Power Output	560 watts

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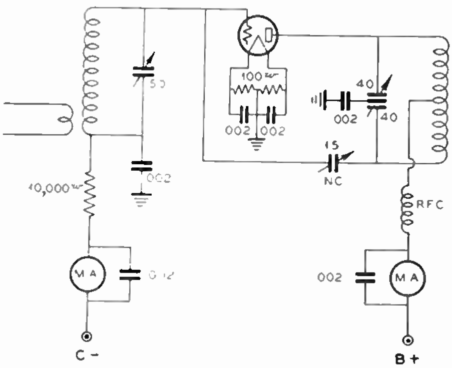
HF-200

Amperex general purpose high frequency triode. Suitable for U.H.F. oscillators.

Note: Grid excitation requirements vary greatly due to plate load, efficiency required, and circuit design.

Frequency Range: 100% ratings up to 45 mc.



HF-200 Amplifier Circuit

Characteristics:

Filament Voltage	10 to 11 volts
Filament Current	3.4 amps.
Amplification Factor	18
Grid to Plate Capacity	5.8 mmfd.
Grid to Filament Capacity	5.2 mmfd.
Plate to Filament Capacity	1.2 mmfd.
Maximum Plate Dissipation	150 watts
Maximum D.C. Plate Voltage	2000 volts
Maximum D.C. Plate Current	200 ma.
Maximum D.C. Grid Current	60 ma.
Base	standard 4 pin, 50 watt

Plate at top, grid at side of envelope.

Class C R-F Amplifier:

D.C. Plate Voltage	1500	2000 volt
D.C. Grid Voltage	—210	—300 volts
D.C. Plate Current	200	200 ma.
D.C. Grid Current	35	35 ma.
Grid Driving Power	13	19 watts
Grid Bias Loss	7.5	10 watts
Power Input	300	400 watts
Power Output	180	260 watts

HK-354

Heintz & Kaufman Triode. Tantalum plate and grid. Class B modulator. Class C r.f. amplifier. Maximum DC plate voltage for plate modulation is 3000-volts.

Note (1): The values of grid drive may be lowered for plate voltages less than 3500 without much sacrifice in plate efficiency. A 50% decrease of grid drive from the above values will drop the efficiency 10% to 15% which will not cause excessive plate dissipation if the load is reduced slightly with correspondingly less output and less plate current.

Note (2): May be used as a linear (Class B) r.f. amplifier as above and also with grid modulation under similar operating conditions, but with higher grid bias.

Note (3): With forced ventilation, the plate dissipation may be increased to as high as 250 watts.

Frequency Range: 100% ratings up to 15 mc. Reduced ratings at U.H.F. (above 30 mc).

Characteristics:

Filament Voltage	5.0 volts
Filament Current	10 amps
Amp. Factor (avg.)	14
Normal Plate Dissipation	150 watts
Grid to Plate Capacity	4 mmfd.
Grid to Filament Capacity	9 mmfd.
Plate to Filament Capacity	0.2 mmfd.
Maximum D.C. Plate Voltage	3500 volts
Maximum D.C. Plate Current	300 ma.
Maximum D.C. Grid Current	50 ma.
Plate Thru Top of Envelope Base	Standard 4-Pin 50 watt

Class B Modulator or A-F Amplifier (2 Tubes):

D.C. Plate Voltage	1000	2000	2500	3000 volts
D.C. Grid Voltage	—60	—150	—180	—225 volts
Zero Sig. D.C. Plate Current (2 Tubes)	20	20	20	20 ma.
Maximum Sig. D.C. Plate Current (2 Tubes)	160	320	345	330 ma.
Load Resistance (Plate to Plate)	15,000	15,000	18,000	25,000 ohms
Peak Driving Power	5.6	21	26	30 watts
Power Output	100	400	560	650 watts
Plate Loss	60	232	300	300 watts

Class C r.f. Amplifier:

D.C. Plate Voltage	1500	2000	3000	3500	4000 volts
D.C. Grid Voltage	—428	—602	—960	—1180	—1300 volts
D.C. Plate Current	285	285	285	285	277 ma.
D.C. Grid Current	50	45	37	36	40 ma.
Grid Driving Power	30	35	45	53	65 watts
Grid Bias Loss	21	27	35	47	52 watts
Power Input	430	572	850	1000	1100 watts
Approximate Power Output	320	450	700	850	950 watts
Approximate A.C. Load Resistance	2340	3060	4690	5630	6750 ohms

Class B R-F Amplifier, Telephony:

D.C. Plate Voltages	1500	2000	2500	3000 volts
D.C. Grid Voltages	—105	—155	—188	—233 volts
D.C. Plate Current	65	84	88	82 ma.
Grid Driving Power	6	11	13	15 watts
Plate Loss	70	116	150	150 watts
Carrier Power Output	27.5	50	70	81 watts

150T

Eimac medium power triode for general use, either in r.f. or audio circuits. More efficient at high frequencies than tubes with higher inter-electrode capacities (of equal power ratings).

Frequency Range: 100% ratings up to 60 mc.

Note (1): Values of grid r.f. excitation vary over wide limits depending upon efficiency desired, circuit losses at higher frequencies, plate load impedance and circuit design. The driver should be designed to provide considerably more output than shown by the table, if possible.

Note (2): For keyed telegraphy, the above ratings may be exceeded by 50%. Higher grid bias and grid drive are desirable if more output is wanted.

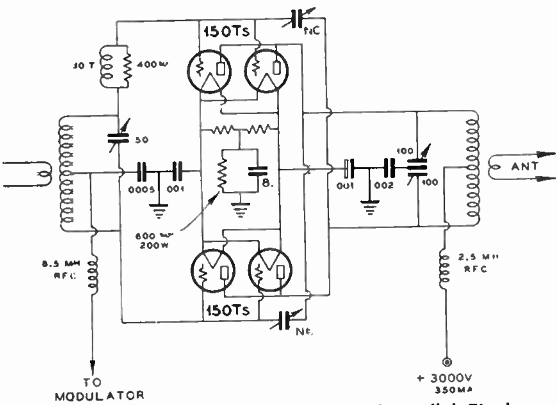
Characteristics:

Filament Voltage	5 to 5.25 volts
Filament Current	10 amps.
Amplification Factor	11
Grid to Plate Capacity	3.5 mmfd.
Grid to Filament Capacity	3.0 mmfd.
Plate to Filament Capacity	0.5 mmfd.
Normal Plate Dissipation	150 watts
Normal Plate Voltage	3000 volts
Normal Plate Current	200 ma.
Normal Grid Current	50 ma.
Base	Standard 4 Pin 50 watt

Plate through top, grid through side of envelope.

Class B Audio Amplifier (2 Tubes):

D.C. Plate Voltage	1000	2000	3000 volts
D.C. Grid Voltage	—75	—160	—230 volts
Zero Sig. D.C. Plate Current (Approximate)	20	20	20 ma.



Circuit Diagram of 150T Push-Pull-Parallel Final Amplifier. Only One Grid Choke Is Required

Maximum Sig. D. C. P rent (Approximate)	400	400	365 ma.
Load Resistance (P Plate)	4500	13,500	20,000 ohms
Driving Power	11	15	17 watts
Output Power	200	450	700 watts

Class C R-F Amplifier Telephooy or Telegraphy:

D.C. Plate Voltage	1000	2000	3000 volts
D.C. Grid Voltage	—200	—400	—600 volts
D.C. Plate Current	200	200	200 ma.
D.C. Grid Current	35	35	35 ma.
Grid Driving Power	14	21	30 watts
Grid Bias Loss	7	14	21 watts
Power Input	200	400	600 watts
Power Output	150	300	450 watts
A.C. Load Resistance	2500	5000	8000 ohms.
Mod. D.C. Load	5000	10,000	15,000 ohms

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T-155

Taylor general purpose triode, suitable for U.H.F. service down to 2 meters.

Characteristics:

Filament Voltage	10 volts
Filament Current	4 amps.
Amplification Factor	20
Grid to Plate Capacity	3 mmfd.
Grid to Filament Capacity	2.5 mmfd.
Plate to Filament Capacity	1 mmfd.
Maximum Plate Dissipation	155 watts
Maximum D.C. Plate Voltage	3000 volts
Maximum D.C. Plate Current	200 ma.
Maximum D.C. Grid Current	60 ma.
Base	Standard 4 Pin 50 watt

Plate through top, grid through side of envelope.

Class C R-F Amplifier:

D.C. Plate Voltage	2500 volts
D.C. Grid Voltage	250 volts
D.C. Plate Current	200 ma.
D.C. Grid Current	50 ma.
Grid Driving Power	22 watts
Grid Bias Loss	12.5 watts
Power Input	500 watts
Power Output	370 watts

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F-108A

Federal Tel. Co. General purpose triode. Especially suitable for very high frequencies.

Note: Grid excitation requirements vary greatly, due to circuit design, plate load, and required efficiencies.

Frequency Range: 100% ratings up to 30 mc.

Characteristics:

Filament Voltage	10 volts
Filament Current	11 amps.
Amplification Factor	12
Grid to Plate Capacity	7 mmfd.
Grid to Filament Capacity	3 mmfd.
Plate to Filament Capacity	2 mmfd.

Maximum Plate Dissipation	175 watts
Maximum D.C. Plate Voltage	3000 volts
Maximum D.C. Plate Current	200 ma.
Maximum D.C. Grid Current	50 ma.

Class C R-F Amplifier:

D.C. Plate Voltage	2000	3000 volts
D.C. Grid Voltage	—400	—600 volts
D.C. Plate Current	200	200 ma.
D.C. Grid Current (Approx.)	40	40 ma.
Grid Drive	26	34 watts
Grid Bias Loss	16	24 watts
Power Input	400	600 watts
Power Output	260	480 watts

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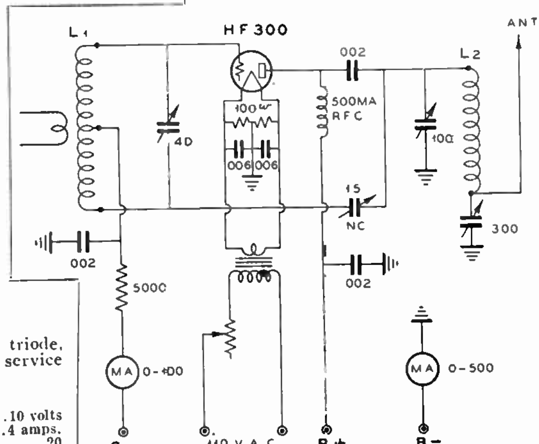
HF-300

Amperex General purpose triode for high frequency and U.H.F. amplifiers or oscillators.

Note: Grid excitation requirements vary greatly due to circuit design, plate load, and required efficiency.

Frequency Range: 100% ratings up to 45 mc.



Grid-Neutralized Circuit for HF-300 Amplifier

Characteristics:

Filament Voltage	11 to 12 volts
Filament Current	4 amps.
Amplification Factor	23
Grid to Plate Capacity	6.5 mmfd.
Grid to Filament Capacity	6.0 mmfd.
Plate to Filament Capacity	1.4 mmfd.
Maximum Plate Dissipation	200 watts
Maximum D.C. Plate Voltage	2500 volts
Maximum D. C. Plate Current	275 ma.
Maximum D.C. Grid Current	75 ma.
Base	standard 4 pin 50 watt

Plate through top, grid through side of envelope.

Class C R-F Amplifier

D.C. Plate Voltage	1500	2500 volts
D.C. Grid Voltage	—200	—300 volts
D.C. Plate Current	275	275 ma.
D.C. Grid Current	60	60 ma.
Grid Driving Power	27	33 watts
Grid Bias Loss	12	18 watts
Power Input	420	700 watts
Power Output	260	500 watts

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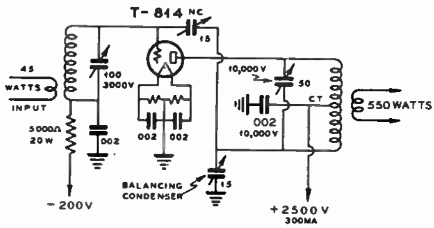
814

Taylor H.F. Triode. Class C r.f. amplifier of high output with relatively low grid-driving requirements.

Frequency Range: 30 to 2 mc.



HIGH POWER FINAL AMPLIFIER

Characteristics:

Filament Voltage	10 volts
Filament Current	4 amps.
Amplification Factor	12
Grid to Plate Capacity	13 mmfd.
Grid to Filament Capacity	7 mmfd.
Plate to Filament Capacity	5.5 mmfd.
Maximum Plate Dissipation	200 watts
Maximum D.C. Plate Voltage	2500 volts
Maximum D.C. Plate Current	300 ma.
Maximum D.C. Grid Current	75 ma.
Base	standard 4 pin 50 watt

Plate through top of envelope.

Class C R-F Amplifier:

D.C. Plate Voltage	2000 volts
D.C. Grid Voltage	—400 volts
D.C. Plate Current	300 ma.
D.C. Grid Current	45 ma.
Grid Driving Power	25 watts
Grid Bias Loss	18 watts
Power Input	600 watts
Power Output	400 watts

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822

Taylor High-Mu Triode. Class B audio amplifier or modulator. May be used in Class C r.f. service.

A.F. Driver: Push-pull parallel 2A3 tubes with input transformer ratio of $\frac{\text{Primary}}{\frac{1}{2}\text{ sec.}} = 1.6$.

Characteristics:

Filament Voltage	10 volts
Filament Current	4 amps.
Amplification Constant	27
Grid to Plate Capacity	14 mmfd.
Grid to Filament Capacity	8 mmfd.
Plate to Filament Capacity	6 mmfd.
Maximum Plate Dissipation	200 watts
Maximum D.C. Plate Voltage	2000 volts
Maximum D.C. Plate Current	300 ma.
Maximum D.C. Grid Current	60 ma.
Base	standard 4 pin 50 watt

Plate through top of envelope.

Class B Audio Amplifier (2 Tubes):

D.C. Plate Voltage	2000 volts
D.C. Grid Voltage (Approx.)	—75 volts
Zero Signal D.C. Plate Current	50 ma.
Maximum Signal D.C. Plate Current	450 ma.
Load Impedance (Plate to Plate)	9000 ohms
Power Output	500 watts
Driving Power	30 watts

Class C R-F Amplifier:

D.C. Plate Voltage	2000 volts
D.C. Grid Voltage	—220 volts
D.C. Plate Current	300 ma.
D.C. Grid Current	50 ma.
Grid Driving Power	20 watts
Grid Bias Loss	11 watts
Power Input	600 watts
Power Output	400 watts

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250T

Eimac general purpose HF Triodes with amplification constants of 30 and 11, respectively. Specially designed for UHF operation.

Tentative Characteristics:

Filament Voltage	5.0 volts
Filament Current	10 amps.
Approximate Grid to Plate Capacity	3.5 mmfd.
Maximum Plate Dissipation	250 watts
Maximum Plate Voltage	3500 volts
Maximum D.C. Plate Current	350 ma.
Maximum D.C. Grid Current	50 ma.

Base: Standard 4-pin 50 watt.
Plate through top, grid through side of envelope.

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204A

Triode (RCA-Amperex-United). Oscillator or amplifier for frequencies below 3000 KC.

Frequency Range: 100% ratings up to 3 mc. 50% at 15 mc.

Note: Grid excitation requirements vary with plate impedance, circuit design and circuit losses, so the driver stage should be able to supply approximately twice as much output as listed for grid drive and bias loss.

Characteristics:

Filament Voltage	11 volts
Filament Current	3.85 amps.
Amplification Factor	25
Grid to Plate Capacity	15 mmfd.
Grid to Filament Capacity	12.5 mmfd.
Plate to Filament Capacity	2.3 mmfd.
Maximum Plate Dissipation	250 watts
Maximum D.C. Plate Voltage	2500 volts
Maximum D.C. Plate Current	275 ma.
Maximum D.C. Grid Current	80 ma.
Base	standard 250 watt

Plate through top.

Class B Modulator or A-F Amplifier:

D.C. Plate Voltage	1500	2000 volts
D.C. Grid Bias (Approx.)	—40	—60 volts
Zero Signal Plate Current (Per Tube)	37	37 ma.
Max. Signal Plate Current (Per Tube)	250	250 ma.
Load Resistance (Plate to Plate)	7800	8800 ohms
Power Output (2 tubes)	400	600 watts

R-F Service

	Class B Telephony	Plate Mod. Telephony	Class C Telegraphy	
D.C. Plate Voltage	2000	1800	1500	2500 volts
D.C. Grid Bias	—70	—250	—150	—200 volts
D.C. Plate Current	160	250	250	250 ma.
D.C. Grid Current	...	70	50	50 ma.
Power Output (Approx.)	100	300	225	400 watts
Grid Driving Power	...	35	17	22 watts
Grid Bias Loss	...	17.5	7.5	10 watts
Power Input	140	450	375	625 watts

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WE-212E

Western Electric general purpose triode for frequencies below 1500 KC. Normally used in audio circuits.

Frequency Range: 100% ratings up to 1.5 mc. 33% plate voltage ratings at 4.5 mc.

Characteristics:

Filament Voltage	14 volts
Filament Current	6 amps.
Amplification Factor	16
Grid to Plate Capacity	18.8 mmfd.
Grid to Filament Capacity	14.9 mmfd.
Plate to Filament Capacity	8.6 mmfd.
Maximum Plate Dissipation	275 watts
Maximum D.C. Plate Voltage	3000 volts
Maximum D.C. Plate Current	350 ma.
Maximum D.C. Grid Current	75 ma.

Special W.E. base.

Class B Audio Amplifier (2 tubes):

DC. Plate Voltage	1500	2000 volts
D.C. Grid Voltage	—75	—105 volts
Maximum Signal D.C. Plate Current	600	600 ma.
Zero Signal D.C. Plate Current	80	100 ma.
Load Resistance (Plate to Plate)	5900	8000 ohms
Power Output	500	650 watts
Driver Power	50	50 watts

R-F Service

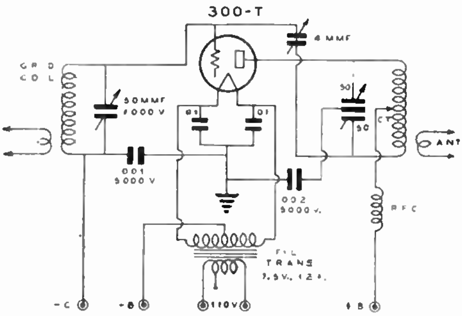
	Class B R-F	Class C Telephony	Class C Telegraphy
D.C. Plate Voltage	2000	1500	2000 volts
D.C. Grid Voltage	—120	—200	—250 volts
D.C. Plate Current	200	300	300 ma.
D.C. Grid Current	...	60	60 ma.
Grid Drive (Approx.)	...	21	25 watts
Grid Bias (Loss)	...	12	15 watts
Power Input	400	450	600 watts
Power Output	135	300	400 watts

300T

Eimac. General purpose "Low C" triode for audio and high frequency amplifiers.

Frequency Range: 100% ratings up to 40 mc.

Note: Values of grid r.f. excitation vary over wide limits so this should be taken into account when designing the driver stage.



1-K.W. AMPLIFIER

Characteristics:

Filament Voltage	7.5 volt
Filament Current	11.5 amps.
Normal Plate Dissipation	300 watts
Amplification Factor (Avg.)	16
Maximum Plate Current	350 ma.
Maximum Plate Voltage	3500 volts
Maximum Grid Current	75 ma.
Grid to Plate Capacity	4 mmfd.
Grid to Filament Capacity	4 mmfd.
Plate to Filament Capacity	0.6 mmfd.
Base	standard 4 pin 50 watt

Plate through top, grid through side of envelope.

Class B Audio Amplifier (2 tubes):

D.C. Plate Voltage	1000	2000	3000	3500 volts
D.C. Grid Voltage (Ap.)	—60	—135	—200	—240 volts
Zero Signal D.C. Plate Current (Approx.)	40	40	40	40 ma.
Max. Signal D.C. Plate Current	700	700	700	600 ma.
Load Resistance (Plate to Plate)	2800	8500	10,000	13,000 ohms
Driving Power	30	38	48	46 watts
Output Power	400	950	1500	1620 watts

Class C R-F Amplifier (1 tube) Telephony or Telegraphy:

D.C. Plate Voltage	2000	3000	3500 volts
D.C. Grid Voltage	—300	—500	—600 volts
D.C. Plate Current	300	300	300 ma.
D.C. Grid Current	40	50	60 ma.
Grid Driving Power (Approx.)	22	40	55 watts
Grid Bias Loss	12	25	36 watts
Power Input	600	900	1050 watts
Power Output	450	700	800 watts
AC Load Resistance	3400	5000	5800 ohms

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HK-654

Heintz and Kaufman Triode for Class B, Modulator and high-frequency RF Service. Especially suitable for Class B RF and grid-modulated telephony. Tantalum plate and grid. 100% ratings up to 15 MC; reduced ratings above 30 MC.

Characteristics:

Filament Voltage	7.5 volts
Filament Current	15 amps.
Amplification Factor	25
Normal Plate Dissipation	300 watts
Maximum D.C. Plate Voltage	5000 volts
Maximum D.C. Plate Current	450 ma.
Maximum D.C. Grid Current	100 ma.

Base: Standard 4-pin 50-watt. Plate through top, grid through side of envelope.

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WE-270A

Western Electric general purpose triode for broadcast station operation in high frequency transmitters.

Frequency Range: 100% ratings up to 7.5 mc. 33% plate voltage ratings at upper limit of 22.5 mc.

Characteristics:

Filament Voltage	10 volts
Filament Current	9.75 amps.
Amplification Factor	16
Grid to Plate Capacity	21 mmfd.
Grid to Filament Capacity	18 mmfd.
Plate to Filament Capacity	2 mmfd.
Maximum Plate Dissipation	350 watts
Maximum D.C. Plate Voltage	3000 volts
Maximum D.C. Plate Current	375 ma.
Maximum D.C. Grid Current	75 ma.

Class B Audio Amplifier (2 Tubes):

D.C. Plate Voltage	2000	2500 volts
D.C. Grid Voltage	—105	—140 volts
Maximum Sig. D.C. Plate Current	750	750 ma.
Zero Sig. D.C. Plate Current	120	120 ma.
Load Resistance (Plate to Plate)	6000	8000 ohms
Power Output	850	1000 watts
Driver Power	75	75 watts

R-F Service

	Class B R-F	Class C Telephony	Class C Telegraphy
D.C. Plate Voltage	3000	2250	3000 volts (max.)
D.C. Grid Voltage	—180	—300	—375 volts
D.C. Plate Current	175	300	350 ma.
D.C. Grid Current	...	70	70 ma.
Grid Driver (Approx.)	....	32	37 watts
Grid Bias Loss	....	21	11 watts
Power Input	525	675	1050 watts
Power Output	175	450	700 watts

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849

Triode. RCA-Amperex-United. Especially suited for Class B modulators. May be used in Class C as well as Class B r.f. amplifiers.

Frequency Range: 100% ratings up to 3 mc. 50% at 15 mc.

Characteristics:

Filament Voltage	11 volts
Filament Current	5.0 amps.
Amplification Factor	19
Grid to Plate Capacity	33.5 mmfd.
Grid to Filament Capacity	17 mmfd.
Plate to Filament Capacity	3 mmfd.
Maximum Plate Dissipation	400 watts
Maximum Plate Dissipation (Telephony)	270 watts
Maximum D.C. Plate Voltage	3000 volts
Maximum D.C. Plate Current	350 ma.
Maximum D.C. Grid Current	125 ma.
Base	250 watt

Plate through top of envelope.

Class B Modulator or A-F Amplifier:

D.C. Plate Voltage	2000	2500 volts
Grid Bias (Approximate)	—105	—130 volts
Zero Sig. Plate Current (Per Tube)	7	10 ma.
Maximum Sig. Plate Current (Per Tube)	325	275 ma.
Load Resistance (Plate to Plate)	7040	11,480 ohms
Power Output	870	920 watts

Class B—R-F Amplifier:

D.C. Plate Voltage	1500	2000 volts
D.C. Grid Bias	—70	—95 volts
D.C. Plate Current	340	265 ma.
Carrier Output	155	175 watts

Plate Modulated Class C. Amplifier:

D.C. Plate Voltage	1500	1800 volts
D.C. Grid Bias	—250	—300 volts
D.C. Plate Current	300	300 ma.
Power Output	300	390 watts

Class C Telegraphy:

D.C. Plate Voltage	1500	2000 volts
D.C. Grid Bias	—175	—200 volts
D.C. Plate Current	300	300 ma.
Power Output	300	450 watts
D.C. Grid Current	75	75 ma.
Grid Driving Power (Approx.)	32	34 watts
Grid Bias Loss	13	15 watts

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861

RCA Screen Grid RF. Amplifier for normal operation up to 20 megacycles.

Frequency Range: 100% ratings up to 20 mc. 75% at 30 mc.

Note (1): Grid driving power requirements vary over wide limits, depending upon load impedance and circuit losses.

Note (2): In modulated operation (plate type) the screen voltage should be modulated simultaneously with the plate voltage. Grid modulation characteristics are approx. similar to Class B r.f. operation, except for grid bias.

Characteristics:
Filament Voltage ....11 volts
Filament Current ....10 amps.
Amplification Factor 300
Grid to Plate Capacity ....0.1 mmfd.
Input Capacity ....14.5 mmfd.
Output Capacity ....11 mmfd.
Maximum Plate Voltage ....3500 volts
Maximum Plate Dissipation ....400 watts
Maximum Screen Dissipation ....35 watts
Maximum D.C. Plate Current ....350 ma.
Maximum D.C. Grid Current ....75 ma.

R-F Service

	Class B Telephony	Plate Mod. Class C Telephony		Class C Telegraphy	
D.C. Plate Voltage	3500	2000	3000 max.	2000	3500 volts
D.C. Screen Voltage	500	350	500	350	600 volts
D.C. Grid Voltage	—60	—200	—300	—150	—250 volts
D.C. Plate Current	145	265	200	300	275 ma.
D.C. Grid Current	...	70	50	60	30 ma.
Grid Driving Power	...	40	35	40	25 watts
Grid Bias Loss	...	14	15	9	7.5 watts
Plate Power Input	510	530	600	600	965 watts
Power Output	160	285	360	325	590 watts

831

RCA and Amperex Oscillator and r.f. amplifier for high frequency operation.

Frequency Range: 100% ratings up to 20 mc. 55% at 75 mc.

Note: Grid driving requirements vary greatly under different values of load impedance, neutralizing circuits and circuit losses which vary with frequency.

Characteristics:
Filament Voltage ....11 volts
Filament Current ....10 amp.
Amplification Factor 14.5
Grid to Plate Capacity ....4.0 mmfd.
Grid to Filament Capacity ....3.8 mmfd.
Plate to Filament Capacity ....1.4 mmfd.
Maximum Plate Dissipation ....400 watts
Maximum D.C. Plate Voltage ....3500 volts
Maximum D.C. Plate Current ....350 ma.
Maximum D.C. Grid Current ....75 ma.

R-F Service

	Class B Telephony	Class C Plate Mod. Telephony	Class C Telegraphy	
D.C. Plate Voltage	3500	3000*	2000	3500 volts
D.C. Grid Voltage	—220	—500	—200	—400 volts
D.C. Plate Current	145	200	300	275 ma.
D.C. Grid Current	...	60	45	40 ma.
Grid Driving Power	...	50	25	30 watts
Grid Bias Loss	...	30	9	16 watts
Power Input	510	600	600	965 watts
Power Output	160	375	400	600 watts

*(Max.)

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500T

Eimac general purpose triode for audio and high-frequency amplifiers. Its low inter-electrode capacities allow effective r.f. amplification at high radio frequencies.

Frequency Range: 100% ratings up to 40 mc.

Note: Values of r.f. grid excitation vary over wide limits so this should be taken into account when designing the driver stage.

Characteristics:
Filament Voltage ....7.5 volts
Filament Current ....20 amps.
Amplification Factor (Average) 13
Normal Plate Dissipation ....500 watts
Maximum Plate Voltage ....4000 volts
Maximum Plate Current ....600 ma.
Maximum Grid Current ....125 ma.
Grid to Plate Capacity ....4.5 mmfd.
Grid to Filament Capacity ....6 mmfd.
Plate to Filament Capacity ....0.8 mmfd.
Base ....Special EIMAC
Plate through top, grid through side of envelope.

Class B Audio Amplifier (2 Tubes):

D.C. Plate Voltage	1500	2000	3000	4000 volts
D.C. Grid Voltage (Approx.)	—110	—150	—225	—310 volts
Maximum Signal D.C. Plate Current	1200	1150	900	800 ma.
Load Resistance (plate to plate)	2400	3000	6800	11300 ohms
Grid Driving Power	90	90	85	80 watts
Power Output	900	1200	1800	2300 watts

Class C R-F Amplifier (1 Tube) Telephony or Telegraphy:

D.C. Plate Voltage	2000	3000	4000 volts
D.C. Grid Voltage	—350	—550	—800 volts
D.C. Plate Current	450	450	450 ma.
D.C. Grid Current	90	90	90 ma.
Grid Driving Power (Approx.)	60	80	110 watts
Grid Bias Loss	31.5	40	72 watts
Power Input	900	1350	1800 watts
Power Output (Approx.)	650	1000	1350 watts

F-100A

Federal Tel. Co. general purpose triode for high frequency transmitters. Useful up to 100 mc.

Characteristics:
Filament Voltage ....11 volts
Filament Current ....25 amps.
Amplification Factor 14
Grid to Plate Capacity ....10 mmfd.
Grid to Filament Capacity ....4 mmfd.
Plate to Filament Capacity ....2 mmfd.
Maximum Plate Dissipation ....500 watts
Maximum D.C. Plate Voltage ....4000 volts
Maximum D.C. Plate Current ....300 ma.

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851

RCA—Amperex—United. High power air cooled triode for AF or RF service.

Frequency Range: 100% ratings up to 3 mc. 50% at 6 mc.

Characteristics:
Filament Voltage ....11 volts
Filament Current ....15.5 amp.
Amplification Factor 20
Grid to Plate Capacity ....55 mmfd.
Grid to Filament Capacity ....30 mmfd.
Plate to Filament Capacity ....7 mmfd.
Maximum Plate Dissipation ....750 watts
Maximum D.C. Plate Voltage ....2500 volts
Maximum D.C. Plate Current ....1 Amp.
Maximum D.C. Grid Current ....200 ma.
Base ....Standard 250 watt
Plate through top of envelope.

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HK-1554

Heintz & Kaufman general purpose triode. Designed for commercial transmitters in the high frequency range.

Note: Air-cooled plate. With forced ventilation, plate dissipation may be increased to 1500 watts.

Characteristics:
Filament Voltage ....11 volts
Filament Current ....17 amps.
Normal Plate Dissipation ....750 watts
Amplification Factor ....14.5 watts
Grid to Plate Capacity ....11 mmfd.
Grid to Filament Capacity ....15.5 mmfd.
Plate to Filament Capacity ....1.2 mmfd.
Base ....Special HK
Plate through top of envelope.

Class B Audio Amplifier:

D.C. Plate Voltage	2500	3000	4000	5000 volts
D.C. Grid Voltage	—160	—200	—275	—350 volts
Zero Signal D.C. Plate Current (2 tubes)	.050	.050	.050	.050 amps.
Maximum Signal D.C. Plate Cur. (2 tubes)	1.74	1.59	1.34	1.15 amps
Peak Driving Power	106	104	100	87 watts
RMS Signal Voltage	375	389	413	445 volts
Power Output (2 tubes)	2850	3260	3860	4260 watts
Load Resistance (plate to plate)	3000	4200	7000	10400 ohms
Maximum Signal D.C. Grid Current (2 tubes)	122	122	98	72 ma.

Class B R-F Telephony:

D.C. Plate Voltage	2500	3000	4000	5000 volts
D.C. Grid Voltage	—160	—200	—275	—350 volts
D.C. Plate Current	448	378	293	242 ma.
Plate Loss	750	750	750	750 watts
Load Resistance	750	1100	2000	3200 ohms
Peak Grid Driving Power	53	45	42	36 watts
Carrier Power	370	385	420	460 watts
Efficiency	33	34	36	38%

Class C Operation (3000 Max. Plate Voltage for Plate Modulation):

D.C. Plate Voltage	2500	3000	4000	5000 volts
D.C. Grid Voltage	—600	—610	—780	—760 volts
D.C. Plate Current	1.00	.930	1.40	1.00 amps.
D.C. Grid Current	110	95	144	95 ma.
Grid Driving Power	117	125	124	120 watts
Grid Bias Loss	66	58	73	72 watts
Load Resistance	1120	1460	1960	2500 ohms
Power Input	2500	2780	4000	5000 watts
Power Output	1750	2030	3040	3950 watts
Plate Efficiency	70	73	76	79%
Plate Loss	750	750	960	1050 watts

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WE-251A

Western Electric H.F. triode broadcast or police transmitter tube for r.f. or a.f. service.

Frequency Range: 100% ratings up to 30 mc. 66% plate voltage ratings at 50 mc.

Characteristics:

Filament Voltage ....10 volts
Filament Current ....16 amps.
Amplification Factor 10.5
Grid to Plate Capacity ....8 mmfd.
Grid to Filament Capacity ....10 mmfd.
Plate to Filament Capacity ....6 mmfd.
Maximum Plate Dissipation ....1000 watts
Maximum D.C. Plate Voltage ....3000 volts
Maximum D.C. Plate Current ....600 ma.
Maximum D.C. Grid Current ....150 ma.
Air-cooled tube.

R-F Service

	Class B R-F	Class C Telephony	Class C Telegraphy
D.C. Plate Voltage	3000	2250	3000 volts*
D.C. Grid Voltage	—300	—470	—550 volts
D.C. Plate Current	400	400	600 ma.
Power Input	1200	900	1800 watts
Power Output	400	600	1200 watts

*(Maximum).

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WE-279A

Western Electric H.F triode broadcast or police station operation for AF or RF service.

Frequency Range: 100% ratings up to 20 mc. 50% plate voltage ratings at 40 mc.

Characteristics:

Filament Voltage ....10 volts
Filament Current ....21 amps.
Amplification Factor 10
Grid to Plate Capacity ....18 mmfd.
Grid to Filament Capacity ....15 mmfd.
Plate to Filament Capacity ....7 mmfd.
Maximum Plate Dissipation ....1200 watts
Maximum D.C. Plate Voltage ....3000 volts
Maximum D.C. Plate Current ....800 ma.
Maximum D.C. Grid Current ....150 ma.

Class B Audio Amplifier (2 Tubes):

D.C. Plate Voltage	2000	2500 volts
D.C. Grid Voltage	—150	—200 volts
Maximum Signal D.C. Plate Current	1600	1600 ma.
Zero Signal D.C. Plate Current	220	300 ma.
Load Resistance (plate to plate)	2240	2800 ohms
Power Output	1760	2200 watts
Driver Power	100	100 watts

R-F Service

	Class B R-F	Class C Telephony	Class C Telegraphy
D.C. Plate Voltage	3000	2250	3000 volts
D.C. Grid Voltage	—325	—450	—600 volts
D.C. Plate Current	600	600	800 ma.
Power Input	1800	1350	2400 watts
Power Output	600	900	1600 watts

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HK-3054

Heintz & Kaufman general purpose triode for commercial application. Largest air-cooled tube made.

Note: Plate dissipation may be increased to 3 KW by forced ventilation, air cooled H.F. tube construction.

Characteristics:

Filament Voltage ....16 volts
Filament Current ....50 amps.
Normal Plate Dissipation ....1.5 kw.
Amplification Factor 20
Grid to Plate Capacity ....15 mmfd.
Grid to Filament Capacity ....25 mmfd.
Plate to Filament Capacity ....2.5 mmfd.
Maximum D.C. Plate Voltage ....5000 volts
Maximum D.C. Plate Current ....2 amps.
Maximum D.C. Grid Current ....0.5 amps.

Class B Audio Amplifier (2 Tubes):

D.C. Plate Voltage	2500	3000	4000	5000 volts
D.C. Grid Voltage	—105	—130	—180	—230 volts
Zero Sig. D.C. Plate Current (2 tubes)	.10	.10	.10	.10 amps.
Maximum Signal D.C. Plate Current (2 tubes)	3.20	3.00	2.50	2.24 amps.
Maximum Sig. Grid RMS Voltage	445	445	445	445 volts
Maximum Sig. D.C. Grid Current	350	300	226	176 ma.
Maximum Sig. Power Input (2 tubes)	8	9	10	11.2 kw.
Maximum Sig. Power Output (2 tubes)	5	6	7	8.2 kw.
Maximum Sig. Grid Drive	300	268	235	190 watts

Class B R-F Telephony:

D.C. Plate Voltage	2500	3000	4000	5000 volts
D.C. Grid Voltage	—105	—130	—180	—230 volts
Load Resistance	350	550	1000	1530 ohms
Grid Drive	150	130	100	80 watts
D.C. Plate Current	.89	.75	.582	.47 amps.
Carrier Output	710	760	830	860 watts
Plate Efficiency	32.0	33.5	35.5	36.5%
Plate Loss	1500	1500	1500	1500 watts

Class C R-F Amplifier:

D.C. Plate Voltage	2500	3000	4000	5000 volts
D.C. Grid Voltage	—492	—800	—1090	—1110 volts
D.C. Plate Current	1.62	1.65	2.00	2.00 amps.
D.C. Grid Current	.23	.20	.22	.22 amps.
Grid Driving Power	193	300	425	440 watts
Power Input	4050	4850	8000	10000 watts
Power Output	2550	2350	5760	7500 watts
Load Resistance	635	790	860	1150 ohms
Plate Efficiency	63	69	72	75%

RECTIFIERS

866-866A-872-872A

Note: The 866-A and 872-A rectifiers are limited to 5,000 peak inverse voltage if the temperature near the base of the tube is below 15° C, or above 50° C.

Uses: Half wave rectifiers, of the mercury vapor type, for high voltage plate supplies in radio transmitters. Two or four tubes may be connected in full wave rectifier circuits. (See power supply chapter.)

Max. Peak inverse voltage is the highest peak voltage that the rectifier tube can safely stand in the opposite direction to which it is supposed to pass current. In a single phase, full wave choke input circuit, the peak inverse voltage is approx. 1.4 times the RMS voltage applied to the tube. In a single phase, half wave circuit with condenser input, the peak inverse voltage may be 2.8 times the RMS value.

Max. peak plate current is the highest value of peak current that the rectifier tube can safely pass. With large choke inductance input to the filter, the peak current is not much higher than the load current. With condenser input, the peak current may be four times as high as the load current.

Characteristics:

	866	866-A	872	872-A
Filament Voltage	2.5	2.5	5.0	5.0 volts
Filament Current	5.0	5.0	10	6.75 amps.
Peak Inverse Voltage..	7500	10000	7500	10000 volts*
Peak Plate Current ...	.6	.6	2.5	2.5 amps.*
Tube Voltage Drop (Approx.)	15	10	15	10 volts
Base	4 pin	4 pin	50 watt	50 watt

*Maximum.

RK-19, RK-21, RK-22

Raytheon Rectifiers. Intermediate between 83 and 866 rectifiers, but of high vacuum type construction. Designed for 1000 volt DC supplies.

Characteristics:

	Full Wave RK-19	Half Wave RK-21	Full Wave RK-22
Heater Voltage	7.5	2.5	2.5 volts
Heater Current	2.5	4.0	8.0 amp.
Maximum RMS Voltage Per Plate.............			1250 volts

Maximum Peak Inverse Voltage ....3500 volts
Maximum Peak Current ....600 ma.
Maximum D.C. Load Current (with Cond. Input)..200 ma.

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866B

Taylor mercury-vapor half-wave rectifier for operation in full-wave or bridge rectifier systems. Intermediate in load capacity between 866 and 872A rectifiers.

Characteristics:

Filament Voltage ....5 volts
Filament Current ....5 amps.
Peak Inverse Voltage ....8500 volts
Peak Inverse Current ....1 amp.

Chapter 12

Radiotelephone Theory

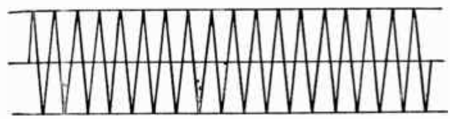
● What can be defined as the average transmitter is that which consists of the following components: (1) a portion that generates and amplifies the radio-frequency carrier wave; (2) a portion that converts the sound waves into electrical waves; (3) a portion that takes amplified audio-frequency currents and mixes them (by a process known as modulation) with the radio-frequency carrier in such a manner that the power output of the transmitter varies in exact accordance with the variation in sound pressure applied to the microphone.

Modulation Fundamentals

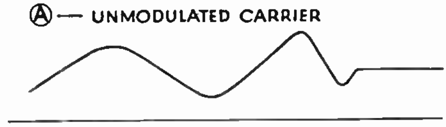
● In general, all communication systems utilize audio-frequency waveforms. These may be either pure tones and square-topped waveforms for use in code transmission, or the waveforms may be quite complex for conveying telephonic speech directly, without translating the intelligence conveyed into dots and dashes of the telegraphic or radio codes. The range of audio-frequencies required to transmit the intelligence varies from a few cycles to 10,000 cycles per second, depending on whether telegraphic or high-definition amplification is used. For amateur purposes, an audio-frequency range of from 200 to 2800 cycles per second will provide intelligibility, although fully natural and pleasing reproduction of the transmitted speech requires a range of from at least 100 cycles to 4000 cycles. For high-definition, frequencies between 80 and 8000 cycles must be faithfully reproduced at the receiving point, such fidelity is seldom secured in amateur practice, but should be attained whenever conditions permit.

In the transmission of telegraphic signals over a radio circuit, the carrier is radiated only during the "mark" period. The "space" is obtained and defined by an absence of the carrier. On the other hand, when telephonic communication is used on a radio channel, the carrier remains on between syllables and words. The audio signal periodically increases and reduces the amplitude of the carrier, while the average amplitude of the carrier remains constant.

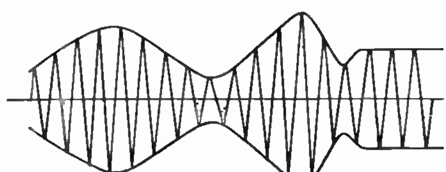
When a modulated carrier is analyzed, it is found that the original carrier is present, plus two groups of the sum and difference frequencies, which have been named the upper and lower sidebands. These sidebands are generated in the transmitter by the familiar heterodyne process. Thus, one sideband consists of the waves whose frequencies equal that of the carrier *plus* that of all the individual audio components, and the other sideband consists of the waves whose frequencies equal that of the carrier *minus* all the audio components. In other words, the carrier and the audio signal were *heterodyned* together into a group of *beat-frequencies* by the action of the modulated amplifier.



Ⓐ— UNMODULATED CARRIER



Ⓑ—AUDIO SIGNAL TO BE APPLIED TO CARRIER



Ⓒ— MODULATED CARRIER

Curve (A) indicates the pure c-w wave applied to the grid of the modulated amplifier. Curve (B) shows the audio frequency output of the modulator. Curve (C) shows the combination of the two after being mixed in the modulated amplifier. Note that the average value of the modulated wave is constant.

The carrier takes up a relatively small position in the frequency spectrum, but, since each sideband contains all the audio signal components, the modulated signal will require a frequency band twice as wide as the highest audio-modulating signal. For example: If the transmitter responds to frequencies between 100 and 4000 cycles per second, then the bandwidth must extend 4000 cycles above and below the carrier. This 8000 cycle band will cause some interference to any other station whose sidebands extend into this particular portion of whatever amateur band the transmitter is working in. Almost 85 per cent of the power radiated in the sidebands consists of the frequencies in the register below 1500 cycles, the remaining 15 per cent consist of frequencies of the upper register, which determine the quality of speech reproduction. The high audio-frequencies contain the greater portion of the harmonic content of sound which, if muted, depletes the fidelity and timbre of natural speech.

Power Distribution in a Modulated Wave

● The amplitudes of the sidebands depend on the percentage modulation; the higher the degree of modulation, the greater the sideband amplitude. It takes *power* to modulate a wave which is expended in altering its amplitude. When a carrier is 100 per cent modulated by a pure audio tone, the power in each of the two sidebands equals one-quarter of the unmodulated carrier power output. Thus the power in both sidebands equals one-half the carrier wave and, therefore, complete modulation increases the average power output of the phone transmitter 50 per cent. If a class C radio-frequency amplifier is plate modulated, the plate power input must therefore be increased 50 per cent in order to get a 50 per cent increase in output, because the plate efficiency remains constant during modulation. This 50 per cent increase in plate input is obtained from the modulator tubes in the form of AC. It is superimposed on the DC plate input in such a manner that the instantaneous plate voltage (and current) is alternately raised to twice the unmodulated value, and then reduced to zero. In order to swing the plate voltage of the class C amplifier from zero to twice normal, the modulators must alternately supply and absorb power. This involves energy storage during the time the plate voltage is below normal. This energy is stored in the Heising choke, or in the modulation coupling transformer, depending upon whether capacitative or inductive coupling is used between the modulators and the modulated amplifier.

One hundred per cent modulation is approached only on the extreme voice peaks. Ordinarily these peaks should seldom be allowed to modulate a phone transmitter more than about 80 per cent, and the average modulation during the time that the operator is actually speaking should approximately average 40 per cent. However, the capability to modulate at 100 per cent is essential to minimize heterodyne interference between or with other stations.

All plate modulated RF amplifiers operate as class C amplifiers which require that the grids of the tubes be heavily excited by a buffer amplifier so that the power output of the stage will rise as the square of the plate voltage without any "dropping off" tendency as the instantaneous plate voltage approaches twice the normal value under modulation. HINT: In practice, choose tubes with as high a mutual conductance as possible to economize on driving power.

The plate input to a class C modulated amplifier increases during modulation, while the plate efficiency remains constant. On the other hand, the plate dissipation will increase when audio modulation is applied, necessitating that the tube operate below its maximum rating in order to allow some reserve dissipation for the heat radiated from the plate during complete modulation; incidentally, the heat increases upwards to 50 per cent during 100 per cent modulation.

Another reason for operating modulated amplifier tubes below their maximum rating is that the peak plate voltage and the peak plate current are doubled during complete modulation.

Shielding RF Portions of Phone Transmitters

● Additional shielding or isolation of the RF portion of the transmitter will be required in order that all RF be kept out of the speech amplifier, such precautions will prevent the amplifier from overloading and "singing"; in some cases it will be even necessary to shield the entire speech amplifying equipment.

Phone Transmitter Components

● The three principal parts of the phone transmitter are: (1) the radio frequency channel; (2) the audio-frequency channel; and (3) the power supplies. In the subsequent treatment, an analysis is given to the major components comprising each of the aforementioned parts.

The RF Channel

● The principal function of this channel is to generate and amplify radio-frequency alternating-current oscillations which are ultimately modulated by the voice impulses and then radiated from the antenna.

The radio-frequency generator consists of a low-power AC oscillator tube whose frequency is held within very close limits in order that the period of oscillation does not appreciably drift. In practically all modern amateur transmitters the frequency is maintained at a near-constant value by a quartz plate oscillator.

While the crystal has a tendency to resist changes in frequency caused by changes in the plate voltage, or by other circuit characteristics, it cannot entirely compensate itself from factors tending to alter the generated frequency. For these reasons, the crystal oscillator cannot be modulated directly without some undesirable frequency modulation. These wide changes in plate voltage will have some effect on the circuit parameters of the most stable of crystal oscillators. Amplifiers which adjoin the crystal oscillator must not be modulated lest some reaction be reflected back into the oscillator which may have (it generally does) some effect on the frequency stability. A crystal oscillator must be isolated by at least one buffer stage between it and the succeeding radio-frequency amplifier which is modulated by the voice impulses.

The Modulated Amplifier

● Power modulation, sometimes called "Heising Modulation," "Plate Modulation," or "Power Supply Modulation," is used in most amateur stations. In a previous explanation it was stated that all forms of plate-modulated amplifiers operated "class C" wherein the negative grid bias is greater than two times that value of bias which would reduce the plate current to zero if the RF grid drive is removed.

The process of plate modulation occurs whenever the plate voltage is varied up and down over its normal value at an audio-frequency rate, the variations being exactly in accord with the voice impulses which strike the diaphragm of the microphone. If the class C RF amplifier is properly biased and driven, the radio frequency AC voltage measured across the plate tank coil will, at all times, be exactly proportional to the instantaneous DC plate voltage. By instantaneous DC plate voltage is meant the sum of the constant DC plate voltage, plus the instantaneous AC voltage which is superimposed on it, and which comes from the modulator tube or tubes. This variation of radio-frequency voltage across the tank coil obviously causes a variation in the power output of that amplifier stage, and if the antenna is coupled to the modulated amplifier the RF energy is modulated in accordance with the variation of sound applied to the microphone. The RF signal in the detector circuit of a distant receiver, when the carrier is unmodulated, is inaudible—unless a beat-frequency oscillator supplies a heterodyning signal. However, as soon as the amplitude (or voltage) of the carrier signal is varied and is present in the distant receiver, the variations are changed by electro-acoustic conversion in the reproducer and are heard as sound.

In order that the amplitude of the RF output shall be an exact replica of the voice impulses, it is essential that there be no regeneration in the class C amplifier. This means that the RF amplifier must be perfectly neutralized. It takes an appreciable amount of regeneration to make an amplifier break into self-oscillation; however, because an amplifier does not oscillate is not an indication that it is perfectly neutralized. There may not be enough regeneration to allow self-oscillation, but even a small amount of regeneration can seriously disturb the linearity of modulation and thereby cause distortion. The modulation must not only be linear, it must be perfectly symmetrical as well. In other words, the positive and negative peaks of modulation must be equal. This necessitates that the carrier output must swing up just as much as it swings down on the immediately succeeding half cycle. Non-symmetrical modulation causes a change in the average amplitude of the modulated wave, which results in carrier shift and serious interference, as well as introducing audio distortion. Interference due to non-symmetrical modulation is very much of the type as that resulting from over-modulation and is sometimes called "sideband splatter."

Non-symmetrical modulation is sometimes caused by having a very low C in the plate tank circuit of the modulated amplifier. If there is an excess of inductance and a deficiency of capacitance in the circuit, the proper amount of circulating current will not flow in the tank circuit to provide the necessary "fly wheel" effect.

See L to C Ratio Chart in *C. W. Theory Chapter* for correct capacity to use at various frequencies.

Frequency Modulation

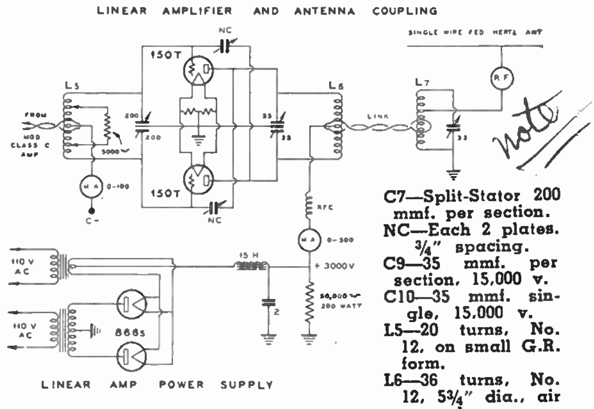
● The oscillator frequency will vary during modulation unless one or more buffer stages are used between the modulated stage and the oscillator. This variation of frequency is called "frequency modulation."

Linear Amplifiers

● To avoid distortion, any amplifier which amplifies a wave previously modulated in some preceding stage must produce output wave shapes which are exactly similar, except for size, to the input wave shapes which excite the grid. This type of amplifier is called a "Linear Amplifier" because its output is a linear function of its input. The most common type of linear amplifier is usually biased exactly to cut-off and it is called a "class B Linear Amplifier."

The reasons why these amplifiers are not more widely used in amateur stations are because they are quite difficult to adjust and they require a rather expensive amount of tube capacity for their carrier output.

It is desirable to operate a linear amplifier at as high a plate voltage as possible to obtain the maximum possible unmodulated plate efficiency. Because the grid current



C7—Split-Stator 200 mmf. per section.
NC—Each 2 plates. ¾" spacing.
C9—35 mmf. per section, 15,000 v.
C10—35 mmf. single, 15,000 v.
L5—20 turns, No. 12, on small G.R. form.
L6—36 turns, No. 12, 5¾" dia., air spaced.
L7—22 turns, 3/16" copper tubing, 4½" dia., air spaced.

The coil data is for 75 meter operation.

varies with the percentage modulation, the grid bias of a linear amplifier must be supplied from a separate source, such as batteries of a low-resistance power supply, to avoid distortion.

Linear amplifiers operate as efficiency modulated devices. The plate efficiency is controlled by the RF excitation voltage applied to the grid. The maximum theoretical unmodulated plate efficiency for a class B linear amplifier is 39 per cent, and 50 per cent for a class BC linear amplifier. In practice, the unmodulated plate efficiency of a class B linear amplifier seldom exceeds 30 per cent, and for the class BC linear amplifier the upper limit is about 40 per cent.

The modulated output is obtained by varying the instantaneous plate efficiency of the linear amplifier between the limits of zero efficiency and twice the normal unmodulated efficiency. Thus a class B linear amplifier might be 30 per cent efficient during periods of no modulation, and during periods of 100 per cent modulation the instantaneous efficiency would be varying at an audio-frequency rate between zero and 60 per cent. During the period of 100 per cent modulation the *average* plate efficiency increases 50 per cent. Because the average plate efficiency is lowest when unmodulated, the plate loss is highest at that point, and it is therefore evident that all linear amplifiers cool off during modulation. Exactly the opposite occurs in a class C plate-modulated amplifier because its plate loss increases 50 per cent during periods of 100 per cent modulation and also because the plate efficiency of a class C amplifier remains approximately constant during modulation, although the average DC plate input is increased 50 per cent.

The Audio Channel

● The fidelity and faithfulness by which the voice frequencies are amplified depends wholly upon the individual characteristics of the parts comprising the audio-frequency amplifying equipment. To satisfactorily pattern any group of instruments into a well-designed speech amplifying system requires that each part be better than just "ordinary" or "cheap."

Microphones

● The function of a microphone is to convert sound energy into electrical energy. In a perfect microphone the electrical output would be an exact replica of the sound input caused by the successive compressions and rarefactions of the air in front of the mouth of the person who speaks into the microphone.

The various types of microphones in use today are:

(1) The carbon microphone (with one or two buttons).

(2) The condenser microphone (air and nitrogen filled).

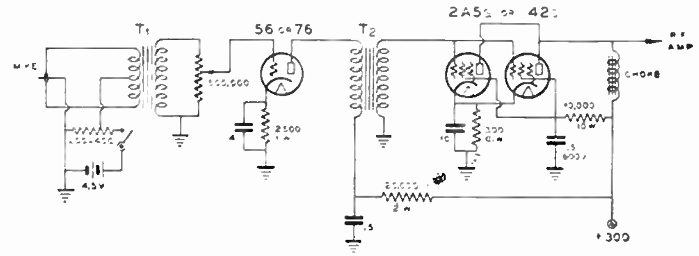
(3) The crystal miscrophone (Piezo-electric type).

(4) The inductive microphone (moving ribbon) (velocity type).

(5) The dynamic microphone (moving coil type).

(6) The non-directional dynamic microphone.

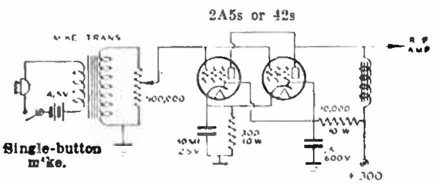
T1 — Double Button Mike-to-Grid Trans.
T2 — 3:1 Interstage Transformer.
Choke: 20 henry, 200 M.A.



10-watt amplifier for double-button microphone.

The Carbon Microphone

● This type of microphone is the most common in use today. The electrical output results from the fact that the resistance of a group of carbon granules varies with the mechanical pressure exerted on them. The pressure is varied by a metal diaphragm whose oscillatory movement is conveyed directly to the pile of carbon particles which varies the microphone battery current flowing through the microphone. In the case of a double-button carbon microphone there are two groups of carbon particles located in metal buttons, one on each side of the diaphragm. This vibrating member is usually stretched so as to remove the mechanical resonant point of the diaphragm out of the most important part of the audio-frequency range. These two-button microphones are connected to a center-tapped primary winding on the microphone coupling transformer so that the buttons are effectively in push-pull. This tends to minimize the even harmonic distortion which is inherent in all carbon microphones.



10-watt amplifier for use with a single-button microphone.

Unfortunately, all resistive types of acouso-electric converters have a rather high background hiss, due to the button current; in addition, are incapable of responding to wide frequency range, and generate more than a good portion of harmonic distortion. Fortunately, carbon microphones being low-impedance devices (200-400 ohms) require little or no shielding. Another feature is that the ruggedness and mechanical construction of the device allows it to be handled without the consideration that would necessarily be required with a more delicate instrument. The output of a highly damped two button type is rated at —45 D.B.

The Condenser Microphone

● This type of microphone is capable of giving all the fidelity an amateur can use. It operates on the principle that any variation in the dielectric spacing of a small condenser generates a small AC voltage across the condenser terminals. A rather high polarizing voltage must be applied between the condenser plates to secure sufficient output; voltages from 90 to 180 volts are common. The condenser microphone has a heavy back plate in front of which is located a thin "dural" diaphragm, tightly stretched to eliminate resonance. The space between the diaphragm and back plate is sometimes filled with nitrogen to improve the over-all response characteristics. The diaphragm is usually a thousandth of an inch thick, with that amount of spacing between the vibrating member and the back plate. When sound waves are impressed on the diaphragm its oscillatory movement varies the electro-static capacity between the two condenser plates, which impresses an AC voltage on the DC polarizing voltage. This AC voltage is then transferred to the grid of the first audio amplifier through a small blocking condenser which isolates the polarizing voltage from the grid of the first audio tube. The output is about —95 D.B. as compared with an ordinary single button telephone microphone with unstretched diaphragm.

The condenser microphone has the advantage that its extremely light diaphragm gives somewhat better high-frequency response than a carbon microphone. In addition, there is no carbon hiss. The disadvantage lies in the fact that the audio output is so low that a "pre-amplifier" is necessary to augment the minute currents up to a level equal to that of a standard 2-button carbon microphone (—45 D.B.). Because the condenser microphone is a very high impedance device, it must be isolated from both RF and AC fields. Weather conditions, such as humidity and barometric pressure, affect the response characteristics of practically all electro-static devices. Cavity resonance, structural and resonance peaks tend to alter the fidelity of many types of condenser microphones, especially those of inferior manufacture. On account of these factors, prospective purchasers should carefully weigh both the electrical and mechanical features of a group of microphones before finally making their acquisition.

The Crystal Microphone

● There are two types of crystal microphones—the diaphragm type and the grill type. Both operate on the piezo-electric principles as defined by Curie. When a dielectric material in a condenser changes its mechanical dimensions or density, a change in capacity occurs. This change in capacity generates a small AC voltage. All crystal microphones use Rochelle salt crystals, which act like small condensers. If these crystals are subjected to a deformation by bending strains caused by an acoustic pressure, a small audio-frequency will be generated across the two small pieces of metal foil which are glued to opposite faces of the crystal. The voltage produced by the crystal is then fed into a pre-amplifier for the necessary amplification.

The *diaphragm type* is the most inexpensive of crystal microphones. While it is capable of somewhat better fidelity than the more common types of condenser microphones, its quality is not comparable to that secured from the better types of electrostatic instruments. No polarizing voltage or magnetic field is required, and the audio output is approximately equal to that obtained from the highly-damped types of two-button carbon microphones. There is no background noise and the fidelity depends upon the care with which the diaphragm has been installed.

The *grill type* of crystal microphone is capable of almost perfect fidelity. It consists of a series of crystals (or sound cells) connected in series-parallel to produce a high output. The energy developed by this type of microphone is equal to that of the lower-level moving coil types, and is somewhat higher than that of the moving coil variety of microphones. Although the device is a high impedance source of audio voltage, its peculiar condenser caracteristics allow the use of a shielded lead which can be 100 feet long between the microphone and its associated pre-amplifier. One important advantage of the grill type crystal microphone is that it is less directional than other types of microphones. The output level varies between —65 and —74 D.B., depending upon the construction.

The Inductive Microphone

● These microphones operate on the principle that the movement of a conductor in a magnetic field induces a voltage in the conductor. The ribbon microphone utilizes a thin corrugated metal ribbon, or tape, a few thousandths of an inch thick, loosely supported between the poles of a form of horseshoe magnet. When actuated by sound waves, the diaphragm or ribbon oscillates in the magnetic field, which induces a very small current in it. The two ends of the ribbon are connected to the primary of a coupling transformer which steps-up the voltage output and applies it to the grid of a pre-amplifier tube. The ribbon microphone is very rugged and is of rather simple construction; in addition, is capable of high-definition in response with regard to the direction of the sound approach. Being actuated by velocity, rather than by pressure, the high frequency doubling is avoided which in other types of instruments impairs the fidelity. The microphone has an extremely low impedance (less than 1 ohm) and is therefore not affected by radio-frequency fields; on account of this feature the device may be placed close to the transmitter. Unfortunately, the microphone is sensitive to 60-cycle or power line fields if in the proximity of these areas. Low frequencies are unduly emphasized when speaking close to the ribbon. Because the audio output is approximately the lowest of all acousto-electric devices, a high-gain pre-amplifier is required to bring the output up to a usable level. The output is about —100 D.B.

The Dynamic Microphone

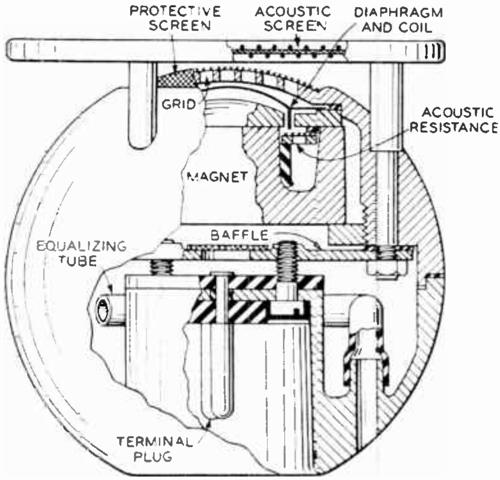
● This type of microphone operates on the same principle as the ribbon type. However, it uses a small coil of wire attached to a diaphragm to generate the audio voltage. A permanent magnet supplies the magnetic field in most cases, and the audio output and fidelity are similar to those of the condenser microphone. The moving coil microphone is a low impedance device and thus can be remotely located from its associated pre-amplifier. The usual impedance of the moving coils is about 30 ohms and the rated output level is —85 D.B.

The moving coil microphone is rapidly gaining popularity amongst the amateur fraternity. It is quite rugged and has the outstanding advantage that its characteristics do not readily change with age or atmospheric conditions; once the device is equalized, its fidelity remains constant.

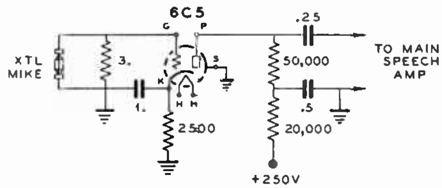
The Non-Directional Microphone

● This is a type of microphone that will respond uniformly to all sound pressure and is built on the moving-coil principle. It differs radically from previous microphones in appearance, consisting of a two and one-half inch spherical housing with a two and one-half inch acoustic screen held a fraction of an inch off the surface. In this type of microphone the directional effect is so slight as to be imperceptible; this effect is largely a function of the size of the microphone relative to the wavelength of sound.

With a spherical microphone mounted with the diaphragm horizontal (see the accompanying figure) there would be a tendency for the response to be too high for high-frequency sounds coming down from above; that is, directly toward the diaphragm, and too low for similar frequencies coming from angles very much below the horizontal. The effects are completely avoided, and an essentially uniform response is obtained from sound coming from all directions, by mounting an acoustic screen in front of the diaphragm. This screen produces a loss in sound passing through it, but reflects back into the diaphragm all sound coming from behind the microphone. It thus compensates for the unequal diffractive effects and makes the instrument non-directional in its response.



Simplified cross-sectional view of Western Electric non-directional microphone.



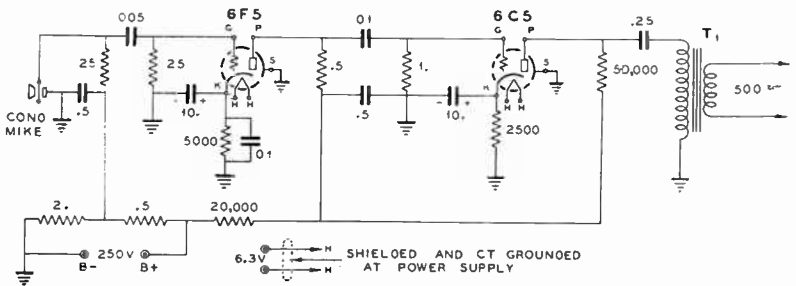
Crystal microphone pre-amplifier. Gain approximately 20 D.B.

The microphone has a uniform characteristic from 40 to 10,000 cycles; it is also free from electrical interference and has such features as: high signal-to-noise ratio, ruggedness, dependability and freedom from temperature, barometric and humidity effects. Another characteristic is the low electrical impedance which allows its use several hundred feet from the amplifying equipment.

Pre-Amplifiers

● Practically all types of high-fidelity microphones have a very low audio-output and require an intermediate device between the microphone and main voltage amplifier to build-up the weak electrical output; this device is called the "pre-amplifier." It consists of two stages of resistance or transformer coupled triodes connected in cascade. The over-all gain of most pre-amplifiers ranges from 35 to 55 D.B., depending upon the particular type of input microphone used; the decibel rating given here represents a voltage amplification of about 250 to 1000 times. (NOTE: It is almost prerequisite that all amateurs acquaint themselves with the D.B. unit; reference should therefore be made to the discussion appearing in Chapter 3, "*Decibels and Logarithms*".

Since it is the function of pre-amplifiers to be associated with minute audio-frequency voltages, emphasis must be placed upon protecting the amplifier from all hum and background noises. To minimize the hum pick-up



Metal tube pre-amplifier for condenser microphone. Gain approximately 50 D.B. T1—tube-to-line output transformer.

requires good shielding as well as RF chokes in the grid leads, the latter being required if the amplifier is to be operated close to a transmitter. The power supply leads energizing the equipment must be well shielded and not run closer than three feet to any choke or transformer which has AC flowing through it.

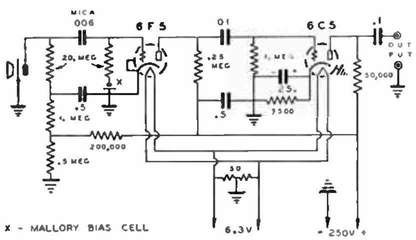
The heaters of the tubes can be operated from 6.3 volts AC if care is taken to completely by-pass and shield the filament leads. Otherwise a small storage battery may be necessary if high gain is desired.

Gain controls are seldom incorporated in a pre-amplifier; this function is best left to a voltage divider or attenuator in the main voltage amplifier. (NOTE: Design information on pre-amplifiers may be found in Chapter 3, *"Decibels and Logarithms"*.

Pre-Amplifier With New Metal Tubes

● The performance of a condenser microphone pre-amplifier cannot be improved on to any great extent, but the new developments in parts and tubes allow a more compact and better mechanical design.

Two of the new metal-envelope type 6F5 and 6C5 tubes form major parts complement of a modern pre-amplifier. Electrically, metal tubes have little advantage over others except for the lower hum level obtained and, in addition, to a slight increase in the gain. These tubes, however, take up less space and



Circuit diagram for condenser microphone amplifier illustrated above. A small dry cell (1.5 volts) can be used in place of the Mallory Bias Cell.

greatly simplify the problem of shielding. An entire two-stage pre-amplifier can be built into a case that formerly housed a "Stromberg-Carlson" audio transformer. The interior partitions are constructed from galvanized iron and then given a coat of lacquer to match the appearance of the case. The mechanical construction is such that all parts in the amplifier are accessible.

A "Mallory" bias cell furnishes the bias voltage on the 6F5. A potentiometer arrangement reduces the polarizing voltage from 250 to 175 volts.

With some types of condenser heads, it is not possible to apply more than 100 volts as a polarizing voltage; the differences in potential can, however, be changed by making the proper adjustments on the potentiometer.

It is recommended that well-designed "noiseless type" resistors will be used. In the second stage the amplification level is of such a value that any good grade of carbon resistors will prove satisfactory. The shielded lead from the positive high-potential plate of the microphone head which energizes the grid circuit of the 6F5 must be well insulated between the shielding and the external wire. Considerable noise will be developed in this circuit if this insulation is faulty.

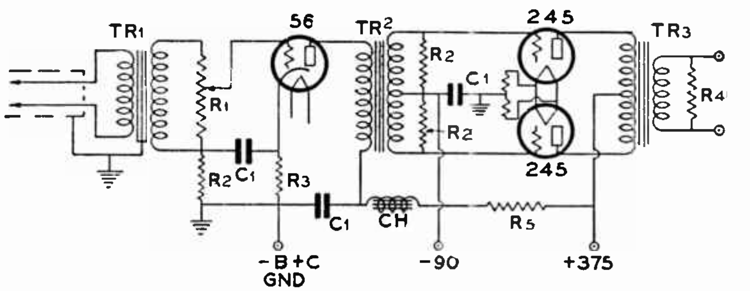
The output impedance of the pre-amplifier is low enough that no line coupling transformers will be necessary for distances up to 100 feet. The output is fed to the grid of the first tube in the main amplifier either through a regular inter-stage audio transformer or a 0.1 mfd. coupling condenser. The transformer should be located at the input of the main amplifier if transformer coupling is used. If resistor coupling is used, the 0.1 mfd. condenser should be located at the input of the main amplifier even though there is already one blocking condenser in the output lead at the pre-amplifier.

The filament leads must be shielded and the grid leads short as possible. It is important that the heaters of the tubes be grounded either at the center-tap winding on the filament transformer or by a center-tap resistor scheme.

The power supply must be well-filtered and provided with at least three filter sections with a total of more than 30 mfd. capacity. Three small 50 hy. (or those having higher values) 10 MA. chokes shunted at each terminus with 8 mfd. electrolytic condensers will provide a hum-free source comparable to battery supply.

The Main Voltage Amplifier

● The main voltage amplifier is not clearly defined in most amateur stations, but is often combined with the driver stage for the high-powered modulator. Briefly, that part of the audio channel which starts at a point roughly corresponding to the output level of a damped high-quality two-button microphone which is approximately —50 D.B. below the zero level is termed the "main voltage amplifier." Throughout this HANDBOOK, a zero level equal to 6 milliwatts (.006 watts)



VOLTAGE AMPLIFIER AND DRIVER.

R1—500,000 ohms. R2—250,000 ohms. R3—3,000 ohms wire-wound. R4—1,200 ohms wire-wound. R5—30,000 ohms wire-wound. CH—50 henry, 15 MA. TRI—Plate to Grid Transformer. TR2—P.P. Input Transformer. TR3—Modulation Transformer. 3-1 stepdown.

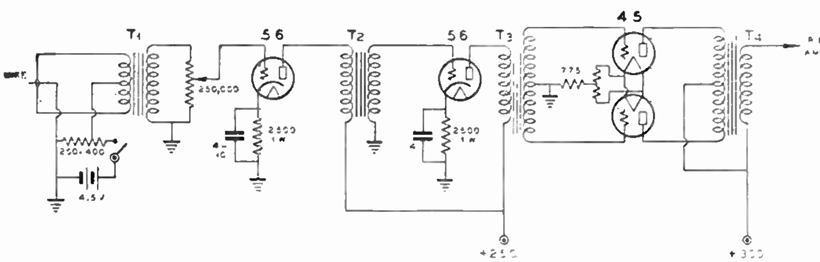
of power will be used as an arbitrary reference level. Thus —45 D.B. corresponds to one-one-hundred thousandth of 6 milliwatts. A good voltage amplifier must be capable of amplifying an input of —45 D.B. up to full output, that is, to the zero level. Such an amplifier can consist of two stages of type 6C6 triodes, transformer coupled.

To control the input to a main voltage amplifier requires the use of some type of attenuating device; this can consist of a potentiometer of about 250,000 ohms whose sliding contact connects to the grid of the first stage.

The main voltage amplifier drives either the "driver power amplifier" or, in certain cases, it directly drives the "low powered modulator." This amplifier operates at a considerably higher audio level than a pre-amplifier, and therefore does not require exceptional filtering or shielding to minimize background noises. However, as a precautionary measure, the first stage should be well-filtered and shielded because of the hum which might occur due to faulty construction or design.

The best inter-stage coupling in amplifiers in which the tube components are either pentodes or screen-grid types is that obtained by resistance coupling. Coupling high-mu tubes with transformers reduces their operating efficiencies to a very low value; and audio chokes, unless specially designed for this service are also taboo. On the other hand, choke or transformer coupling will give splendid fidelity when functioning in conjunction with medium- or low-mu triodes. Resistance-coupling is ideally suitable to the following screen-grid, pentodes or high-mu triodes; these are the 75, 2A6, 40, 6C6, 57, 6F5, or 6J7.

Widely Used Main Voltage Amplifier and Audio Driver



5-Watt Amplifier for use with highly-damped type of carbon microphones.

T1—Mike to grid transformer. **T3—Push-pull input transformer.**

T2—Interstage audio transformer. **T4—Push-pull output transformer.**

The Modulator and Its Associated Driver

● A modulator which operates Class A does not require that its driver supply power, but instead it necessitates that its input be supplied with a certain voltage; this is due to the fact that the control grid of a class A amplifier, or modulator, is never driven positive, and so never draws grid current. The driver, therefore, will function splendidly with the following tubes as voltage amplifiers: the 6C6, 56, 76 and others. With the 845, 849 or 212D operating in a class A modulator, the driver should be chosen from among the small tubes, such as the 45, 42 (triode), 210, etc. The larger tubes operating class A require somewhat more grid voltage swing than can be supplied by the smaller voltage amplifier triodes.

When modulator tubes are employed in push-pull class B or class AB stages, the driver is frequently required to supply some grid power; this amount varies widely depending on the plate voltage and power output conditions. Class B modulators require slightly more grid driving power than class AB modulators, but class B modulators are often somewhat more economical to build and operate.

For example, class B 46s and class AB 50s have the same maximum undistorted power output of approximately 23 watts for two tubes at rated plate voltage. The grids of the 46s require almost two watts of power, whereas the two 50s require only about .4 watt for the same output. Thus another 46 operating as a low-mu triode must adjoin the driver for the class B 46s, while push-pull 76s can easily supply the small grid driving power required by the class AB 50s. However, the 46s are more modestly priced and operate with less plate voltage than the 50s. Offsetting this economy is the fact that the input and output transformers for the class B 46s may be more expensive than the input and output transformers for the class AB stage with the type 50 tubes.

The choice of a modulator tube depends on the DC plate input power drawn by the class C RF amplifier which is to be plate modulated. The maximum undistorted audio power output of the modulator stage must be 50 per cent of the DC power input to the class C amplifier.

Reference to the tube tables will indicate the audio output to be expected from the more common modulator tube combinations, at commonly-found plate voltages. The same table will also suggest satisfactory tubes serviceable as drivers.

Low power modulators (up to 200 watts of audio power) often operate from either a single-ended or push-pull driver chosen from the following list of the most popular low power drivers: 45, 46 (low-mu triode), 59 (low-mu triode), 2A3, 71, 42 (triode), 2B6 and 50.

Power Modulation

● Power modulation includes all forms of plate modulation because it involves the modulation of the source of power which is converted into RF carrier power by a vacuum tube amplifier. A radio-frequency class C amplifier normally operates under conditions such that the power output changes with the square of the plate voltage; thus the RF voltage output changes in exact accordance with the variation in the plate voltage. Ordinarily, all modulated class C amplifiers operate at a practically constant plate efficiency, but with a peak plate input varying above and below the normal unmodulated value in accordance with the audio-frequency AC supplied by the modulator. The plate efficiency of a plate-modulated class C amplifier can be made quite high; 92 per cent has been reached in laboratory amplifiers, although 65 per cent to 85 per cent is more common in amateur stations.

A study of the power distribution in a completely modulated wave shows that two-thirds of the total power consists of the carrier, and the other one-third is divided equally between the two sidebands. Thus the average RF power output must be increased 50 per cent for complete 100 per cent modulation, and proportionately less for lower percentages.

The plate efficiency remains approximately constant during plate or power modulation, and so the RF power output can be increased only by increasing the plate input power during modulation. In order to derive a 50 per cent increase in average power output during complete modulation, the plate power input must also be increased by 50 per cent. Because the audio-frequency modulator, or modulators, are the sole source of this increase in power, it is seen that the maximum undistorted power output of the modulators must be equal to 50 per cent of the constant DC plate input supplied to the unmodulated class C RF amplifier. The modulator, or modulators, must be coupled in the circuit between the source of DC plate power and the class C amplifier so that the peak AC voltage output and the peak AC current output of the modulators just equals the unmodulated DC plate voltage and plate current drawn by the class C stage. Under complete modulation, therefore, the constant DC plate input is alternately doubled and neutralized as the audio-frequency AC wave goes through its maximum positive and negative values. This shows that the impedances of the load represented by the class C plate circuit and the impedance of the AC power source, which is the modulator tube, or tubes, must be matched to each other if the AC voltages and currents are to exactly double and then neutralize the constant DC voltage and current, which represents the unmodulated plate current input power to the class C amplifier.

Efficiency Modulation

● The average plate efficiency must increase 50 per cent during complete modulation of an efficiency modulated RF amplifier, and the plate peak efficiency can never exceed 100 per cent; hence, the unmodulated plate efficiency must be less than 50 per cent.

Efficiency modulated amplifiers include practically all forms of grid modulated amplifiers, whether they are modulated by variable excitation, in which case they are usually termed "linear amplifiers," or whether they are modulated by variable grid bias, in which case they are called "grid bias modulated amplifiers."

Grid Bias Modulation

● When the axis of the AC grid excitation voltage is shifted by the audio-frequency modulating voltage, it is termed grid bias modulation. If the control grid of the modulated tube draws any DC grid current, then enough audio must be supplied from the modulator tube to modulate this DC grid current. Frequently this current is quite small in comparison to the DC plate current and a real economy of audio power can be effected by grid bias modulation instead of plate-power modulation. Under certain conditions the vacuum tube amplifier can be operated so that the control grid draws no DC current, even when most positive, so that the modulator tube need not supply any power to effect deep modulation, as the effective grid impedance is, in that case, very high. It is poor economy to operate a RF amplifier control grid wholly on the negative side of zero bias because the efficiency of the plate power conversion is then low, unless high plate voltages are used together with a tube of exceptionally high mutual conductance. Most grid-bias modulated amplifiers operate so that some DC grid current is drawn, at least on the peaks of modulation.

Screen Grid Modulation

● Practically all screen-grid tetrodes and pentodes built at the present time are incapable of complete and linear 100 per cent modulation when the AC modulating voltage is applied to the DC screen voltage.

It is theoretically possible to design a screen-grid pentode which will allow perfect and complete modulation to be effected by cascade screen voltage modulation, but such a tube has not been built to date, and even if such tubes were available, the use of two cascaded efficiency modulated stages would not be economical.

Suppressor-Grid Modulation

● Suppressor-grid modulation is used quite extensively among amateurs in the United States. If some means can be found to increase the unmodulated plate efficiency around 40 per cent, suppressor-grid modulation should become universally acceptable, because it is probably the least critical modulation method of any in regards to adjustment.

Summary of Efficiency Modulation

● In all known efficiency-modulation systems, the plate power input must remain constant, if linear modulation is desired. The unmodulated plate efficiency could be about doubled if it were possible to make some form of grid-modulated amplifier release its own additional plate input from the DC plate supply source during modulation.

In general, efficiency modulation is characterized by the fact that it is rather difficult to adjust without the aid of an oscilloscope; there is also some question as to whether it is more economical to employ a large tube operating at 35 to 40 per cent efficiency and a minimum of audio equipment, or to use a small high-efficiency class C amplifier stage together with extensive modulator and power supply apparatus.

Class AB Audio Considerations

● The best load impedance for class AB tubes is difficult to calculate accurately. As in class B, for a limited grid voltage the output power will be greatest when a plate load is chosen such that the product of plate voltage swing and plate current swing is a maximum. For maximum power with minimum distortion, the load resistance will decrease as the driving power is increased. In other words, with greater driving power the plate current swing on the output tube can be increased and greater power output will consequently be developed across a lower load. This again is governed by the peak current which the plate supply can deliver. It is not good practice to place a low load resistance in the circuit if the plate supply regulation is poor. This and the foregoing factors are of more or less importance, depending upon the magnitude of values in the particular design. However, a general method of determining load impedance for push-pull tubes where the grids are not driven very positive is shown in Figure 1, applied to 845 tubes. The published

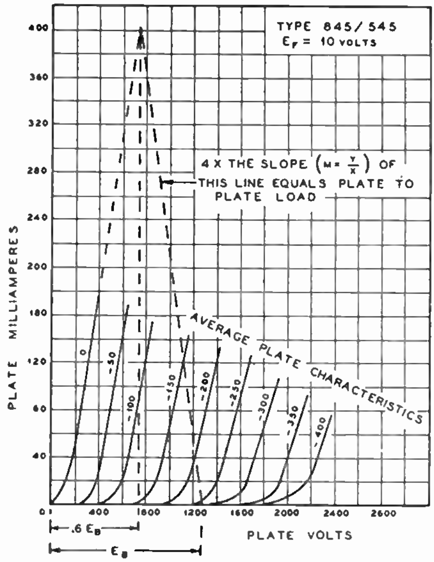


FIG. 1
Method of graphically computing proper load impedance (see text).

plate characteristic must be obtained and an operating voltage E_b selected. A vertical line is erected at $.6E_b$ and the $E_c = 0$ line is extended to meet it. A line is then drawn from the intersection to E_b. The slope of this line multiplied by 4 is the proper plate-to-plate load. In the example drawn this load is equal to

$$\frac{1250 - 750}{400} \times 4 = 5000 \text{ ohms.}$$

If the grids are driven sufficiently positive to make the normal output about four times that of a single class A amplifier with the same tube, this value of load impedance will have to be reduced about 20 per cent. If the plate supply regulation is better than 10 per cent, this load impedance can be reduced another 5 per cent. In the case shown, this would mean an effective plate load of 3750 ohms. The recommended RCA value is approximately this value.

The calculation of maximum power output is given herewith:

The power is equal to:

$$P = \frac{\text{Max. plate current} \times \text{plate voltage}}{5}$$

As shown in Figure 3, this gives

$$\frac{.40 \times 1250}{5} = 100 \text{ watts}$$

From a summary of the above notes it will be seen that AB amplification is a system lying between class A and class B; high biased near cut-off. Not all tubes are suitable for this class of service. Those most applicable are the 42, 245, 2A3, 250, 845, WE283A, 212D and E, and 849.

Class B Audio Considerations

● For obtaining high quality amplification from a class B amplifying system requires the consideration of the following precautions:

(1) The driver stage must be able to supply about two or three times the actual power required to drive the grids of the class B stage. This reserve power is necessary so that the driving voltage shall have good regulation under the variations in the load represented by the class B grids. In general, the driver output should be from 5 to 15 per cent of the class B stage.

(2) The class B input transformer must have sufficient step-down so that the driver load impedance never goes below the plate impedance of the driver tube, when the class B grids are most positive. It follows that less step-down is necessary when the class B tubes have a high grid impedance. By the same token, the choice of the driver tube with a low plate impedance, such as the 45, 50, 2A3, 2B6, and 42 triode is necessary for minimum step-down ratios.

(3) The load impedance into which the class B stage works must be fairly high in comparison with the plate impedance of the class B tubes. The actual value of load impedance is not especially critical, and for practically all common tubes it can be between 5,000 to 20,000 ohms plate-to-plate.

When the plate load impedance of a class B stage is varied, the following action occurs: As long as the load impedance exceeds the static plate resistance of the tube, an

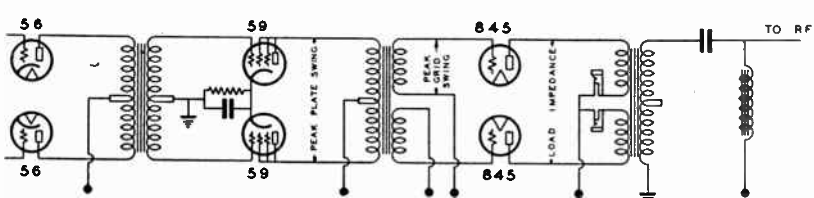


FIG. 2—A-prime 845s used for high level plate modulation.

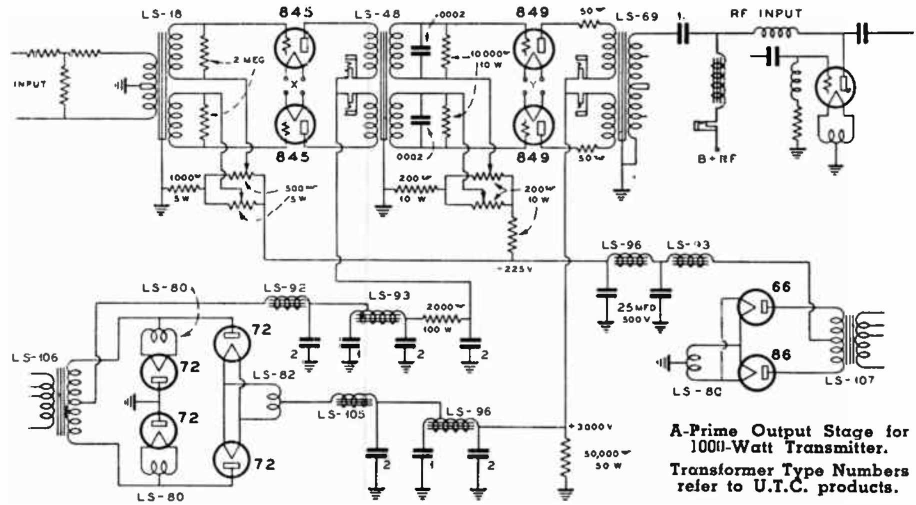


FIG. 3—The 849 bias should be adjusted so that the no-signal plate current is 40 M.A. per tube for Class A-prime operation, or 10 M.A. per tube for class B operation. Other constants are not altered.

increase in load impedance will improve the quality by reducing the harmonic distortion; in addition, the power output will be reduced for a given grid excitation, and therefore more energy will be required for the same power output, with higher loads. The plate efficiency increases as the load impedance is increased, so that more output can be delivered for a fixed plate loss by merely augmenting the grid drive. However, as the load impedance and the grid drive are increased, it is necessary to raise the plate voltage to prevent the maximum grid voltage from exceeding the minimum plate voltage at the peaks of the grid drive.

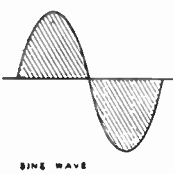


FIG. 4

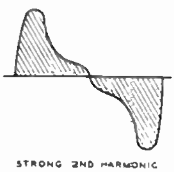


FIG. 5

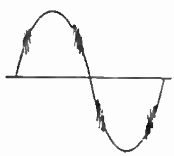


FIG. 6

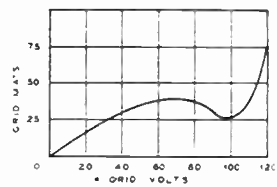


FIG. 7

(4) The two halves of the circuit must be accurately matched. Because each class B tube works for only half the cycle, it is essential that they receive exactly the same driving voltage and that they each draw the same plate current in the resting condition. No two tubes will maintain their characteristics for any length of time and it is essential that individual bias adjustments be provided so that the stage can be balanced. This precaution is only applicable with other than zero grid-bias tubes, which include the 46, 59, 19, 49, 89, 53, 79, RK31 and 838.

(5) The plate power supply must have good voltage regulation because the plate current varies quite widely with the grid drive. Any variation in plate voltage with changes in plate current will cause amplitude (harmonic) distortion, and is to be avoided. Low resistance windings on the power transformer and filter chokes are essential. The use of a saturated, or swinging, input choke helps to keep the output voltage constant with variation in current. Mercury-vapor rectifiers have an inherent voltage drop that is independent, to a great extent, of the load current, and thus cause no sacrifice of regulation, as is the case with thermionic rectifiers.

(6) With certain tubes, notably some makes of 210s, 203As, 211s, 800s, 204As and 849s, it is essential to take precautions against dynatronic distortion (see Figure 6). This type of distortion occurs when a stage starts to oscillate on the peaks, which gives rise to a rasping effect which greatly impairs the quality. This tendency toward oscillation is caused by a "dynatronic kink" in the grid characteristic of the tube; it can be

"swamped out" by placing 40-ohm parasitic resistors in each plate lead, combined with 5000 to 20,000 ohms shunted across each half of the input transformer secondary. Sometimes it is even necessary to shunt each side of the input transformer with .001 mfd. condensers.

It is common practice to consider the average or effective audio power necessary to modulate 100 per cent, but the peak audio power is the correct accounting factor. When the peak audio voltage and power reaches a value equal to the DC input voltage and power on the modulated amplifier, 100 per cent modulation is attained. The average audio power at this point is of a value that is not known unless the wave form of the audio is known. The wave forms of voice or music are very complex and the effective power in them is much less than in a sine wave of equal peak voltage, although the peak voltage and peak power are the same. Because direct-current meters read average values, it is difficult to determine when the peak current has reached the correct value for 100 per cent modulation, the average values for voice and music being lower than for a constant sine wave input. The average audio power with a sine wave of constant amplitude necessary to modulate a carrier 100 per cent is 50 per cent of the DC input to the class C amplifier. But, with voice or music, the average power necessary is considerably less.

The shaded areas of Figures 4 and 5 show the average power in two different wave forms of equal peak voltage and power. Figure 4 shows the power in a pure sine wave with no harmonics. Figure 5 shows the power in a wave of the same fundamental frequency with a strong second harmonic. The aggregate or combined peak power of the wave is equal to that of Figure 4, but the average power over the entire cycle is much less.

The illustrations indicate that under certain conditions the output from a given tube or tubes is greater with a normal voice input than one having a constant tone.

Because the "saturation plate current" is the value flowing on peak audio swings during maximum output, further excitation will cause distortion. However, by increasing the plate voltage and load impedance, the power output can be raised up to such factors as that which limits the insulation of the tube terminals and the stem seal. Tubes with the plate-lead coming out of the top are ideal as the plate voltage can be increased to a high value, resulting in higher audio outputs.

The grid voltage and grid current characteristics of a tube are the most important insofar as the quality or fidelity of the class B amplifier is concerned. When the grid goes positive, grid current flows, and

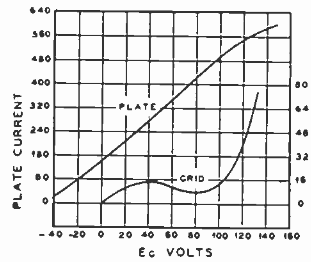


FIG. 8—203A operating characteristics.

if this curve is a straight line, little trouble will be encountered; however, such is seldom the case. As the grid becomes more positive, the grid current rises more rapidly until finally the grid current curve becomes almost vertical. Some tubes have a negative grid current slope such as shown in Figure 7. This gives rise to transient oscillation of the dynatronic variety and occurs only during a portion of the audio cycle. These parasitic oscillations cause a sort of "fuzz" to appear on the output. They can be analyzed only with the aid of a cathode-ray oscillograph; the transients are too fast to be recorded on galvanometric mirror type. In practice, the type 203A tube usually produces the spurious oscillatory effect; it can be reduced by placing a small capacitor (.0005 mfd.) from grid to ground of both tubes, or by incorporating some scheme of neutralization.

Apparently it would seem that a tube of high amplification factor would be the most appropriate tube for class B service, due to the lower value of excitation voltage necessary, but actually more power is required to excite a pair of 203As to 200 watts output than a pair of 211s. The grid current rises to a higher value and there is a greater grid loss in the 203A type than in the 211. Of course, the C bias supply for the lower-mu type of tubes must be given consideration. Owing to the much lower grid current surges, the C bias supply can be of a type of small power supply employing an 83 rectifier, whereas if the C bias supply were to be used on 203As, it would have to maintain a constant of 30 volts at current changes as high as 75 milliamperes. Practically the same power output can be obtained with any of the 100 watt type tubes, such as the 203A, 211, 838, provided the proper excitation is applied. The high-mu types require lower excitation voltage, but better voltage regulation of the driver output is needed. The low-mu type tubes require more excitation voltage, but because of lower grid current the source does not need such good regulation. The tubes of medium-mu are usually the best, all points considered.

Transformer Design

● Many types of audio distortion can be produced in a class B amplifier if the transformers have been improperly designed. The input transformer must deliver perfect quality to the class B grids, even though the grids are drawing current from zero to maximum during any one audio cycle. The grids of the class B tubes offer a load that fluctuates from infinity down to several hundred ohms. It is therefore requisite that the input transformer supply a perfect reproduction of the signal wave-form without distortion, even though the load is of a varying character.

The driver must be capable of delivering sufficient power to maintain the grid voltage swing with the current of the class B tubes flowing through the secondary of the input transformer; furthermore, the secondaries must have a very low DC resistance so that the bias on the class B tubes does not vary appreciably with the grid current. This fault is common with most input transformers. All these points must be maintained with a fair degree of constancy over the entire frequency range.

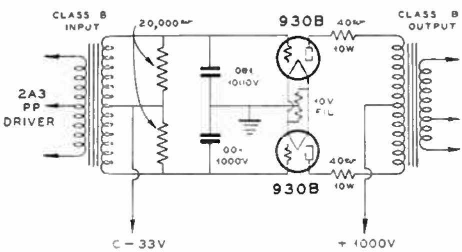
The coils must be designed so that the primary has identical relationship with both halves of the secondary. The capacity and the leakage reactance must be the same for the primary and each secondary. If these precautions are not taken, the wave form of the voltage supplied to the class B grids is not the same for each grid and distortion of the wave form occurs, giving rise to harmonic distortion.

The input transformer must have a step-down ratio of such a value that the signal voltage applied to the class B grids is just sufficient to give the required output. This improves the regulation of the driver output voltage.

Most output transformers are designed to carry the current of the modulated stage, but this practice is not advisable if the best quality is to be had.

When the secondary is made to handle high currents, a large air gap in the core is necessary to prevent saturation. This, in turn, necessitates increasing the number of turns on the coils, which increases the DC resistance, the leakage inductance, and the distributed capacity to a point where the frequency response is impaired over a large portion of the frequency spectrum. When the secondary carries no DC, the core can be assembled without an air-gap, resulting in much better quality and greater output.

It is very important, however, when this practice is followed, that the tubes have like characteristics and are adjusted to identical static plate currents. The output of a single tube working class B consists essentially of a fundamental and a series of even harmonics, chiefly the second harmonic. If two tubes are properly balanced in a push-pull circuit, the output will be free from even harmonic distortion. A correctly designed output transformer has a core of such dimensions that the flux density at peak plate current will be close to the upper bend of the B & H curve, in other words, close to saturation. Unless this is done, the incremental permeability will fall to a very low value for low percentage modulation, with a resulting loss of low frequencies. The unbalanced plate current will swing the iron through different ranges of flux density on alternate half cycles, producing high amplitude harmonics. These harmonics can produce severe over-modulation and cause the carrier to "splatter" over a wide frequency band, even though the fundamental frequency is modulating less than 100 per cent.



150-200 watt Class B modulator with 930-B tubes in push-pull.

In a class B circuit only one tube conducts at a time, so it is assumed that one tube is supplying all the power during one-half cycle and the other tube is supplying no power. The rated safe plate loss averaged over any audio-frequency cycle is 20 watts, which is a conservative value. Considering that either tube is supplying no power one-half of the time, the plate loss can be increased to double the rated value during the half cycle it is working. This would mean an average loss during the half cycle of 40 watts. The maximum loss does not occur at maximum plate current but usually near zero grid voltage, so that the plate voltage, plate current curves of the tube must be consulted to determine the average plate loss. The average plate loss of the 801 is computed from the curves supplied by the manufacturer. The plate supply voltage is 750 volts, and the peak or maximum plate current is 250 MA. The plate losses for the different grid voltages are given below:

Average loss 36.2 over one-half cycle or 18.1 watts loss over the whole cycle. This leaves some margin of safety below the

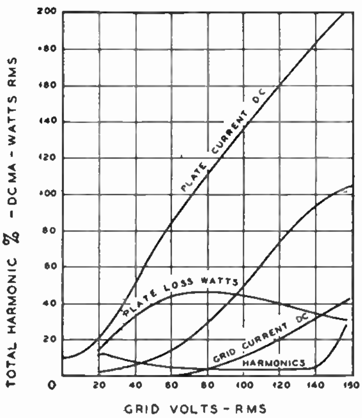


FIG. 10—Characteristics of a class B amplifier using push-pull 801 tubes.

rated 20 watt dissipation. Using the equation

$$I_p\ MAX^2\ R_L = PO_{max},$$

where R_L represents the load impedance, and I_p MAX, the peak plate current.

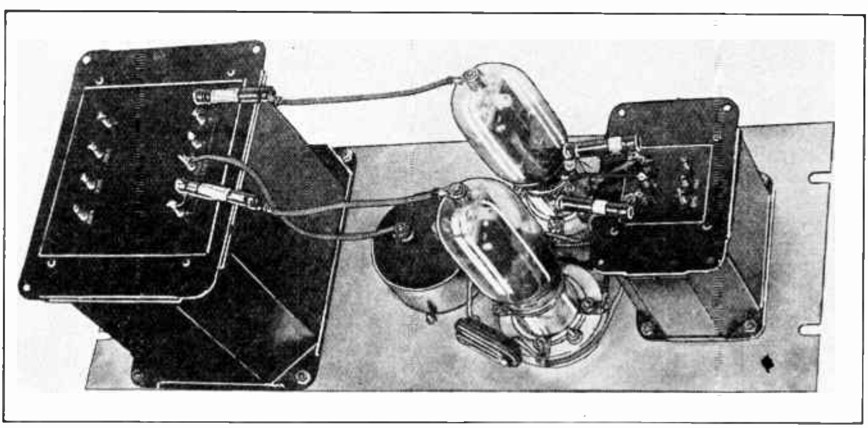
With the peak plate current of .250 ampere and a load of 2500 ohms, the result is 156.2 peak watts, or an effective power of 78.1 watts, which will modulate a DC input into a class C amplifier of 156.2 watts.

This output is possible with a pure sine wave of constant amplitude and with the tubes operating below rated plate loss, consequently, with normal voice or music input, the average or effective power being less than with constant sine wave input, the peak power can be increased to a value where the average plate loss is equal to the rated value.

Class C Amplifier Load Calculations

● The correct terminal or output impedance of a class C amplifier is important for plate modulated phone transmitters. A class B modulator must be matched correctly to the stage being modulated and the output transformer secondary to primary turns ratio is the method generally used. For example, if the class C stage is operating at 400 volts plate supply and drawing 110 MA. under load, the impedance to the modulator is 400/.110, or about 3600-ohms. The class B transformer then must have a turns ratio such that this value of impedance will be correctly transformed for the class B tubes. This impedance ratio varies as the square of the turns ratio, hence, if the class B tubes work into a 5800-ohm load (class B 46 tubes), the output transformer must step-up the 3600-ohm load to 5800 ohms. The impedance ratio is 5800/3600, or 1.6. The turns ratio would be the square-root of 1.6 or 1.26, and the output transformer would require a step-down turns ratio of 1.26 to 1 into the load.

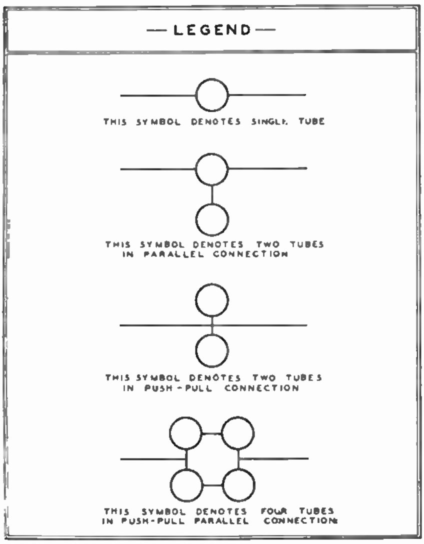
Quite often the class C load is higher in value so a step-up ratio is needed in the output or modulation transformer. For example, a class C 50T tube operating at 2000-volts plate supply at 100 MA. The impedance is 2000/.100. or 20,000 ohms. The class B audio power required is ½ × 2,000 × .1 or 100 watts. This power can be obtained from a pair of RK31 tubes at 1000 volts plate supply. These tubes require a load of 3400 ohms per tube or a total of 6800 ohms from plate to plate: 20000/6800 = 2.94 impedance ratio, with a turns ratio of $\sqrt{2.94}$, or approximately 1.7 to 1 step-up turns ratio. The secondary in this case would have 1.7 times as many turns as the whole primary winding.

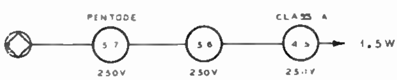


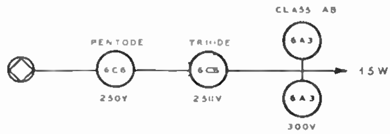
930-B (or 830-B) modulator shown in diagram shown on preceding page.

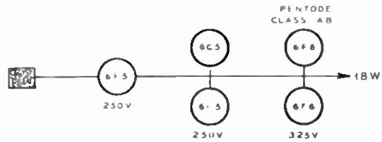
Audio Output Block Diagrams

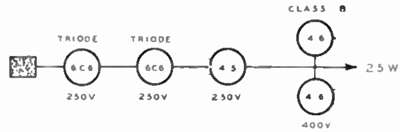
● From the group of 22 block diagrams here shown, the reader can quickly find a satisfactory tube complement for audio outputs ranging from 1.5 watts to 600 watts. The *Legend* explains the various connection systems shown in the block diagrams; crystal or carbon microphones or pre-amplifier are denoted by the conventional symbol, shown directly below the *Legend*. Correct operating plate voltages are shown under the tube symbols in each diagram. The arrow to the far right denotes the audio output of the amplifier. Outputs are listed in the respective order of the diagrams, beginning with the lowest (1.5 watts) and ending with the highest (600 watts).

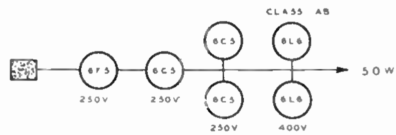


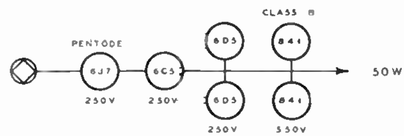


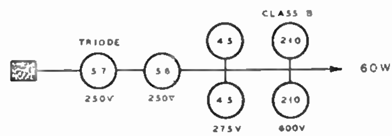


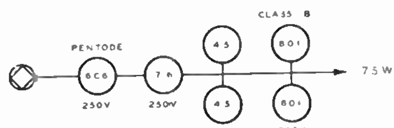


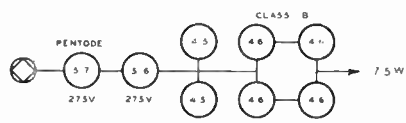


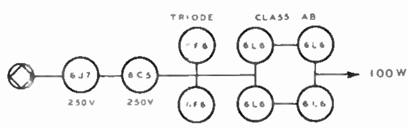


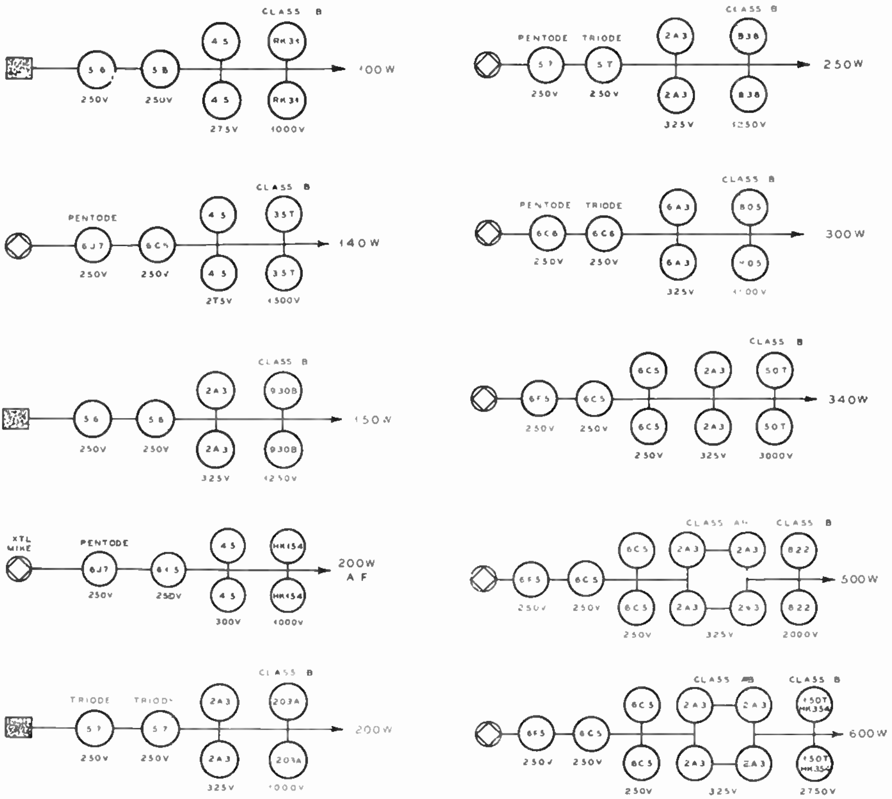


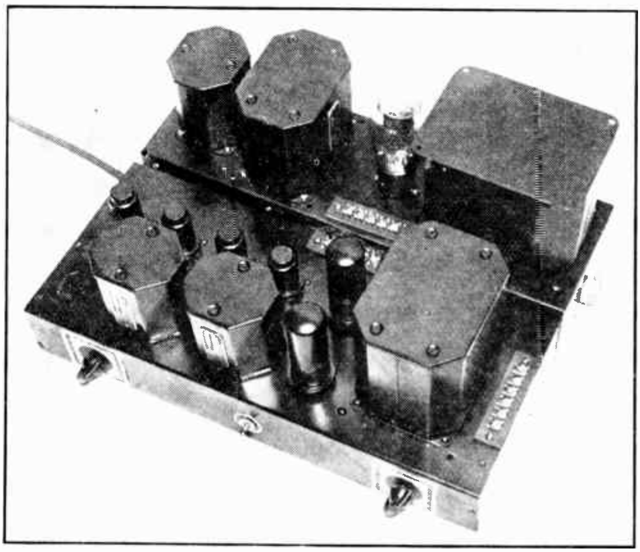










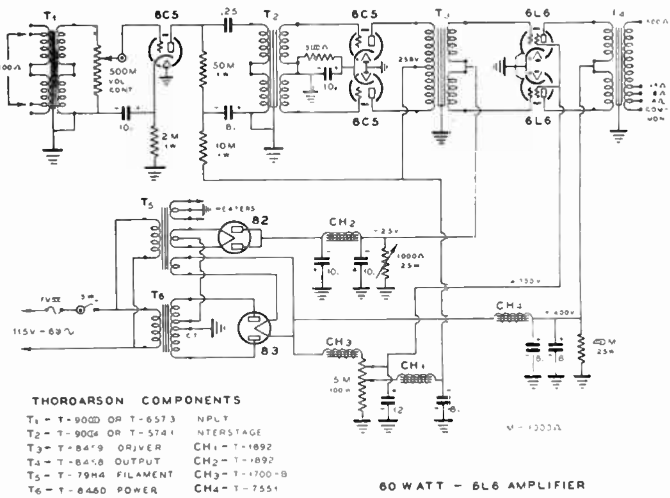


Beam-Power Amplifiers

● An inductive load on a 6L6 power amplifier does not present a constant load impedance. A loudspeaker, or a bank of loudspeakers, does not have a constant impedance over the voice frequency range, in contrast with a Class C R-F amplifier load which has nearly pure resistive load characteristics. By means of stabilized feed-back in the 6L6 amplifier, the effect of a variable load impedance can be practically eliminated, with the result that the distortion can be reduced from about 10% to less than 2% over the voice frequency range. The illustration above shows the new **U.T.C. Beam Power Amplifier** with stabilized feed-back for Public Address service.

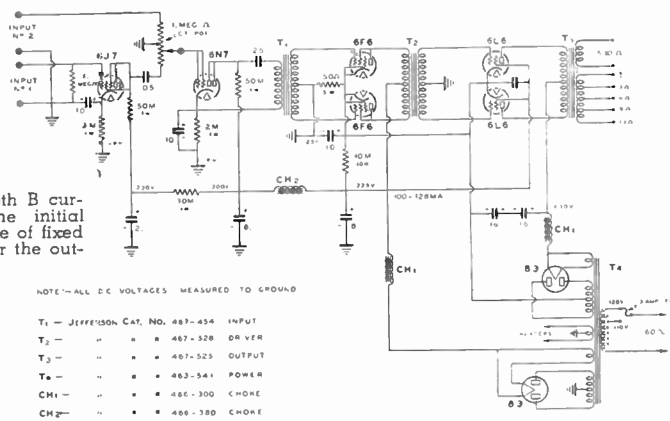
Thordarson 60-Watt 6L6 Amplifier

• By incorporating the new Thordarson "Tru-Fidelity" Transformers in the amplifier here shown, the hum level with gain open is approximately 58.7 DB down from maximum output or 18.7 DB down from zero level. The slider on the voltage divider must be adjusted for 300 volts on the screen of the 6L6 tubes, with negative 25 volts bias. Voltage measured from plate to ground on the 6C5 tube should be 258 volts. Total plate current of final stage, 100 to 110 ma. with no signal.

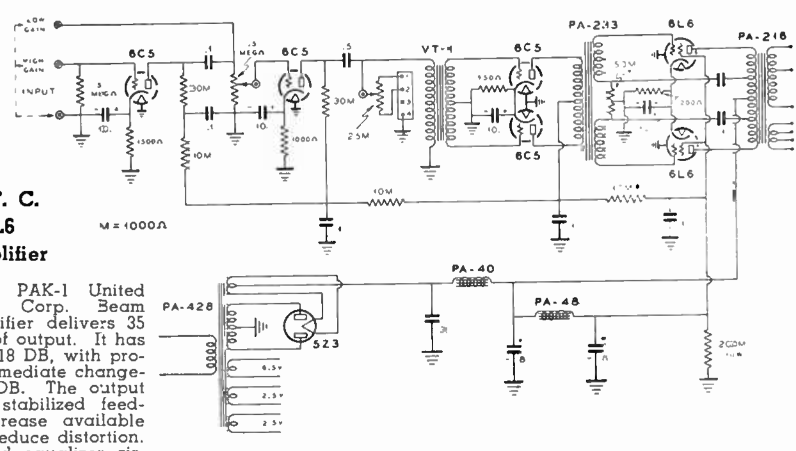


Jefferson 60-Watt 6L6 Amplifier

• Two 6L6 tubes in Class AB. The power transformer has one set of windings for supplying both B current requirements for the initial stages and a steady source of fixed bias and screen voltage for the output stage. Frequency range: 30 to 12,000 cycles. Gain 120 DB, or 88 DB, depending upon input channel connection.



U. T. C. 6L6 Amplifier



• The Type PAK-1 United Transformer Corp. Beam Power Amplifier delivers 35 to 55 watts of output. It has high gain, 118 DB, with provision for immediate changeover to 95 DB. The output circuit has stabilized feedback to increase available output and reduce distortion. Self-contained equalizer circuits enable bringing up the low frequency, or both low and high frequencies simultaneously. All resistors are rated at one watt, except bleeder and 6L6 cathode resistors, which are 20 watt.

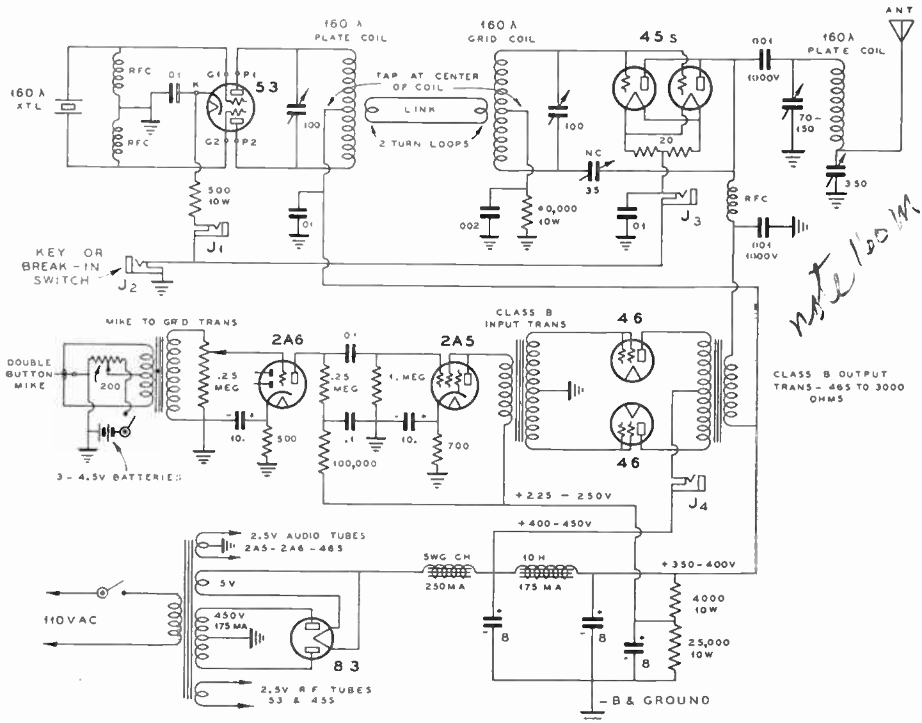


FIG. 11—R.F. speech and power supply for modern 160 meter phone, pictured in Fig. 13. All values are clearly shown.

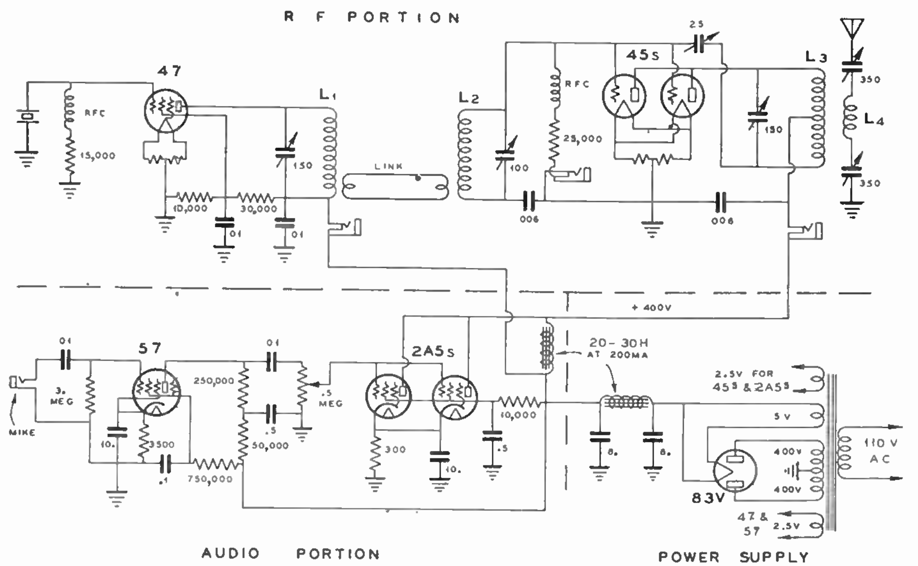


FIG. 12—Practical circuit for 25-watt phone with 47 oscillator link coupled to two 45s.

Chapter 13

RADIOTELEPHONE CONSTRUCTION

25-Watt 160 Meter Phone Transmitter

● Two typical 160 meter phone transmitter circuits for newcomers are shown on the facing page. In the illustration in Fig. 13, a 53 or 6A6 push-pull oscillator drives a pair of 45s in the final amplifier. The circuit diagram is shown in Fig. 11. Approximately 25 watts output is delivered by the final amplifier. These transmitters should be used only on the 160 meter band. If they are to be operated on the higher frequencies, a buffer stage should be added. The coil winding data for the oscillator is the same as that shown for the single 53 push-pull c-w transmitter described in the c-w chapter, i. e., 60 to 70 turns of No. 22 DSC wire, close wound and center-tapped, on a 1½-in. dia. plug-in coil form. The larger plug-in forms, 2¼-in. diameter, can also be used, but fewer turns will be required. Fifty-five turns of No. 22 DSC close wound will suffice. The oscillator coil should be tuned with a 100 mmf. or 150 mmf. condenser. A reasonable amount of "C" should always be in use. Remove turns from the coil and increase the tuning capacity, so as to give a certain amount of leeway in adjusting the 160 meter circuit.

Link coupling is used between the oscillator and the amplifier. The coupling loops have two turns each. One of the 2-turn loops is coupled around the center of the oscillator coil, the other around the lower end of the amplifier grid coil. The circuit shown in Fig. 12 uses a 47 crystal oscillator, link coupled to a pair of 45s in the final. It is just as satisfactory as the circuit shown in Fig. 11. From 60 to 70 turns of No. 22 DSC, close wound on a 1½-in. dia. coil form is suitable for the oscillator coil winding. The final amplifier plate coil has 55 turns, tuned with a 100 mmf. or 150 mmf. condenser. note 160 m

47-46-210 Phone—25 to 50 Watt Carrier

● This is a standard low-power transmitter for operation on 160, 75 or 20 meters. It is extremely simple to construct. The CW portion of the transmitter should be constructed first. It is pre-requisite that the 46 and 210 stages be both perfectly neutralized. Next, the audio channel can be constructed and tested. The test simply consists of energizing the amplifier by either phonographic or radio program material; during the procedure the output terminus R-13 should be shunted with a pair of headphones for aurally detecting the fidelity and over-all response. The audio modulation should not be applied to the plate supply of the Class 210 stage until both portions of the transmitter are working 100 per cent. The plate currents read at the various plate current telephone-jacks, must remain constant during modulation, with the exception of the modulator plate current read at jack J6. The speech amplifier has ample gain to work out of the average double-button carbon microphone. If any of the low-level microphones are used, a pre-amplifier must be added and coupled to T1 in the conventional manner.

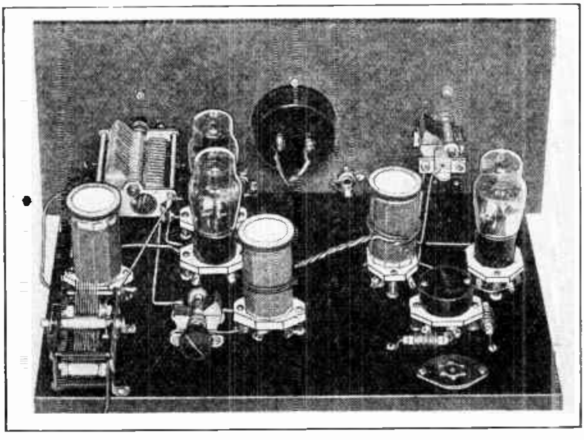


FIG. 13—160 meter phone, 53 or 6A6 and two 45s. See Fig. 12 for circuit.

75-Watt Modulator

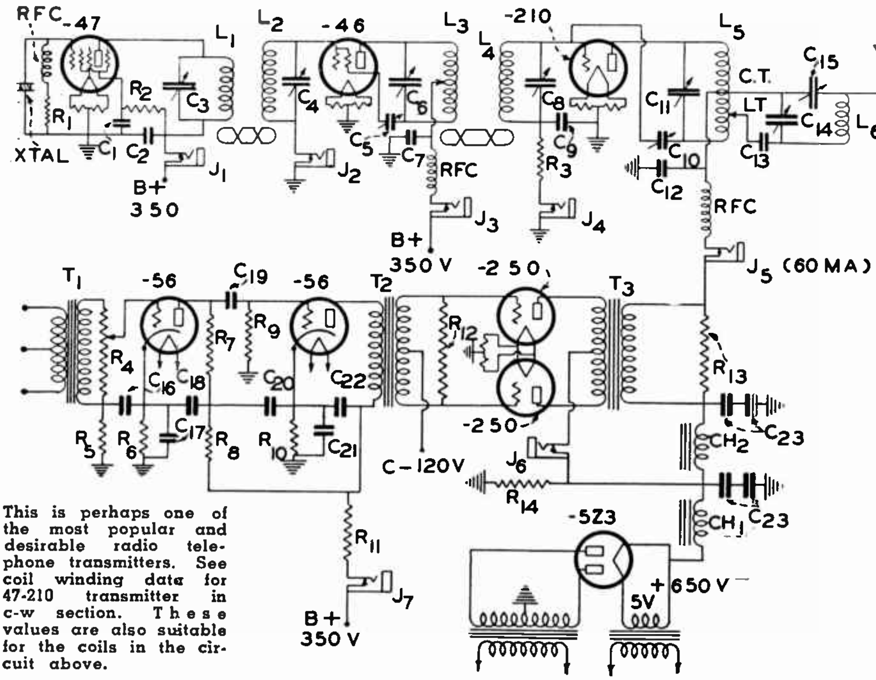
● More than 75 watts of audio output power is supplied by the unit described herein. This power is sufficient to plate-modulate a 211 or 203A operating at 1000-volts with 150 to 160MA of plate current. The device will economically modulate an input of at least 150-watts, or will fully modulate a 100-watt carrier at 100 per cent.

The advantage of using four 46s, rather than a pair of 801 tubes in this class B audio circuit, is in the lower cost. No C-bias is required with these tubes, hence, only a very modestly-priced power supply is needed.

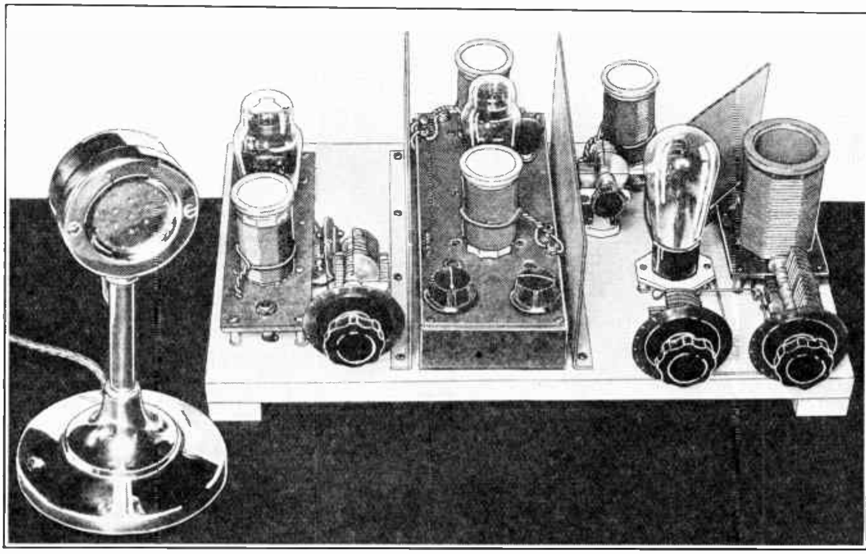
Technical Details

● The 20,000 ohm grid resistors across the input class B transformer provides a more constant load to the driver stage. The .001 1000-volt mica condensers across each grid to ground tend to prevent high-frequency oscillation under conditions of high input. In some cases, 40 ohm 10-watt resistors must be inserted in series with the plate leads to prevent parasitic oscillation.

If the microphone is of the diaphragm-



This is perhaps one of the most popular and desirable radio telephone transmitters. See coil winding data for 47-210 transmitter in c-w section. These values are also suitable for the coils in the circuit above.



Conventional phone transmitter of standard design.

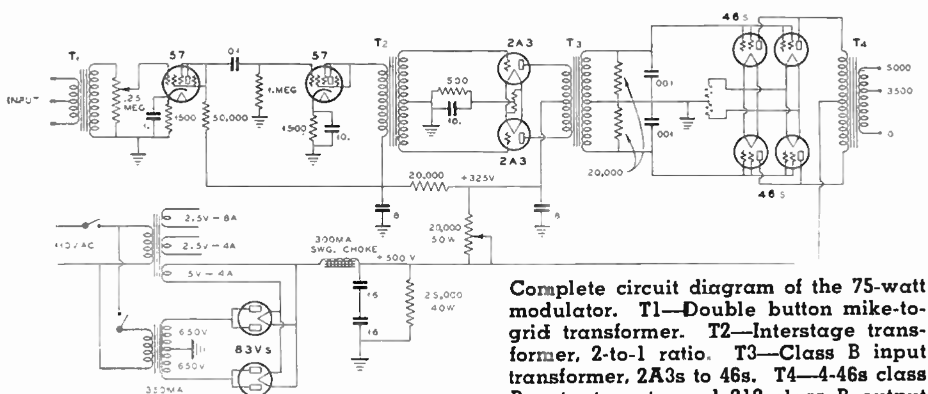
crystal-type, the input transformer should be eliminated and the first 57-tube connected as a high-gain pentode with a 250,000 ohm plate-resistor, 2 megohm series screen resistor and a .1 mfd. by-pass, and a 3500 ohm cathode resistor. The input should be shunted with a 3 or 5 megohm resistor, as well as being fully shielded.

The cases of the transformers, the volume control mounting bracket, and either center or one side of the input transformer must be grounded. In cases of audio-frequency feedback, it is suggested that the transformer connections be reversed. Often the input transformer and tube must be double-shielded to prevent RF feedback or hum pick-up.

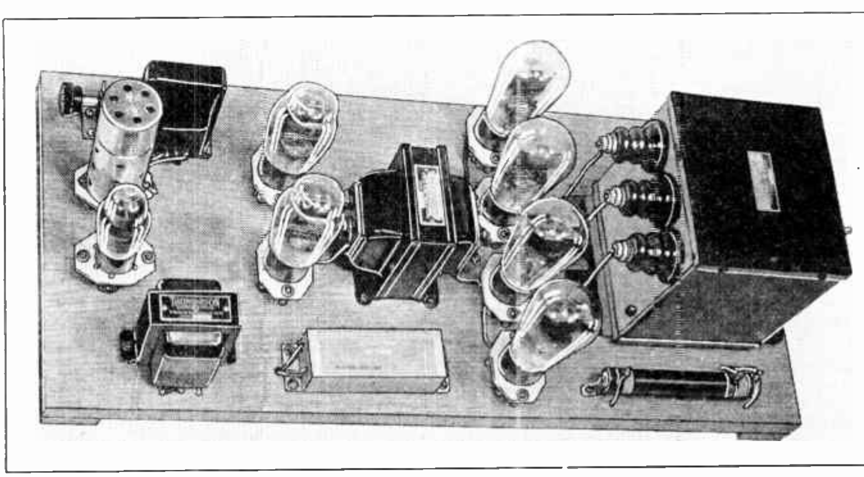
Other than the power supply filter, additional filtering is given to the 2A3 stage by means of a semi-variable 50-watt 2000-ohm resistor and another 600-volt 8 mfd.

Legend for 47-46-210 Phone circuit

R1—25,000 ohms. R2—30,000 ohms. R3—15,000 ohms. R4—200,000 ohms (tapered pot.). R5—100,000 ohms. R6—2,500 ohms. R7—100,000 ohms. R8—10,000 ohms. R9—500,000 ohms. R10—2,500 ohms. R11—5,000 ohms. R12—200,000 ohms. R13—100,000 ohms, 10 watts. R14—30,000 ohms, 100 watts. C1, C2, C7, C9—.001, C3, C4, C5, C6, C8—100 mmf. C10—35 mmf. double spaced. C11—50-70 mmf. double spaced. C12, C13—.006 mica. C14, C15—350 mmf. single spaced. C16—1/2 mfd. C17 to C22 —Any value from 1/2 mfd. to 2 mfd. C23—16 mfd. 450 v. (2-8 mfd. units in series). T1—Mike-to-grid transformer. T2—Plate to push-pull grids. T3—Class A-prime output, 1.25-to-1 step-down. CH1—15 henrys, 200 MA. CH2—30 henrys, 75MA. Two power transformers are required, one 650 to 800 v., one 1200 to 1400 v., center-tapped.

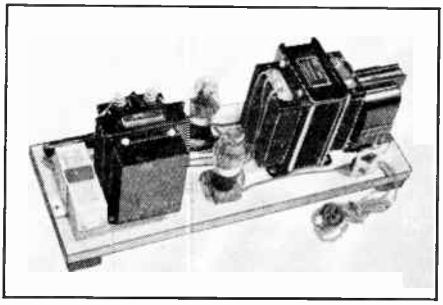


Complete circuit diagram of the 75-watt modulator. T1—Double button mike-to-grid transformer. T2—Interstage transformer, 2-to-1 ratio. T3—Class B input transformer, 2A3s to 46s. T4—4-46s class B output, or tapped 210 class B output transformer.



75-watt class B modulator for modulating any class C stage with inputs up to 150 watts.

condenser. The voltage at this point is between 325 and 350 volts. Further filtering in the form of a 20,000 ohm 5-watt resistor and an 8 mfd. condenser is imposed on the two 57 stages. This in effect gives three sections of filter for the first two stages of hum-free audio amplification. Triode 57 stages give more gain than 56 stages.



Power supply for 75-watt modulator.

The amplifier baseboard is 24 in. x 11 in. x 1 in. with a cleat at each end so that resistors, wiring and terminal strips can be mounted underneath. The power supply baseboard is 20 in. x 8 in. x 1 in.

The total plate current drain is about 150MA at 500 volts with no speech input, and on speech peaks the meter should not read more than 300MA. By exercising these precautions, the 46 tubes will never operate at more than about 160 MA on voice input. On a steady sine wave tone input the plate current may increase to a total value of 350 to 400MA for the same peak power output.

Practical Grid-Bias Modulation

● The economical factors entering into the carrier powers obtained from either a bias or high-level plate-modulated transmitter are approximately equal. The reason may be attributed to the fact that certain tube combinations happen to work better for one or the other two systems of modulation.

The most outstanding feature of a bias-modulated transmitter (see the fundamental circuit shown in Figure 2) is that a minimum of audio equipment is required, in comparison to a plate modulated transmitter of the same power output. This is an invaluable feature for anyone who spends the greater part of the time operating on CW. Instead of having over half the transmitter idle, as when working CW with a plate modulated phone, less than 10 per cent remains inoperative when the bias-modulated transmitter is used for this class of service.

Several different types of grid bias modulation systems have been brought forward in the past years, one of the best systems from a quality standpoint being a class BC amplifier which is characterized by a constant angle of plate current flow. The most practical test for linearity of any bias modulated amplifier is to determine whether or not the average plate current remains absolutely constant for all percentages of modulation up to 100 per cent. The class BC amplifier is the only one, at the present time, which fulfills this requirement.

Amplitude or harmonic distortion occurring in other systems manifests itself because the average value of plate current is not proportional to the peak value of the same current during modulation. As the grid swings more positive (during modulation), plate current flows during a longer time interval, and as the grid goes more negative, plate current flows for a shorter time interval than when the bias is unmodulated. For distortionless modulation, the interval during which the plate current flows must remain constant, regardless of the percentage modulation. This condition is fulfilled only when the fixed bias is exactly equal to the cut-off value. However, while fixed cut-off bias is entirely workable for a class B linear amplifier, which is amplifying a wave which was modulated in some preceding stage, it cannot be used in a grid modulated amplifier because the operating bias must always exceed cut-off by an amount equal or greater than one-half the audio signal voltage, in order to keep the negative halves of the RF excitation cycles from crossing the cut-off point during modulation.

Fundamentals of Grid-Bias Modulation

● Grid modulation is characterized by the fact that very little audio power is necessary to modulate the grid bias of an RF amplifier. However, the complexity of adjustment in the older systems has prevented about 99 per cent of those attempting it from obtaining satisfactory results. Usually terrific distortion and over-modulation followed most attempts to obtain the combination of 100 per cent modulation capability and high plate efficiency.

When audio modulation is used the radio-frequency carrier has two sidebands which carry the transmitted intelligence. Mathematics shows that one-third of the power in a completely modulated signal is contained in the two sidebands, while the other two-thirds consists of the carrier. Thus the problem which faces the builder of a phone transmitter is to increase the power output of the transmitter, during modulation, up 50 per cent for complete modulation. This additional power must be released in exact accordance with the variations in sound pressure which the operator's voice impresses on the microphone.

The source of power that increases the carrier output when the biased-modulated amplifier is modulated is explained as follows: The fundamental nature of a vacuum tube amplifier might be defined as a device which converts DC (plate power) into AC (RF output) power; but since the conversion process is never 100 per cent efficient, it must be concluded that the difference between the plate input and the power output energies are dissipated from the plate of the tube in the form of heat. The efficiency of a vacuum tube amplifier depends on numerous factors which vary widely for different types of amplifiers. If a given amplifier is, for example, 25 per cent efficient under a given set of conditions, it will have a certain power output. By maintaining a constant DC plate input to the amplifier and by changing some of its operating conditions, it is possible to increase the average plate efficiency 50 per cent by swinging the instantaneous plate efficiency between zero and twice the unmodulated value.

By measuring the power output, it will be found that when the average plate efficiency is increased, while the plate input remains constant, the power output increases one and one-half times more than its former value. Thus, if some means is found to cause the plate efficiency to increase 50 per cent, it will be possible to obtain a similar increase in average output necessary for complete modulation. Under certain conditions the grid-bias voltage affords this means of varying the plate efficiency of the amplifier.

Therefore, *all grid modulation systems whether they use the control-grid, screen-grid or suppressor-grid for the audio control, operate with constant plate input and variable efficiency.*

In class BC amplification (see Figure 1) the fixed bias is equal to cut-off bias. This bias should usually be supplied from batteries. Additional bias approximately equal to the fixed bias is obtained from a cathode bias resistor connected in the conventional manner. The extra bias supplied by the voltage drop through this resistor is proportional to the plate current and therefore to the grid voltage. When the ratio of grid voltage to this excess bias voltage is a constant, a condition arises where the plate current impulses all flow for the same time interval, regardless of their peak amplitude.

In the older bias modulation systems the distortion increases almost directly as the ratio of fixed bias to cut-off bias. This limits any attempt to increase the plate efficiencies by using higher values of bias and driving voltage. However, in the class BC the total bias may be as high as desired in search for a higher plate efficiency and the absolute value of the total bias, and therefore the driving power is dictated by the usual class C amplifier considerations. A limiting factor in class BC is the voltage drop across the cathode resistor which represents a waste of plate volts, as the bias is increased. There is no objection to driving the grid of the class BC amplifier to positive saturation, although extremely high values of grid current will cause some slight distortion because the grid current flows through the cathode resistor. Therefore the plate voltage should be as high as the tube insulation and gas content will

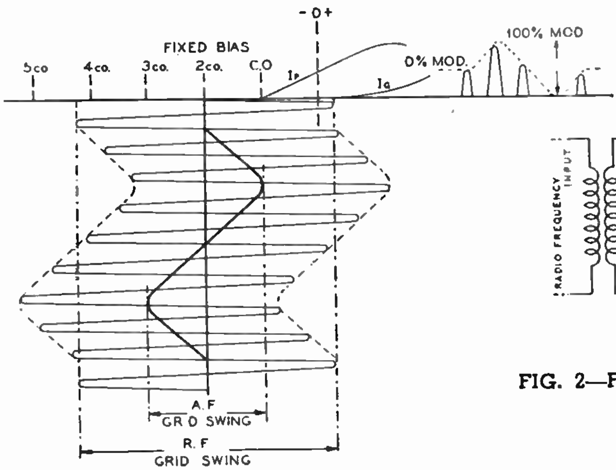


FIG. 1 — Graphic representation of class BC bias modulation.

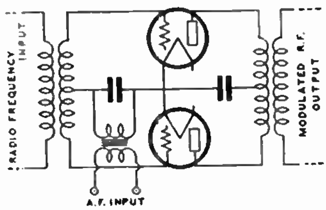


FIG. 2—Fundamental circuit of grid modulation.

allow, so that positive saturation will be as close to the zero bias line as possible.

The best tubes for class BC amplifier service are those of medium mu, such as the 210, 211, 800, RK18, 242A, 852, 50T, HK354, and 150T. The high-mu tubes, such as the 841, 203A, 830B, 46, 838 and the screen-grid tubes have an advantage in that a smaller cathode-resistor can be placed in the circuit because less bias is necessary to reach any given number of times cut-off. However, the high plate impedance of these tubes makes their use undesirable because it is difficult to secure a linear dynamic characteristic. This limits the undistorted power output.

The low-mu tubes (245, 2A3, or HK255) have the most linear characteristic but the cathode-bias resistor must be so large in order to get enough bias for efficient operation that a large proportion of the plate voltage is lost. If there are no limitations to the plate voltage available, the low-mu tubes will give slightly better results than the medium-mu tubes. Perhaps the best single index of merit is the grid-plate transconductance, although this factor of tube merit is measured under such widely varying conditions that direct comparisons should be made with caution, except for tubes of the same general type.

Designing the Bias-Modulated Amplifier

● The relationships which exist in the class BC amplifier circuit are given below so that the designer can calculate the unknown factors from those already known.

Technical note: The unmodulated plate efficiency of a class BC amplifier is approximately 40 per cent, but rises up to 60 per cent during complete modulation. The limitation on the output of all bias modulated amplifiers is the available plate dissipation of the tube (or tubes) used in the amplifier.

The known factors in designing the bias-modulated amplifier are:

(1) E_b = DC plate supply voltage, in volts
(2) $W_{plate\ loss}$ = rated plate dissipation of the tube in watts.
(3) μ = amplification factor of the tube.

The above factors can be determined from tube tables and the plate supply voltage with a high voltage voltmeter. From this information, the designer must determine in advance all of the unknown factors, in order to allow the amplifier to operate properly. This is the only bias-modulation system which allows such data to be accurately determined in advance. The unknown factors which are to be determined from these shown above are:

(4) W_{input} = DC plate input power, in watts.
(5) W_{output} = RF unmodulated carrier output in watts.
(6) I_p = DC plate current, amperes.
(7) E_{cco} = DC battery bias equal to theoretical cut-off bias (one-half total bias).
(8) R_k = cathode bias resistance, in ohms.

The information given above simply describes the conditions under which the class BC amplifier will operate when properly adjusted. E_{cco}, which equals the amount of DC bias equal to theoretical cut-off at the plate voltage used, is the battery bias which must be used, and is also equal to the voltage drop across the cathode bias resistor. The following formulas define the unknown factors in terms of those already known:

(9) $W_{input} = 1.66 W_{plate\ loss}$
(10) $W_{output} = .66 W_{plate\ loss}$

$$(11)\quad I_p = \frac{1.66\, W_{plate\ loss}\,(1+\mu)}{\mu E_b}$$

$$(12)\quad E_{cco} = \frac{E_b}{1+\mu}$$

$$(13)\quad R_k = \frac{E_b^2\,\mu}{1.66\, W_{plate\ loss}\,(1+\mu)^2}$$

The above formulas are based on 40 per cent plate efficiency, which can be realized from any tube operated at, or above its rated plate voltage. The class BC amplifier requires closer coupling to the antenna than is commonly used in CW transmitter.

Table of Data for Class BC Amplifier Operation

Tube Type	Input W	RF Unmodulated Carrier Power Output W	Plate Loss W	μ
210	25	10	15	8.3
801	33	13	20	8.5
800	60	25	35	15
50T	125	50	75	13
211-242A	166	66	100	12
852	166	66	100	12
354	250	100	150	13
150T	250	100	150	13
212D	333	133	200	16
204A	416	166	250	24
270A	500	200	300	16
849	583	233	350	19
851	1000	400	600	20
251A	1250	500	750	10.5

NOTE: The class BC amplifier makes an exceptionally good linear RF amplifier for amplifying a previously modulated wave. It is capable of somewhat better linearity and plate efficiency than the conventional class B linear amplifier.

The RF excitation should be adjusted to the point where d-c grid current starts to flow. When audio-frequency is applied from the modulator, small amounts of grid current may flow on the peaks. The amount of audio-frequency power required for 100 per cent modulation of carrier powers up to 200 watts can be supplied by small audio amplifier, such as push-pull 45 or 2A3 tubes. The impedance of the modulated RF amplifier varies under operating conditions and is lowest when grid current flows. For this reason the modulator should be terminated with a resistance which will tend to properly match the output of the modulator. For systems which require high fidelity, push-pull 45 or 2A3 tubes give low distortion with sufficient output for modulating final amplifiers having carrier outputs up to at least 200 watts. The audio output (modulation) transformer should have a primary-to-secondary step-down turns ratio of 1½-to-1, or 2-to-1, in cases where the required audio peak voltage can be obtained without exceeding the limits of the modulator tube or tubes. Satisfactory voice quality can be obtained with a 1-to-1 ratio transformer, even with modulator tubes of the pentode type, such as a 6L6 or 42. This transformer, in all cases, should be large enough, physically, to handle from 3 to 15 watts of audio power without core saturation, and the windings should not have over 500 ohms DC resistance. Small class B input or output transformers are usually suitable for this purpose.

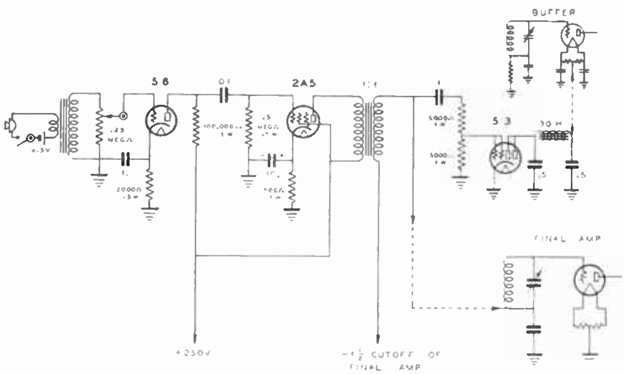
A relatively small RF amplifier, such as a grid modulated 211 stage, does not require as much RF or audio excitation as in the case of larger tubes, such as a 300T or a pair of 354, 150T, HK200, or Taylor 814 tubes. The audio swing will range from 75 volts to upwards of 600 volts for various types of RF amplifiers. This value is dependent upon the plate voltage, tube amplification constant, and the amount of cathode resistor bias. The latter introduces degeneration when it is not by-passed for audio frequencies which may require as much as 50 per cent increase in audio frequency excitation. The phone quality at high percentage of modulation is improved when the cathode bias resistor is not by-passed for audio frequencies, small RF by-passes from each side of the filament to RF ground alone are needed. The capacity of these condensers should be not over .005 mfd. in order to effectively by-pass RF, but *not* the audio frequencies. The cathode resistor should provide bias of at least half cut-off value; if high efficiency is desired this bias can be made greater than cut-off. The fixed bias in series with the grid return should always be equal to cut-off.

For proper operation with grid modulation, the antenna loading should be much greater than normally used with class C c-w or phone transmitters. This adjustment is easily made by increasing the antenna coupling slightly beyond the point of greatest antenna or feeder RF current, as indicated by a thermo-ammeter, field strength meter, or even a small incandescent lamp in series with the antenna. The value of tuning condenser capacity to inductance ratio in the final amplifier should be rather high. The tuning capacity should be at least twice as high as the values shown for CW operation in the LC chart in the CW *Transmitter Theory Chapter.*

High output grid modulation can be secured if both the RF and AF excitation is varied simultaneously. The RF excitation in this case must be varied in accordance with the voice envelope, and the resultant carrier will vary in a manner similar to that secured in a controlled carrier transmitter. The variation in average carrier amplitude need not be more than 2-to-1, or 3-to-1, in order to obtain outputs approximately equal to the rated plate dissipation of the final amplifier tube. In order to secure these high outputs, relatively high plate voltages are needed; this system can best be applied to tubes having very high vacuum, such as the tantalum plate types.

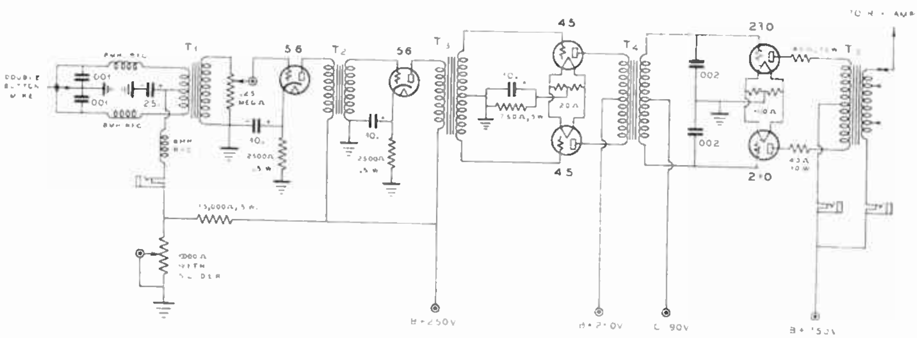
Grid Modulator

● Any cw transmitter with well-filtered plate supply can be converted into a grid-modulated phone, as shown in the circuit diagram to the right. A variable carrier control varies the buffer stage RF output in accordance with the voice envelope for a modified controlled carrier effect. The final amplifier is grid-modulated by means of the 2A5 audio amplifier. The power output, when this circuit is used, is at least 50 per cent greater than with conventional grid-modulation. A 10,000 to 20,000 ohm 10 watt resistor must sometimes be connected from the plate of the 53 to its cathode to serve as a bleeder for the buffer tube plate current in order to reduce the degree of RF control.

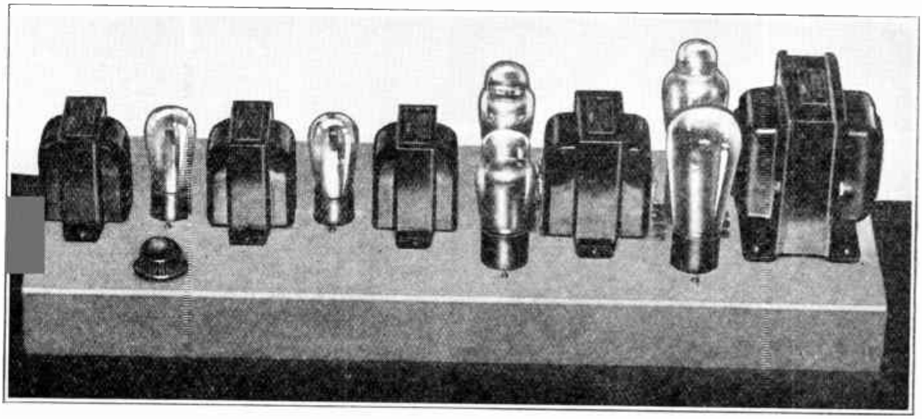


"HIGH POWER GRID-MOD" UNIT FOR ANY CW TRANSMITTER

● A popular standard type of Class B modulator is shown in the diagram and photograph below. It will modulate Class C amplifiers with inputs as high as 120 watts. T1 is a double-button mike-to-grid transformer; T2 is a 3-to-1 inter-stage transformer; T3 is a push-pull inter-stage transformer with 2-to-1 step-up turns-ratio. T4 is a Class B input transformer for push-pull 45s to type 210 tubes; T5 is a large Class B output transformer.

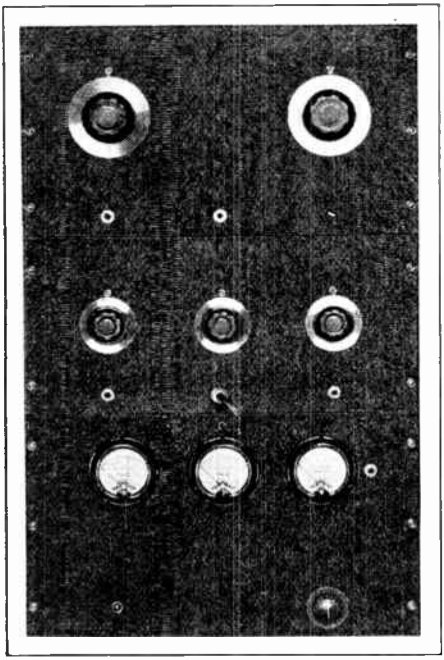


Complete Circuit Diagram for 60-Watt Modulator Shown in the Picture Below.



211 Plate Modulated Phone

● Plate modulation has long been popular because it is quite simple to put into operation, and its high efficiency results in high output. Normally the antenna coupling should be less for phone than for cw operation, in order to obtain proper circuit "Q" in the final tank circuit. For a given value of plate voltage in the final amplifier, nearly as much output is secured on phone as on c-w. Various forms of grid modulation are less costly, yet they are more difficult to get into correct operation, and they give much less carrier output.



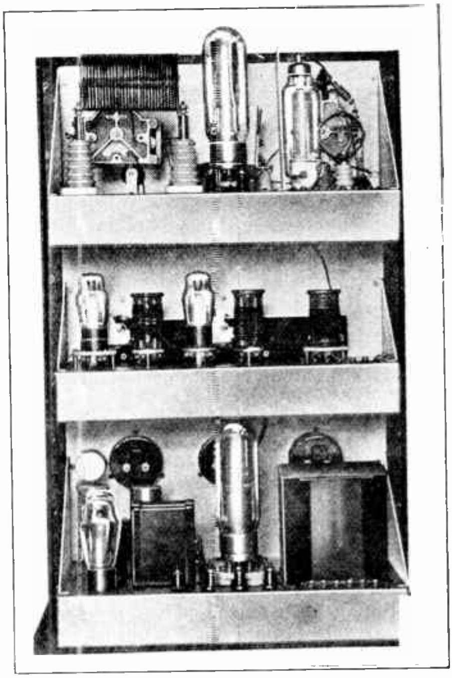
211 Phone Relay Rack Mounted

The transmitter here illustrated consists of complete RF and AF portions for a 200 or 250 watt carrier phone station. The DC input to the final amplifier can be run to slightly over 400 watts, and a Class B modulator supplies at least 200 watts of audio power for 100% modulation. The transmitter is built into a standard relay rack of the table mounting type. A 5 or 6 foot rack could be used in place of the 30" size if the various power supplies are to be mounted in the same frame.

Technical Notes

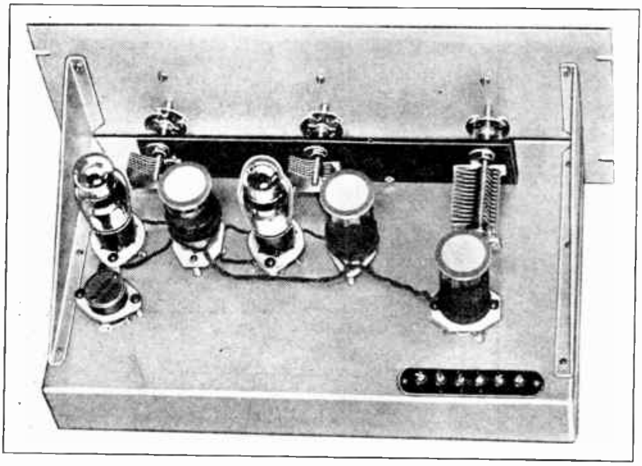
● A pair of 211, 838 or 203A tubes can be used in the final RF amplifier, and the same holds true for the Class B audio modulator, providing proper C bias connections are made. Similarly, the RF buffer can be a 211, 830B, RK18, 203A, or 838 tube.

For operation at 1000 volt plate supply, approximately 250 volts negative bias is needed for the 211 tubes, and —120 for 203As or 838s for phone service in Class C. From a separate 1000 volt supply, 838s in Class B audio require no C bias, 203As about —40 volts and 211s about —80 volts grid bias. B batteries, or a well regulated C bias supply are suitable for the bias on the modulator. The output impedance from plate to plate of a pair of 838 tubes should be about 11,000 ohms, or about 5800 ohms for a pair of 203As, and 7000 ohms for a pair of 211s. A separate plate supply is needed because a pair of 866 rectifier tubes will not handle both the RF and modulator loads without greatly exceeding the peak current ratings of the rectifiers.



Rear View of the Complete 211 Phone

The buffer operates from the 1000 volt Class B power supply system, and since it is coupled directly into the final grid circuit, it is heavily loaded. A 3000 ohm semi-variable resistor can be adjusted so as to drop the plate voltage to a point where the plate current rating of the RK18 tube is not exceeded. No difficulty is evidenced in obtaining 40 to 50 grid milliamperes in the final amplifier from this buffer stage. Higher efficiency could be had in the buffer stage with link coupling, but at the expense of another tuned circuit and additional space requirements. The method shown is better for 211s than for 203A or 838 tubes in the final RF amplifier, because 211 tubes have a higher grid input impedance, with consequent decrease in the load on the buffer stage.



Push-Pull 6A6 Exciter and Push-Push 6A6 Doubler for Plate Modulated 211 Phone Transmitter

A 6A6 push-pull crystal oscillator or a push-pull 6A6 frequency doubler drives the RK18 buffer stage. Approximately 300 volts plate supply is ample to provide sufficient drive to the RK18 grid because this tube is not required to operate at peak efficiency in order to excite the 211 tubes. A combination of grid-leak and fixed bias on the buffer and final stages allows cw keying, or "push-to-talk," in the crystal oscillator cathode circuit. Series connection of the two-turn coupling links provides grid excitation to the RK18 on either of two bands, depending upon the frequency selected by the buffer tuned grid circuit. Only one doubler stage is included, because either a 40 or 20 meter crystal can be used for 20 meter operation. 10 meter operation at reduced input could also be accomplished, although 211-type tubes are not as effective as the more modern Low C tubes at such high frequencies.

The speech amplifier consists of a 57 pentode actuating a 57 triode amplifier through resistance coupling. This provides enough gain for close-talking operation of a crystal microphone without raising one's voice above normal. The 57 triode drives a pair of 2A3 tubes in push-pull which act as a driver for the Class B modulator stage. 838 tubes were chosen because no C bias is needed for this Class B stage. The output transformer is large enough, physically, to handle the plate current of the RF amplifier thru its secondary. Some types require a coupling condenser (2 to 4 mfd.) and a 20 to 30 henry choke for shunt feed of the RF amplifier DC plate current.

A pair of .001 mfd. condensers and 20,000 ohm resistors shunt the secondary of the Class B input transformer in order to improve audio quality and prevent parasitic oscillation on voice peaks. The 40 ohm 10 watt plate resistors also aid this purpose, although they are not generally needed.

Constructional Notes

● Relay rack construction makes a neat and inexpensive installation. Changes can be made at future times without completely rebuilding the transmitter, because individual chassis can be added or removed with ease.

A standard relay rack panel is 19" long and some multiple of 1¾" high, such as 1¾", 3½", 5¼", 7", 8¾", 10½", 12¼", 14", etc. For clearance between panels, about 1/32" is allowed, which means that the 7" panel would actually be cut to 6 31/32"x19". For amateur use, steel panels of 14 gauge are heavy enough to support a chassis. A 1/8" thickness is much easier to drill than a 3/16" or ¼" thickness, such as is customary for commercial purposes.

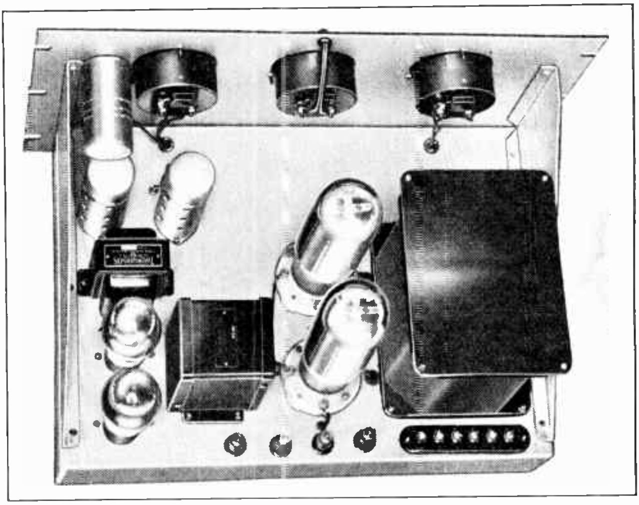
30 or 36 inch relay racks can be supported on fairly light channel iron frames, or even hard wood. When made of iron, the frame or rack should be drilled and tapped for 8-32 or 10-32 machine screws, starting ¼" from the top. Holes are also drilled 1½" below the first hole, then ½", then 1½" again, etc., down the sides of the rack. These rows of holes should be about 18½" apart and the rack channels should provide 17½" clearance so that 17" chassis will fit into place. All these holes are not used at one time but they are a convenience when changing to panels of different size. Normally the panels are slotted 1½" from top and bottom, with center slots when needed, if the panels are more than 8¾" wide. The slot should be ⅜" long to a ¼" diameter hole in the panel.

Standard sizes for the chassis are 17" long with quite a variation in width and depth. Those shown are 12" and 10" wide and 2½" deep. All corners in both the chassis and frame are welded, taking care to see that all units are square while being welded. End triangular pieces on each chassis form a rigid mount to the front panel. A 16 ga. or 18 ga. chassis is rigid enough if the bottom edges of the chassis are turned in and the corner pieces welded into place. Black crackle paint on the front panels, and aluminum paint on the rear, provides a neat appearing job to the finished product.

In this transmitter the bottom panel is 10½" wide and the chassis 12"x17". The complete speech system is built on this bottom chassis and three meters mounted on the front panel. Different makes of transformers and parts require different mounting holes and the task of punching the holes is more easily accomplished by first laying all of the parts on the chassis and then marking the location of the holes. The microphone jack shield is made from a pair of tube shield can tops. This "can" holds the jack, grid resistor and *Mallory* bias cell. The entire input circuit must be shielded, even to the microphone plug, tube and grid lead, in order to prevent AC hum pick-up or RF pick-up. One meter serves as a universal milliammeter because it terminates on a plug and measures grid or cathode currents of several stages when plugged into the proper closed-circuit jack. Some of these jacks must be insulated from the front panel since the grid current flows in the opposite direction to that in the cathode circuits and therefore the connections to the jacks must be reversed.

The crystal exciter is built on a 17"x10"x 2½" chassis and mounted behind an 8¾"x19" panel. This exciter circuit provides symmetrical leads and condenser mountings. It is practically sure-fire in operation. The crystal, tube, and coil sockets are mounted above the chassis with a large hole under the sockets to pass the connecting leads thru the chassis. The exciter tuning condensers are mounted on an insulated sub-panel, 2½"x13", with insulated shaft couplings for connection to the tuning dials. Each common ground point of each stage is bonded to the others with copper wire. The RK18 tuned grid circuit is also mounted on this chassis in order to shield it from the final amplifier by means of the top chassis. The grid lead from the RK18 socket (mounted below the surface of the top chassis) is less than 6" long.

The top chassis is 17"x12"x2½"; it supports the buffer and final amplifier stages



The Modulator Deck. The Tube-Shield Can for the Microphone Jack Circuit Is at the Far Left, Near the Top of the Front Panel

An aluminum shield prevents reaction between the two tuned circuits.

The capacity of the RK18 neutralizing condenser is only 4.8 mmfd. This condenser can be made by rebuilding a *Cardwell* midget condenser to about ⅜" spacing between adjacent rotor plates. Four rotor and four stator plates remain, although two of each would be sufficient. The 211 neutralizing condensers are made of 14 gauge aluminum in the form of "U"-shapes, supported by another aluminum strip ¾"x1½". The latter is bent to a near right-angle and mounted on top of a stand-off insulator. The entire assembly bends back or forward, and once adjusted needs no further attention until tubes are changed or the transmitter shipped to some other location. The "U"-shaped pieces are made so as to have sides 2½" square with ¾" spacing. Two sets form a neutralizing condenser with four plates, separated nearly ⅜" between adjacent plates. These neutralizing condensers require little space, are economical, and supply 10 to 15 mmfd. capacity for neutralizing any tubes of the 211 type. The grid leads cross-over to opposite neutralizing condensers, and the plates tie to adjacent ones,

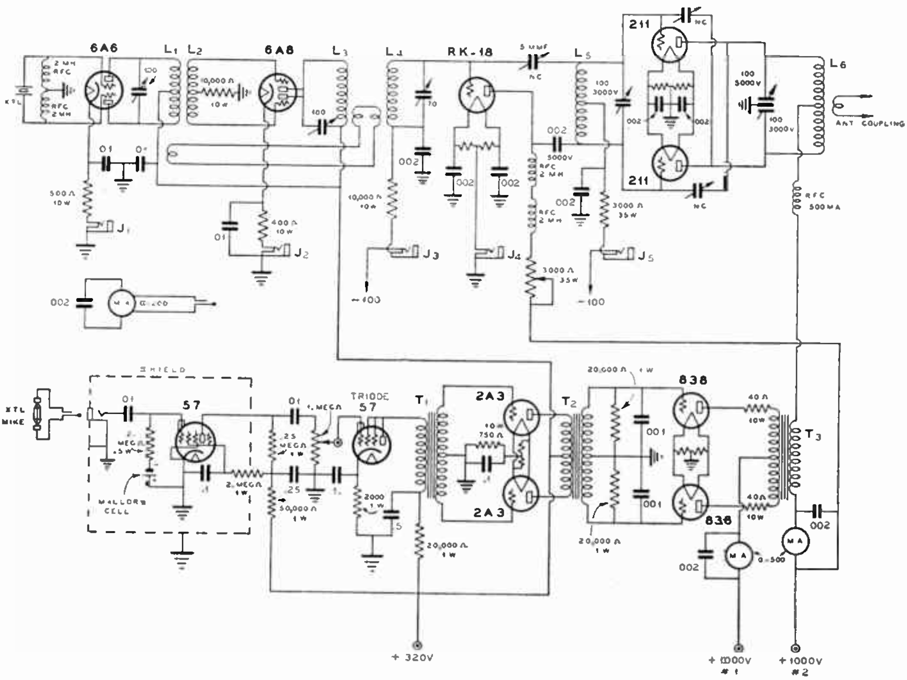


FIG. 1

R-F and Audio Portion of 211 Plate Modulated Phone Transmitter

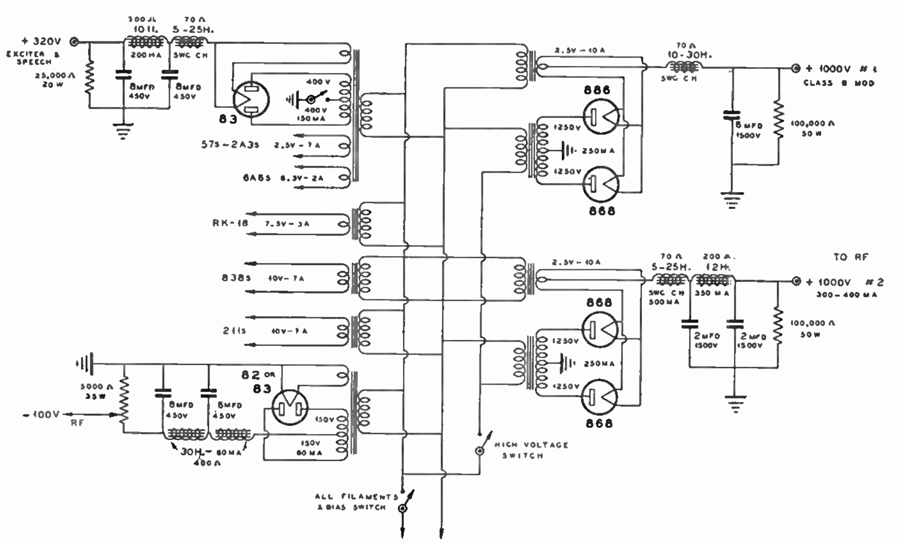
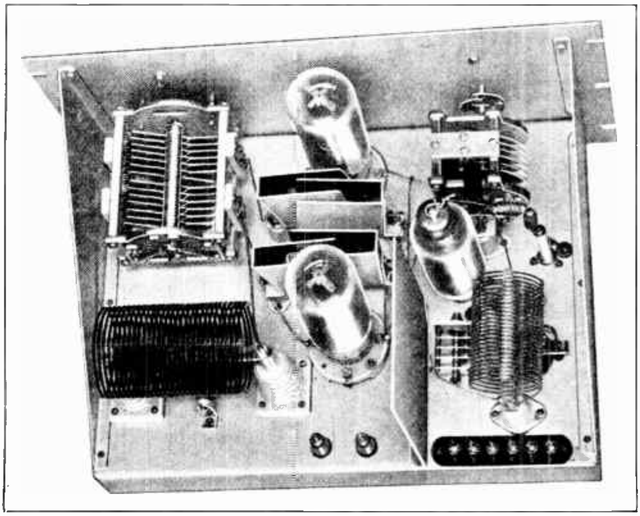


FIG. 2

Complete Power Supply for Transmitter Circuit Above



RK-18 Buffer and Push-Pull 211 Final Amplifier. The home-built Neutralizing Condensers Are Clearly Shown. Note Placement of Baffle Shield Near Buffer Plate Coil.

resulting in short leads and absence of parasitic oscillations.

The 211 grid coil for 80 meters is made of No. 14 wire, 7 turns per inch, 2" diameter and 3½" long. The plate coil is made of No. 12 wire, 6 turns per inch, 2⅝" diameter and 4½" long. Both coils are wound over thick celluloid strips supported by a cardboard tube. Duco cement is applied liberally to the wire along the celluloid strips, and the coils allowed to dry for a day before removing the cardboard. The coils are center-tapped and mounted on coil plugs for quick band changing. Link coupling is necessary for coupling the final amplifier to the antenna circuit.

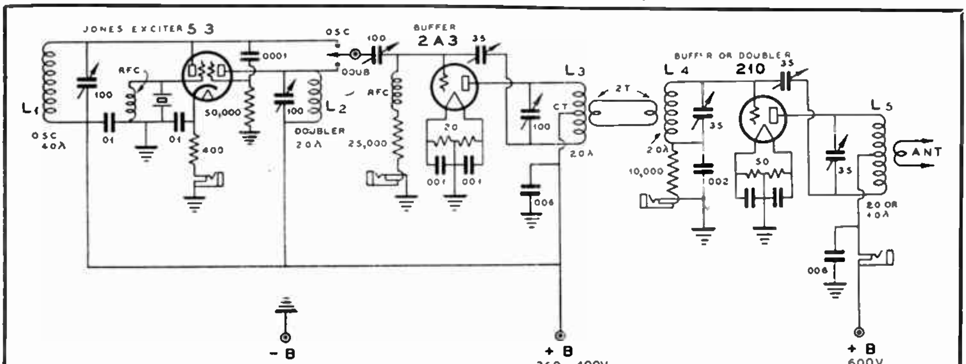
The 160 meter crystal oscillator coil is made of 60 turns No. 24 DSC wire, close-wound on a 1½" form. The grid coil of 40 turns is wound over this coil on a celluloid spacer. Both coils are center tapped. The doubler and grid coils for 80 meters are made of 35 turns of No. 18 wire, wound to cover 1½" on a 1½" dia. form.

Operating Notes

● An oscilloscope should be available for checking the amount of speech input necessary for peaks of 100% modulation. The oscilloscope is convenient for neutralizing and as a check for voice quality in the modulator. The swing of Class B modulator plate current with average speech will serve as a volume indicator after checks have been made with an oscilloscope.

Each stage should be tuned without plate voltage on the succeeding stages, until everything is operating satisfactorily. Three or four 100 watt Mazda lamps are useful as a dummy antenna for tuning a transmitter and making preliminary modulation tests.

The Class B modulator should work into about an 11,000 ohm load for 838 tubes. The Class C stage at 1000 volts and 350 ma. presents a little less than 3000 ohms, therefore the output transformer had a step-down ratio of nearly 2-to-1. The Class B input transformer has a turns-ratio of 1.7-to-1 of primary to ½ secondary. The transformer for the 57 triode to 2A3 grids can be an ordinary interstage push-pull unit with a step-up ratio of 1-to-2, or 1-to-3, primary to total secondary.



Circuit Diagram of Typical R.F. Portion of 50-Watt Transmitter Using Receiver Type Tubes

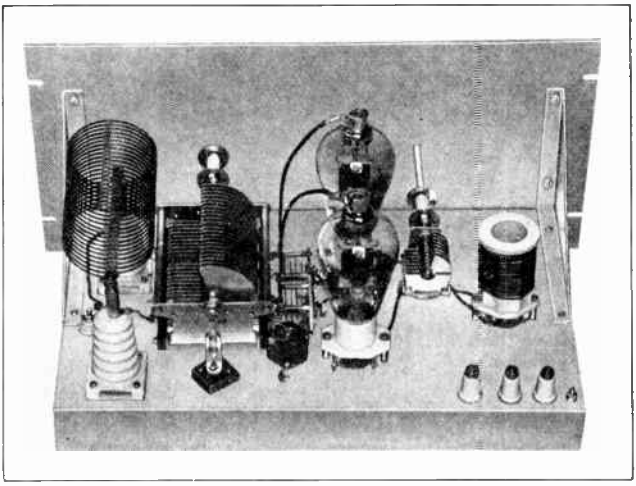
Push Pull Amplifier With Taylor T-55 Triodes

● High output at any amateur frequency can be obtained from a pair of Taylor T-55 high-mu triodes. The amplifier here illustrated will deliver as high as 250 watts output with 1250 volts on the plates. The unit was designed for a plate-modulated phone or c-w relay-rack transmitter.

In order to drive this amplifier to full output, a preceding stage with a single 210 tube with 550 volt plate supply is needed, link coupled to the grids of the T-55 tubes. A push-pull 210 or 801 buffer with lower plate voltage can also be used as a driver. A circuit for such a stage is shown on this page.

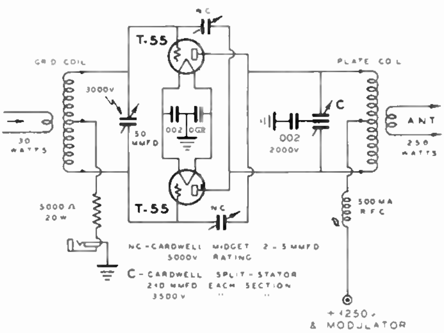
The rotor of the plate turning condenser is insulated from the chassis, but bypassed with a 2,000 volt mica condenser as a safeguard against damage in case of flashover between condenser plates during peaks of modulation.

The chassis is 10 inches wide, 17 inches long and 1¾ inches deep. The front panel is a standard 8¾ inch x 19 inch relay rack panel. The arrangement of parts on the chassis provides a symmetrical dial lay-out for the front panel and still maintains very short RF leads for effective operation at frequencies as high as 28 mc.



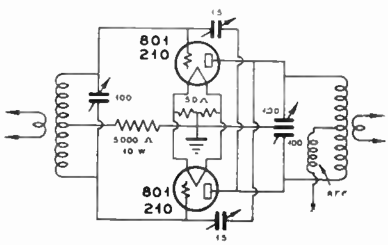
250-Watt Push-Pull T-55 Amplifier.

The tuning condensers shown in the illustration are large enough to tune the plate and grid circuits to 160 meters, with the proper coils.



¼ KW OUTPUT R F AMPLIFIER

Circuit for Taylor T-55 Amplifier.



TYPICAL CLASS C PUSH-PULL AMPLIFIER

A Suitable Driver for T-55 High Output Final Amplifier.

Controlled Carrier Suppressor—Modulated Transmitter

● Here is a good low power phone or c-w transmitter that will not become obsolete when more power is desired at some future time. A high power linear amplifier can always be added to give several hundred watts output at relatively high efficiency. Such a unit can be built into a similar 30-inch high relay rack as the companion unit. The c-w output will depend upon the plate voltage available. Up to 150 or 160 watts can be secured from a pair of RK-20 or RCA-804 tubes. A phone carrier output of 30 watts is realized with good quality and voice controlled carrier.

Circuit Notes

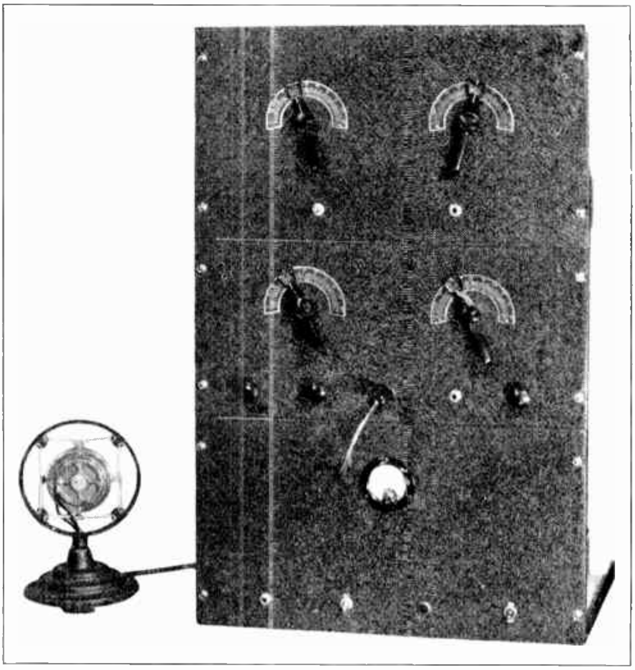
● A 53 push-pull crystal oscillator drives a 53 push-push doubler for output on any two bands, depending upon the frequency of the crystal and the coils in service. More output is available than is needed for a pair of RK-20 tubes in parallel or push-pull. Push-pull is desirable for 10 or even 20 meter operation, but parallel connection allows either one or two tubes to be used without any circuit changes.

Crystal circuit keying is most suitable for c-w or push-to-talk operation on phone. The screen current on the RK-20s runs a little high when the final plate circuit supply is primary-keyed. On c-w, the suppressor grids are at a positive potential of 50 volts with respect to filament.

A 57 pentode amplifier tube and a 45 power stage furnish modulating voltage for the negative suppressor grids. A high-quality 2-button carbon microphone drives the 57 grid circuit through a mike-to-grid transformer. A separate 3 to 4½ volt dry battery or C battery supplies current of 8 or 10 ma. to each button of the microphone. A crystal microphone would require an additional audio stage, such as a resistance coupled 56 tube.

A 1-V rectifier tube functions as a simple diode control element for varying the suppressor grid bias. For controlled carrier, the suppressor grid bias is varied from negative 67½ or 90 volts down to about 50 volts, the normal voice operating point. This is accomplished by rectifying some of the modulator voice output voltage, filtering it, and using this current through a resistor to change the suppressor grid-bias voltage. This bias varies in accordance with the voice envelope, and since the carrier output varies with the suppressor voltage, a simple method of controlled carrier is the result.

The small 50 henry choke and 1 mfd. 400 volt condenser serves as a filter and audio by-pass so that the controlled carrier system will not affect the voice quality. A 10,000 ohm variable resistor forms a control of the degree of carrier control by varying the amount of voice input to the diode circuit. A 1-to-1 ratio small Class B output transformer couples the 45 modulator tube into the 1-V tube and into the suppressor grid circuit.



Front of Controlled Carrier Suppressor-Modulated Phone

A series link coupling provides fundamental or second harmonic input to the final grid circuit, depending upon the tuning of this final grid circuit. Normally the DC grid current should be 12 to 16 ma., and the plate current from 25 to 90 ma. on phone and about 160 ma. on c-w. for a pair of RK-20s.

A separate C battery supplies negative bias for the control grid and suppressor grid. The latter may be set at either 67½ or 90 volts, depending upon the amount of "idle" carrier desired.

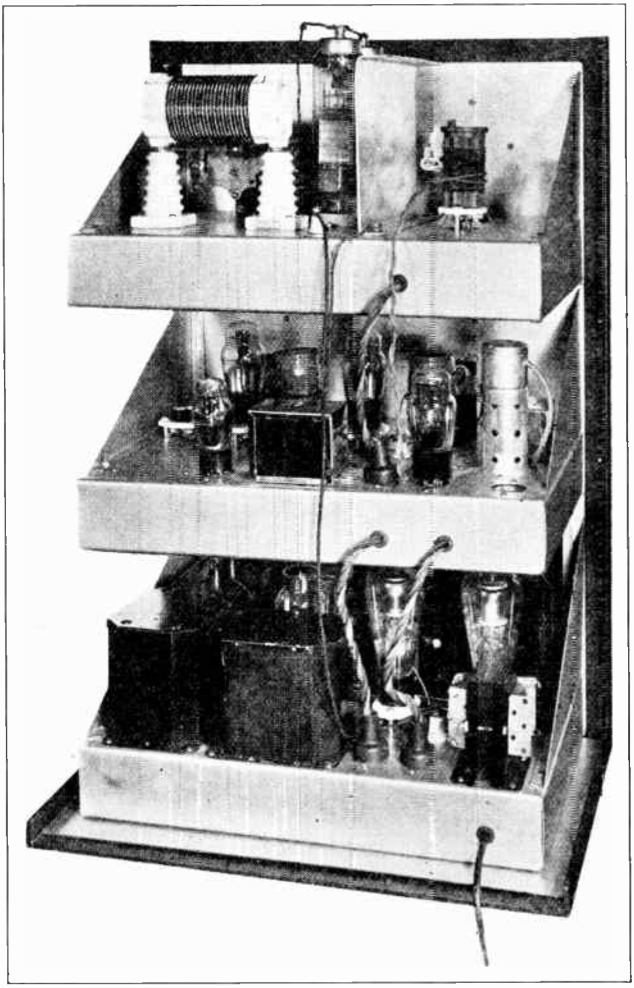
Constructional Notes

● The three chassis are 12"x17"x2" each, made of No. 18 gauge iron, with end supports to the front panels. The latter are of 14 gauge iron, 19" long. The power supply and final amplifier panels are 10½" wide and the exciter panel is 8¾" wide. A heavy aluminum shield separates the RK-20 grid and plate circuits. Insulated shafts extend out to the tuning dials for all four variable condensers which are mounted on insulated vertical subpanels.

The speech and modulator apparatus is built into the exciter chassis and because the audio leads are below the chassis, and all RF leads above it, no RF feedback takes place. The microphone plug and cable are shielded and the shielding is grounded. One plug-in milliammeter measures plate current in all stages by means of closed-circuit jacks.

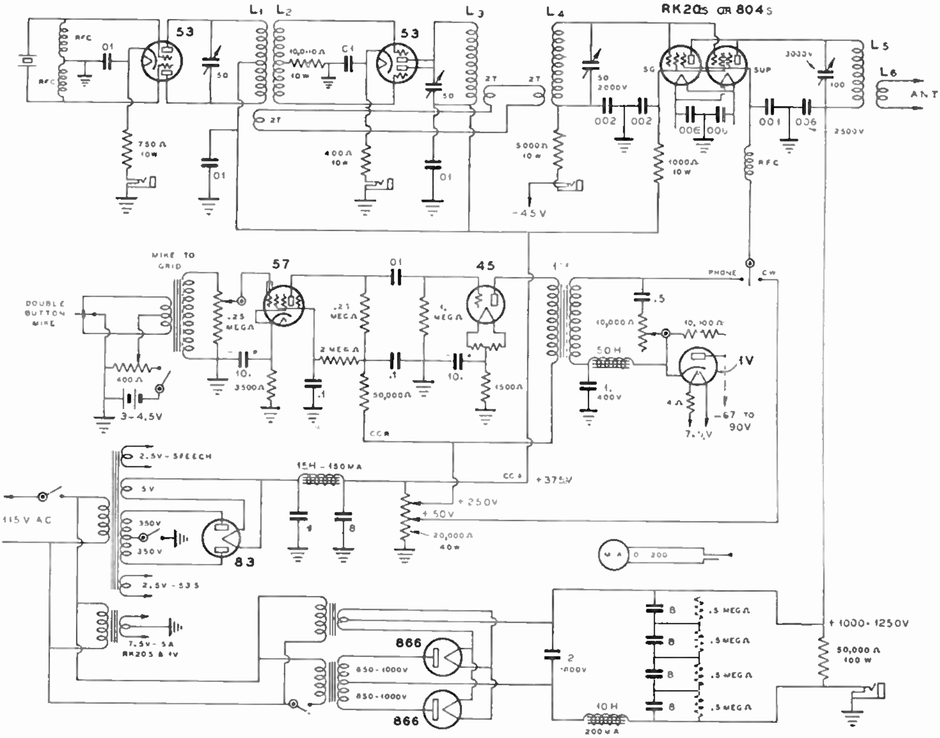
For 80 meter operation from a 160 meter crystal, the oscillator coil has 60 turns of No. 24 DSC, center-tapped, on a 1½" diameter plug-in coil form. The doubler grid coil has 50 turns of No. 24 DSC with center-tap, wound over the oscillator coil with a layer of celluloid to separate the coils. A ⅛" space is left open at the center, and the coils are all close-wound from this center space.

The doubler plate and final grid coils are alike. For 80 meters each has 35 turns of No. 20 DSC wire, wound on a 1½" form to cover a winding length of 1¾". The final tank coil consists of 22 turns of No. 12 wire on a 2½" form, wound to cover 3" of space. Coils for other bands can easily be made by referring to the coil data for other transmitters.

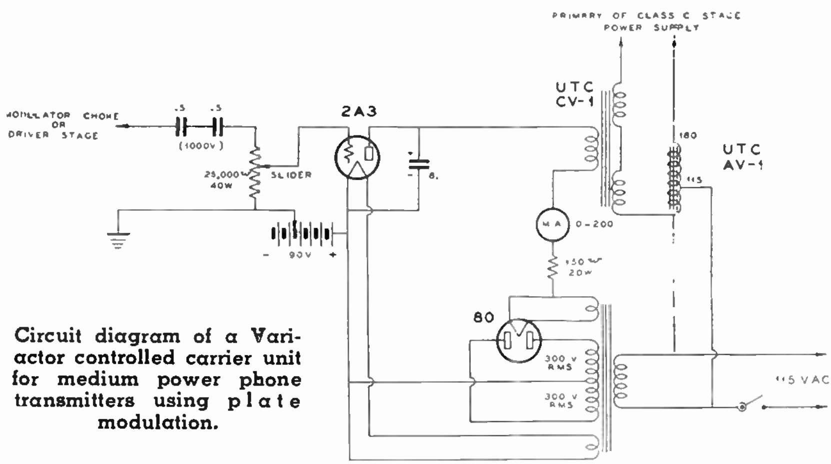


Rear of Controlled Carrier Suppressor-Modulated Phone.

The controlled carrier circuit could be changed to constant carrier output by removing the IV diode tube from its socket and reducing the external fixed C battery bias to —45 volts. The controlled carrier would then enable high output to be secured from a higher power linear amplifier. A single RK-20 will drive a pair of 211, 211H or RK-36 tubes to nearly ¼-KW in a linear amplifier in the latter case, whereas with constant carrier the output from the linear amplifier would be less than half this value. The linear amplifier would be an economical means for securing relatively high power operation.



Complete Circuit Diagram of RK-20 or RCA-804 Controlled Carrier Suppressor-Modulated Phone Transmitter



Circuit diagram of a Variactor controlled carrier unit for medium power phone transmitters using plate modulation.

275 Watt Modulator With Varimatch Transformer

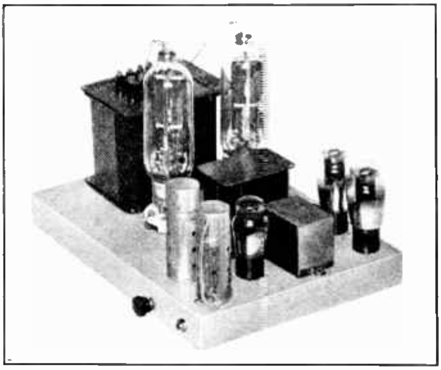
● Any Class C RF amplifier with inputs as high as 550 watts can be modulated with the audio system here described. The output transformer is a special type for matching the Class B audio amplifier into any Class C load. Type 203-H tubes are shown in this amplifier, but other types such as 838, 203A, 211, 50T, HK-154, T-55 and HF-100 can be used in place of the 203-H.

Higher output can be secured with larger tubes such as the HK-354, 805, 150T, Taylor 822 or HF-200. When these tubes are used, the output ratio of 2A3 driver stage output transformer will depend upon the grid circuit impedance of the Class B tubes.

The UTC *Varimatch* transformer should be connected in such a manner that the particular Class C load calculated from the value of DC plate voltage divided by DC plate current provides the proper load impedance to the Class B tubes. Reference to the *Transmitter Tube Chapter* will show the proper value of plate-to-plate impedance for any of the aforementioned tubes.

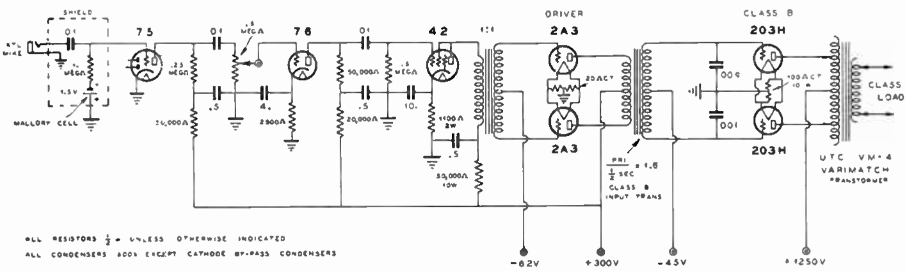
The value of C bias and Class B input transformer ratio will vary with the different types of Class B audio tubes. The push-pull 2A3 (or 6A3) driver is suitable for any of above-named tube combinations. A 42, triode connected, serves as a driver for tube. The shield around the microphone jack and its associated parts is under the chassis; a shielded lead connects to the grid of the 75 tube.

The .001 mfd. mica condensers from grids of the 203-H tubes to ground prevent parasitic oscillation which is present in some



Varimatch High Power Class B Amplifier.

Class B modulator systems in the form of raspy quality. The 40 ohm 10-watt resistors



275 WATT MODULATOR FOR CLASS C INPUTS UP TO 550WATTS

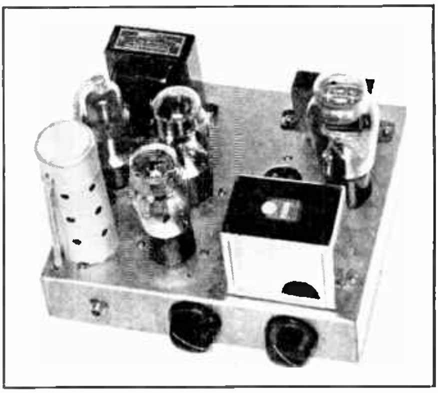
the 2A3 tubes and it, in turn, is driven by a speech amplifier consisting of a 75 and 76 tube with resistance coupling. Sufficient gain is available to permit operation from a crystal microphone. The microphone jack, grid condenser and grid-leak should be shielded in order to prevent AC hum pickup. A Mallory Bias Cell, or a single 1½ volt dry cell, supplies fixed bias to the 75 audio connected in series with the 203-H plate leads must sometimes be added to prevent parasitic oscillation. The complete amplifier is mounted on a metal chassis, 17 in. x 12 in. x 1¾ in.

The transformers are: UTC Interstage Transformer, Type PA132. UTC Class B Input Transformer, Type PA-52AX. UTC Varimatch, Type MV-4.

Controlled Carrier Grid-Bias Modulated Phone

● Excellent results can be obtained with grid bias modulation when used in conjunction with controlled carrier. The final modulated amplifier stage operates more efficiently, with the result that more output for a given amount of plate dissipation, or the same equivalent output with much less tube heating, is obtained.

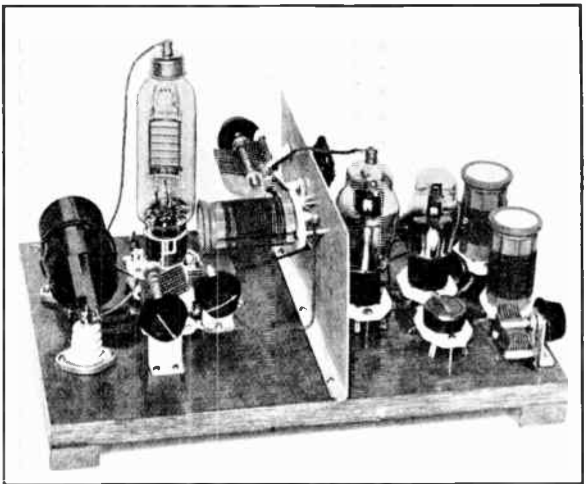
One or two 2A3 tubes, biased to approximately cut-off, serve as a control for carrier output in the grid-modulated phone transmitter here illustrated. A picture of the carrier control and speech channel is shown.



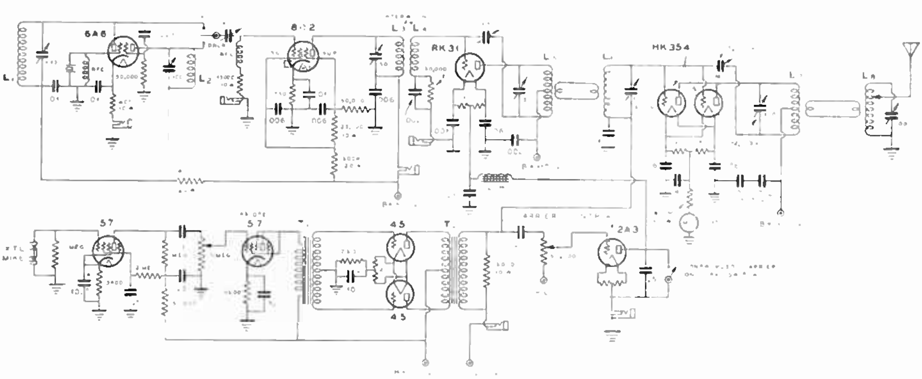
Speech channel for Grid-Bias Phone

Two 2A3 tubes in parallel will enable the RK-31 buffer stage to operate at a lower value of plate voltage than that shown. The 2A3 tube serves as a cathode grid bias resistor which varies in accordance with the syllabic modulation of the voice. The audio components are filtered by means of a 20 henry filter choke and two ½ mfd. condensers. These condensers should have a rating of 600 volts. The grid bias on the 2A3 tube should be no higher than that required to reduce the RK-31 plate current to about 10 or 20 MA., and the link coupling should be adjusted so that the final amplifier will deliver from 25 to 50 watts carrier. The buffer and final amplifier plate currents increase when modulation is applied, and thus 300 watts of carrier can be obtained.

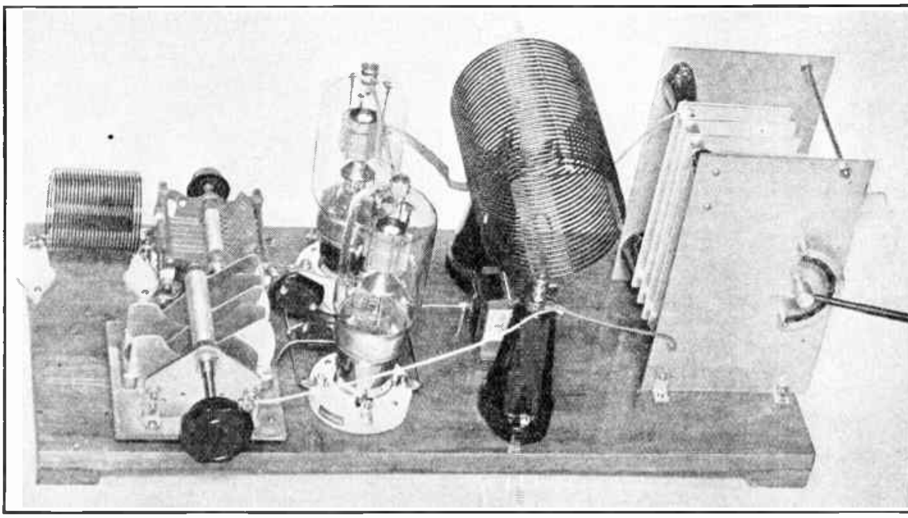
With a plate supply of 3,000 volts, the actual plate-to-filament voltage will run approxi-



Right: Jones Exciter, 802 buffer-doubler and RK-31 buffer for high-power final amplifier shown below. Two HK-354 Gammatrons are used.



300 watt phone, 800 watt c-w transmitter, controlled carrier grid-bias modulation.



Final Amplifier for 300 Watt Grid-Bias Controlled Carrier Phone.

mately 2,750 volts because there should be a drop of more than 200 volts across the cathode or filament center-tap resistor. On voice peaks the plate current should run at about 320 watts, since the side-bands use up the remainder of the power, being 50% of the carrier at 100% modulation.

Although the carrier output efficiency will not run over 40%, the fact remains that the actual output efficiency during modulation runs about 60%, which explains why 50% more power output can be obtained when

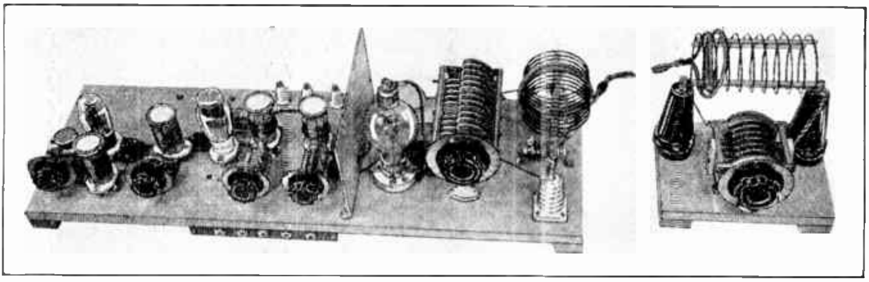
Coil Winding Data for High-Power Controlled Carrier Grid-Bias Modulated Phone

Band	6A6 Osc. or Doubler	802 Plate Coil	RK-31 Plate Coil	Final Grid Coil	Final Plate Coil
16	56 turns, No. 24 DSC, 1½-in. dia. Close-wound.	56 turns, No. 24 DSC, 2-in. long, 1½-in. dia. 50 turns, No. 24 DSC, wound over plate coil for grid winding.	65 turns, No. 16 SCC, 2½-in. dia. Close-wound, center-tapped.	40 turns, No. 16 Enam., 2¾-inch dia. 3-in. long.	40 turns, No. 12 Enam., 5-in. dia. 7-in. long. Center-tapped.
80	30 turns, No. 20 DSC, 1½-in. dia. 1½-in. long.	36 turns, No. 22 DSC, 1¾-in. long, 1½-in. dia. 28 turns, No. 24 DSC, close-wound.	44 turns, No. 16 Enam., 2-in. dia. 3¾-in. long. Center-tapped.	20 turns, No. 14 Enam., 2¾-in. dia. 2¾-in. long.	24 turns, No. 10 Enam., 4½-in. dia. 6½-in. long. Center-tapped.
40	20 turns, No. 20 DSC, 1½-in. dia. 1¾-in. long.	16 turns, No. 22 DSC, 1½-in. dia. 1¾-in. long. 16 turns, No. 24 DSC, Interwound.	22 turns, No. 12 Enam., 2-in. dia. 3-in. long. Center-tapped.	11 turns, No. 14 Enam., 2¾-in. dia. 2½-in. long.	18 turns, No. 10 Enam., 3½-in. dia. 6½-in. long. Center-tapped.
20	10 turns, No. 20 DSC, 1½-in. dia. 1¾-in. long.	7 turns, No. 20 DSC, 1½-in. dia. 1½-in. long. 7 turns, No. 20 DSC, Interwound.	10 turns, No. 12 Enam., 2-in. dia. 3-in. long. Center-tapped.	6 turns, No. 14 Enam., 2½-in. dia., 2¾-in. long.	9 turns, No. 10 Enam., 3¼-in. dia., 6½-in. long. Center-tapped.

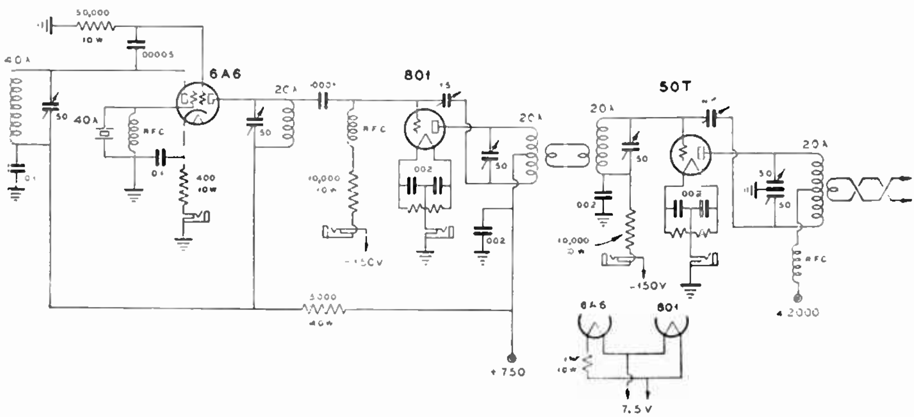
using carrier control with less plate heating than when normal grid-bias modulation is used. When no voice input is applied, the final amplifier is not putting out more than a small fraction of its normal output, which means that the plate dissipation is below normal, even if the efficiency during such times was as low as 20%.

This transmitter uses a 6A6 oscillator-doubler with either an 802 or RK-25 tube in the buffer or additional doubler stage. The screen grid tube requires no neutralizing when used as a buffer, and as a doubler the output is ample for driving the RK-31 tube which is rated at 40 watts plate dissipation. For c-w operation this tube has sufficient output to drive the final amplifier to more than 1 k-w input at high efficiency on any band from 20 to 160 meters. If 10 meter operation is desired, the final amplifier can be operated as a doubler. It would be better, however, to use push-pull connection for the HK-354 tubes because the circuit shown has too much regeneration at 10 or 20 meters to allow satisfactory operation in the final amplifier.

R. F. Portion of Standard 20 Meter Phone



Complete 150-Watt 20-Meter Transmitter and Antenna Coupler. The Circuit Diagram Is Shown Below. A 40-Meter Crystal Is Used in the Jones Exciter Unit Capacitively Coupled to an 801 Buffer Which Drives the 50T in the Final Amplifier.



Circuit Diagram for 150-Watt 20-Meter Phone.

Coil Data for 20 Meter Operation

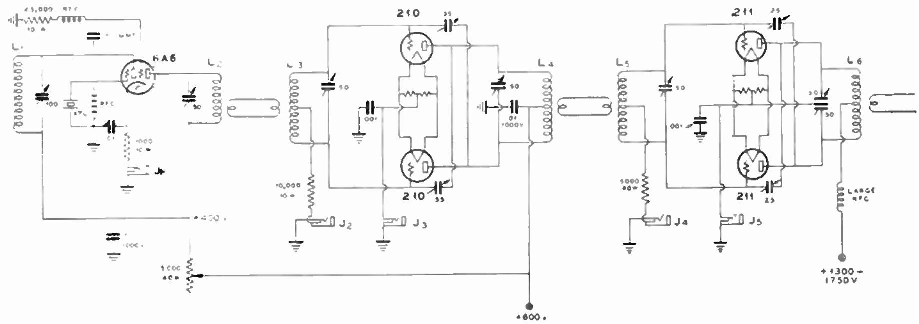
Final Plate Tank	Final Grid Coil	Buffer Plate	Doubler	Osc.
10 turns No. 10 E. 3½-in. dia. 3-in. long. CT.	11 turns No. 16 E. 1½ in. dia. 1⅜-in. long.	11 turns No. 16 E. 1½-in. dia. 1⅜-in. long. C.T.	9 turns No. 16 E. 1½-in. dia. 1⅜-in. long.	20 Turns No. 18 E. 1½ in. dia. 1⅝-in. long.

400 Watt Plate-Modulated Phone Transmitter

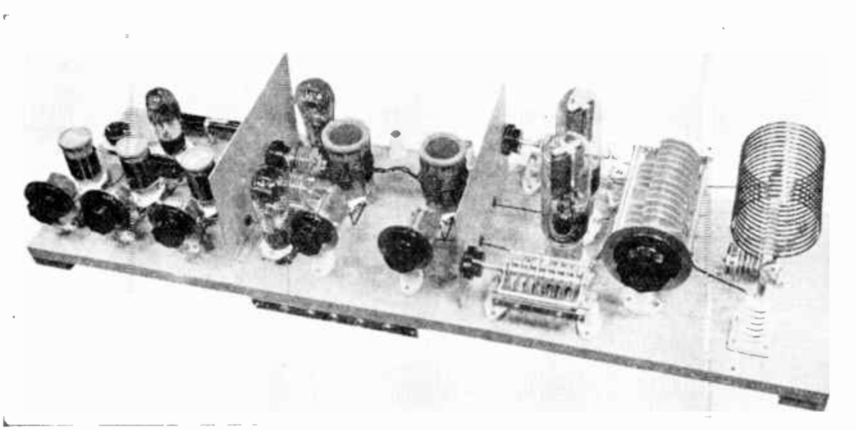
● A 6A6 crystal oscillator-doubler is link coupled to a push-pull 210 buffer RF stage, which serves as the driver for the push-pull 211 final amplifier in the 400 watt phone transmitter shown in the accompanying pictures and diagrams. The final amplifier is plate-modulated by means of a Class B audio amplifier with a pair of 838 zero-bias tubes. This circuit design readily lends itself to relay-rack construction, in which case another stage of 56 resistance-coupled speech amplification could be added without introducing serious hum problem. Close talking into the microphone is essential with the circuit as shown, in order to obtain full output from the modulator, unless a sensitive crystal microphone is used.

The power supply for the 838 modulator should be able to supply 350 ma. at 1150 volts, with swinging-choke input to the filter for good voltage regulation. The power supply for the 211 RF stage should be able to supply as high as 350 ma. at 1100 volts. A separate power supply is needed for the RF and modulator stages. The power supply for the crystal oscillator and 210 buffer stage should supply 200 ma. at from 600 to 700 volts.

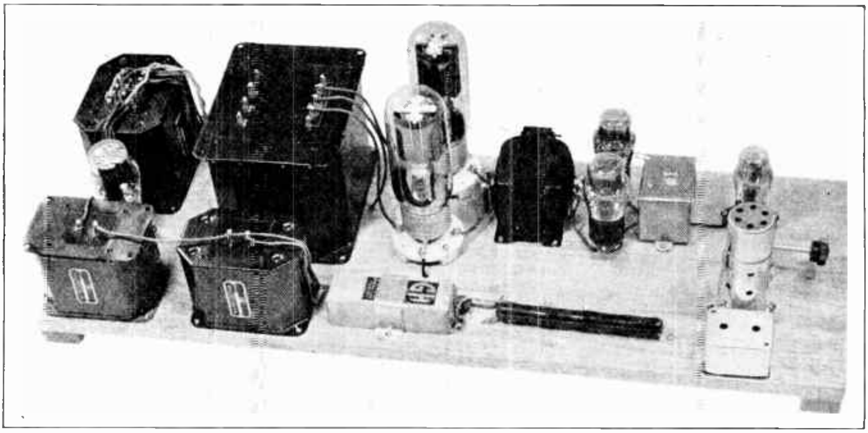
The RF stages are link coupled in order to obtain maximum grid drive with minimum buffer stages. The 210 buffer is operated between Class B and C. The plate tuning condenser for this stage should be of the split-stator type if 20 meter operation is contemplated. A RF choke must then be connected into the center-tap of the coil L4;



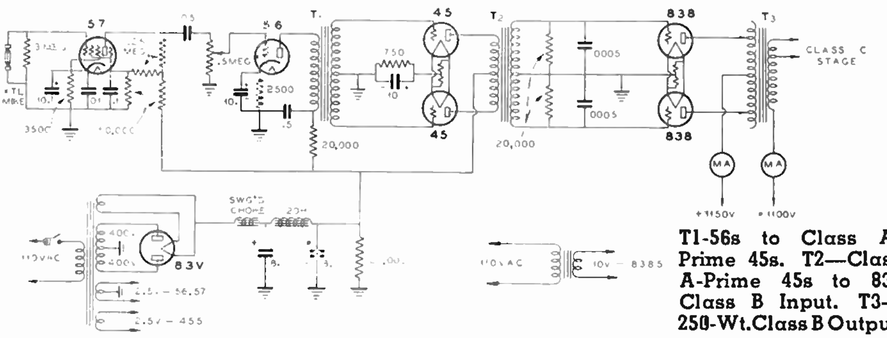
RF Portion of 400-Watt Transmitter. The Companion Modulator Is Shown on the Facing Page.



Breadboard Construction of the 400-Watt Transmitter With a Pair of 211 Tubes in the Final



High-Power Modulator With RCA-838 Tubes for 400-Watt Phone Transmitter Shown on Facing Page.



T1-56s to Class A-Prime 45s. T2—Class A-Prime 45s to 838 Class B Input. T3—250-Wt. Class B Output.

Complete Circuit Diagram of the 838 Modulator for Crystal Mike Operation.

the circuit diagram does not show this choke, because it is not needed for 75 and 160 meter operation.

When this transmitter is used for cw, primary keying is advocated because the key-click is eliminated, which is not the case when the center-tap in the final stage is keyed, unless an effective key-click filter is connected in the circuit.

A ½-mfd. 400 volt paper condenser should be connected from ground to the common point of connection of the three resistors in the 57 screen and plate circuits. This condenser was inadvertently omitted in the circuit diagram.

Coil Table

Final Amplifier Plate Coil:

80 Meters—20 turns No. 10 enameled, 4½ in. dia., 5½ in. long, center-tapped.
40 Meters—16 turns No. 10 enameled, 3½ in. dia., 5¼ in. long, center-tapped.
20 Meters—8 turns, No. 10 enameled, 3¼ in. dia., 5½ long, center-tapped.

Final Amp. Grid and Buffer Amp. Plate Coils:

80 Meters—30 turns No. 16 enameled, 2¼ in. dia., 2 in. long, center-tapped.
40 Meters—15 turns No. 16 enameled, 2¼ in. dia., 1¾ in. long, center-tapped.
20 Meters—9⅓ turns No. 16 enameled, 1½ in. dia., 1½ in. long, center-tapped.

Buffer Amp. Grid and Doubler Plate Coils:

80 Meters—36 turns No. 22 DSC, 1½ in. dia., 1½ in. long, center-tapped.
40 Meters—22 turns No. 18 enameled, 1½ in. dia., 1¾ in. long, center-tapped.
20 Meters—10 turns No. 18 enameled, 1½ in. dia., 1¾ in. long, center-tapped.

Oscillator Coils:

160 Meters—56 turns No. 24 DSC, closewound, 1½ in. dia.
80 Meters—31 turns No. 18 enameled, closewound, 1½ in. dia.
40 Meters—22 turns No. 18 enameled, 1½ in. dia., 1¾ in. long.

300-T Phone Transmitter

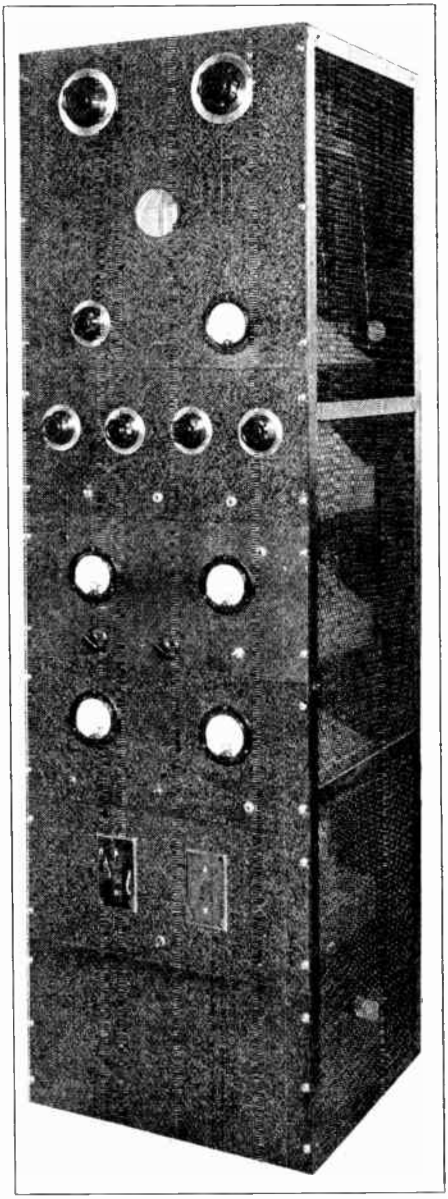
● This phone transmitter has a grid-modulated controlled carrier stage driving a 300-T linear amplifier on all bands from 10 to 160 meters. Due to the varying carrier wave impressed on the grid of the linear stage, outputs of more than 300 watts of equivalent carrier can be obtained. On cw, the final stage works as a class C amplifier with ample grid drive for about 750 watts output on any band with one KW input. The phone quality is excellent.

Circuit Notes

● A 53 crystal oscillator-doubler drives a 2A3 buffer stage which has a variable grid bias depending upon the voice input to the modulated stage. The 2A3 drives a pair of 801 tubes in push-pull, grid modulated, and which have a variable RF input to obtain controlled carrier output.

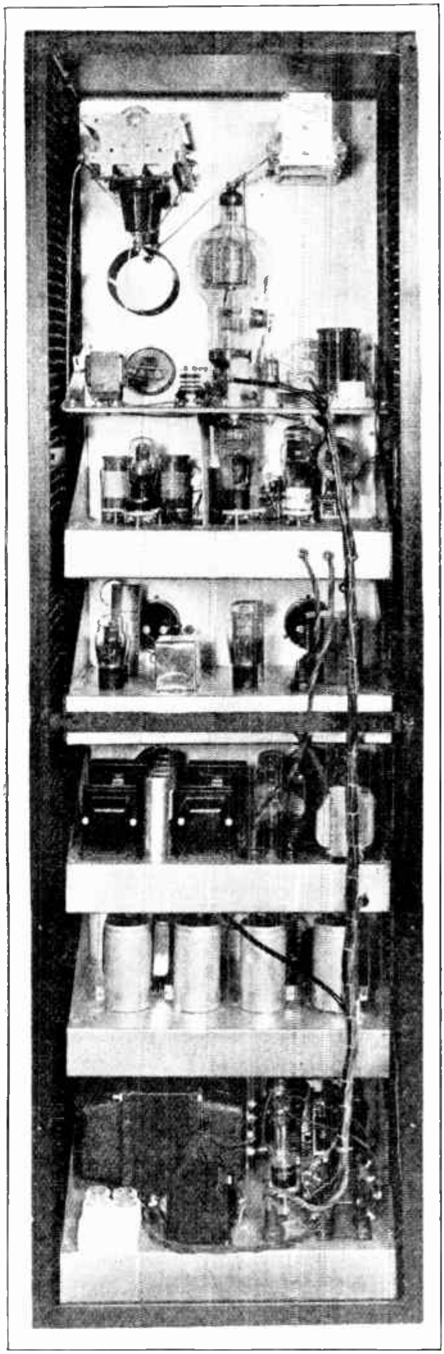
The 300-T tube stage is grid-neutralized in order to make use of a simplified antenna matching network for an end-fed or single-wire-fed Hertz all-wave antenna. A split-stator grid tuning condenser is necessary for 10 meter operation in order to prevent instability when plate voltage is applied. This method reduces grid excitation due to lack of regeneration for c-w. A 1,000 ohm 10 or 20 watt grid resistor serves as an RF choke in the final split-grid coil circuit without allowing a low frequency parasitic to appear, as often happens in linear stages with both grid and plate RF chokes. A value of 1,000 ohms or less does not cause much distortion on phone because the grid current, even on peaks, is only a few milliamperes. The plate RF choke is placed across the antenna tuning condenser only, since both plate and antenna variable condensers are widely spaced (7,500 to 9,000 volt breakdown rating). A .002 mfd. 5,000 volt RF bypass condenser insulates the antenna lead from the 2700 or 2800 volt supply. This places less RF strain on the RF choke.

The speech amplifier and modulator are of the usual design for crystal microphone input. A 2-to-1 small Class B output transformer connects the 42 triode modulator tube to the 801 grid circuit. A 2A3 tube serves as a controlled carrier bias tube, with its grid driven by the 42 modulator plate circuit. This 2A3 serves as a cathode bias on the RF 2A3 stage, and voice input reduces its resistance, thus increasing the RF output in accordance with the voice envelope. A small 30 henry choke and a pair of ½ mfd. 600 volt condensers filter the voice pulsations from the 2A3 tube circuits, leaving only a varying DC biasing effect of varying intensity. The 2A3 control tube is shunted by a 15,000 ohm resistor to prevent complete cut-off of carrier input to the 801 stage during periods of no-voice input. For c-w, a switch short-circuits this



Front View of 300-T Phone Transmitter

2A3 plate circuit, and more output is then available.



Rear View of 300-T Phone Transmitter

The set is completely AC operated. An 866 bridge rectifier supplies high voltage to the final stage. The 300-T tube will handle higher plate voltages than those used, but a full 1KW input can be obtained on c-w without exceeding the plate current rating of the 300-T for intermittent operation at the voltage shown.

Plug-in coils (listed in the coil table) provide operation on any band from 160 to 10 meters, inclusive. A 20 meter crystal is desirable for 10 meter operation, although the 2A3 can be used as a regenerative doubler with fair success when only a 40 meter crystal is available. An additional 53 push-push doubler could be added, if needed.

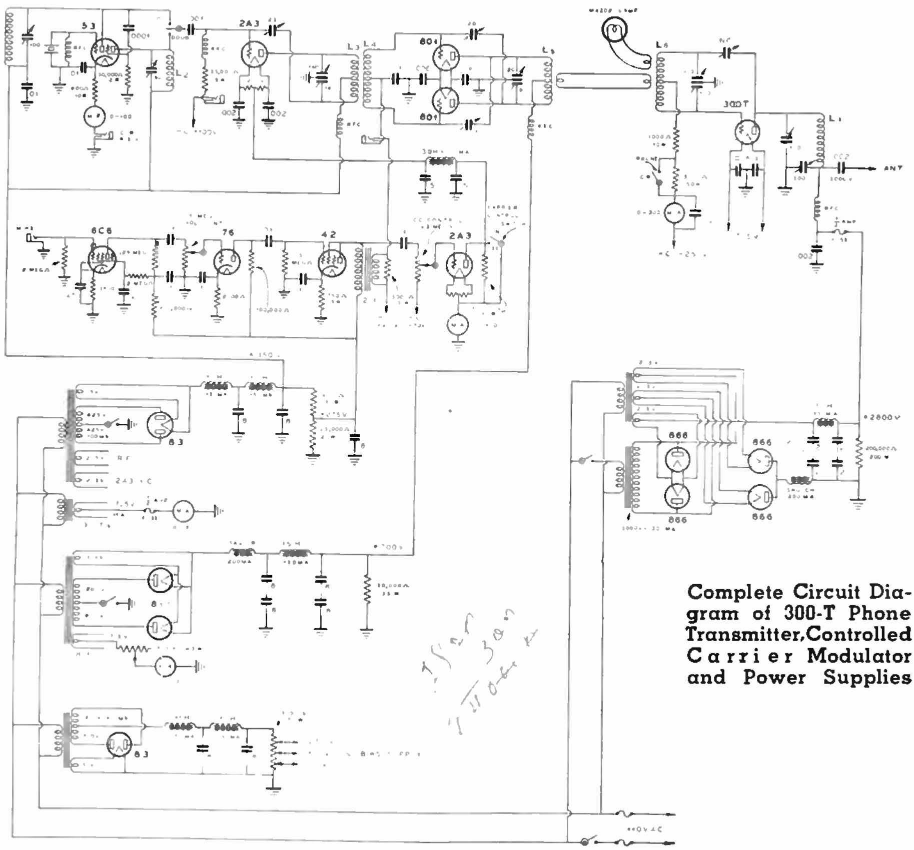
Tests

● The usual neutralizing and line-up routine can be followed for c-w operation. The final grid current should run at least 20 to 30 ma. The various bias voltage taps can be varied to obtain best quality and maximum output. All stages should be biased to approximately cut-off. Cathode bias resistors or grid leaks increase this grid bias to the proper value during either phone or c-w operation. On c-w, the 53 crystal oscillator is keyed, and this also enables push-to-talk phone operation.

On phone, the 2A3 plate circuit generally requires detuning in order to reduce the 801 grid current to 2 or 3 ma. on voice peaks. Fewer grid turns on the 801 grid coil will reduce the c-w output, thus detuning is the easiest method for securing proper RF grid excitation on the 801 tubes. A phone monitor is needed to check the voice quality in the output of the 801 stage, and to make certain that good voice quality is evident at this point before plate voltage is applied to the linear high power stage. The grid circuit link coupling and Mazda lamp load must be sufficient to load the 801 stage for grid modulation linearity.

The final stage should run with no grid current, except on voice peaks, which may run it up to 10 or 15 ma. Normally the 300-T plate current will vary from about 80 or 90 ma. up to 200 or more on phone, and steady at 300 to 350 on c-w, with the key down. Primary keying tests resulted in several blown-out 20 and 25 ampere line fuses due to exciting current line surges. "Littlefuses" in the final amplifier circuit prevent DC arc damage in the event of unexpected RF tuning condenser flashover

The 50 watt Mazda lamp load can be link-coupled to either the final grid or 801 plate circuit by means of 2 to 4 turns of hook-up wire around the center of the plug-in coil. The complete circuit diagram for this transmitter is shown on the following page.



Complete Circuit Diagram of 300-T Phone Transmitter, Controlled Carrier Modulator and Power Supplies

Final Amplifier Plate Coils

160 Meters—34 turns No. 12 Enameled, 5" long, 5" dia.
80 Meters—18 turns No. 10 Enameled, 4½" long, 4¾" dia.
40 Meters—12 turns No. 10 Enameled, 3¾" long, 3⅝" dia.
20 Meters— 6 turns No. 10 Enameled, 4" long, 3⅜" dia.
10 Meters— 5 turns No. 8 Enameled, 3" long, 1⅝" dia.

Final Grid Coils and 801 Plate Coils

Both these coils are exactly similar, and both are center-tapped

160 Meters—62 turns No. 18 Enameled, close-wound, 2⅞" long, 2¼" dia.
80 Meters—32 turns No. 16 Enameled, space-wound over 2½", 2¼" dia.
40 Meters—16 turns No. 16 Enameled, space-wound over 2", 2¼" dia.
20 Meters—10 turns No. 16 Enameled, space-wound over 1½", 1½" dia.
10 Meters— 5 turns No. 16 Enameled, space-wound over 1¼", 1½" dia.

2A3 Plate Coils, Wound on 6-Prong Forms, 1½" diam.

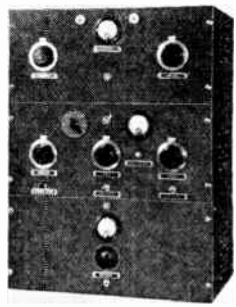
160 Meters—Primary: 66 turns No. 24 DSC, 1¾" long, center-tapped. Secondary: Wound on celluloid strip over primary, 30 turns No. 24 DSC, close-wound, center-tapped.
80 Meters—Primary: 40 turns No. 24 DSC, 1⅞" long, center-tapped. Secondary: Interwound with primary turns, starting at center and then winding 14 turns each way towards ends of primary, 28 turns in all, No. 24 DSC.
40 Meters—Primary: 20 turns No. 20 DSC, 1½" long, center-tapped. Secondary: 20 turns No. 24 DCC, interwound with primary.
20 Meters—Primary: 10 turns No. 20 DSC, 1⅜" long, center-tapped. Secondary: 10 turns No. 24 DCC, interwound with primary.
10 Meters—Primary: 5 turns No. 18 DCC, 1½" long, center-tapped. Secondary: 5½ turns No. 18 DCC, interwound with primary.

53 Oscillator and Doubler Coils. (These coils are interchangeable.) These coils wound on standard 1½" dia. receiver type plug-in coil forms

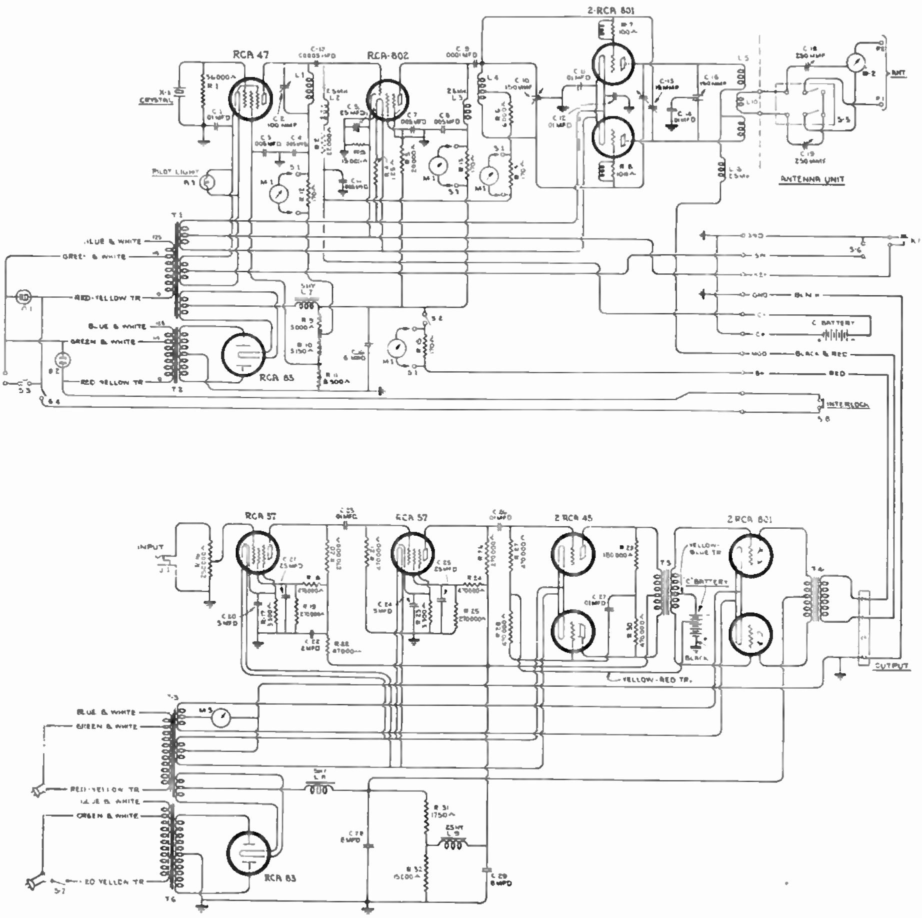
160 Meters—67 turns No. 24 DCC, 2⅛" long.
80 Meters—28 turns No. 18 DCC, 1½" long.
40 Meters—16 turns No. 18 DCC, 1½" long.
20 Meters— 7 turns No. 18 DCC, 1½" long.
10 Meters—3¾ turns No. 18 DCC, 1½" long.

RCA Phone Transmitters

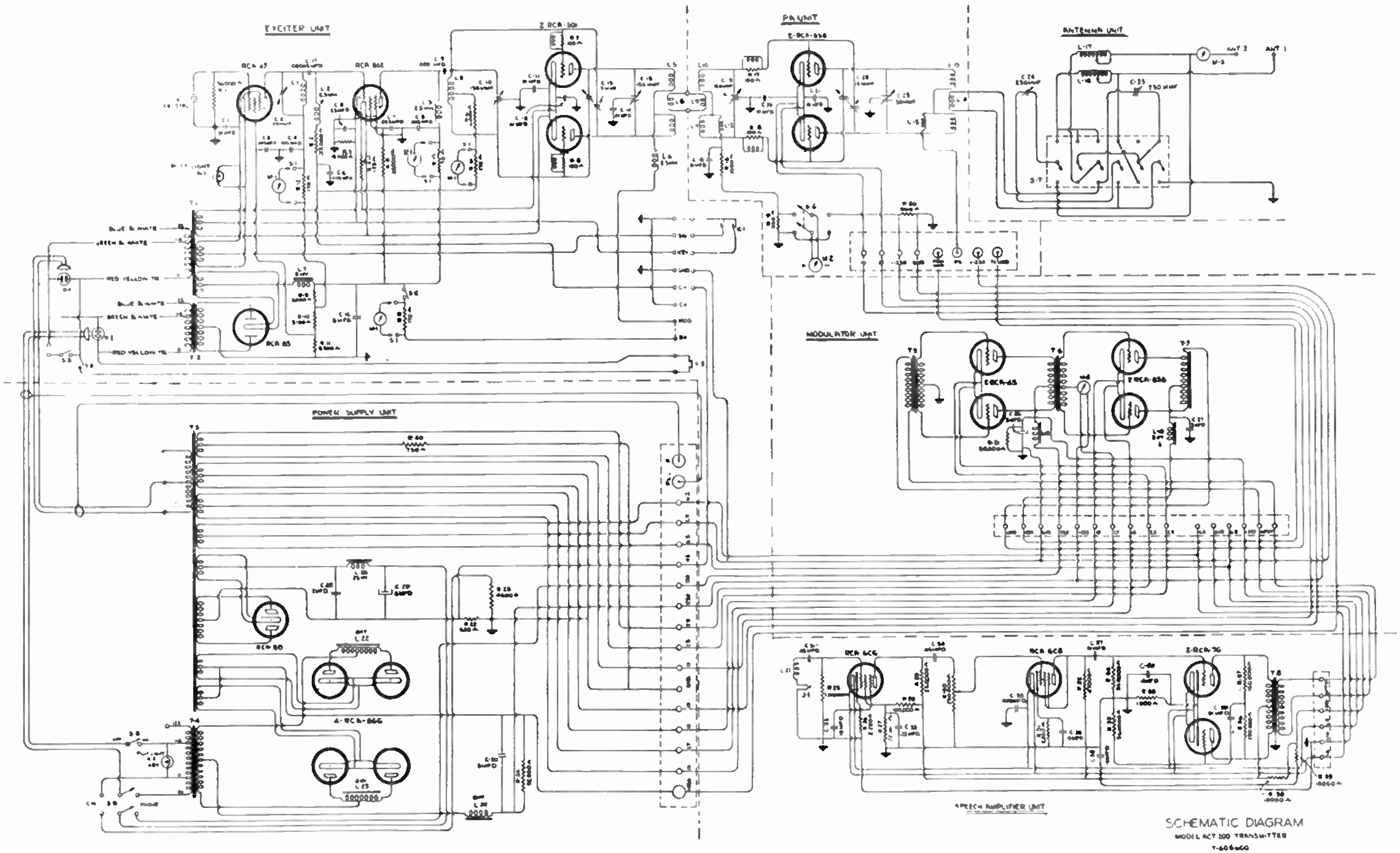
● Circuit diagrams for two RCA factory-built amateur transmitters are here shown. The smaller of the two, ACT-40, delivers 40 watts on phone and has a pair of RCA-801 tubes in push-pull in the final amplifier. The speech channel consists of a 57-57-45-and-push-pull 801 tube complement. The RCA ACT-200 is a 200 watt output phone transmitter, shown in the circuit diagram on the facing page. Two RCA-838 tubes are in the final RF amplifier, with a similar pair of tubes in the final stage of the modulator. Both transmitters can obviously be operated on c-w, as well as on phone. These transmitters are mounted in commercial relay-racks, fully encased, with access to the components from the rear.



RCA ACT-40 Transmitter



RCA Type ACT-40 Phone—C. W. Transmitter



RCA Type ACT-200 Phone and C. W. Transmitter

Chapter 14

ULTRA-HIGH-FREQUENCY COMMUNICATION

● The portion of the short-wave radio spectrum that lies below 10 meters is commonly referred to as the *Ultra-High-Frequency* range. Beginning with the amateur band of 10 meters, and continuing down the spectrum in wavelength (upward in frequency), the following radio services are in operation:

7 to 9 meters, approximately, *Police and Experimental.*
5 to 8 meters, approximately, *Television and Experimental.*
5 meters, *Amateur.*
4 to 5 meters, approximately, *Television.*
3 meters, *Aircraft Beacons For Landing Services and Facsimile Systems.*
2½ Meters, *Amateur.*
From 2½ meters to 1 meter, *Experimental and Remote Pick-up* with the exception of the 1¼ meter band which is for *Amateurs.*
1 meter to 1 centimeter (0.1 meter), *Experimental Micro-Wave Region.*

The ultra-high-frequency amateur bands are in harmonic relation with one another, i.e., the harmonic frequencies fall in succeeding bands, such as 10, 5, 2½ and 1¼ meters. These wavelengths correspond to frequencies of 30, 60, 120 and 240 megacycles, respectively. A megacycle is 1,000,000 cycles; it is simply another term that expresses operating frequency.

The speed of light is approximately 300 million meters per second (approximately 186,000 miles per second), and in order to show the relation between the frequency and wavelength of radio waves the following formulas are given:

$$F = \frac{300,000,000}{\lambda}$$

$$\text{or } \lambda = \frac{300,000,000}{F}$$

Where F is the frequency in cycles per second.
λ is the wavelength in meters.

The micro-waves extend into the region of heat-wavelengths, thence into wavelengths of light. Light waves are extremely short but there are other wavelengths still shorter, such as *X-rays, Gamma-rays* and *Cosmic-rays.*

A radio transmitter sends a wave into space; the required band width for each type of transmitter varies with the type of service. Some services, such as television, require an extremely wide band, and thus the actual number of channels available between 1 and 10 meters is not as great as would be indicated by the tremendous range of frequencies involved. A very large number of stations can be accommodated in the ultra-high-frequency spectrum. The theoretical number of available frequencies between 1 and 10 meters exceeds the range of the combined total of all short-wave, broadcast and long-wave services.

Radio experiments were first conducted before the close of the last century on the ultra-high-frequencies by *Hertz,* and others. Most of the practical developments, however, were contributed within the last ten years.

Ultra High-Frequency Phenomena

● Very short radio waves behave more like light waves, whereas longer radio waves are reflected back to earth by the *Heaviside Layer.* The direct or ground waves travel in optical paths. The wavelength, however, is thousands of times greater than that of light, resulting in a greater curvature of the paths of the waves. For this reason the range is greater than that which can be obtained by means of light rays, and signals can be received from points somewhat beyond the horizon. The range of transmission is governed by the height of the transmitting and receiving antennas. Objects that lie in the path between transmitting and receiving antennas introduce a *"shadow effect"* which often prevents reception of the transmitted signal. Objects such as hills, buildings, and even individual trees will often reflect or attenuate the radio wave. This shadow effect can be overcome to some extent by using greater power in the transmitter in order to produce a proportionately greater field strength at the receiving antenna. Long-distance communication is extremely erratic; occasionally the radio waves between 5 and 10 meters are reflected back to earth by the *Heaviside Layer* with the result that they are sometimes received over great distances. This effect depends upon the degree of ionization in the *Heaviside Layer,* which varies with the season of year, time of day, and also seems to depend on sunspot activity. At distances somewhat beyond the horizon, transmission and reception is often erratic because the atmosphere changes its degree of temperature in layers close to the earth, which in turn may change the degree of refraction of these ultra-short radio waves. Refraction bends the radio wave into a curve along the earth's circumference, and therefore increases the range of the radio wave beyond the optical distance.

Remarkably little power is required and for communication over a range of only a few miles of free space, a transceiver output of less than one watt will provide very satisfactory results.

Technical Considerations

● A simple ultra-high-frequency receiver circuit is shown in Fig. 1. It is similar to longer-wave receiver circuits, the only change being in the physical size of the components, such as the antenna, tuning coil and condenser, and the degree of regeneration. Another important factor in ultra-high-frequency receiver design is the length of the connecting leads in all radio-frequency circuits; these leads must be very short.

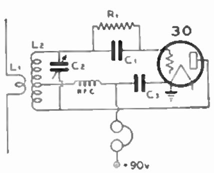


FIG. 1.

Fundamental U. H. F. Receiver Circuit.

Various forms of regenerative, super-regenerative and superheterodyne circuits are used for receiving. Fig. 1 can be operated in either a regenerative or *super-regenerative* condition, depending upon the applied plate voltage and the value of the grid-leak resistor *R1.*

Super-regeneration is regeneration carried *beyond* the point of oscillation without distortion to the received signal; this is accomplished by allowing the detector to oscillate, then damping-out the oscillation a great many times per second at a rate above audibility. Super-regeneration is a great deal more sensitive for weak signal reception, and becomes extremely effective in the ultra-short-wave range. The quenching or damping effect can be accomplished either by a blocking grid-leak action or by means of separate low-frequency oscillation applied to grid or plate voltage of the detector. The circuit in Fig. 1 can be used as a blocking grid-leak type of super-regenerator by choosing the values of *C3, R1* and *C1* in such a manner that radio-frequency oscillation is started and stopped at a rate above audibility. This circuit functions as an ordinary oscillator in which the resistance of the grid-leak is too high to permit the electrons on the grid to leak off at a rate that gives a constant value of grid-bias voltage. This blocking action causes a change in the average bias and stops the oscillation, because the plate current is decreased and the mutual conductance of the tube also decreases. If the circuit constants are correct, the blocking action takes place at an inaudible rate and super-regeneration is accomplished.

Another form of damping or quenching makes use of a separate oscillator functioning at approximately 100,000 cycles per second to control the ultra-high-frequency oscillation. The circuit is shown in Fig. 2.

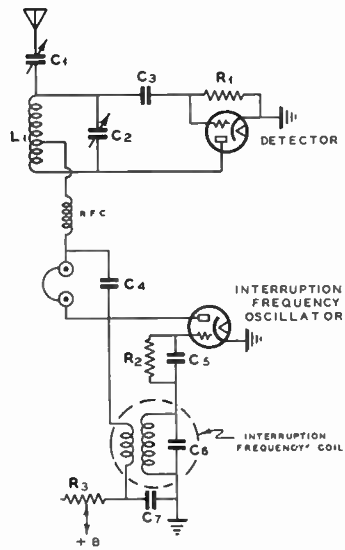


FIG. 2.

U. H. F. Receiver Circuit with Separate Oscillator.

The low-frequency oscillator voltage is coupled into the detector plate circuit. In this case, the interruption frequency varies the detector plate voltage to such an extent that the detector tube goes in and out of oscillation at a rate determined by the low-frequency oscillator. The circuit is similar to that of *Heising* Plate Modulation, as used in radio transmitters.

In either circuit, fairly heavy antenna loading is needed in order to obtain good quality and sensitivity; the antenna coupling can be varied by means of the coupling condenser C1 in Figs. 1 and 2, or by means of variable inductive coupling between the antenna and detector tuned circuit. Too much antenna coupling will tend to pull the detector out of super-regeneration.

Super-regeneration has a very distinct advantage; it provides high sensitivity to weak signals, and low sensitivity to strong signals. This automatic volume control action greatly reduces automobile ignition interference because this kind of signal is of very short duration. The detector sensitivity automatically drops down during the small fraction of a second in which this impulse is present, and although the desired signal is also reduced the human ear will not respond to changes of such short duration. The ignition interference in this way does not cause an excessively loud signal in the audio amplifier output as compared with the strength of the received phone signal. Super-regeneration also provides very high sensitivity in relatively simple circuits. The hiss, or rushing sound, audible in the output of a super-regenerative receiver, is due to thermal and contact circuit noise. The detector is in an extremely sensitive operating condition when no signal is present, thus the noise is greatly amplified and made audible in the loud-speaker or head-set. A carrier signal automatically reduces the sensitivity and consequently decreases the background noise or hiss. A strong signal will completely eliminate the background noise.

Unlike ordinary regeneration, super-regeneration always broadens the tuning. Super-regenerative detectors radiate a signal fully modulated by the quenching frequency. This signal will cause bad interference in other receivers within a radius of several miles. The blocking grid-leak detector is more troublesome in this respect and a RF amplifier should be placed betwen the antenna and any super-regenerative detector in order to minimize radiation. The RF amplifier will also provide some increase in sensitivity.

Receivers designed for 5-meter operation are generally of the super-regenerative or super-heterodyne type. Regenerative or super-heterodyne circuits are more desirable for 10 meter reception because this band is used for both telegraph and phone. In the micro-wave range, below ½ meter, super-regeneration is difficult to obtain and *Barkhausen-Kurz* oscillator circuits are more suitable. The circuits are covered elsewhere in these pages.

Transmitters

● For short range portable operation, self-excited modulated oscillators are widely used. The circuit in Fig. 3 is a typical example of a transceiver and low-power transmitter.

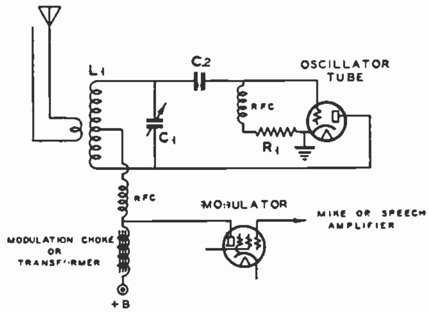


FIG. 3.

Self-Excited Modulated Oscillator.

The radio-frequency circuit is quite similar to that used for receiving, shown in Fig. 1, except that the value of grid-leak *R1* is so low that no blocking effect takes place and stable oscillation is maintained. The modulator supplies an audio-frequency voltage which varies the effective plate voltage of the oscillator tube, resulting in a modulated carrier signal.

In the micro-wave region below 1 meter, regenerative oscillators with Acorn tubes are suitable for operation down to approximately 40 centimeters. *Barkhausen-Kurz* or *Gill-Morrel* electronic oscillators are often used below 1 meter. *Magnetron* oscillators also provide a means of obtaining RF output down to a few centimeters in wave-length.

Crystal controlled transmitters give greater stability than any other form in the range between 3 and 10 meters, but at the disadvantage of requiring more tubes and equipment. Resonant line oscillators have fairly good frequency stability, consistent with economy, and they are very popular for ultra-high-frequency transmission.

Modulated oscillators with tuning coils and condensers are suitable for portable operation because of their compactness but these oscillators are subject to excessive frequency modulation. This effect is detrimental to audio quality and causes the transmitted signal to spread out over a band of frequencies several times as wide as normally required for transmission of intelligence.

Transmitters for portable operation can operate successfully with power outputs of one watt or less. Those for mobile operation should have an output of from 5 to 10 watts; fixed amateur stations require power outputs varying from 5 to 30 watts. Experimental and commercial stations require higher outputs; several hundred watts will provide general coverage over a radius of 25 or 30 miles.

Antennas and Transmission Lines

● Point-to-point communication is most economically accomplished by means of directional antennas which confine the radiated fields to a narrow beam in the desired direction. If the power is concentrated into a narrow beam, the apparent power of the transmitter, or the sensitivity of the receiver, is increased a great many times. For general coverage in all directions the half wave vertical antenna is almost universally used. A vertical antenna transmits a wave of low angle radiation parallel to the surface of the earth and is therefore especially satisfactory for ultra-short-wave operation. Horizontal antennas are more directional in two directions, but they waste a great deal of the radiation in an upward direction. The radiation in a direction parallel to the earth is the only portion that is useful. The radiation from a horizontal antenna is horizontally polarized, thus it is best received on a horizontal antenna. Vertically polarized radio waves are not as easily reflected upward by the surface of the earth as are horizontally polarized waves.

The antenna system for either transmitting or receiving should be as high as possible above the earth and nearby objects. The physical size of half wave antennas is small, thus an effective system of supplying power from the transmitter to the radiator must be provided. The same holds true for receiving. Transmission lines serve this purpose; they consist of twisted-pair wires, spaced wires, concentric lines or single wire feeders. Two-wire spaced feeders, such as two No. 14 or 16 gauge copper wires spaced 2 to 4 inches apart, have the lowest losses. Concentric line feeders have lower losses than twisted-pair lines and they are nearly as efficient as spaced feeders. Single-wire feeders are not much more efficient than tuned feeders, such as those used with Zepp. antennas. Tuned feeders are only desirable for very short transmission lines.

Circuit Design

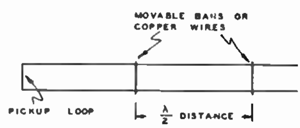
● Rigidity and compactness, with very high-quality insulation and correct arrangement of parts are essential in ultra-high-frequency equipment design. Ceramic materials or their equivalent should be used for sockets, condenser insulation, coil supports and stand-off insulators. All parts should be rigidly mounted so that no frequency variation will result from vibration. All radio-frequency wiring should be very short and direct, well soldered with non-corrosive solder. Pastes and acids must be avoided as well as excessive amounts of rosin on the joint to be soldered. Tuning condensers must be remote from metal panels, and control shafts should extend to control dials by means of bakelite extension shafts. Slight changes in physical design often change the value of resistors and condensers for satisfactory operation in both transmitters and receivers.

Wavelength and Frequency Determination

Lecher Wires

● The wavelength of an ultra-high-frequency receiver or transmitter can be measured by means of parallel wires (*Lecher Wire Systems*), by wavemeters or by means of harmonics from calibrated low-frequency oscillators.

Lecher Wire measuring systems are shown in Figs. 4 and 5. They are suitable for wavelength measurements over the entire ultra-high-frequency range. An accuracy of approximately 1% can be expected; for more accurate frequency or wavelength determination the harmonic method should be used to supplement these measurements. A Lecher wire system consists of two parallel wires coupled to the transmitter or receiver by means of a closed loop or pickup coil, as shown by the *Oscillator Coil* in Fig. 5.



LECHER WIRE SYSTEM

FIG. 4.

Standing waves of voltage and current will occur along the parallel line, and these standing waves can be located with a sliding bar or copper wire, as shown in Fig. 5.

The parallel line can be constructed of bare copper wire, spaced about three inches apart. The length of each wire will depend upon the wavelength being measured, such as 35 or 40 feet for 5 and 10 meter measurements, 17 to 20 feet for 2½ meters, or 5 to 7 feet for wavelengths below 1 meter.

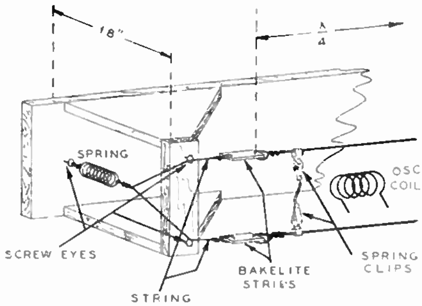


FIG. 5—Lecher Wire Measuring System.

When these wires are coupled to the oscillator, standing waves are produced in the wire, and the distances between points of maximum current are equal to half wavelengths. The oscillator should have an indicating device, such as a DC milliammeter in either its grid or plate circuit. When the wavelength of a receiver is being measured, a variation in super-regeneration or oscillation intensity will be audibly heard in the output of the receiver. Another indicator for transmitter measurements consists of a small turn of wire and a 6-volt flashlight globe, or a RF thermo-galvanometer coupled to the closed end of the Lecher Wire system. A deflection in plate current, or dimming of the lamp, will be noticed when the shorting link is across some half wave point on the parallel wires. The exact wavelength of the oscillating circuit is found by sliding the shorting link betwen the first and second points of indication, making note of the points, then measuring the distance with a scale or tape measure. To obtain the wavelength in meters, this distance must be converted from feet into meters by multiplying the number of feet by 0.656, or the number of inches by 0.0547. This factor takes into consideration the half wave points when converting the results into actual wavelength.

Wavemeters

● Lecher Wire systems are bulky and considerable time is consumed in making the desired measurements. Wavemeters are more convenient and easy to construct. A simple absorption wavemeter, having a range of between 4.7 and 7 meters, consists of a 25 mmfd. midget variable condenser paralleled with a 3-30 mmfd. semi-fixed condenser of the "padder" type, and a coil wound with 5 turns of No. 10 wire in a winding space of one-inch, a half-inch in diameter, self-supported.

Another form of absorption wavemeter, having a range of from 4 to 14 meters, can be made from a 150 mmfd. variable condenser connected across a 2-turn coil of No. 10 wire, 2-inches in diameter. See Fig. 6.

The coil should be supported on bakelite spacers. A neon lamp or vacuum-tube diode can be shunted across the circuit for indicating resonance. In the design of any wavemeter, the entire circuit should be rigidly constructed. Hand-capacity effects can be eliminated by tuning the condenser with an extension handle of wood or bakelite.

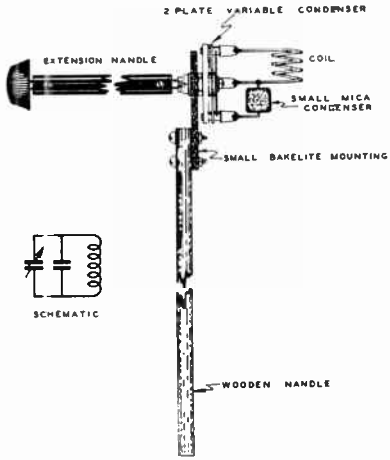
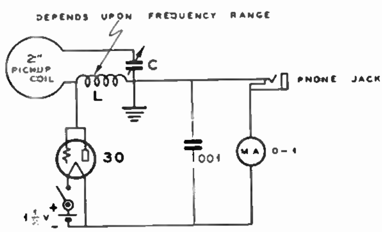


FIG. 6.

For 2½ meter measurements, a one-turn coil of heavy wire, approximately 1-inch in diameter, and shunted with a 15 mmfd. midget variable condenser, will serve as an absorption wavemeter.

The wavemeter can be calibrated over the tuning condenser scale by coupling the coil to an oscillator circuit; the oscillator wavelength can be varied and its frequency determined by Lecher Wires. When the wavemeter is tuned to resonance, the oscillator milliammeter or RF indicator will provide an indication. After the wavemeter has been calibrated, it can always be used for measuring the wavelength of oscillating receivers and transmitters.



WAVEMETER WITH DIODE INDICATOR
FIG. 7.

Fig. 7 shows a wavemeter that is quite sensitive in the region of 3 to 10 meters. A type 30 tube with a single 1½ volt flashlight cell serves as a diode to rectify the radio-frequency. A 0-1 d-c milliammeter is the resonance indicator. A closed-circuit telephone jack enables this wavemeter to be used as a monitor for checking phone quality and over-modulation.

5-Meter Field Strength Meters

● Field strength meters give an indication of the power in a transmitter antenna. The circuit diagrams for two such devices are shown in Figs. 8 and 9. The field strength meter is placed in the vicinity of the transmitter antenna and maximum indication of the instrument denotes maximum antenna power. Field strength meters should be housed in completely shielded metal cans.

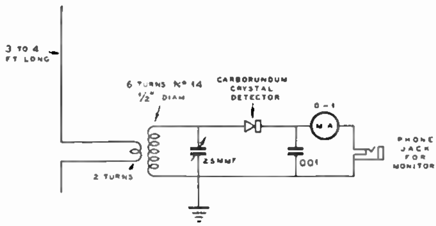


FIG. 8
5-Meter Field Strength Meter. The Two Antenna Wires Are Each 3 to 4 ft. Long.

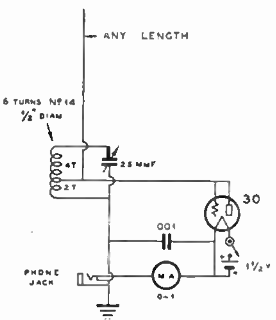


FIG. 9
Field Strength Meter with Diode Tube.

Harmonic Frequency Determination

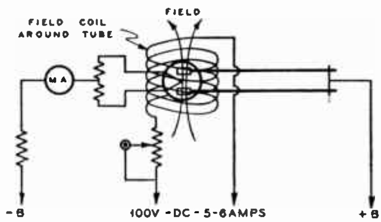
● The harmonics of a quartz crystal oscillator provide an accurate means of frequency determination. An oscillating crystal in the 160 meter or broadcast band will produce strong harmonics in the ultra-high-frequency region between 2 and 10 meters. A super-regenerative receiver, when tuned to this region while loosely coupled to the oscillator, will indicate the harmonics by sharp reductions in hiss level in the receiver output. An oscillating regenerative receiver can be tuned to zero-beat with these harmonics, and then to the ultra-high-frequency transmitter for accurate frequency determination. An absorption wavemeter is a necessary adjunct for approximate wavelength measurements in order to make certain that operation is secured from the desired harmonic.

Micro-Waves

● Micro-waves, as previously related, are those whose length is less than one meter. Micro-waves are generated by means of *Magnetrons, Electron-Orbit Oscillators,* and *Regenerative Oscillators.* Micro-waves are used by broadcast stations for remote pickup, by amateurs and experimenters, and for occasional telegraph and telephone communication, such as the British Channel spanning system. The technical problems of this field are numerous, yet new tubes designed for micro-waves have been instrumental in increasing the usefulness of the band.

The Magnetron Oscillator

● The Magnetron is a specially designed tube for very-short-wave operation. It consists of a filament or cathode between a split plate, as shown in Fig. 10.

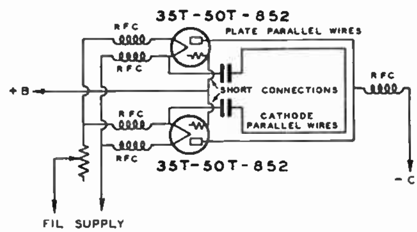


SPLIT MAGNETRON OSCILLATOR
FIG. 10

A magnetic field is produced at the filament by means of a large external field coil which is energized by several hundred watts of DC power. Ultra-high-frequency oscillations are produced in the split-plate circuit when this magnetic field is in the correct direction, and of the proper intensity. A parallel wire tuned circuit can be used for wavelengths below one meter, or for ordinary tuned circuits with wavelengths above one meter. These tubes are available for experimental purposes and will produce outputs of several watts. The frequency stability is not very good and it is difficult to obtain satisfactory voice modulation from Magnetron Oscillators.

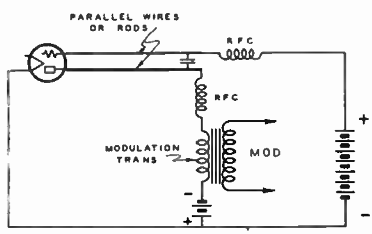
Electron Orbit Oscillator

● The range of oscillation in ordinary circuits is limited by time required for electrons to travel from cathode to anode. This transit time is negligible at low frequencies, but becomes an important factor below 5 meters. With ordinary tubes, oscillation cannot be secured below 1 meter, but by means of *Electron Orbit Oscillators,* in which the grid is made positive and the plate is kept at zero or slightly negative potential, oscillation can be obtained on wavelengths very much below 1 meter. Parallel wire tuning circuits can be connected to these tube oscillators in order to increase the power output and efficiency. The tubes most suitable for this type of operation have cylindrical plates and grids, and their output is limited by the amount of power which can be dissipated by the grids. For transmitting, tubes such as the 35T, 50T or 852 can be used in the circuit shown in Fig. 11, which is a modification of the *Gill-Morrel Oscillator.* More output is obtained by using a tuned cathode, instead of tuned grid, circuit. Modulation can be applied to either the plate or grid. The frequency stability is very poor. The circuit in Fig. 11 is an early type oscillator.



KOZANOWSKI OSCILLATOR

FIG. 11



B - K OR G - M OSCILLATOR

FIG. 12

Figs. 13 and 14 illustrate a ¾-meter transmitter and receiver used in 1933 by the author. The power output is rather low, but telephone communication over short distances can be satisfactorily accomplished.

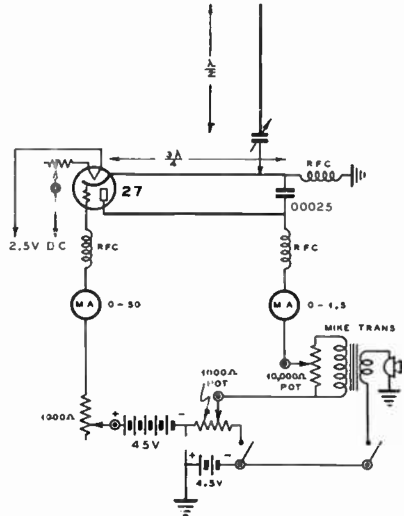


FIG. 13
¾ Meter Circuit Used by Jones in 1933.

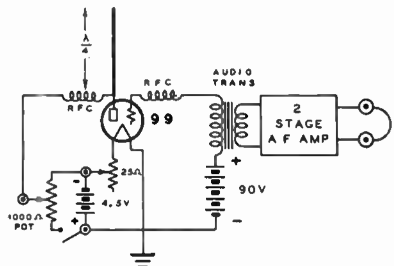


FIG. 14
¾ Meter Receiver (1933).

Regenerative Oscillators

● The introduction of the *RCA Acorn 955,* and *Western Electric* 316-A tubes made ½-meter regenerative oscillators practical. These tubes are more efficient than ordinary types for ultra-high-frequency work. Fig. 15 illustrates the RCA Acorn triode. Circuits, such as that shown in Fig. 16, and a constructional plan in Fig. 17, are satisfactory for low-power transmitters and super-regenerative receivers. The 955 Acorn can be used as an oscillator in super-heterodyne receiver circuits with its companion tube, *RCA 954 (or 956) Acord Pentode,* in the RF portions of the circuit. The regenerative circuits are quite similar to those for longer wavelengths, except for the physical size of condensers and coils. The tube element spacing in these *Acorn* tubes is made so small that electron transit time becomes a negligible factor for wavelengths above 0.6 meter.

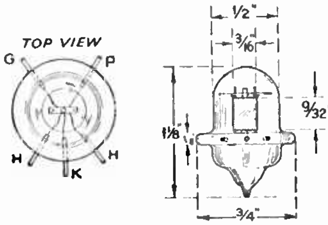


FIG. 15
RCA Acorn 955

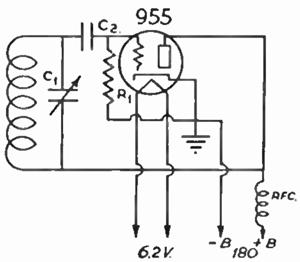


FIG. 16
RCA 955—Circuit Diagram and Suggested Layout.
L1—8 turns, 1/2-in. outside diameter, No. 18 wire, spaced 1/4-in. between turns.
C1—Tuning condenser; 2 circular brass plates 3/4-in. in diameter; 10/32 thread on adjusting screws.
C2—.00025 mica condenser, postage stamp type.
R1—15,000 ohms, 1 watt carbon resistor.
RFC—1/4-in. bakelite rod wound 1 1/2-in. with No. 32 DCC wire.

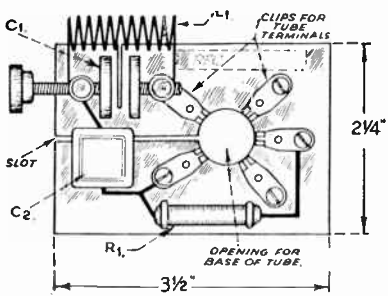


FIG. 17—Plan view of transmitter.

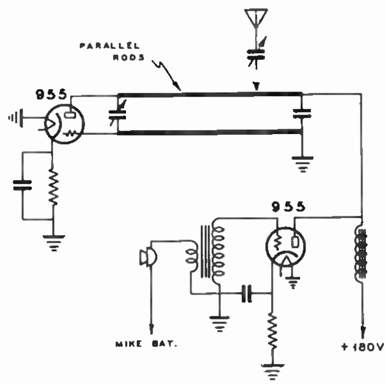
Micro-Wave Tube Characteristics

RCA 954 PENTODE

Heater voltage	6.3
Heater current	0.15 amp.
Grid-to-plate capacity	.007 mmfd.
Input capacity	3 mmfd.
Output capacity	3 mmfd.
Max. plate voltage	25 volts.
Max. screen voltage	100 volts.
Grid voltage	—3 volts.
Suppressor tied to cathode	
Amplification factor	Over 2000.
Plate resistance	Over 1.5 megohm.
Mutual conductance	1400 mhos.
Plate current	2 ma.
Screen current	0.7 ma.

RCA 955 TRIODE

Heater voltage	6.3
Heater current	0.15 amp.
Max. plate voltage	180 volts.
Max. plate current	7 ma.
Amp. factor	25.
Plate resistance	12,500 ohms.
Mutual conductance	2,000 mhos.



320MC TRANSMITTER
FIG. 18

Micro-Wave Transmitters

● A micro-wave transmitter for operation slightly below 1 meter is illustrated in Fig. 18. The *RCA 955 Acorn* is used in a parallel-rod oscillator with cathode, rather than grid-leak, bias. Another 955 serves as the modulator. This transmitter is similar to one built into a silk-top hat, and used by the NBC for remote pickup of commercial broadcasts. The antenna protrudes through the hat, the batteries and modulator are carried in a leather belt. A similar oscillator was built into a walking cane, the cane holds both the parallel-rod oscillator and antenna. Signals have been received over distances of 3 miles. Automobile ignition interference is practically absent at wavelengths below 1 meter.

66 CM (2/3-Meter) Transceiver

● This is perhaps the first disclosure of a transceiver that operates successfully on 1/2- or 2/3rds-meter. Operation at these very short wavelengths is accomplished with an Acorn triode and parallel wire circuits for grid, plate and filament. See Fig. 19. The filament cathode circuit is tuned with a quarter wave parallel wire section which is adjusted by sliding a .001 mfd. mica condenser along the parallel wires. See Fig. 20. plate and grid parallel wires. For ⅔-meter, this bridging condenser is about 1½ in. away from the glass envelope of the 955 Acorn tube. 40 CM oscillation takes place when the condenser is bridged across the wires at the point of connection to the terminal clips of the tube. The wavelength of

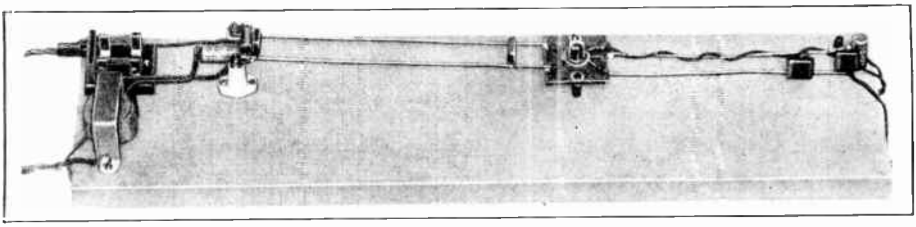


FIG. 19—66 cm. Transceiver with 955 Acorn Triode.

When this filament circuit is properly tuned, oscillation and super-regeneration can be obtained with relatively low values of plate voltage, even at wavelengths of 40 CM. This adjustment is not very critical over a range of a few centimeters. The ends of the quarter wave section have high RF potential; the short-circuited end (.001 bridging condenser) have zero RF potential, and thus the parallel wires can extend a few inches beyond the short-circuited end. The cathode resistor, filament by-pass and cathode by-pass condensers can then be connected in place without need of varying their position for tuning purposes. The insulated filament lead is twisted around the cathode filament wire in order to make the combination act as a single RF conductor. A small mica condenser connected between this wire and the cathode or ground wire will increase the capacity and prevent RF absorption by the extended filament leads. The latter may connect to either a 6.3 volt AC source, or to a 6-volt storage battery.

operation increases as this condenser is slid outwardly along the parallel wires toward the other .0001 mfd. bridging condenser near the end of the parallel wires, at which point 1½ meter operation can be secured.

As illustrated in the photograph and circuit diagram, the portion of plate-grid parallel wires between the two .0001 mfd. condensers serves as a quarter wave tuning section which provides high efficiency when operating below ¾-meter. The RF potential across the .0001 mfd. condenser nearest the tube is not exactly zero at the ends of the condenser, since the physical length of the condenser becomes an appreciable portion of the tuned circuit between grid and plate. The quarter wave section, which at ⅔rds-meter is about 6½ inches, serves the purpose of two radio-frequency chokes for connection to the audio components of the transceiver. A quarter wave section is much more effective than RF chokes in the micro-wave region.

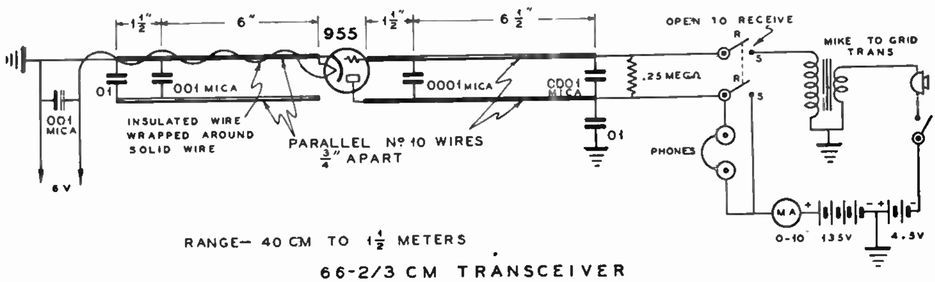


FIG. 20

The frequency or wavelength is adjusted to the desired value by means of a .0001 mfd. mica condenser connected across the

The antenna can be inductively coupled to this transceiver by supporting a ¾-turn loop (¾ in. dia.) close to the parallel wires in the grid and plate circuits of the 955 tube. This loop should be coupled to the oscillator between the tube and the .0001 mfd. bridging condenser nearest the tube. A half wave antenna for ⅔rds-meter is approximately 13 inches long. A two-wire Zepp. feeder, or matched impedance line, couples the antenna to the transceiver. A directive antenna array, or a *Yagi* antenna, is infinitely better for increased range at these very short wavelengths.

With the DPST switch closed, the 955 operates as a grid-modulated oscillator with plate current of approximately 6 to 7 MA.

With the switch open, the headphones are connected in the plate circuit, and the microphone transformer is disconnected from the grid circuit. Reception is obtained by superregeneration in the detector circuit, and the plate current drops to a value of between 1 and 2 milliamperes.

Plate modulation in the transmitter will give two to three times as much output, if more output is needed.

The RF circuit is very effective below 1 meter and outputs of ¼ to ½ watt can be expected between ½ and 1 meter. At 66⅔ (⅔rds-meter) the transmitter output is high enough to give more than half-scale deflection on a thermo-galvanometer having a range of 115 MA.

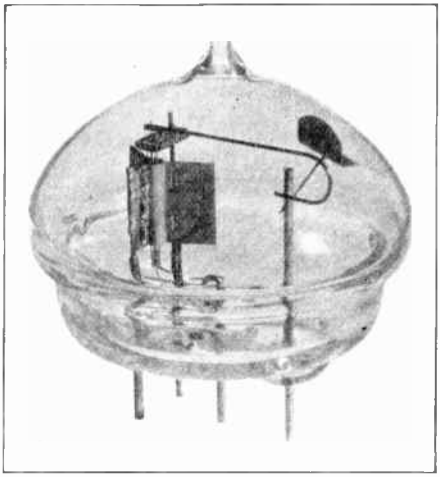


FIG. 21—W.E.-316A U.H.F. Triode.

W.E.316-A Micro-Wave Oscillator

● Western Electric has produced a new micro-wave triode which delivers from 5 to 10 watts output on wavelengths as low as ½ meter. The element spacing is so close that the tube operates efficiently as a regenerative oscillator with negative grid and positive plate for frequencies as high as 750 mc. The maximum plate dissipation is 30 watts. The transmitter illustrated in Fig. 22 delivers aproximately 7.5 watts with 400 volts on the plate. This power output is sufficient for coverage over a visual range, although in one case a ¾-meter signal was heard over a distance of 80 miles, which is far beyond the optical path. A large variety of circuits could be suggested for microwave operation, but the most simple of these is the one shown in Fig. 22. It consists of two parallel half wave rods, spaced about ¼-inch apart, to provide a ¾-meter tuned circuit of fairly-high "Q". See Fig. 23. The grid and plate of the tube are connected to the copper rods; this capacity causes the physical length to be less than a half wavelength. As can be seen from the photograph, the plate RF choke and grid-leak do not connect to the center of the rods, but rather across the voltage node. The distance between this point and the free ends of the rods is a quarter wavelength. The other distance is shortened by the tube capacity. Filament RF chokes, or tuned filament leads, are desirable for operation below 1-meter be-

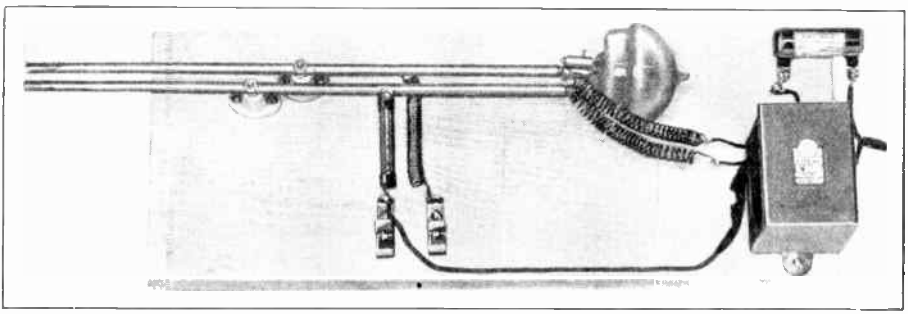


FIG. 22—W.E.-316A ¾-Meter Oscillator.

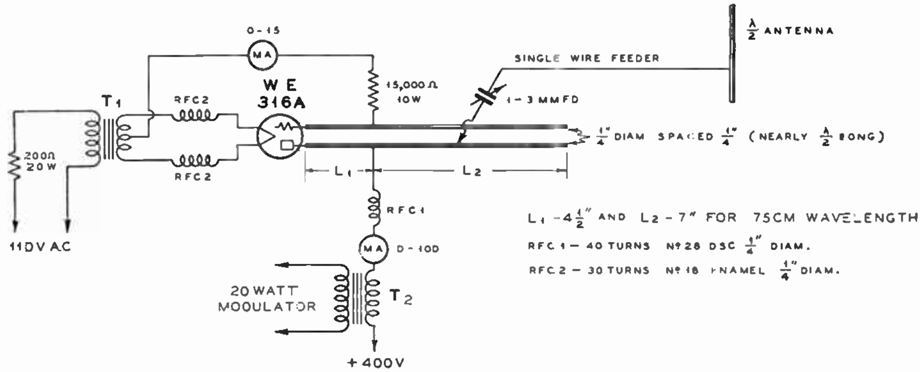


FIG. 23—W.E.-316A ¾-Meter Oscillator Circuit.

cause the filament is near a point of high RF potential in the oscillating circuit. These filament chokes consist of 30 turns of No. 16 enameled wire, wound on a ¼-inch rod, then removed from the rod and air-supported, as the picture shows. The length of these chokes is aproximately 3 inches. A 200 ohm resistor is placed in series with the 110-volt AC line to the filament transformer in order to reduce the transformer secondary voltage from 2½ to 2 volts, because the filament of the tube operates on 2 volts at 3.65 amperes. This particular oscillator gave outputs in excess of 5 watts on ¾ meters, even when no filament RF chokes were used.

This oscillator, when loaded with antenna, draws from 70 to 80 milliamperes at 400 volts plate supply. An audio modulator, such as a pair of 2A3 tubes, class AB connection, will supply approximately 15 watts of audio power for modulation. The oscillator should be tested at reduced plate voltage, preferably by means of a 1000 to 2000 ohm resistor in series with the positive B lead, until oscillation has been checked. A flashlight globe and loop of wire can be coupled to the parallel rods at a point near the voltage node, in order to indicate oscillation.

A 15-inch antenna rod or wire can be fed by a one-or-two-wire feeder of the non-resonant type. A single-wire feeder can be capacitively coupled to the plate rod, either side of the voltage node, through a small blocking condenser. If a two-wire feeder is employed, a small coupling loop, placed parallel to the oscillator rods, with the closed end of the loop near the voltage node of the oscillator, will provide a satisfactory means of coupling to the antenna. The power output is high enough so that operation is as simple as any 40 meter c-w transmitter.

W. E. 316-A Characteristics

Filament voltage	2 volts a-c or d-c.
Filament current	3.65 amperes.
Average thermionic emission	0.45 amperes.
Amplification factor	6.5.
Plate-to-grid capacitance	1.6 mmfd.
Grid-to-filament	1.2 mmfd.
Plate-to-filament	0.8 mmfd.
Max. plate dissipation	30 watts.
Max. d-c plate voltage	450 volts.
Max. d-c plate current	80 MA.
Max. d-c grid current	12 MA.

1¼ Meter Receiver

● Extremely small capacity between tube elements, and very small values of tuning capacities and inductances are essential for 1½ meter receivers. Conventional triode tubes have too much grid-to-plate capacity for effective operation at 1¼ meters. However, once the correct components are chosen, it is a very simple matter to build a high-sensitivity 1¼ meter receiver. See Fig. 24.

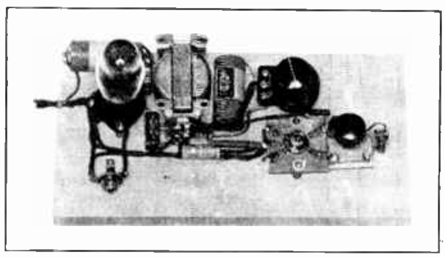
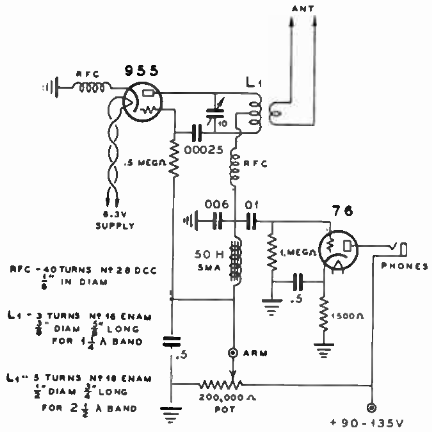


FIG. 24
1¼-Meter Receiver.

The grid and plate leads to the tuning condenser are so short as to be almost negligible. Either a coil or parallel wires forms an inductance for connection across the tuning condenser. Parallel wires occupy a few inches more of space, but they are more efficient because the circuit "Q" is higher.



1¼ λ AND 2½ λ BAND RECEIVER

FIG. 25

The circuit shown in Fig. 25 is almost self-explanatory. Super-regeneration is secured by means of a blocking grid-leak condenser system. A cathode RF choke is generally necessary in order to obtain super-regeneration. Impedance coupling is shown between the detector and 76 audio stage because this method of coupling gives sufficient volume for headset reception. An audio transformer could be substituted, together with a type 41 pentode tube, if loudspeaker reception is wanted. A potentiometer controls the plate voltage to the super-regenerative detector; adjustment should be made for greatest detector sensitivity. Insufficient detector plate voltage will generally result in an audio howl. Super-regeneration takes place at slightly higher voltages, up to the full battery voltage supply. Greatest sensitivity occurs when the actual detector plate potential is nearly 45 volts. The proper setting will depend upon the characteristics of the particular 955 Acorn tube in the circuit, and the degree of antenna coupling.

The RF coil, L1, can be compressed or extended in order to permit the tuning condenser to cover the 1¼ or 2½ meter bands. Lecher wires provide a most convenient method for checking the wavelength of the receiver.

1¼ Meter Transmitter with RCA-834 UHF Tube

● The advent of several new tubes particularly designed for the ultra high frequencies makes possible the construction of a transmitter which will deliver from 10 to 50 watts on wavelengths below 5 meters. Ratheon RK-32, Western Electric 304-B, and RCA 834 are equally suitable for use in the transmitter shown in Fig. 26. The characteristics of all three tubes are similar.

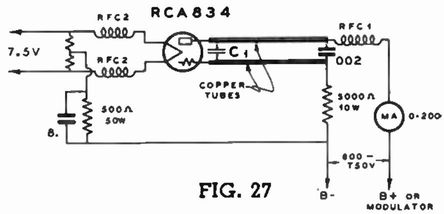


FIG. 27

1¼-Meter Transmitter.

C1—Aluminum Plates, 1¼ in. square.
Copper Tubes—3-in. long for 1¼ Meters.
9 in. long for 2½ Meters.
RFC1—40 turns No. 28 DSC, ¼-in. dia.
RFC2—25 turns No. 14 Enam., ½-in. dia.

The grid and plate leads are brought out through the top of the tube envelope in all cases, resulting in operation down to ¾-meter.

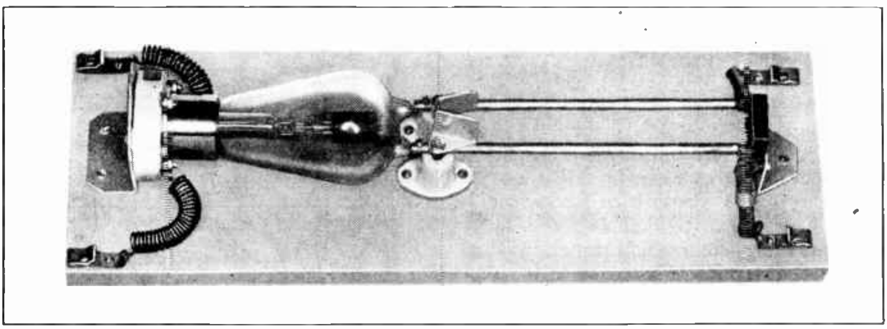


FIG. 26—1¼-Meter Transmitter with RCA 834 U.H.F. Triode.

The circuit in Fig. 27 is suitable for oscillation between 1 and 3 meters, depending upon the length of the parallel rods or pipes.

A slight variation of frequency is possible if two condenser plates each ¾ in. square, are connected across the pipes near the tube leads. This type of circuit works more efficiently than a conventional coil and condenser oscillator circuit. The tube leads fit into the ends of copper pipes, and small set screws provide good electrical contact between pipe and tube leads. This type of mounting must be used with care in order to avoid breakage of the tube envelope. The tube socket mounting strip should have slotted holes in order to make correct alignment with the copper pipes.

Filament RF chokes are necessary below 3 meters in order to secure oscillation. At 1¼ meters, the metal shell of the tube socket, and the metal support that holds the socket, introduce excessive capacity to the filament circuit of the tube, resulting in stoppage of oscillation if either of these metal surfaces is grounded. A non-metallic socket and bakelite socket support would be preferable if operation in the neighborhood of 1-meter is wanted. A tuned filament circuit, somewhat similar to that illustrated in the *66 CM Transceiver*, will work more effectively than RF chokes for wavelengths below 1½ meters.

The antenna feeder is coupled to the parallel pipes or tubes by means of a coupling loop. A half or quarter wave antenna can be capacitively coupled through a very small variable condenser to the plate rod at a point approximately one to two inches from the plate blocking condenser. Transmission ranges of 3 to 50 miles are possible if the antenna is located at high elevation. Even 1¼ meter waves tend to curve along the surface of the earth to such an extent that communication can often be obtained beyond the optical range.

2½ Meter Transmitter

● An RK-34 twin-triode tube is connected in a tuned-grid-tuned-plate circuit for 2½ meter operation in the transmitter illustrated in Fig. 28. A parallel rod or wire tuned-plate circuit gives good efficiency on 2½ meters, proved by tests where efficiencies of

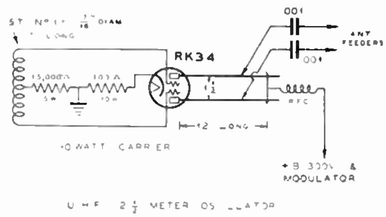


FIG. 28

approximately 50% were realized. A carrier power output of 10 to 15 watts is easily obtainable on 2½ meters. The circuit is shown in Fig. 28. If a more powerful modulator is connected to the oscillator, together with plate potentials of 500 to 600 volts, outputs of 25 to 30 watts can be secured.

A 15.000 ohm grid-leak and 300 ohm cathode resistor give stable grid bias for the oscillator. The cathode resistor prevents all tendency for the plate current to "run away" during operation. The grid coil consists of 5 turns of No. 18 wire, wound to cover a length of one inch, with an inside diameter of 7/16-inch. This coil is soldered directly to the tube socket terminals. The antenna feeders can be capactively coupled to the plate circuit through a pair of .001 mfd. mica condensers. If a two-wire spaced feeder is used, these wires tap across the plate rods about two inches from the shorting bar.

The plate circuit is tuned to the desired frequency by sliding the shorting-bar along the rods. Antenna coupling is adjusted by

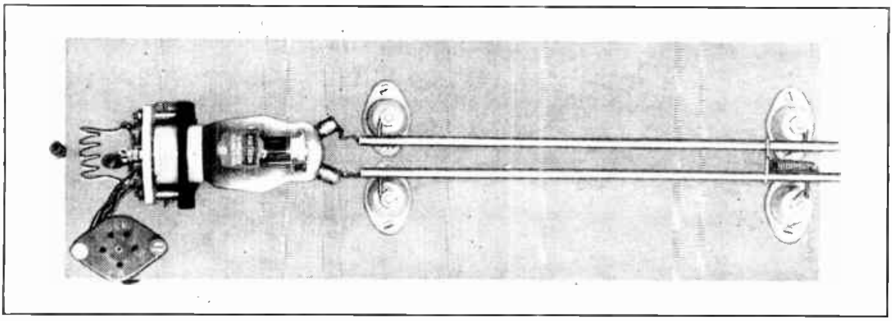


FIG. 29—Raytheon RK-34 2½-Meter Oscillator.

sliding the antenna taps along these rods until normal plate current is drawn. The inductance in the grid circuit can be slightly varied in order to obtain the best amount of feedback for high output.

A suitable modulator consists of a pair of type 42 pentode tubes driven by a 76 speech amplifier. The 42 tubes can be operated from the common 350 volt plate supply by means of a 30 henry, 150 ma., modulation choke. The screen voltage should be reduced through a resistor from the 250 volt supply; a 10 watt, 10,000 ohm resistor is of the correct size. A ½ mfd. bypass condenser from screen to ground will pass the audio frequencies from screen to ground for normal operation. The cathode resistor of 300 ohms, 10 watt rating, should be bypassed by means of a 25 mfd. low voltage condenser. If greater input is applied to the oscillator, a more powerful modulator is needed. Class B 46 tubes, or push-pull 6L6 tubes, will give ample audio power for inputs as high as 40 or 50 watts on the RK-34 tube. Normal plate current to the latter is 80 ma., although in actual practice this oscillator has been operated over considerable periods of time at 100 ma. plate current.

Single-Tube 2½ Meter Transceiver

● An exceedingly simple 2½ and 5 meter transceiver can be built to operate from a type 76 tube. The set is shown in Fig. 30.

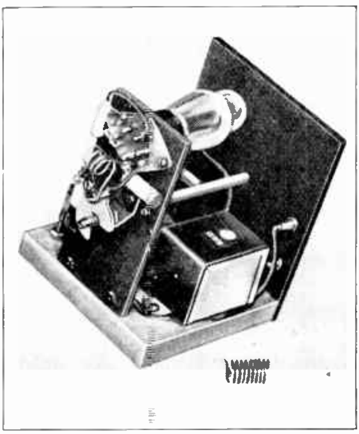


FIG. 30—Single-Tube Transceiver.

The 76 has low interelectrode capacities and high mutual conductance, thus it performs better than most other types of conventional tubes on 2½ meters.

The 76 tube acts as a grid-modulated oscillator for transmitting, and as a super-regenerative detector for receiving, in the circuit shown in Fig. 31. Switching from send to receive is accomplished with a DPST switch, the "on" position shorts-out the headset, and connects-in the grid modulation transformer when transmitting. In the receive position, the half-megohm (500,-000 ohm) grid-leak produces super-regeneration.

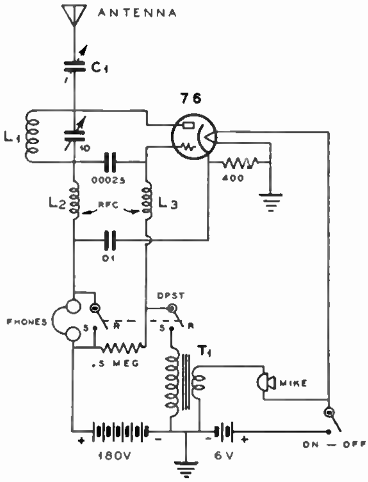


FIG. 31—Circuit Diagram.
T1—Mike-to-grid transformer.
C1—Antenna lead twisted around plate lead.
L2-L3—(RFC)—Two RF chokes, each 100 turns.
No. 34 DSC, ⅜-in. diameter.

The modulation transformer can be any type of carbon microphone-to-grid transformer with a secondary resistance (grid winding) of from 3,000 to 5,000 ohms. The primary is connected in series with a single-button microphone and battery. If AC is used on the heater of the 76 tube, a 4½ volt "C" battery can be connected in series with the microphone, switch and transformer primary, without a connection to the tube heater circuit. A 6-volt storage battery or four dry cells in series will normally provide heater and microphone current, as shown in the circuit diagram.

For receiving, the ½-megohm grid-leak connects to plus *B* in order to provide high audio output from the super-regenerative detector. When transmitting, grid-bias is supplied by a 400 ohm cathode resistor and

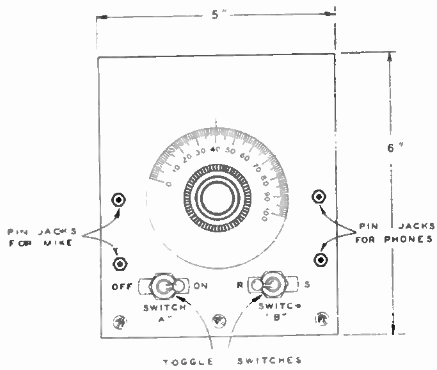


FIG. 32—Front Panel Layout.

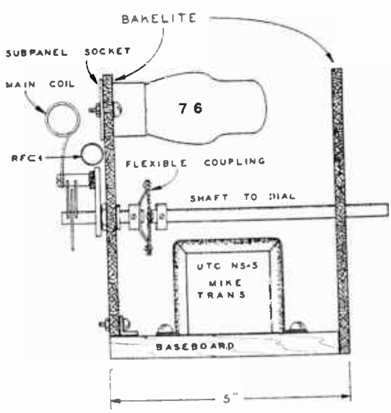


FIG. 33
Side View, Showing Coil Support and Condenser Extension Shaft.

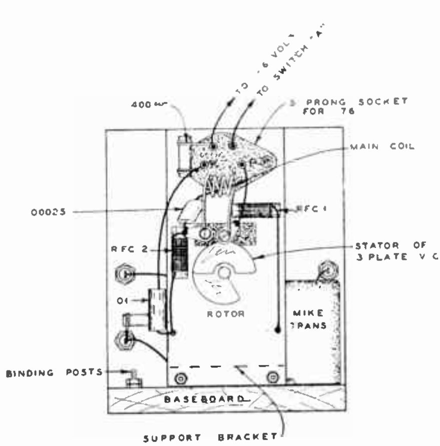


FIG. 34—Rear View.

the grid current through the resistance of the modulation transformer. Understandable voice modulation can be secured from grid modulation with a minimum of parts.

Very short leads to the grid and plate terminals of the 76 tube socket permit operation in the 2½ meter band. The tuning condenser shaft is insulated from the front dial with a flexible shaft coupling and extension shaft to the variable tuning condenser. The antenna is coupled by twisting one to three turns of insulated hook-up wire around the plate lead of the 76 tube. This capacity coupling should be as great as possible, *without causing a cessation of the super-regenerative hiss in the headphones when the control switch is in the receive position.* Coupling must be as tight as possible, however, in order to obtain a high degree of modulation when transmitting.

2½ and 5 Meter Transceiver

● A simple breadboard-mounted transceiver is shown in Figs. 35 and 36. It uses a 76 tube as an oscillator and super-regenerative detector and a 41 tube as a modulator and audio amplifier. A DPDT switch changes the 76 tube from a super-regenerative detector into a RF oscillator for transmitting; at the same time the 41 tube is changed from an audio amplifier into a modulator for transmitting. The circuit is shown in Fig. 37.

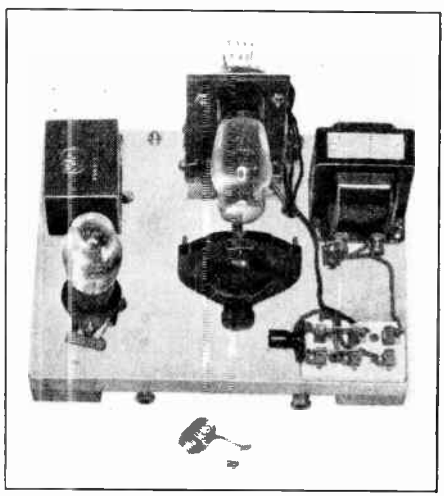


FIG. 35

Simple 2½ 5-Meter Transceiver. The 5-Meter Coil Is in the Foreground.

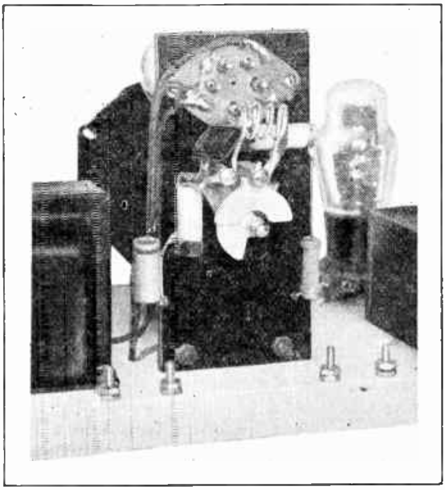


FIG. 36

Close-up of Mounting Bracket, Showing Correct Placement of Condenser, Coil, Chokes, Resistor, etc.

The transceiver is mounted on either a wood or metal chassis, 7 in. x 8 in. The tuning dial is connected to the condenser through an insulated coupling. The 76 tube is mounted horizontally on an insulating sub-panel, 2½ in. x 5 in. This method of mounting facilitates the use of very short and direct leads to the tuning condenser and coils, resulting in high efficiency on both 2½ and 5 meters. The home-made RF choke coils are rather critical as to their number of turns, if operation on both bands is desired. If the values are not correct, dead spots will be found within the tuning ranges. This effect can also be checked by coupling a 6.3 volt pilot lamp in series with a turn of wire to the RF coil in the transmit position. If the light goes out within the tuning range, RF choke trouble can be suspected. Modulation can also be checked with the aid of this lamp indicator. Brilliance should increase when the microphone is spoken into.

Antenna coupling should be as tight as possible without loss of super-regeneration, as evidenced by a loud hiss in the receive position. Either an AC power pack or batteries can be used for the power supply. The "B" voltage can be any value from 180 to 250 volts. A conventional single-button microphone and a 4½ volt C battery can be used in the mike circuit. A switch should be connected either in the microphone circuit or as an integral part of the microphone so as to cut off the microphone current when the transceiver is either in the receive position or not in use. The layout of the transceiver should be as shown in the illustrations. If the leads are too long, or if

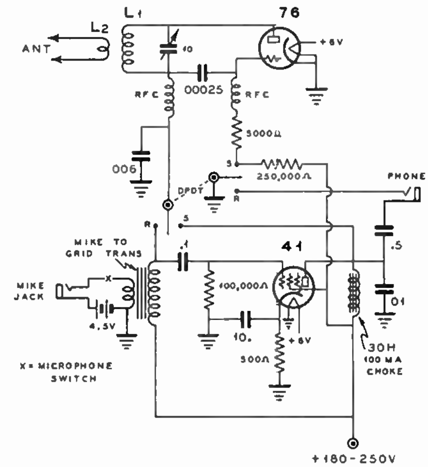


FIG. 37

2½- and 5-Meter Transceiver.

L1—4 Turns No. 14, ⅜-in. dia., ⅝-in. long for 2½ Meters.

L1—9 Turns No. 14, ⅛-in. dia., 1¼-in. long for 5 Meters.

L2—1 Turn Hook-up Wire Over Center of L1.

RFC—100 Turns No. 34 DSC on ⅜-in. rod.

Resistors—All One-Watt Rating.

the resistor and condenser values are not as specified, the set will not super-regenerate or oscillate on 2½ meters, and possibly not even on 5 meters. The 76 tube socket should be of a good grade of bakelite, or preferably ceramic material. Either a 76 and 41, or the 6C5 and 6F6 metal tube equivalents can be used. The transmit-receive switch can be of the toggle or knife variety.

The antenna coupling coil consists of one turn of insulated hookup wire slid between the center turns of the transceiver coil. Capacity coupling can be used, if desired, in which case one to three turns of insulated wire would be wrapped around the grid or plate lead of the 76 tube. The output of this set is approximately ½ to 1 watt, depending upon the plate voltage.

76-41 2½ or 5 Meter Transceiver

● The power drain of a 2½ or 5 meter transceiver is low because the same tubes are used for both phone transmission and reception. On the other hand, the receiver radiates badly, causing "whistles" and interference in other sets within a radius mile or two. Generally the receiver frequency is not exactly the same as the transmitted frequency, even though the same tuned circuits and tubes are used in both cases. The change of grid or plate voltage when switching from transmit to receive always tends to change the tube element capacities which are in shunt with the tuned circuit, thus causing a change in frequency. This effect is usually more pronounced on 2½ than on 5 meters, but it can be minimized by proper design. In spite of these disadvantages, the low first cost, economy of operation and compactness warrants the use of transceivers in many cases.

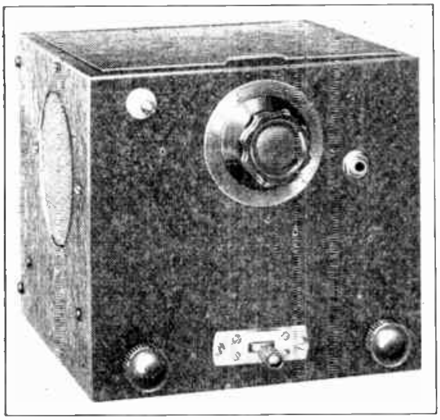


FIG. 38
Front View of 2½ or 5 Meter Transceiver. Loud Speaker Grille on Left Side.

● This transceiver has a 76 and a 41 tube in a conventional circuit, with certain refinements. The 76 acts as a super-regenerative detector of the blocking grid-leak type, transformer coupled to the 41 pentode audio amplifier in the receive position. In the transmit position the 76 acts as an oscillator, modulated by the 41 tube which serves as an amplifier for a single-button microphone. When receiving, a variable control of plate voltage for the 76 tube prevents excessive receiver radiation and holds the hiss level to a minimum, thus maximum sensitivity is realized. The 4-pole-double-throw switch connects the loudspeaker, increases the 76 grid-leak resistance for super-regeneration, cuts in an audio amplifying transformer and converts the 41 tube into a power audio amplifier for loudspeaker reception. The receiver audio volume control operates only on the grid of the 41 tube while actually receiving, so it has no effect on the microphone-to-grid circuit, such as is the case in most transceivers. The complete circuit is shown in Fig. 40.

In the transmit position the switch opens the loudspeaker circuit, reduces the grid-leak to the proper value for transmitting, connects-in the microphone circuits, and converts the 41 tube into a modulator system. A 41 tube will furnish sufficient audio gain and output to fully modulate a 76 tube for a plate voltage range of from 180 to 250 volts. An ordinary single-button hand microphone has enough electrical output for voice input and thus it is not necessary to shout into the "mike" in order to obtain a high degree of modulation.

A separate 4½ volt C battery serves as a microphone battery in order to simplify the power supply. The latter consists of 180 to 250 volts of either B batteries or rectified and filtered AC power supply, and either a 6 volt storage battery or 6.3 volt AC supply for the heaters. The separate "mike" battery makes it possible to use AC on the 76 and 41 tube heaters when an AC power supply is preferred, such as at a fixed station.

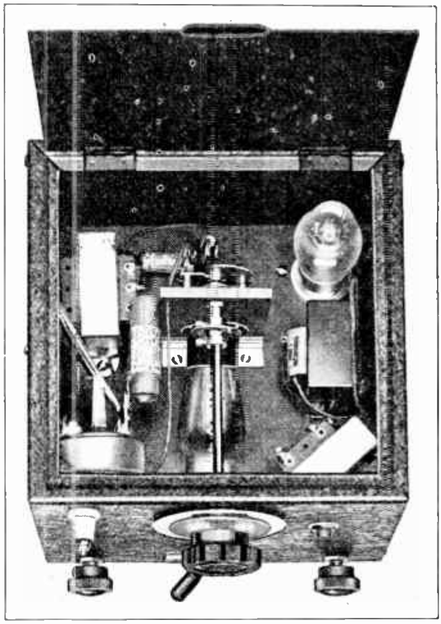


FIG. 39
Looking Into the 2½ or 5 Meter Transceiver.

● The transceiver is built into a 7¾ in. x 7¾ in. x 7 in. can, with a chassis 1¾ in. high for sub-base mounting of parts. The power socket is mounted at the rear, so that either battery or AC power pack supplies can be plugged in at will.

The tuning condenser has two plates. One rotor plate is first removed from a standard 3-plate midget condenser. This small condenser capacity gives better bandspread on 2½ or 5 meters. The condenser and the 76 tube socket are mounted on a vertical bakelite sub-panel, 2¼ in. x 4 in. x 3/16 in., which in turn mounts on chassis with a right-angle bracket. This tuning condenser must be well insulated from the chassis. A ¼ in. diameter bakelite rod couples the dial to the condenser. The RF leads for 2½ meters must be extremely short. A horizontal mounting of the 76 tube places the grid and plate terminals near the tuning condenser and coil. Change from 2½ to 5 meters is accomplished by changing the 4-turn coil to one with about 9 turns of No. 14 wire, ½ in. diameter, and spaced slightly between turns. The coil is soldered to the condenser.

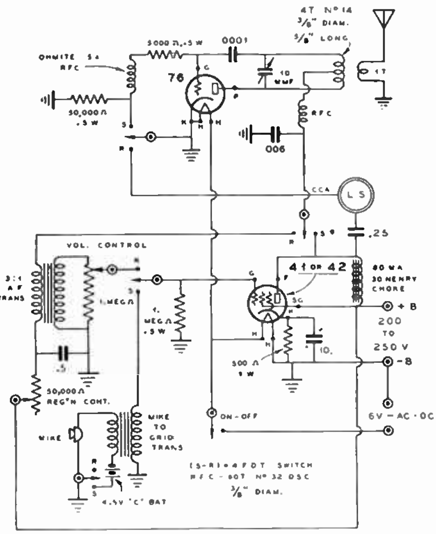


FIG. 40

2½- and 5-Meter Transceiver for Loud Speaker Operation.

No particular care need be exercised in the audio wiring circuit. The parts can be placed in any convenient location and ordinary push-back hook-up wire serves for all connections. The *C* battery, or microphone battery, can be placed either under or on top of the chassis, or wedged behind an audio transformer.

Ground leads often cause trouble on 2½ meters. By changing the length of these leads, the output may be doubled. A 6.3 volt pilot lamp connected through a ¾ in. diameter loop of wire will serve as a good test for RF output and degree of modulation when coupled to the transceiver coil. The lamp should light with a moderate yellow color, and increase in brilliance when the microphone is spoken into. On 5 meters the effect of the length of the ground lead is not very pronounced, and the location of the .01 mfd. by-pass condenser ground, 76 cathode ground and heater ground leads are not as critical. When the set is functioning properly it should super-regenerate easily over the entire dial range, and the RF output should not drop appreciably over the entire dial range when transmitting.

The audio output is sufficient to operate the small magnetic loudspeaker which is mounted behind a wire-screen grill on the side of the cabinet.

A one-turn antenna coupling loop is self supporting. The antenna lead connects to a through-type insulator on the front panel and passes through a hole in the bakelite panel, where it is cemented into the hole in order to give it rigidity.

● The receiver should super-regenerate over the 2½ meter range when 180 volts or more of plate potential is applied. The regeneration control in the plate circuit of the 76 tube is of more practical use on 5 meters than on 2½, since lower plate voltages will cause super-regeneration on the longer wavelength.

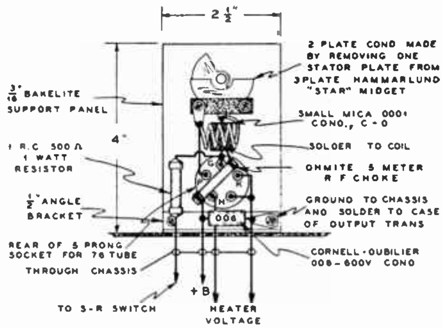


FIG. 41

Rear of Control Panel.

The voice quality when transmitting should be checked by listening to a phone monitor, or on another 2½ meter receiver. With a good microphone, the voice is clear and comparable to that on an ordinary telephone line. High quality audio and microphone transformers are not needed for amateur service. Small units are desirable in order to conserve space and weight.

A Lecher wire system, absorption wavemeter or another 2½ meter (or 5 meter) station can be used to check the 2½ meter band location on the tuning dial.

The possible range of this transceiver depends upon the type of antenna and its height above nearby objects or ground. A range of 2 or 3 miles can be expected.

High-Output 6A6 5 Meter Transmitter-Receiver

● It was previously stated that 5-meter transceivers have many disadvantages, including excessive receiver radiation, low output when transmitting, poor sensitivity, high receiver hiss level, and variation of transmitter frequency with receiver frequency shift. The unit here shown has a separate transmitting RF circuit, a common audio system, and separate receiver RF circuits. This permits the use of a RF stage which increases sensitivity and prevents receiver radiation. The transmitter frequency can be set to some fixed value, and the output is several times as high as that from a transceiver.

This transmitter-receiver is not much larger than a transceiver, in spite of its being a separate receiver and transmitter for 5-meter operation. The receiver has a separate quench frequency tube and associated controls, thus the hiss level can be set at such a low value that it is no higher than the external interference noise in most locations. Regenerative RF amplification with regeneration control gives extremely high sensitivity when needed. A Class B 6A6 modulator supplies sufficient audio output to modulate the 5-meter oscillator at approximately 5 watts carrier output when a 300 volt plate supply is available. Either an AC power supply, or B batteries and a 6-volt storage battery, can be used for portable or fixed station operation. The B supply can be of any value from 150 to 325 volts, much better results being secured with the higher values around 280 to 300 volts.

A small magnetic loudspeaker is built into a cabinet only 14 in. x 7 in. x 7½ in. This set has all of the best features of mobile or medium power station units built into one, and it can be highly recommended for general 5 meter operation.

Technical Notes

● The transmitter has a TNT push-pull oscillator with a 6A6 tube in a cathode bias arrangement. A Class B 6A6 modulator is driven by a 6A6 speech amplifier which delivers 8 to 10 watts output at 300 volts. The microphone is an ordinary single-button type.

The same two 6A6 audio tubes serve as an audio amplifier for the receiver when the 4-P-D-T. switch is thrown to the receive position. The latter also switches the antenna from transmit to receive. The 76 super-regenerative detector is not self-quenching, but uses a separate 76 interruption frequency oscillator. The latter permits a setting of the detector plate voltage to such a value that the tube continues to super-regenerate, but with a very low hiss level. This means that a great portion of the troublesome loud hiss or roar can be eliminated, even when no station is tuned-in on the 5-meter band.

The regenerative RF stage has a 6K7 metal tube, requiring less space and shorter leads. A slight amount of regeneration actually gives some RF gain on 5 meters and very weak signals can be received which would otherwise be inaudible. A 954 acorn RF tube will give more gain, but at a considerable increase in cost, thus a compromise was made in the form of the 6K7 tube.

The interruption frequency oscillator has two small universal-wound coils in a small shield can beneath the chassis. This oscillator functions at about 100KC and causes a variation at 100 KC per second of the plate voltage on the 76 detector. This variation causes super-regeneration, with a gain of several thousand times on weak signals.

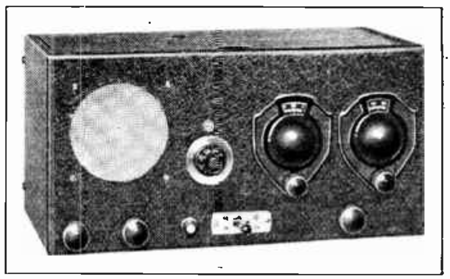


FIG. 42.

Front View of High-Output 6A6 Transmitter-Receiver.

Audio volume is controlled, in the receiver only, by shunting a tapered 50,000 ohm control across the grid circuit of the first audio stage. The microphone-to-grid transformer carries the detector plate current through its secondary when receiving; it should therefore be wound with sufficiently heavy wire in order to carry approximately 5 ma. A push-pull pentode to dynamic loudspeaker voice coil transformer can be substituted for the "mike" transformer. The voice coil winding then becomes the microphone winding, and the detector lead can be connected through the switch to the center-tap, or to the grid ends of the secondary. The loudspeaker connects from one of the Class B plates through a ½-mfd. condenser back to a switch contact which disconnects it when transmitting. This send-receive switch also connects the B supply voltage to either the transmitting 6A6 oscillator or to the detector and RF stages.

The 6A6 oscillator draws from 30 to 60 ma., depending upon plate voltage and antenna loading. The plate impedance is some value between 5,000 and 10,000 ohms and the Class B output transformer should therefore have a total primary-to-secondary turns-ratio of between 1.4-to-1 and 1-to-1. The transformer shown was rated for a 5,000 ohm load out of a 6A6 Class B tube, which would indicate a 1.4-to-1 ratio. The class B input transformer can be any type designed for a 6A6 or 53 driver into a 6A6 or 53 class B amplifier.

Construction

● The sheet-iron can is 14 in. long, 7 in. high and 7½ in. deep, a standard size available from many radio supply houses. A 1¾ in. chassis depth is ample for the 4-P-D-T switch, variable and fixed resistors and fixed condensers.

The 4-prong wafer socket for the power cable and the insulated microphone jack are insulators. The two corresponding vernier tuning dials are of bakelite, thus a one-inch front panel hole insulates the tuning condensers from ground. Other types of dials would require an insulated coupling on the tuning condenser shafts in order to prevent RF noise, in one case, and a short circuit in the other.

The 6K7 RF tube mounts horizontally on a 4 in. x 5 in. No. 12 aluminum shield. The latter has a ½-in. lip bent at right angles along the bottom so that a pair of 6/32 machine screws will hold it rigidly in place. Shakeproof lock-washers should be placed under all machine screw nuts if the set is operated in mobile service. The RF stage by-pass condensers, RF choke and plate coupling condenser mount directly at the 6A7 tube socket, with short leads to the aluminum sheet for a ground connection. All ground points are bonded together with

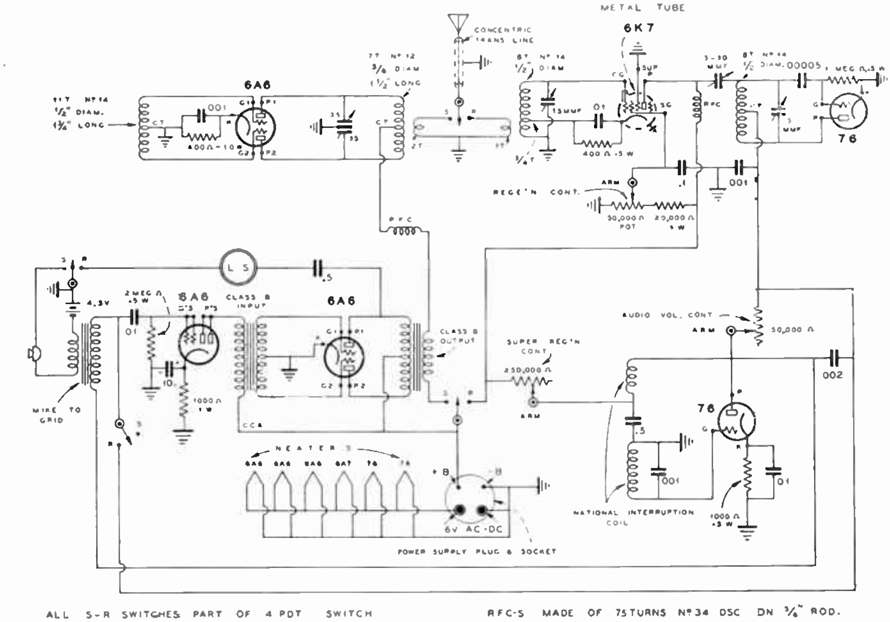


FIG. 43—Complete Circuit Diagram of High-Output 6A6 Transmitter-Receiver.

mounted in the rear. The class B transformers are placed in such a manner that space is available for a 4½ volt C battery for microphone supply. The separate mike battery makes possible the use of either DC or AC for the heaters without wiring changes. The 5-inch magnetic speaker is covered with a metal screen grill behind a 4-inch diameter hole in the front panel.

The two receiving 15 mmfd. tuning condensers mount on small porcelain stand-off hook-up wire and connected to the minus *B* power socket terminal.

The RF chokes are made by winding about 75 turns of No. 34 DSC wire on a ⅜-in. diameter bakelite rod. The detector coil has 8 turns, ½-in. inside diameter, tapped near the center, and the turns are spaced approximately the diameter of the No. 14 wire. The RF coil is similar in construction, except for the cathode tap, which is taken at about ¾-turn. The plate coil of the 6A6 oscillator has 7 turns, 5/8-in. diameter, 1½-in. long. The wire for the coils should be No. 12, or preferably No. 10 copper. The 6A6 grid coil has 11 turns of No. 14 wire, ½-in. diameter, with a center-tap. This coil mounts on small stand-off insulators beneath the chassis and the two grid leads extend through the insulators directly to the grid terminals on the isolantite socket of the 6A6. This arrangement gives equal and very short grid and plate leads to the 6A6 RF tube. The 6A6 RF tube and 76 detector both mount on isolantite sockets above the chassis in order to reduce the length of the RF leads.

All coils are soldered to their terminals so as to prevent loose connections, losses and noise. The two antenna coils are made of No. 18 insulated hook-up wire and the coupling can thus be varied for best results with different antennas.

Operating Notes

● When first testing the receiver, the RF regeneration control should be set so that the value of screen voltage is approximately zero. The super-regeneration control should be decreased in resistance until a super-regenerative hiss is audible in the loud-speaker. The RF control can then be rotated until RF oscillation takes place (without antenna), as indicated by a sudden cessation in hiss output when tuning the RF dial across its scale. When actually operating the receiver with an antenna, the RF regeneration control should never be set to the point of RF oscillation. A check on the operation of the RF stage and its tracking qualities with the detector tuning dial can be secured with the oscillation test just described.

A little practice is needed to operate the receiver for maximum sensitivity, because it has two tuning dials and two regeneration controls. For normal operation the RF stage tunes very broadly, and the RF gain control need not be set to its critical position. The detector super-regeneration control should always be set to a position where it will maintain a low degree of hiss level when no signal is received. The RF stage prevents radiation of super-regeneration squeals from the detector circuit and therefore serves a good purpose; careful tuning of the RF stage will give a decided gain in receiver sensitivity on weak signals.

The transmitter should be tuned to some frequency within the 5-meter band between 56 and 60 megacycles by means of a wavemeter or by checking it against another receiver. A diode tube field strength meter-monitor should be available for checking modulation. A single turn of wire in series with a 6 volt pilot lamp makes a good tuning indicator, in addition to the field strength meter. The lamp, when coupled to the 6A6 plate coil, should light up more brilliantly when the microphone is spoken into or energized by a whistle. Fairly heavy antenna coupling is essential for best results. The modulation percentage is greatest at a point where the RF current in the antenna begins to drop slightly on steady carrier, due to close coupling to the antenna feeder. The lamp indicator will also show a greater variation in RF current when modulating with a heavy antenna load. The spacing of the grid coil turns, and the value of the cathode resistor, both affect the degree of modulation for a given degree of antenna coupling.

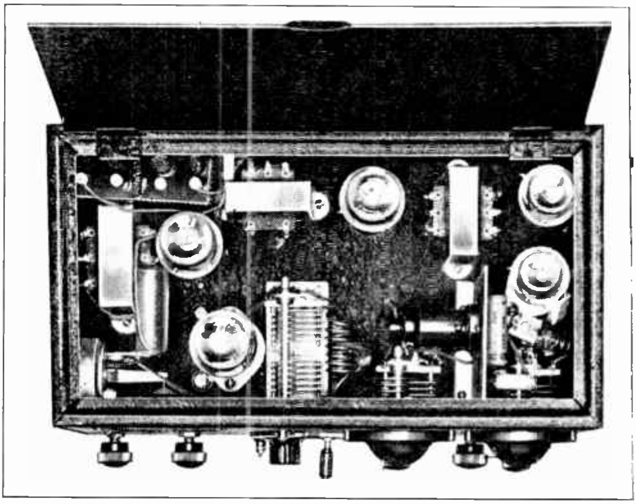


FIG. 44—Looking Into the High Output Transmitter-Receiver.

The antenna coupling system is suitable for a spaced two-wire RF feeder, a single-wire feeder, or to a concentric feed line. The latter is of especial benefit for automobile installations, and is also best from a standpoint of minimum noise pick-up at fixed stations. The antenna can be a vertical half wave Y-fed wire or rod, about 8 feet long, or a "J" type. A directional array will give better performance than a single element half wave antenna. For automobile installations the antenna can be 4 feet long, with the inner conductor of a concentric line feeding the lower end of the 4-foot insulated rod.

Metal Tube 5-Meter Transmitter-Receiver

● This 5-meter transmitter and receiver has a separate RF unit and a conventional audio amplifier for loudspeaker and modulator operation. Metal tubes conserve space and give entire satisfaction on 5 meters. The 6D5 tubes are similar to glass type 45s. The beam power tube 6L6 serves as a modulator. A 6J7 pentode functions as a regenerative RF amplifier which gives some amplification and minimizes radiation from the self-quenching super-regenerative 6C5 detector. This set is designed around standard circuits that have given most satisfactory service for portable 5-meter operation.

The principles of operation and construction are similar to those of the 6A6 glass tube 5 meter transmitter-receiver, described at more length elsewhere in these pages. The detector is self-quenching with a blocking grid-leak. A 6L6 serves the same purpose as the 6A6 driver and 6A6 class B stage shown in the 6A6 glass tube set previously referred to. The 6D5 tubes give about the same carrier output as a 6A6 push-pull oscillator.

This set requires less space than most other sets of similar general design. The chassis is only 9 in. x 6 in. x 1¾ in. The cabinet is 2 in. longer in order to make space for a small magnetic loudspeaker at one end. The cabinet measures approximately 6 in. x 6 in. x 11 in. and is formed by two U-shaped pieces with a flange along the edges of one piece. Self-tapping screws hold

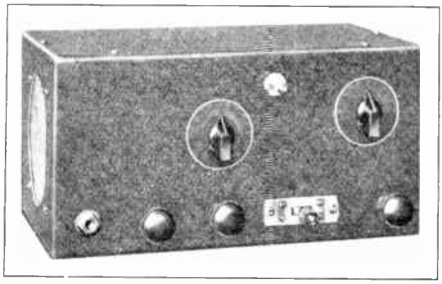


FIG. 45—Front and Side View of Metal Tube Transmitter Receiver, Showing Loud-Speaker Grille on Left Side of Cabinet.

the top-back-bottom piece in place. The 6D5 grid coil consists of 14 turns of No. 14 wire, ½-in. diameter, 1¾-in. long, with a center-tap. The plate coil has 7 turns of No. 10 wire, center tapped, ⅝-in. diameter,

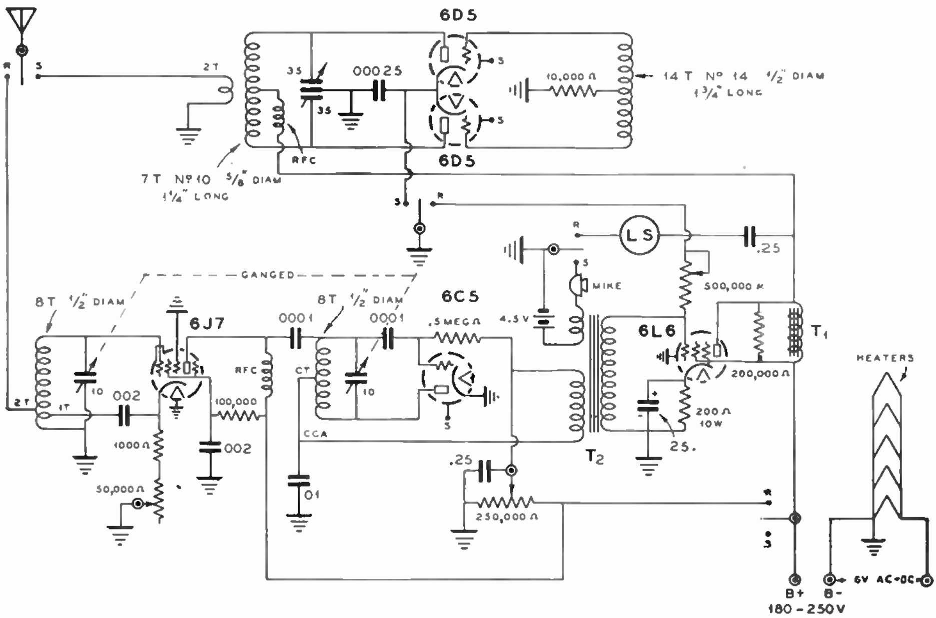


FIG. 46.

Metal Tube 5-Meter Transmitter Circuit. Type 6C5 Tubes Can Be Substituted for 6D5s, Shown in the Circuit, if the Value of the Grid-Leak Is Reduced to 2,500 Ohms.

1¼-in. long. A 2-turn pick-up coil of 18 ga. hook-up wire serves as an antenna coil which connects through the low capacity send-receive switch. All RF chokes can be made of 75 turns of No. 34 DSC wire, close wound on a ⅜-in. bakelite rod. The modulation choke should have at least 15 henrys inductance at 150 ma. DC. The audio input transformer can be any type of three-winding transceiver transformer.

The 6J7 RF coil has 8 turns, ½-in. diameter, about 1¼-in. long, and is similar to the detector coil except for location of taps. The cathode tap is made on the first (one) turn, the antenna tap at two turns, or a separate antenna coil can be used. The detector coil is center-tapped. These two circuits are made to track by compressing the turns on the coils, also by bending one of the plates on each of the 2-plate condensers which are ganged together for single-dial tuning. The RF and detector tuning adjustments are not very critical. A regeneration control on the super regenerative detector permits adjustment of plate voltage to the value of lowest hiss level, with good sensitivity and ability to handle strong signal inputs. A 50,000 ohm cathode resistor provides a combination regenerative RF volume control for the 6J7. The latter was selected in preference to a 6K7, because 5-meter signals are seldom strong enough to cause cross-talk in the RF stage; the high value of the cathode fixed resistor (1000 ohms) acts as a RF choke to force the cathode RF current through the cathode condenser and cathode coil tap. Short RF leads are essential in the RF and detector stages. The shields of the 6D5 and 6C5 are not grounded.

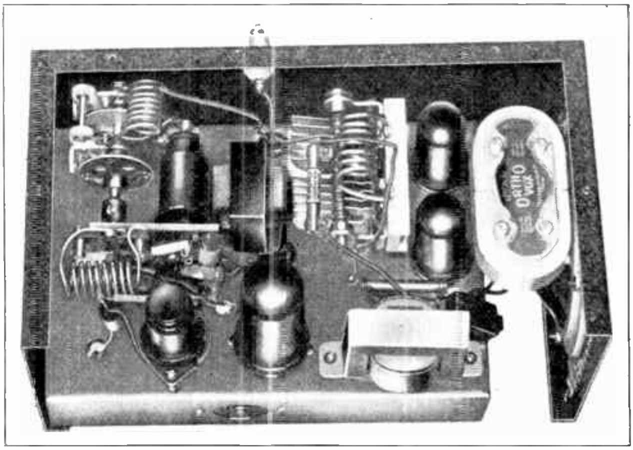


FIG. 47
Looking Into the 5-Meter Transmitter and Receiver.

A separate 4½ volt microphone battery enables the tube heaters to be connected to either a 6-volt storage battery or to a 6.3-volt AC source. Heavy-duty B batteries for portable operation, or an AC line power supply can be plugged-in for operation at a fixed station location. Approximately 5 watts of carrier output can be secured from a 230 to 250 volt power supply. The constructor is urged to closely adhere to the mechanical design, otherwise the final results may not be satisfactory. Coil winding specifications should also be carefully followed. Some slight "pruning" of the coils will usually be necessary; this is accomplished by slightly compressing or expanding the coils until they cover the correct frequency range. All ground leads should connect to a common bus-bar.

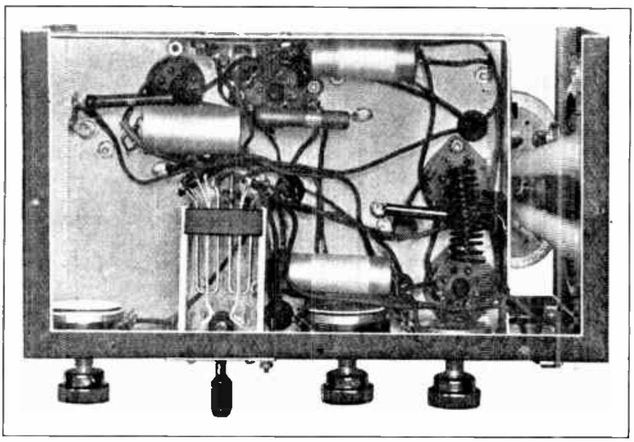


FIG. 48—Under-Chassis View of Transmitter-Receiver.

2½-5-Meter Metal Tube Transceiver

● Metal tubes fit readily into the design of a very compact and powerful transceiver for 5- and 2½-meter operation. This unit here illustrated transmits more power than most transceivers because heavy antenna loading is permissible for both transmitting and receiving. It is quite sensitive and the hiss level is low. The radiated interference is much less than from most transceivers while receiving, due to the separate interruption frequency coil circuit.

The set is built into a 5½ in. x 5½ in. x 4¼ in. steel can formed into two U-shapes with lips along the top and bottom edges of one of the U-shaped pieces. The chassis is 4 in. x 5⅜ in. x 1¾ in., thus making it somewhat difficult to wire-up the 4-pole-double-throw switch, but this job can be accomplished with a little patience. The tuning condenser, plug-in-coil and 6C5 tube are mounted on a vertical bakelite subpanel, 3⅜ in. high, 2¼ in. wide and 3/16 in. thick. The RF chokes are made both 5 and 2½ meters must be wound to the correct size of inductance so that no resonant absorption dips occur in either band. About 75 turns of No. 34DSC wire, closewound on a piece of ⅜-in. bakelite rod, serves the purpose. The terminals of these RF chokes are made by drilling small holes thru the ends of the bakelite rod and then soldering the fine wire to a piece of No. 22 wire twisted thru and around the ends of the rod.

The interruption frequency coil provides super-regeneration in the 6C5 tube when receiving, thus heavy antenna loading and low plate voltage can be used on 5 meters. On 2½ meters, the plate voltage should be 200 volts, preferably 250, if available. The transmitter output with 135 volts supply on 5 meters will be approximately ⅓ watt, and 1¼ watts at 200 volts, which is greater than the output obtainable from most other transceivers. A 6F6 power pentode acts as modulator when transmitting and as an audio amplifier when receiving. The output in the latter condition is sufficient to drive a small magnetic loudspeaker to moderate volume. The detector regeneration control can be set to a point of very low hiss level and high sensitivity.

A separate 4½ volt microphone battery allows the use of either AC or DC supply for the heaters of the two tubes. Either an AC power supply or batteries can be used for home or portable operation. Variable antenna coupling capacity will permit the use of any type of 5 or 2½ meter antenna. The coupling condenser can be adjusted through a hole in the front panel by means of a bakelite screw driver. The shield of the 6C5 tube should "float," i.e., it is not connected to ground, as is the usual practice.

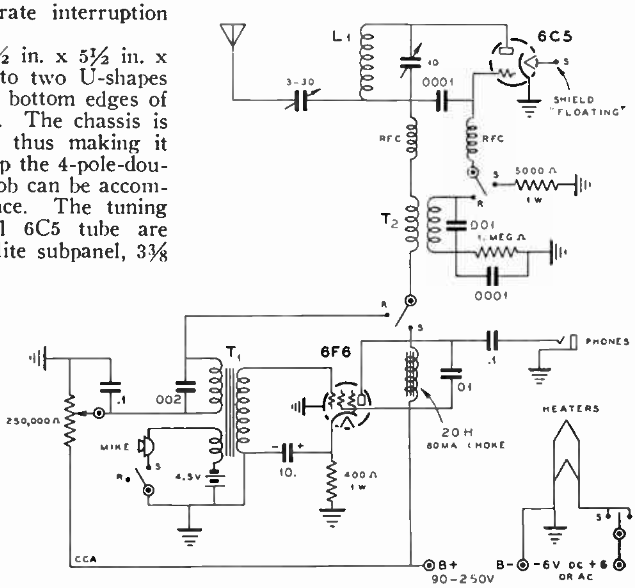


FIG. 49—Metal Tube 2½-5-Meter Circuit Diagram.

The 5-meter coil consists of 9 turns No. 14 wire, ½-in. diameter and 1½ in. long. The 2½-meter coil has 3 turns, ½-in. diameter, wound to a length of between 1 in. and 1½ in., depending upon the length of RF leads in the RF tuning assembly. Pin jacks serve as terminal plug receptacles for the little plug-in coils. The send-receive switch in its center position opens the heater supply circuit, but does not disconnect the B battery; consequently if dry cells are used, the regeneration control will absorb a small amount of current, even when the set is turned off.

This transceiver can be built on a larger chassis, if space requirements permit. The 6C5G and 6F6G large glass tube equivalents of the little 6C5 and 6F6 metal tubes can be substituted without change in circuit constants. Operation on 2½ meters should be slightly more efficient when using the glass 6C5G tube. These glass tubes have octal bases, but they require more space.

The same arrangement of horizontal RF tube mounting, very close to the tuning con-

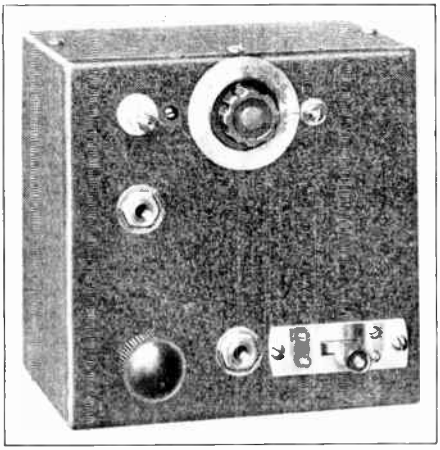


FIG. 50.
Front View of Metal Tube Transceiver.

denser and coil, is recommended if 2½-meter operation is desired. The tuning condenser has two plates. An insulated shaft connects the condenser rotor to the dial.

The three-winding midget audio transformer is manufactured by several concerns.

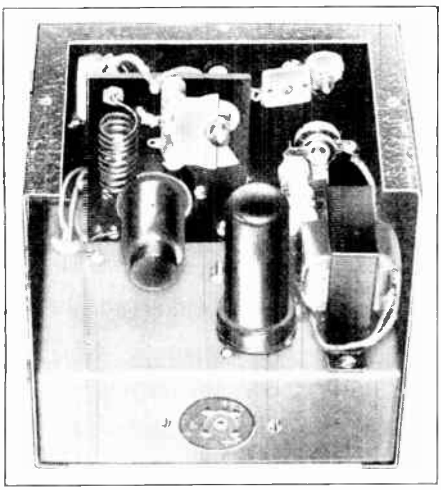


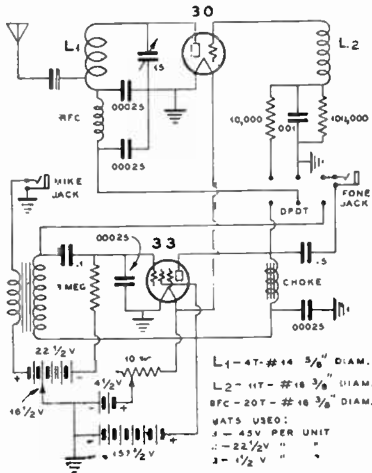
FIG. 51.
Interior View, Showing Coil and Condenser Support. Also Horizontal Mounting of 6C5.

Any small 20 or 30 henry, 50 ma. filter choke is suitable for the modulation choke.

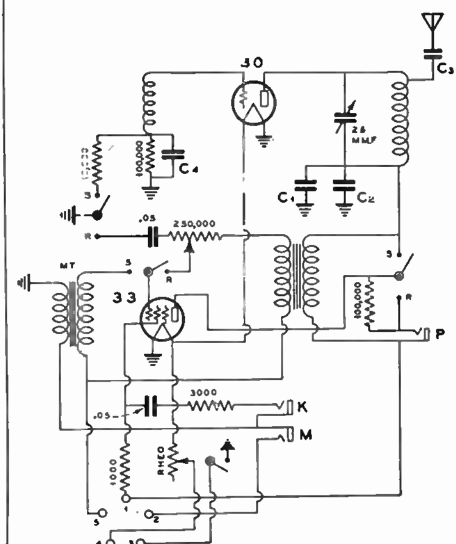
The performance of this unit is so superior to most other transceivers that it is highly recommended for the amateur.

Two-Tube Commercial Transceiver Circuits

● Those who wish to design two-tube transceivers after the circuits adopted by manufacturers will find the following schematic diagrams of practical interest. In general, constructors are advised to follow the details as close as possible to those given if good results are to be expected.



Haigis Portophone Model PF-1.



Haigis "A-M" DeLuxe Transceiver.

Resistance-Coupled 5-Meter Super-Heterodyne

● One of the most widely imitated Jones developments is the simple 5-meter resistance-coupled super-heterodyne shown in Figs. 52 and 53. The receiver has four tubes; a 6C6 autodyne detector, two stages of resistance-coupled IF amplification with 6D6 tubes, and a 76 triode second detector. The values of resistors and condensers in the IF amplifier are correct to bypass the intermediate frequencies only; the coupling condensers and resistors are too small in value to pass audio frequencies. The response curve of the amplifier is quite broad in order to receive 5-meter phone signals.

All of the .0001 mfd. condensers should be of the mica "postage-stamp" variety. The resistors can all be ½ watt in rating. The 500,000 ohm screen control potentiometer in the 6C6 detector stage should be advanced only to the point where the detector oscillates weakly, and never to the point of howling or super-regeneration.

The coupling between the antenna coil and the first detector should be adjusted for best weak-signal reception. Too much coupling to a resonant antenna will prevent detector oscillation and proper super-heterodyne action. In tuning the receiver dial, it will be found that all 5-meter signals will have two points on the dial, very close to each other, because the detector functions in a simple autodyne circuit.

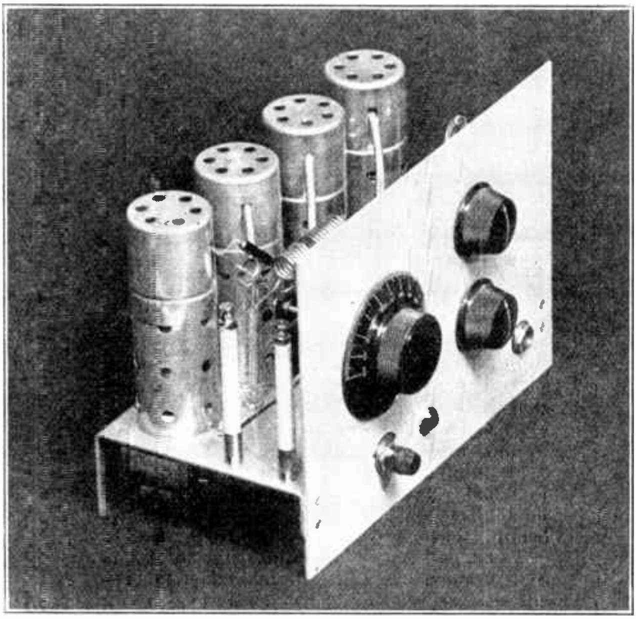


FIG. 52—The Complete 5-Meter Super-Heterodyne.

7-Tube Resistance Coupled Super

● When loudspeaker reception is demanded, together with somewhat better sensitivity, the larger receiver illustrated in Figs. 54 and 55 will give adequate satisfaction. A resistance-coupled IF amplifier simplifies the construction of the set. A semi-tuned RF stage isolates the autodyne first detector from the antenna circuit. This RF stage resonates at the low-frequency end of the 5-meter band

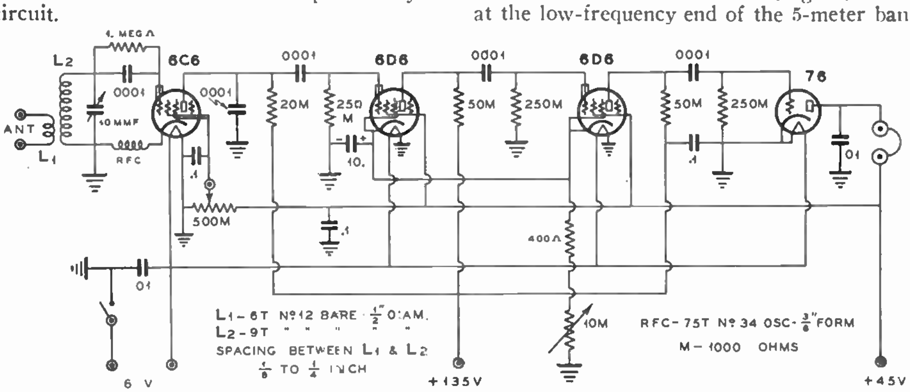


FIG. 53—The Extremely Simple Circuit Diagram of the 5-Meter Super.

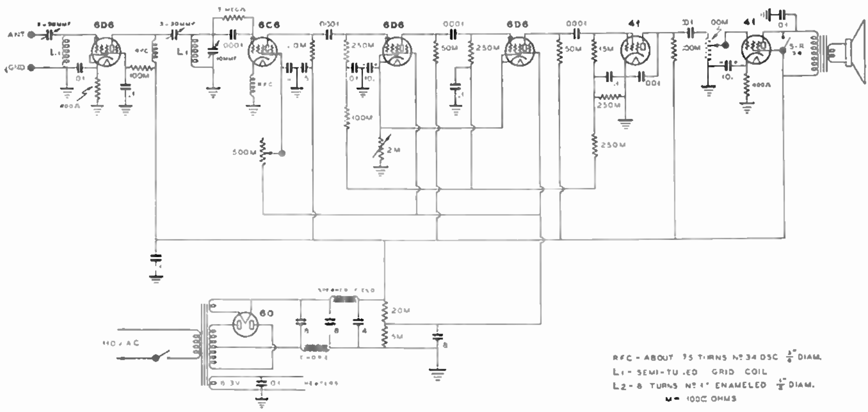


FIG. 54—Frank Jones' 7-Tube 5-Meter Superheterodyne Circuit.

by means of a variable antenna coupling condenser and resonant grid coil. This coil, L1 in the circuit diagram, is made of 16 turns of No. 16 enameled wire, 3/8-in. diameter self-supported. The length of the coil is varied until greatest sensitivity is obtained at approximately 55 megacycles for a medium capacity setting of the antenna coupling condenser. The RF plate-to-first-detector coupling condenser should be adjusted to a point which does not prevent oscillation in the first detector. The semi-tuned RF amplifier simplifies the receiver and prevents interlock between the oscillating first detector and RF grid circuit. Interlock can be defined as the action which takes place when the two tuning circuits react upon each other, making it difficult to align the circuits.

The second detector functions somewhat like a Class B tube, in that grid current starts to flow as soon as a signal is impressed. Detection is obtained in this tube and amplified by another type 41 tube connected as a pentode audio amplifier. The rectified grid current provides semi-AVC action, the voltage of which is fed back to the grids of the IF amplifiers.

The set is built on an 18 in. x 17 in. x 1½ in. chassis, made of 12-gauge aluminum. A standard 7 in. x 19 in. relay-rack is the front panel. All resistors are of the 1-watt size, except the power supply bleeder resistor, which should be rated at 35 watts. The .0001 mfd. condensers are of the small mica type, the other condensers are of the 600-volt paper variety.

The power supply rectifier circuit includes a 700 volt center-tapped transformer, a 20 henry 80 ma. filter choke, and a 2500 ohm loudspeaker field.

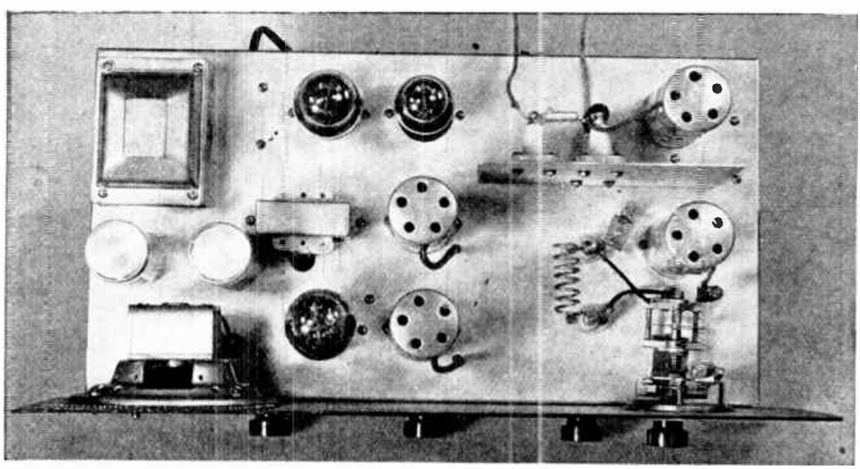


FIG. 55—The 7-Tube 5-Meter Super Should Be Laid Out as Shown in the Illustration Above.

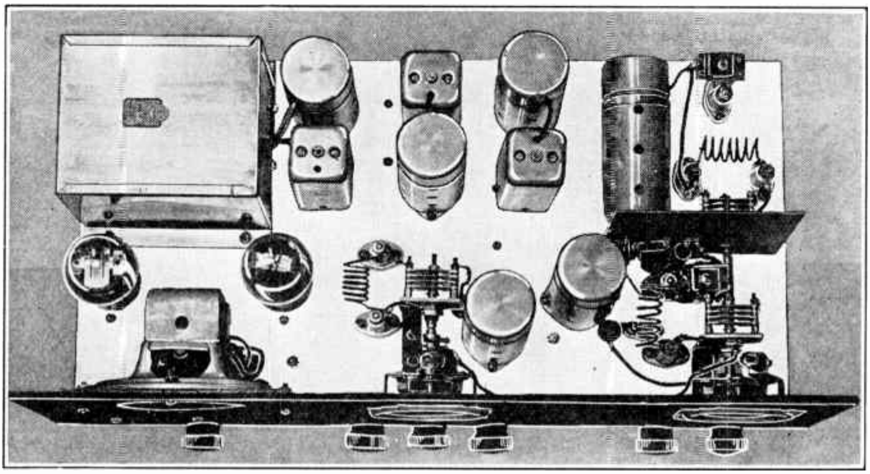


FIG. 56—Looking Down Into the 5-Meter Super. The RF Coil Is Mounted Horizontally to Permit Use of Very Short Leads. An Aluminum Shield Isolates the RF Stage From the Detector.

8-Tube 5-Meter Superheterodyne

● By incorporating regeneration in either the RF or first detector stage of a superheterodyne, the sensitivity can be increased from 5 to 50 times. A regenerative first detector is used in preference to a regenerative RF stage in order to eliminate antenna tuning dead-spots.

The choice of a suitable intermediate frequency and the degree of coupling in the IF transformers depends upon the received band width. If modulated oscillator type phone reception is desired, the IF amplifier should pass a band at least 50 kilocycles wide. The IF transformers in this receiver were designed with this purpose in mind. They are made by winding 120 turns of No. 34 DSC wire, jumble-fashion, on ⅜-inch diameter

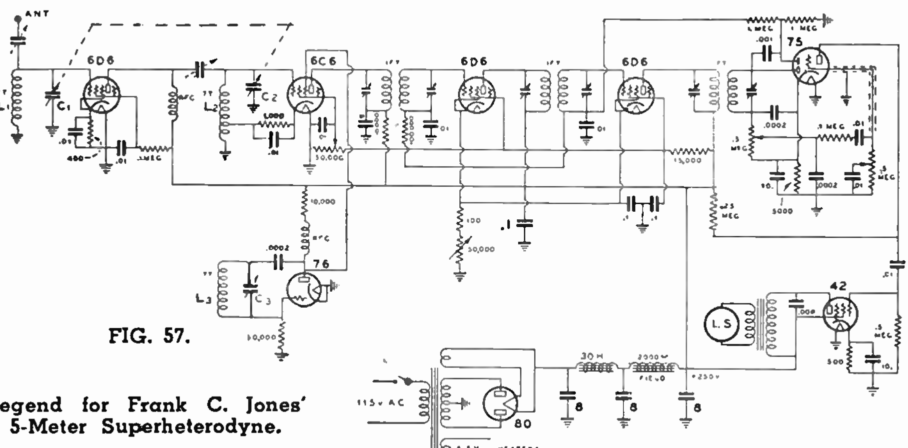


FIG. 57.

Legend for Frank C. Jones' 5-Meter Superheterodyne.

L1 and L2—Each 1½ in. Long, 7 Turns, No. 14 Enameled Wire, ½ in. Dia. L3—1 in. Long, 7 Turns, No. 14 Enameled Wire, ½ in. Dia. C1, C2, C3—100 uufd. Double-Spaced Variable Condensers, With Only 7 of the Original Plates Remaining. Maximum Capacity of These Re-built Condensers to Be About 18 uufd. I.F. Transformers Tuned to Approximately 2,000 KC.

tubes, two of these windings being required. Each winding is 3/8-inch long, and there is a space of 1/8 inch between the two coils. The coils are tuned with mica trimmers which are an integral part of the original 465 KC transformers. The 465 KC windings are removed, and the new windings put on the form. The IF amplifier is aligned to 2.7 megacycles by means of an all-wave test oscillator.

All 5-meter coils are supported on small stand-off insulators, close to the tuning condensers. The RF tube is mounted in a horizontal position in order to provide a short plate lead to the detector tuned circuit. The RF chokes in the oscillator and RF stage are made by winding 75 turns of No. 34 DSC wire on a 3/8-inch diameter bakelite rod. A type 75 tube serves as a diode detector, AVC tube, and first stage audio amplifier. Loudspeaker operation is from a type 42 pentode audio amplifier.

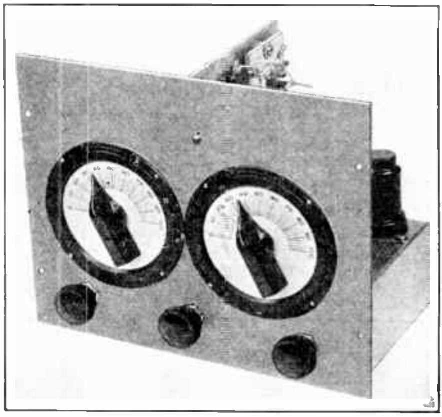
The chassis is No. 14 gauge aluminum, 9 in. x 17 in. x 1 3/4 in., mounted behind a standard 7 in. x 19 in. relay-rack panel. A separate dial tunes the oscillator, although it is possible to gang all three tuning condensers to one dial by using a wider chassis. Either capacitive coupling to the antenna, as shown, or the same condenser connected to ground as a padder and inductively coupled to the antenna, will give satisfactory results. Inductive coupling will reduce ignition interference if a twisted-pair lead-in is connected to a half wave antenna.

5-Meter Regenerative RF Receiver

● Extremely high sensitivity is obtained when a 954 Acorn regenerative RF stage is connected ahead of a super-regenerative detector. A separate interruption frequency oscillator, a 6C5 tube, provides a type of super-regeneration in the 955 detector which can be adjusted to operate with very low hiss level. A 6F6 serves as an ordinary pentode amplifier of conventional design.

Regeneration in the RF stage makes the receiver more sensitive to weak signals and also improves the selectivity. A cathode tap on the RF tuned circuit coil provides regeneration which is controlled by means of a 25,000 ohm potentiometer. The degree of super-regeneration in the detector is controlled by means of another 25,000 ohm potentiometer. Audio volume is controlled by a 500,000 ohm potentiometer in the 6F6 audio amplifier, and either headphone or loudspeaker operation can be had at will.

The chassis is 6 in. x 9 in. x 2 in., with a shield partition in the center which supports the two Acorn tubes and shields the RF from the detector stage. The RF tube extends through this partition. Separate tuning controls permit exact tuning of the RF stage at the peak of regeneration. Small tip jacks are mounted in hard rubber panels for plugging-in the coils. The disadvantage of two separate tuning controls is more than offset by the great sensitivity which can be obtained by careful adjustment of RF regeneration and tuning.



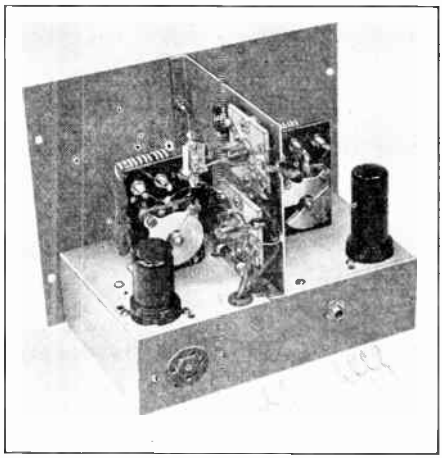


FIG. 58—Front and Rear Views of U.H.F. Receiver With Metal Tubes and Regenerative RF Stage.

The correct value of the fixed condenser in shunt with the interruption frequency grid coil (labeled .0005 and connected across the *I.F. OSC. COILS* in the circuit) depends upon the particular make of coils. Standard interruption frequency coil units are available from radio dealers, and it is desirable to purchase these coils ready-made because they consist of many turns of fine wire, honeycomb wound.

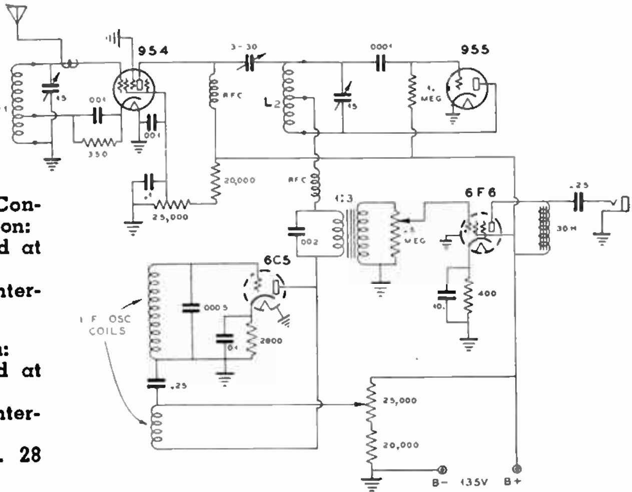


FIG. 59.

Complete Circuit Diagram. Constants for 5-Meter Operation:
L1—10 Turns, No. 12 Tapped at 1 Turn.
L2—10 Turns, No. 12, Center-Tapped.

For 2½-Meter Operation:
L1—4 Turns, No. 12, Tapped at 1 Turn.
L2—4 Turns, No. 12, Center-Tapped.
R-F Chokes: 75 Turns, No. 28 DSC, ¼" Dia.

Parallel Rod Oscillators

● Push-pull oscillators of the type shown in Figs. 60, 61 and 62 give good frequency stability in ultra-high-frequency transmitter circuits. The parallel grid rods act as a high "Q" circuit for frequency control. The plate parallel rods are tuned to resonance by sliding a shorting-bar along the rods to a point which gives lowest plate current. For 5-meter operation, the grid rods are 4½ feet long and the grids connect to each rod ⅕ to ⅓ of the way up from the shorted end. Since the shorted end has no RF voltage, these rods can be supported in holes bored into a wood block.

A parallel rod oscillator can be plate-modulated without excessive frequency modulation, as shown in Fig. 62.

High Power M.O.P.A. Transmitter

● Power output of 250 watts can be secured on 5-meters with the M.O.P.A. transmitter shown in Fig. 63. A stabilized 50-T oscillator is link coupled to a neutralized push-pull 50-T amplifier. Tubes with low inter-electrode capacities function satisfactorily in this circuit. Frequency stability in the oscillator is obtained by a critical value of RF

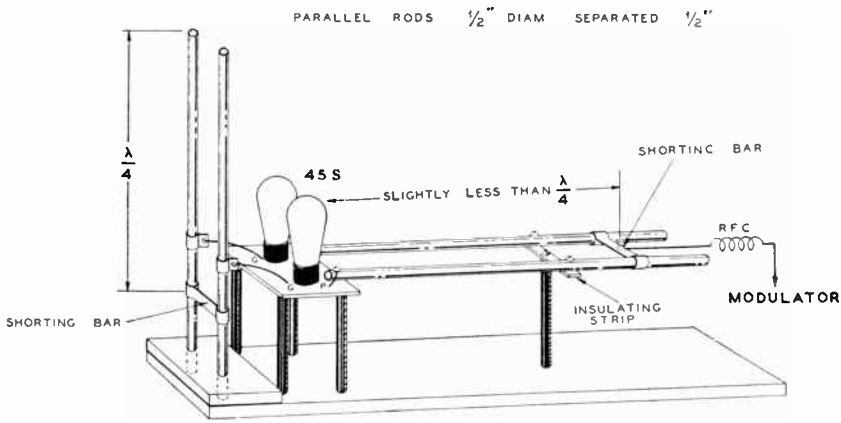


FIG. 60.

feedback to the grid circuit. Mechanical rigidity is also necessary. Correct ratio of condenser plate spacing in the oscillator will provide a circuit having good frequency stability over a fairly wide range of plate voltage. Somewhat better frequency stability can be obtained in the oscillator portion by means of concentric pipe oscillators, similar to the one described elsewhere for 2½ meter operation.

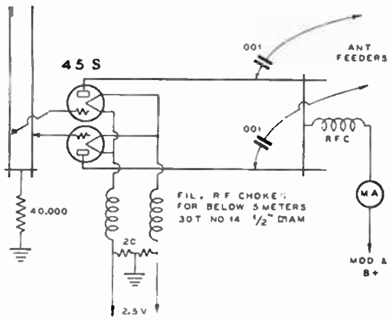


FIG. 61—Parallel-Rod Oscillator Circuit.

Crystal control can be applied by means of the *Jones* 4-6A6 *Exciter,* operating in conjunction with a 35-T doubler and 35-T buffer. Type 50-T tubes can be crystal controlled on 3 meters in this manner, if an additional 35-T doubler is added to the circuit.

For 5-meter operation, the amplifier plate tuning condenser consists of two aluminum plates, No. 12 gauge, 3 in. square, mounted 1 in. apart. A grounded plate is placed midway between the two other plates. The neutralizing plates are 1 in. x 1½ in. pieces of No. 12 gauge aluminum, separated nearly ½ in. Fig. 63.

The oscillator condenser is made of three parallel plates of No. 12 gauge aluminum, also mounted rigidly on stand-off insulators. The two plates across the coil are 4 in. x 4 in., and the grid coupling plate is 3 in x 4 in. Tuning is accomplished by varying the length of the coils and the plate spacing of the tuning condensers. These adjustments are not easily made, therefore operation should always be on a fixed frequency.

Low P. F. Line Oscillator

● Large diameter pipes, a quarter wave long, are a practical means for stabilizing the frequency of u.h.f. oscillators. RCA has been using these "pipe lines" for frequency control in preference to a quartz crystal oscillator over the range of from 7 to 500 megacycles. Castings and heavy pipes are utilized in commercially-built lines, and temperature compensation is secured by means of a semi-flexible metal bellows and invar-rod within the inner pipe.

The construction can be greatly simplified for amateur operation below 10 meters. The complete copper concentric line for a 2½-meter oscillator can be built in a sheet metal shop for less than $5.00. This is only a fraction of the cost of a crystal control unit, yet comparable results can be obtained.

Crystal oscillators provide good frequency stability because of their relative "stiffness" of circuit constants. The circuit "Q" is much higher than can be obtained with a variable condenser and coil. Similarly, the

effective $Q = \frac{VA}{W}$, proving that oscillatory-energy-to-power-loss is very high in a concentric line of the proper size. The "Q" is inversely proportional to the square-root of the pipe material resistivity, therefore the use of copper is desirable. The "Q" is proportional to the square-root of the frequency, consequently the lines become more effective at 2½ meters than at 5 meters. The "Q" is proportional to the diameter of the pipes

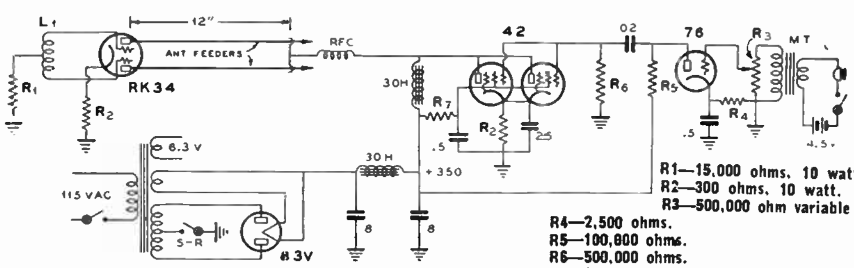


FIG. 62—Circuit Diagram for the Complete 2½-Meter Transmitter.

R1—15,000 ohms, 10 watt.
R2—300 ohms, 10 watt.
R3—500,000 ohm variable pot.
R4—2,500 ohms.
R5—100,000 ohms.
R6—500,000 ohms.
R7—10,000 ohms, 10 watt.
L1—5 turns, No. 18, 1" long, 7/8" dia.
RFC—30 turns, No. 22, ¼" dia., self-supporting.

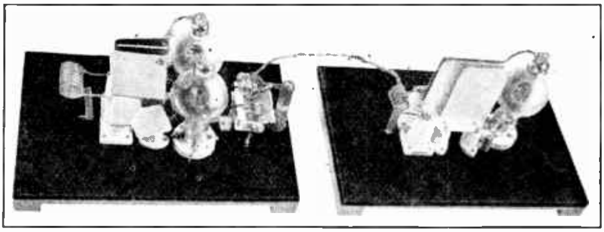


FIG. 63—High Power M-O-P-A Transmitter.

for a given ratio of diameters. The outer pipe is often made 2 ft. in diameter, the inner about 6 inches for 5 meter oscillators. The length of the inner pipe should be ¼ wavelength and the outer pipe should connect to the inner at one end by means of a copper plate or casting, and the open end extends a few inches beyond the inner pipe.

The pipe or line oscillator illustrated in Figs. 64, 65 and 66 should have a "Q" of nearly 8,000 at 2½ meters, which is high enough to give excellent frequency stability. The inner pipe is made of 1½-in. diameter copper tubing, about 27 in. long. Two-inch diameter tubing would be even more satisfactory. The outer pipe is made of 16-oz. sheet copper, from a piece 30 in. x 24 in. The diameter of the finished pipe is 7⅓ in. The average sheet metal roller equipment will handle lengths up to 30 in.

One end of the pipe is soldered to an 8 in. x 12 in. x 18 ga. piece of sheet copper. A 1¼-in. diameter hole is punched in the center in order to pass the inner pipe; the hole is then carefully reamed to a diameter of 1½ in. in order to give a tight sliding fit of good contact to the inner pipe. Waxed linen cords are wrapped around the free end of the smaller pipe, which is then centered in the larger pipe by three small holes in the outer pipe (not shown in the photographs) through which the waxed cord is passed and knotted.

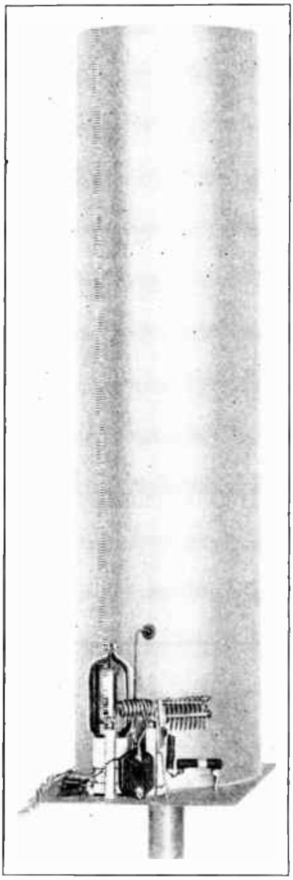


FIG. 64.
Low Power-Factor Line Oscillator.

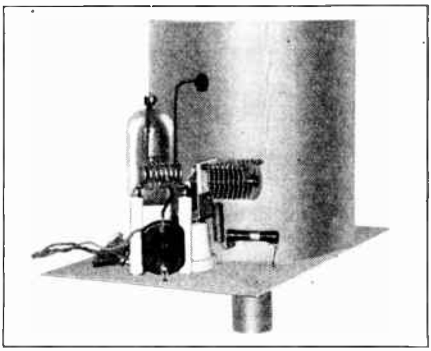


FIG. 65.
Close-Up of Line Oscillator Components.

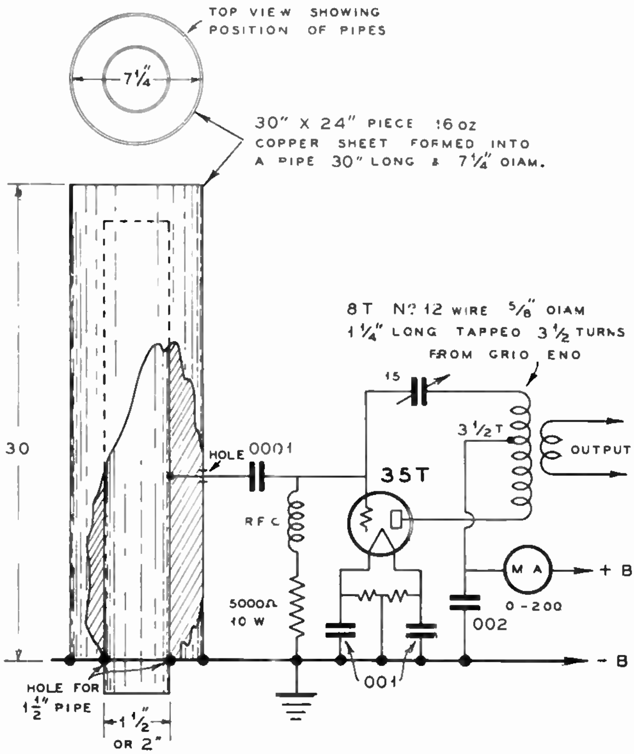
A wire connection to the inner tube is made at 5 in. to 6 in. from the closed end, which in this case is 8 in. from the actual end of the 27-in. tube. 24 in. to 25 in. of actual inner pipe length (inside the large pipe) is approximately correct for the 2½-meter band.

A 35T is used as a regenerative Hartley oscillator in a low C plate-tuned circuit, shown in Fig. 66. A small variable condenser could be connected across the plate coil for convenience in tuning, but with a reduction in the L-to-C ratio. Frequency control is due entirely to the large low-power factor line which connects across the grid and filament of the oscillator tube. Regeneration (and plate tuning, to some extent) is varied by means of a 15 mmfd. grid excitation condenser. The capacity of this condenser should be varied until the tube oscillates (under load) over a range of pipe lengths. The plate current is relatively low when the proper adjustment is found. When the adjustments are not correct, the plate current is two or three times as high, and the heterodyne note against a stable oscillator's harmonics will vary greatly with changes in plate voltage. The plate voltage can be varied 50%, up or down, with hardly a perceptible change of beat note when the circuit is properly adjusted. The entire transmitter should be suspended on a shock-absorbing system in order to prevent vibration, otherwise the frequency stability will be impaired. Without temperature control, the frequency drifts quite rapidly out of the range of audibility in the harmonic monitor for a few minutes during "warm-up" time. The 35-T can be plate-modulated without appreciable frequency modulation, as could be determined on a fairly-selective super-heterodyne receiver.

The plate coil consists of 8 turns of No. 12 wire, 5/8 in. average diameter, and wound to cover a length of 1¼ in. The tap is made at 3½ turns from the grid end. An absorption wavemeter can be used to tune the oscillator to 2½ meters as a preliminary adjustment with the concentric line disconnected.

The efficiency apparently runs quite high; values of 50% can be obtained. At a plate potential of 500 volts, plate current was 25 ma.; at 700 volts, 35 to 40 ma.; at 1000 volts, from 75 to 90 ma. under load, in laboratory tests.

This type of frequency control line is superior to a parallel-rod oscillator with small pipes.

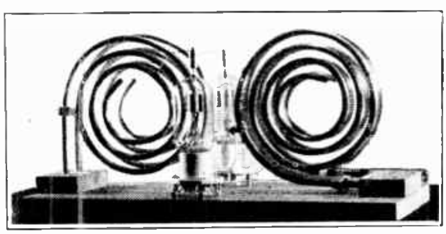


2½ METER STABILIZED OSCILLATOR

FIG. 66.

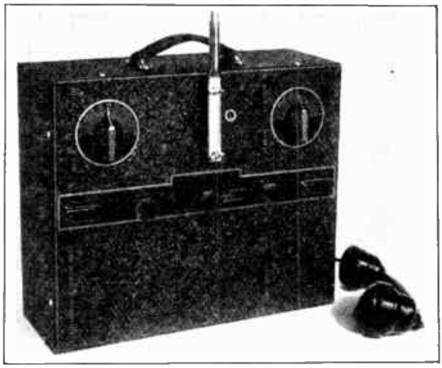
Spiral Rod Oscillator

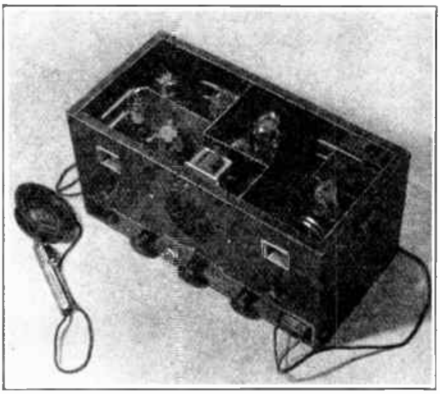
● A standard push-pull parallel rod oscillator can be coiled into a spiral, as shown in the illustration to the right, in order to conserve space. The spirals should be rigidly supported with high-grade insulation so as to prevent mechanical vibration. Adjustments are the same as for a conventional parallel rod oscillator. 400 watts input can be supplied to the 35T spiral rod oscillator here shown.

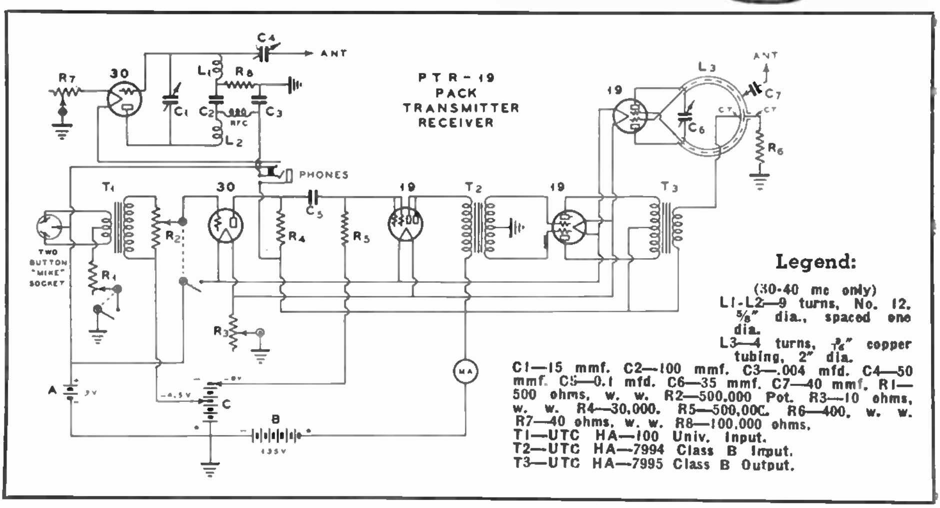


Factory-Built U.H.F. Sets

● There is nothing very unusual in the design of factory-built 5-meter sets because they conform to standard practice and the circuits are almost identical with those so widely used by amateur constructors. Only those who have long engaged in u-h-f manufacture have been successful in marketing their products because the engineering of a 5-meter set calls for more than ordinary experience and knowledge. On the several pages that follow, a number of the better-known factory products are shown. Those on this and the facing page are manufactured by *Radio Transceiver Laboratories* of Richmond Hill, New York. The photographs to the right show the *RTL—"Compact"* (top), and (below) the *PTR-19 Pack Transmitter Receiver.* The photo to the left, at the top of the circuit diagram, shows the *TR-53-6A6 Duplex Transmitter-Receiver.*



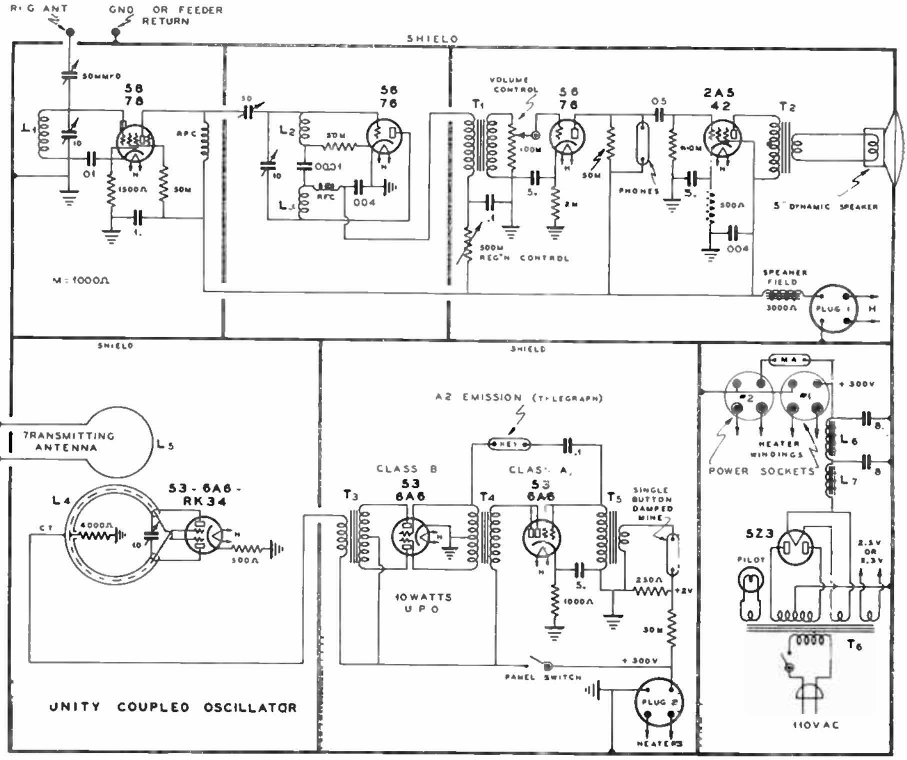




Legend:

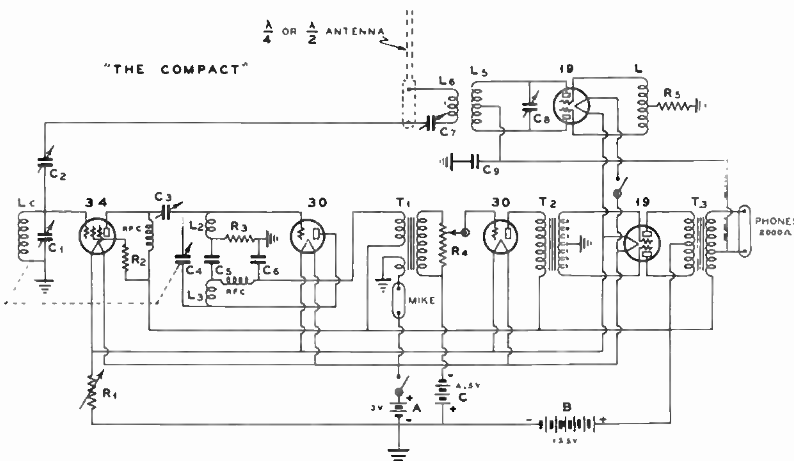
(30-40 mc only)
L1-L2—9 turns, No. 12, 5/8" dia., spaced one dia.
L3—4 turns, 3/8" copper tubing, 2" dia.
C1—15 mmf. C2—100 mmf. C3—.004 mfd. C4—50 mmf. C5—0.1 mfd. C6—35 mmf. C7—40 mmf. R1—500 ohms, w. w. R2—500,000 Pot. R3—10 ohms, w. w. R4—30,000. R5—500,000. R6—400, w. w. R7—40 ohms, w. w. R8—100,000 ohms.
T1—UTC HA—100 Univ. Input.
T2—UTC HA—7994 Class B Input.
T3—UTC HA—7995 Class B Output.

Circuit Diagrams of Factory-Built 5-Meter Sets



Radio Transceiver Laboratories TR53—6A6 Transmitter-Receiver.

L1, L2, L3—7 turns No. 14, 5/16" dia., spaced one diameter. L4—2 turns, 1/4" tubing, 2" dia.

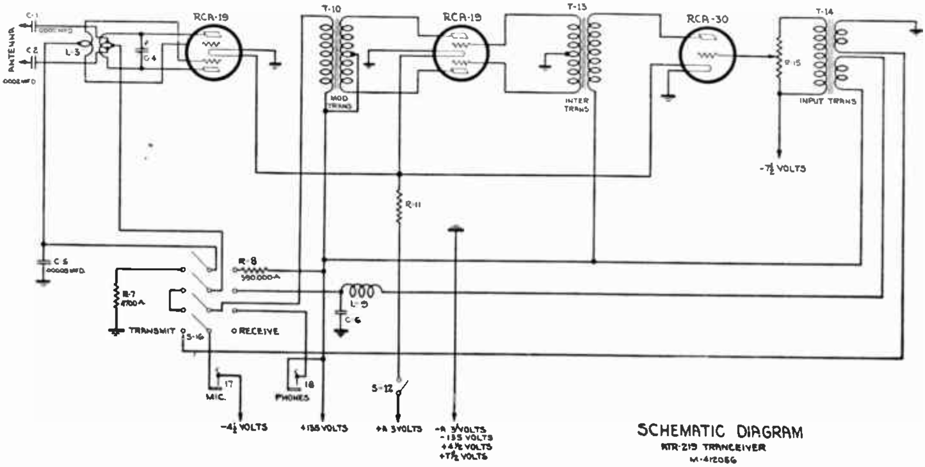


Legend:

L—15 T. No. 14, 5/8" dia., spaced one dia.
L1-L2-L3 — 7 T. No. 14, 5/8" dia., spaced one dia.
L5—6 T. No. 12, 5/8" dia., spaced one dia.
L6—2 T. No. 20 CORLAC, 5/8" dia.
C1—10 mmfd.
C2—50 mmfd.
C3—50 mmfd.
C4—10 mmfd.
C5—100 mmfd.
C6—.004 mfd.
C7—50 mmfd.
C8—20 mmfd.
R1—10 ohms, wire wound.
R2—30,000, 1/2 w.
R3—100,000, 1/2 w.
R4—500,000 pot.

Radio Transceiver Laboratories "Compact."

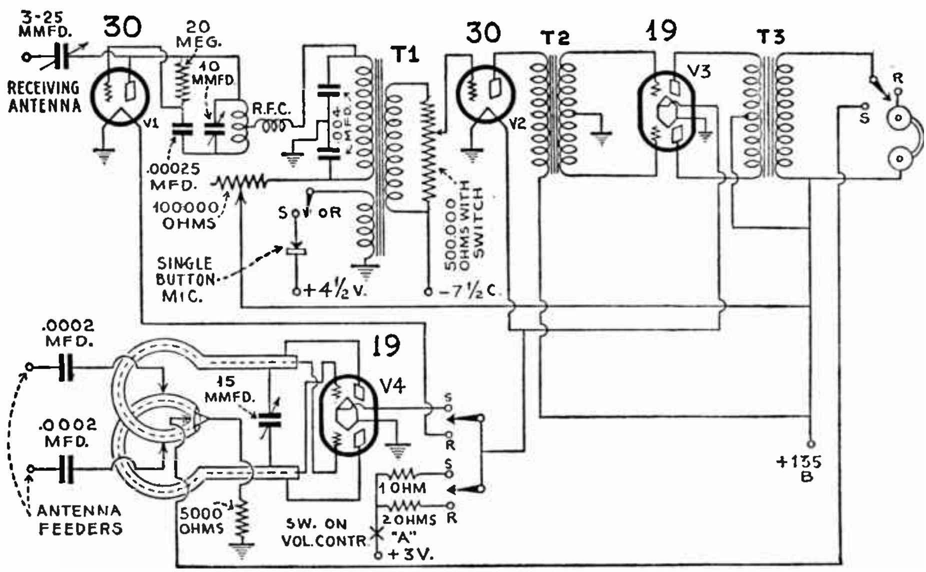
Factory-Built U.H.F. Transceivers



RCA ATR—219 Transceiver.

● The tube complement for this transceiver consists of two RCA-19 twin-triodes and one RCA-30 triode, connected as shown in the circuit diagram above. The transceiver is housed in a small case, equipped with a handle, so that it can easily be carried from place to place.

● Another transceiver circuit is shown below. It is the Wholesale Radio Company's "*Transceptor*," designed by Frank Lester, W2AMJ. In the transmit position, the type 19 tube in the lower portion of the circuit acts as a unity-coupled push-pull RF oscillator. For receiving, a separate antenna is connected to the first type 30 tube which functions as a self-quenching super-regenerative detector.

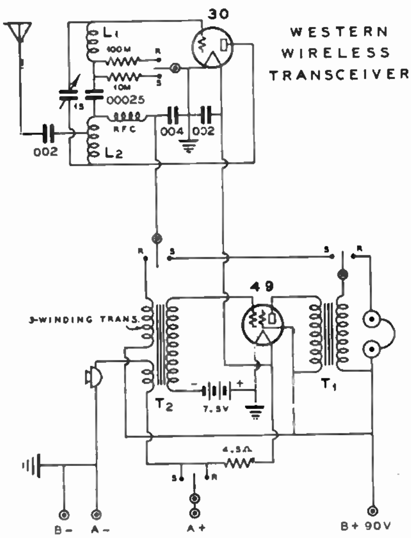


"Transceptor"—Wholesale Radio Service Co., Inc., New York City.

Forest Service Transceiver

● Built into a compact carrying case, 6 inches wide, 9 inches long and 7 inches deep, the *Forest Service Transceiver* pictured to the right is one of the smallest factory-made portable units for u.h.f. service. Miniature dry batteries are housed in the carrying case, and in spite of their small size they will give approximately 8 hours continuous service. A 4-P-D-T anti-capacity switch changes the circuit from send to receive.

Two-volt tubes are used, a type 30 and a 49. The circuit diagram shows the values of condensers, resistors, etc. Coils L1 and L2 are the same as those for home-built transceivers shown elsewhere in these pages. The coils are "air supported" and wound with heavy enameled wire. A 15 mmfd. midget variable condenser is mounted directly below the coils. The antenna is ca-

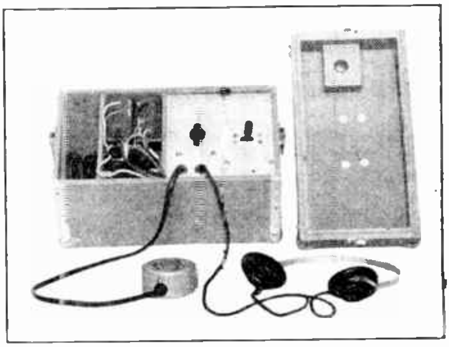


Circuit for Western Wireless Transceiver.

pacitively coupled through a .002 mfd. mica fixed condenser, mounted above the coil.

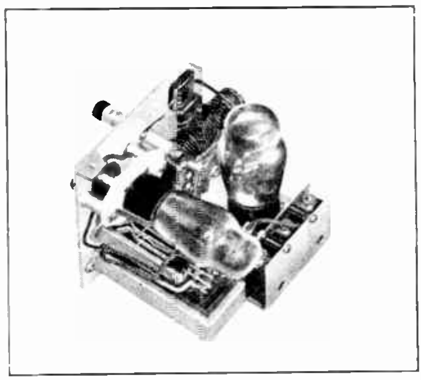
The front panel of this transceiver is of cast aluminum. A through-panel porcelain insulator carriers the antenna lead through the panel and to the coil. The antenna is connected to a binding post which can be seen in the photograph of the complete transceiver. The other controls on the front panel are the condenser tuning knob and the 4-P-D-T switch handle. A small carbon microphone and a pair of headphones fit into the compartment to the far right of the carrying case.

From the circuit diagram it is seen that the type 30 tube acts as a super-regenerative detector in the receive position, or a modu-



Carrying Case, Showing Compartments for "A" and "B" Batteries, "Mike" and Phones.

lated oscillator for transmitting; the 49 tube serves as a tetrode audio amplifier for receiving, and a modulator tube for transmitting. Transformer T1 serves the dual pur-



The Chassis. A 7½-Volt Miniature Battery Is Mounted Behind the 49 Tube.

pose of a modulation transformer for transmitting, or an output choke for receiving. The RF choke is a conventional 5-meter type.

High Power 10 and 5 Meter Power Amplifier

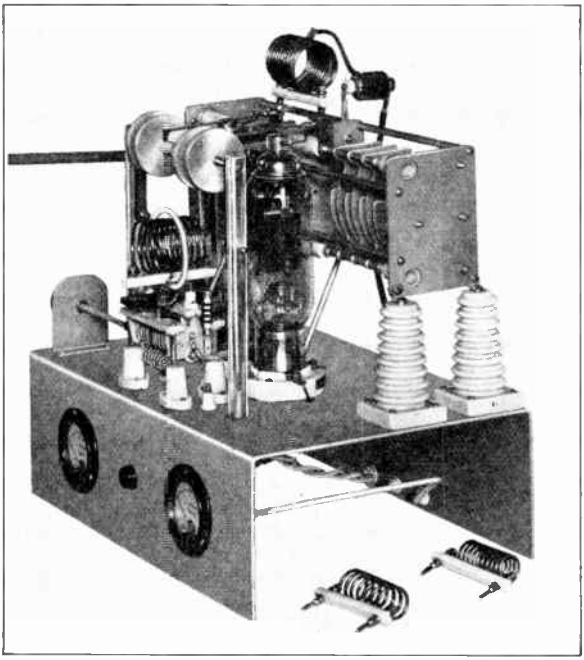


FIG. 69—High Power 10 and 5 Meter Amplifier with HF-200 Tubes in Push-Pull.

● A good mechanical layout for a high-frequency final amplifier with a standard neutralized push-pull circuit is shown in the photograph, Fig. 69.

The grid and plate leads are very short and direct, with the result that the amplifier can be used effectively on 5 meters, as well as 10 and 20 meters. The tubes are type HF-200, with the plates at the top and the grids at the side, making for short RF connections throughout. The 10 meter coils consist of 10 turns of No. 8 copper wire, 2 in. diameter, wound to cover a length of approximately 4 inches. The 5 meter coils have 7 turns of No. 8 wire, 1-inch diameter, 4 inches long. These coils are mounted on standard Johnson 4-inch glazed porcelain antenna spreaders. Coil plugs are secured to these spreaders by means of 6/32 machine screws. Center-tap connections to all coils are made with flexible leads and clips. A one-turn coupling link, 2½ inches in diameter, is wound around the center of grid coil and this link is fed with a twisted line of No. 8 rubber covered wire. This amplifier can be driven by a HF-100 RF stage.

The final plate tuning condenser is an Audio Products Type WS-1502035, having a maximum capacity of 35 mmfd. per section. The grid tuning condenser is the new high-frequency Cardwell split-stator type. The neutralizing condensers consist of two machined aluminum plates, ¼-inch thick, 2½ inches in diameter, with an adjustable gap which is varied by means of a machine-screw threaded rod.

Chapter 15

RADIO THERAPY*

● One field of electronics that is growing to an extent little realized by many involves the use of ultra-high frequencies by the medical profession. While the therapeutic values of various frequencies is still under investigation by many research groups and hospitals, still enough has already been proven so that this apparatus is becoming a standard item in medical treatment. Data is becoming available for the standardization of treatment as to frequency, length of treatment and the amount of power applied, for each of a long and growing list of physical abnormalities.

Much of the equipment that is now in use has been designed without due regard for stability and reproductability in the matter of frequency and power, so that the results from various investigations cannot be compared directly, at least at present, since these and other factors shift frequently, even during a single test.

The wide variety of tissues in the body—cartilage, muscular, fatty, bone, etc., all respond differently to applied radio waves. Some of these tissues are dielectrics, others are effective conductors, while most of them have an intermediate characteristic—that of a "leaky" dielectric—shunted by a capacitance. It is in such tissues that the heat is most intense. The actual energy dissipation therefore takes place as a dielectric loss, with some conductance current loss added. It is generally assumed that there are no "ideal" frequencies to use, even for a single type of ailment (frequencies in which local resonance occurs) and at which very definite action results. On the other hand, definite effects are noted as the frequency is varied, wherein the change of the relation between conductive and dielectric losses may influence the location and degree of heating.

Since a highly complicated electron tube oscillator must be operated by non-technical users, it becomes necessary to exactly predetermine and compensate automatically for all circuit variations, leaving only those controls that are a part of standard prescribed treatments. The correct "dosage" for a particular treatment can be prescribed in terms of "frequency," "power" and "length of treatment." Other factors are the selection of a useful size and shape of the electrodes and their placement.

*This Chapter courtesy of Ralph R. Batcher.

Radio amateurs are quite frequently confronted with technical questions concerning this field of short wave therapy. While the oscillator itself does not present unusual difficulties to a transmitter man, still there are a large variety of unusual loading conditions that must be met, and building such an outfit or servicing one is likely to prove a long and tedious job in some cases. The output load impedance varies over wide limits due to the changes in the size of the applicator pads and their location on the body, to the frequency and also to variations in the spacing between the applicator pads and the skin (such spacing is due to the rubber insulation on the electrodes, to the patient's clothing and to inserted spacing mats). Another type of loading condition is found with the use of surgical cutting instruments and similar appliances.

The various manufacturers of this equipment have not standardized on a set of output load tests, so that there is very little agreement as to the load limits of working conditions. Many use lamp loads, others use salt water absorption tanks. Salesmen are accustomed to apply actual tests on a person. Most of these have been empirically determined, and as they stand, do not give much data as to comparative merits of any particular system.

Borrowing from experience in radio matters, a lamp load has been determined which will enable fairly accurate tests of the output of any equipment. As is well known, a 500 watt lamp has a different impedance than five 100 watt lamps in series. Although the power absorption is the same, a different load ratio adjustment must be used with each. By comparative impedance tests, it is desirable, according to *The Allen D. Cardwell Manufacturing Corporation*, to use the following load to simulate actual body loads and thus to do away with the necessity of a "human" guinea pig.

A special lamp bank output load can be made either with a number of 230 volt lamps in parallel having a combined absorption equal to the rated load of the equipment, or else from a series parallel combination of 115 volt lamps also equivalent to the desired load.

In building up this lamp bank load the arrangement shown in *Fig. A* may be useful. Here the required lamps (in the arrangement shown four 100 watt 115 volt

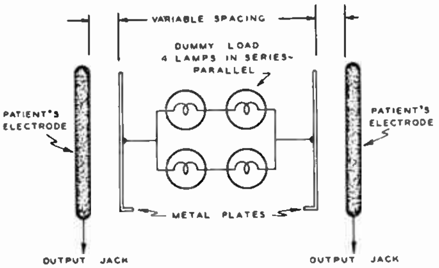


FIG. A

lamps are connected series parallel) are connected between two parallel pick-up plates, about 8 in. square. The output electrode pads from the apparatus are each placed parallel with one of these pick-up plates, with an adjustable spacing, varying from three or four inches down to no spacing, to simulate various load impedances. Such an arrangement will prove the equivalent of the majority of the actual output loads found in practice, but as a final test actual loads should be used.

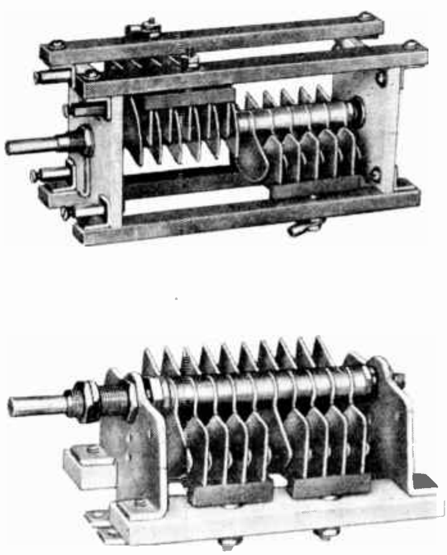


FIG. B. High power Cardwell short-wave condenser suitable for diathermy or transmitter service up to 500 watts.

It is an easy matter to locate troubles if the equipment has been well engineered at the start. The usual circuit is the well known "T N T" arrangement* and is always self excited. Sometimes a cross connected grid pick-up coil is used, however, closely coupled to the plate coil. The output is usually a small coil similar to the first half of a link circuit. This coil may be shunted by a tuning condenser (of the split-stator type) but usually is tuned with two series condensers, one section in each output lead of either type, such as shown in Fig. B.

These condensers were developed mainly for therapy and high power short wave transmitters, and have a minimum of metal in the field, wide spacing between plates (which are of highly polished metal) and mycalex and isolantite insulation throughout. Since they are of heavy duty construction they are used in short wave circuits up to 500 watts.

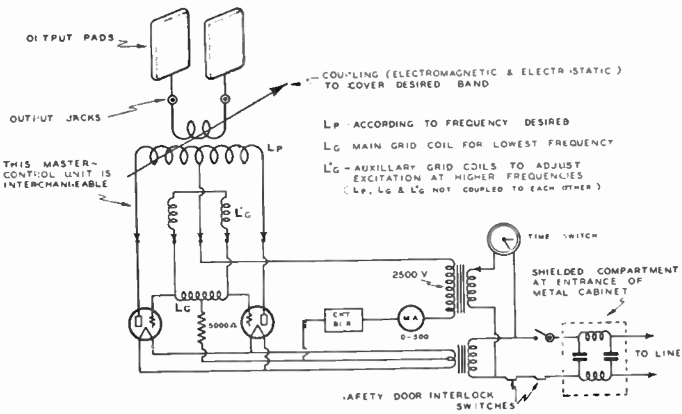
It is usually desirable to wire in a grid current meter temporarily while checking excitation values. The most usual troubles are those common to radio transmitters, such as an open grid leak, power transformer failures, an unbalanced load condition between the tubes, or a faulty tube.

A number of tubes are on the market which have found extensive use in therapy equipment. It is desirable that the data which accompanies these tubes as to maximum plate load, excitation, etc., be followed. Too much excitation is likely to cause undue dielectric strain in the glass parts of the tube, and too little will of course permit the tubes to pull out with immediate self destruction. Such accessories as overload circuit breakers and automatic cut-off timers are easy to install and are easily sold due to the additional safety which they provide.

Half wave self-rectified plate current is generally used in this equipment. This calls for a transformer with an unusually large amount of iron, and an air gap in the core. In full wave rectifier operation the current flows alternately through one-half the secondary winding and then in the other half. Assuming the same power output from half wave operation, a much larger pulse of current flows through a single winding, and if non-saturation is to be avoided ample core size should be provided. The effect is the same as if a DC component equivalent to the plate load flows through the secondary winding. It is usual practice to provide an air gap in this core to take care of this flux saturation.

In designing this transformer, or buying one, remember that inadequate insulation will turn this machine into a lethal instrument. As pointed out by others, it may be better to use a separate rectifier when building such an outfit, if you are favored with an order from a doctor. In addition to reduced interference, an improvement in the matter of surgical cutting will be noted, unless considerable experimenting is done.

*These remarks refer to the usual machine handled by medical supply equipment firms throughout the country. They do not necessarily represent, in all cases, the best practice in the matter of circuits.



Complete circuit diagram of diathermy machine manufactured by Allen D. Cardwell Corp.

The main disadvantage of the self-rectified system is that a very large load is applied to the power line on every other half cycle which produces a very distorted wave form on the power line. If two or more machines are used on the same line (as in hospitals and clinics), it would be desirable to polarize the line connections so that the load is more evenly divided, one-half of the machines are plugged in the opposite way so as to utilize both halves of each cycle. This is done by measuring the line voltage with one machine connected, and to connect the second machine and to note the change in line voltage due to the extra current load. The machine's input line should then be reversed and the voltage drop again noted. It should be left with the connections that produce the minimum voltage drop.

In order that any oscillator be equally efficient over a wide range of frequencies, accurate control of the excitation and other factors at each of those frequencies must be accomplished. This is done, as the photograph shows, by the use of interchangeable master control elements, one of which is supplied for each frequency required. These elements establish the values of the circuit constants which are correct for the particular frequency. They are supported in special ceramic holders so that a physician can insert the particular unit desired from the "library" depending upon case requirements. From a practical standpoint, this arrangement also assures the purchaser that some future research, which might show the advantage of a particular frequency for some special purpose, will not render his apparatus obsolete.

Medical research has indicated that several effects are produced by high frequency fields which may be summarized briefly as follows (it being assumed that all effects of actual conduction currents, the diathermal principle, are absent): At lower frequencies, say from one to fifteen megacycles, the temperature increase has the effect of lowering the viscosity of the blood and dilating the blood vessels, which causes the blood to flow faster. The temperature increment in the portion of the body under the influence of the field is due primarily to dielectric losses from both electrostatic and electromagnetic fields, although the heat is distributed and probably enhanced by the increased action of the blood flow as well.

At higher frequencies a germicidal action also occurs along with the localized fever, which if accurately controlled can be beneficial. At still higher frequencies (of the order of 50 megacycles or over) other effects have been noted and their applications are still under investigation.

Carrying out the conditions usually asked for by medical men, of not desiring to fuss with any controls that do not have a bearing on the treatment, the system here shown has only three controls, corresponding to the above three factors: frequency, length of dosage and power. The proper preliminary selection of a suitable size and location of the electrode pads is assumed. Frequency is controlled by the insertion of the correct master unit. The output power is controlled by handwheels on either side of the apparatus, and the value indicated by the panel meter. The output circuit is arranged so that variations in the load impedance (i. e. the size, location and spacing of the electrodes) do not shift the frequency to any great degree, and permit loading up the tubes to their full limit (if desired) under any load impedance values. The output is strictly aperiodic, as it is found that small shifting of the position of the electrodes on the patient often produces large changes in the load conditions, when tuning is resorted to. This would alter the effectiveness of the treatment. A time switch is incorporated in the circuit so that the treatment is automatically terminated at the end of the predetermined interval.

The problem of radio interference can be tackled and some improvement accomplished by the use of all metal cabinets. While the interference with tube oscillators is much less aggravating to the radio engineer than

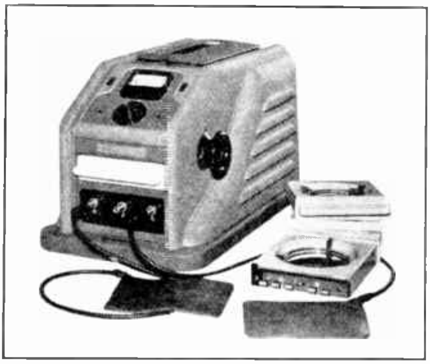
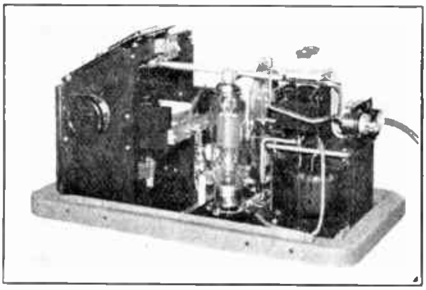


FIG. C—Exterior view of Cardwell diathermy machine.

that produced by the quenched gap type of diathermal unit, on the other hand the wave lengths are usually lower with tube oscillators, so that even short wires are good radiators. Unlike most of the other apparatus heretofore available, this apparatus is enclosed in a metal cabinet as shown, with an appearance consistent with modern trends of styling. The cabinet is grounded when installed, and the input power lines are filtered in such a way that radiation back into the power lines is eliminated. Radiation from the leads to the rubber covered electrodes is still possible, but the only improvement in this regard seems to be the use of shielded rooms or compartments for the patient. The leads are usually kept in a position where they remain parallel for a part of the distance, so as to keep radiation low.



Interior view of diathermy machine.

In the outfit shown, frequencies within the range of 6 to 16 meters are the ones most commonly utilized. The maximum power output is in excess of 400 watts.

Chapter 16

CATHODE-RAY TELEVISION*

● With more television broadcasting stations on the air today than there were sound broadcasting stations fifteen years ago, and with the likelihood that the number will increase rapidly within the next year, radio experimenters in many localities may receive the transmissions by means of home-assembled equipment. This is now possible at a comparatively low cost, though the expense of picture transmission is too great for the average pocketbook. For the information of the reader who may not be familiar with the fundamental principles of television equipment the following elementary exposition is presented prior to an account of the circuit employed in a typical receiver.

The major problems of television were solved by imitating the action of the human eye, which constitutes a complete television system in miniature. In the eye, a lens focuses an optional image of a scene on the retina. This consists of about 130-million tiny cells which convert light energy into an electrical current whose fluctuations correspond in strength to the variations in brilliance of the light from various parts of the scene. The function of the cells is to dissect a continuous image into a discontinuous mosaic of separate areas. Of these millions of cells, perhaps a hundred thousand are in sharp enough focus to give a clearly-defined image of the central portion of the scene, while the others give an indistinct image of the periphery. The eye quickly traverses the entire scene to bring all parts of it into focus, this process being facilitated by the fact that each cell retains the impression of a flash of light for about a tenth of a second after it has disappeared. It is this "persistence of vision" that makes possible the illusion of motion in the motion picture and in television.

Each cell is connected to the brain by a tiny nerve filament, millions of which are bundled together in the cable of the optic nerve. Each filament conducts its tiny electrical current to a brain cell which detects or converts it into the physical sensation of light. The aggregate of these tiny effects reconstruct the scene as an optical image.

The first difficulty encountered in imitating the action of the eye was that of providing the thousands of sets of light-sensitive cells and connecting wires which are necessary for the production of a high-definition picture. The mechanical complexities and expense are so great that it has not yet been satisfactorily accomplished directly. But it is done indirectly by taking advantage of the eye's persistence of vision so as to allow a picture to be "scanned."

FIG. 1—Farnsworth Portable Pick-up Camera and Pre-Amplifier

The scanning process is comparable to the action of the eye in repeatedly reading an entire page of printed matter in 1/10th second or less. Suppose, for example, that a 10x10 in. photograph be cut into 240 narrow strips each 1/24th in. wide, and that each strip be cut into 240 sections each 1/24th in. long. The picture will then be dissected into 57,600 elementary areas, which can be assembled in proper order and position like a jig-saw puzzle. Let the entire picture be pasted on the wall of a room so dark that the picture is invisible. Then assume that a brilliant light is

*This Chapter Contributed by Arthur H. Halloran, Television Consultant.

focused into a narrow beam 1/24th in. in cross-section and by some ingenious means is caused to traverse the picture in a series of successive horizontal sweeps, all within the brief period of 1/10th second. The eye would then receive and retain the same impression as if the entire picture were steadily illuminated by a broad beam of dimmer light.

This, in effect, is the indirect means employed in scanning a television picture. It substitutes a rapid sequence in time for the actual sequence in space position of the elements in the picture. The television pick-up equipment dissects or analyzes an optical image into a time sequence of electric currents and the receiving equipment assembles the image into a space sequence of light flashes which reproduce the scene of action as a motion picture. This is done by means of two types of cathode-ray tubes: The pick-up tube converts variations in the intensity of the light from different parts of the scene into corresponding fluctuations in an electrical current. The delivery or receiving tube changes the fluctuations in electric current into variations in the intensity of light.

The action of both tubes, as does also the action of the cathode-ray tube in an oscillograph, depends primarily upon the emission of electrons from a cathode and their travel at high velocity to a highly charged anode. Their direction of travel is controlled by electric or magnetic fields which are used to focus them into a slender beam, or cathode-ray, and to deflect that beam in any desired manner.

FIG. 2—"Shooting" a Television Picture in The Studio.

The Pick-up Tube

● The tube first used by Farnsworth is an evacuated glass cylinder containing a photo-sensitive cathode at one end and an anode target at the other. Electrons are emitted from the cathode by the action of light on a thin layer of caesium deposited on a silver-oxide surface. The light causing the emission is an optical image of a scene of action which is focused by a lens on the cathode in the same manner as an image is focused on the ground-glass plate of a camera or on the retina of the eye.

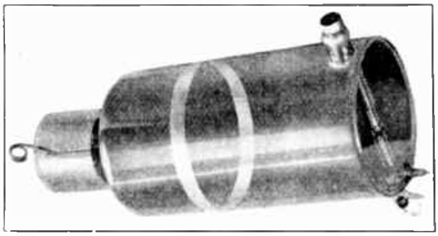


FIG. 3—Farnsworth Dissector Tube with Electron Multiplier for Use at Transmitter.

The number of electrons emitted from any portion of the image focused on the photo-sensitive surface depends upon the brightness of the light shining on a given spot. A large number of electrons are emitted from a bright spot in the image and a small number from a dim spot. Consequently, all of the scene's gradations in light and shade are duplicated in the number of electrons emitted therefrom.

All of the emitted electrons are attracted toward the positively-charged target at the other end of the tube. They have a natural tendency to repel one another and thus cause the cathode-ray to diverge or expand as it travels from the source. This natural tendency is counteracted by the magnetic field from a coil within which the entire tube is placed like a finger in a glove. The strength of the field is adjusted so as to hold all of the electrons in their same relative position throughout the length of the tube. Consequently, when they reach the plane of the target, they constitute what is called an electron image, in any portion of which the number of electrons is proportional to the intensity of the light in the corresponding portion of the scene.

At the center of the plane of the target is a tiny hole through which are projected the electrons from that particular part of the electron image which covers the hole.

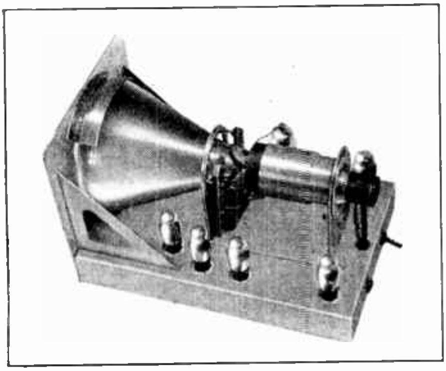


FIG. 4—Farnsworth Oscillight Assembly with Focusing and Deflection Coils.

These electrons are collected on a wire inside the target which is connected through a resistance to the positive terminal of a battery. As the electrons are drawn through the resistor they cause a difference in voltage which is proportional to the intensity of the light in that particular portion of the scene.

Assuming a 57,600-element picture, we have accounted for only one elementary area. From what has already been said about scanning, it should be obvious that if each of the other 57,599 elements could by some means be brought successively in front of the aperture, their corresponding electrons would likewise be projected through it. There thus would be produced an electric current whose fluctuations would be proportional to the variations in the intensity of the light in various parts of the scene. Furthermore, if the operation could be repeated at least ten times per second, the optical image would be converted into an electric current which can be reconverted into an optical image in the receiving tube. In actual practice, the operation is repeated 24 or more times per second to reduce the effect of flicker.

Such a means is provided by deflecting the cathode-ray between the poles of two sets of electromagnets supplied with alternating currents of 24- and 5760-cycles per second, respectively. The poles of the 24-cycle magnet are placed above and below the tube so as to establish a vertical magnetic field acting in the same direction 24 times per second. Those of the 5760-cycle magnet are placed on either side of the tube so as to establish a horizontal magnetic field acting 5760 times per second in the same direction. The resultant effect of their combined action is to deflect the entire electron image past the stationary aperture as a series of 240 horizontal sweeps 24 times per second. If the diameter of the aperture is 1/240th the width of the image, 57,600 elementary areas are successively swept past the tiny hole in 1/24th second.

Each of these elementary areas has its own characteristic number of electrons and thus produces it own characteristic electric current as its electrons are projected through the aperture. As these currents pass through the resistance they produce corresponding differences in voltage which are amplified prior to radio transmission to the receiver. In this manner the variations in the light intensity of an optical image which is focused on a photo-sensitive surface produce a variable-intensity cathode-ray and thus an electric current whose fluctuations are proportional to the variations in light intensity in the scene.

FIG. 5—P. T. Farnsworth at Transmitter Controls

The steady magnetic field for focusing the beam is maintained by a DC supply from a battery or power-pack. The AC field for deflecting it vertically is maintained by a 24-cycle current generated by a vacuum

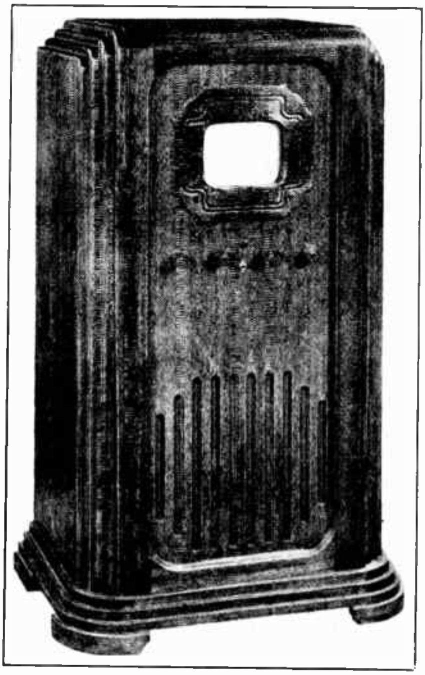


FIG. 6—Farnsworth Television Receiver.

tube circuit. The horizontal deflecting field is likewise maintained from a 5760-cycle source. The AC current waves have a saw-tooth shape so as to deflect the beam at a relatively slow speed in one direction and so quickly in the opposite direction that practically no electrons are projected through the aperture during the return sweep. Details as to how these currents are generated are too lengthy to be given now, especially as they tend to distract attention from the general method of operation.

The same comment applies to the means utilized to amplify the exceedingly small voltages from the pick-up tube. This is a stupendous task in itself, involving a million-fold amplification without distortion in a broad band of frequencies extending from 24 cycles to 1080 kilocycles. It may be accomplished by resistive-capacitive coupling of a number of radio tubes in series, or better yet by a method of electron multiplication recently perfected by Farnsworth.

Radio Transmission

● The amplified picture-currents, together with the 24-cycle and 5760-cycle scanning pulses, are used to modulate or shape a radio carrier in much the same manner as a carrier is modulated by the audio frequencies used in broadcasting speech and music. But there is one very important difference. The broadcasting of sound requires a channel width of only 10 kilocycles so that 96 channels are available in the 960 kilocycle spectrum allocated to all the North American broadcast stations. The broadcast of one 57,600-element picture 24 times per second requires a channel of nearly four times the width that suffices for 700 stations in the 200-550 meter range. Evidently there is no room for television in this portion of the radio spectrum.

Ample room is available, however, in the portion of the spectrum below 10 meters. So the Federal Communications Commission has allocated several wide channels in the 2½-7½ meter band for experiments in broadcasting television. Experience has shown that these ultra-short wavelengths have several advantages, particularly as regards the elimination of double images and of interference between stations.

On the longer wavelengths, the signals travel to a receiver along two paths. One, known as the ground-wave, follows the curv-

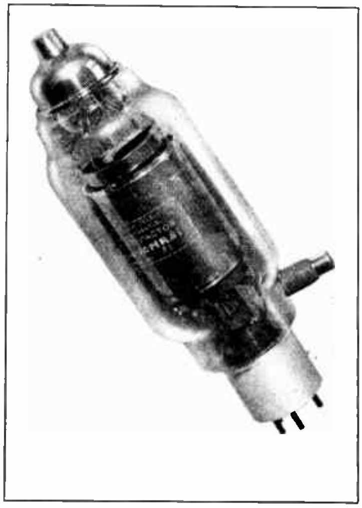


FIG. 7—Farnsworth "Multipactor"

ature of the earth. The other, known as the sky-wave, goes out into space until it is reflected and refracted in the upper atmosphere so as to return to earth at a considerable distance from the transmitting station. Most of the long-distance reception of radio signals is due to the sky-wave. The two waves interfere with one another and cause the "fading" which is so bothersome in long-distance reception. In television, they cause two images to appear at the receiver.

The sky-wave resulting from ultra-short

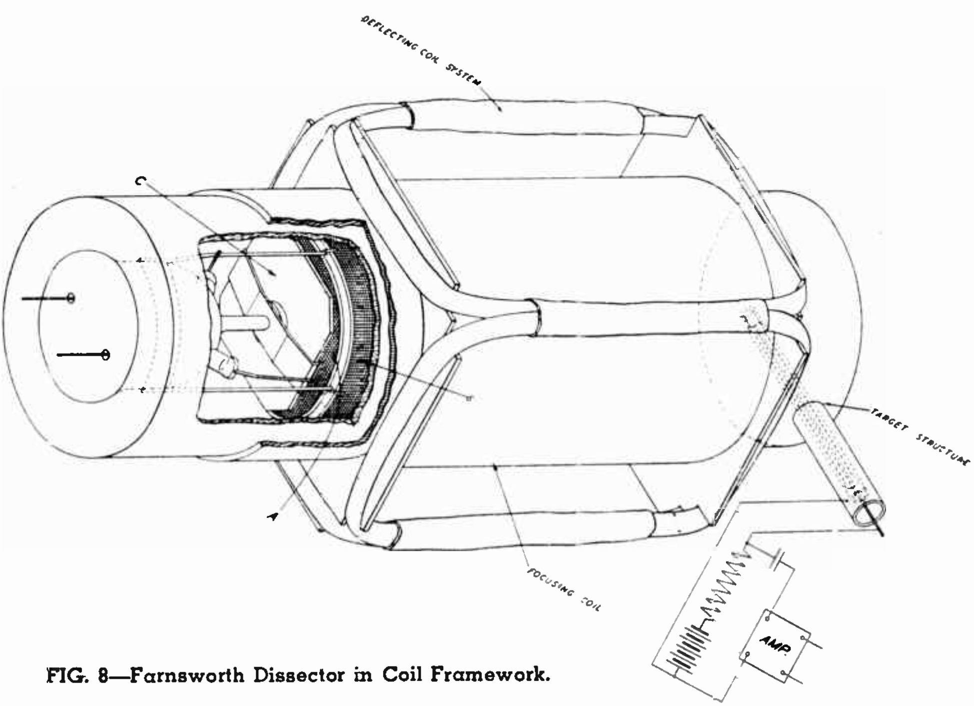


FIG. 8—Farnsworth Dissector in Coil Framework.

wave transmission seems to be reflected and refracted beyond the boundaries of the earth. Consequently only the ground-wave is received, and there is no interference and no double image. Reception is normally limited to the area defined by the horizon of the transmitting antenna. This general rule is subject to some modification by effects which are not yet well understood. But hundreds of television stations can operate on the same wavelength without interfering with one another, provided that their horizons do not overlap. One channel thereby suffices for a great number of stations which are geographically situated about a hundred miles apart.

The Television Receiver

● The receiver must be capable of being tuned to the ultra-short wavelengths on which both the picture- and the sound-currents are carried. The sound-reproducing equipment is the same as that employed for reception on the longer wavelengths, but the essential part of the picture-reproducing apparatus is a cathode-ray tube.

The cathode-ray receiving tube differs from the pick-up tube in several respects. In its simplest form it contains four elements which are assembled in an evacuated glass tube; a heated filament or electron source, a positive plate to which the electrons are attracted, an intermediate grid which varies the strength of the electron flow in accordance with the intensity of the received signal, and a fluorescent screen on which the picture appears or from which it is projected to a larger exterior screen.

The entire tube is housed in a framework of electromagnetic coils, similar to that at the transmitter, thus providing means for focusing and deflecting the cathode-ray. Quite a number of inventors have devised such tubes, which differ mainly in structural details. Any of them can be adapted to receive pictures from various types of pick-up equipment. The tube developed by Farnsworth serves to illustrate the principle which is applied in all of them.

The invisible cathode-ray is established by a difference in voltage between the filament and plate, the latter containing an aperture through which the electrons are projected into the vacuous space beyond. Here the concentric magnetic field focuses the beam of high-velocity electrons to a small spot at the far end of the tube, which is coated with a fluorescent material. This material glows brilliantly wherever the cathode-ray strikes it, the end of the ray thus becoming visible as a tiny spot of brilliant light. The vertical and horizontal deflecting fields cause the spot to traverse the entire coating in a series of 240 closely adjacent horizontal lines 24 times per second, the general method of

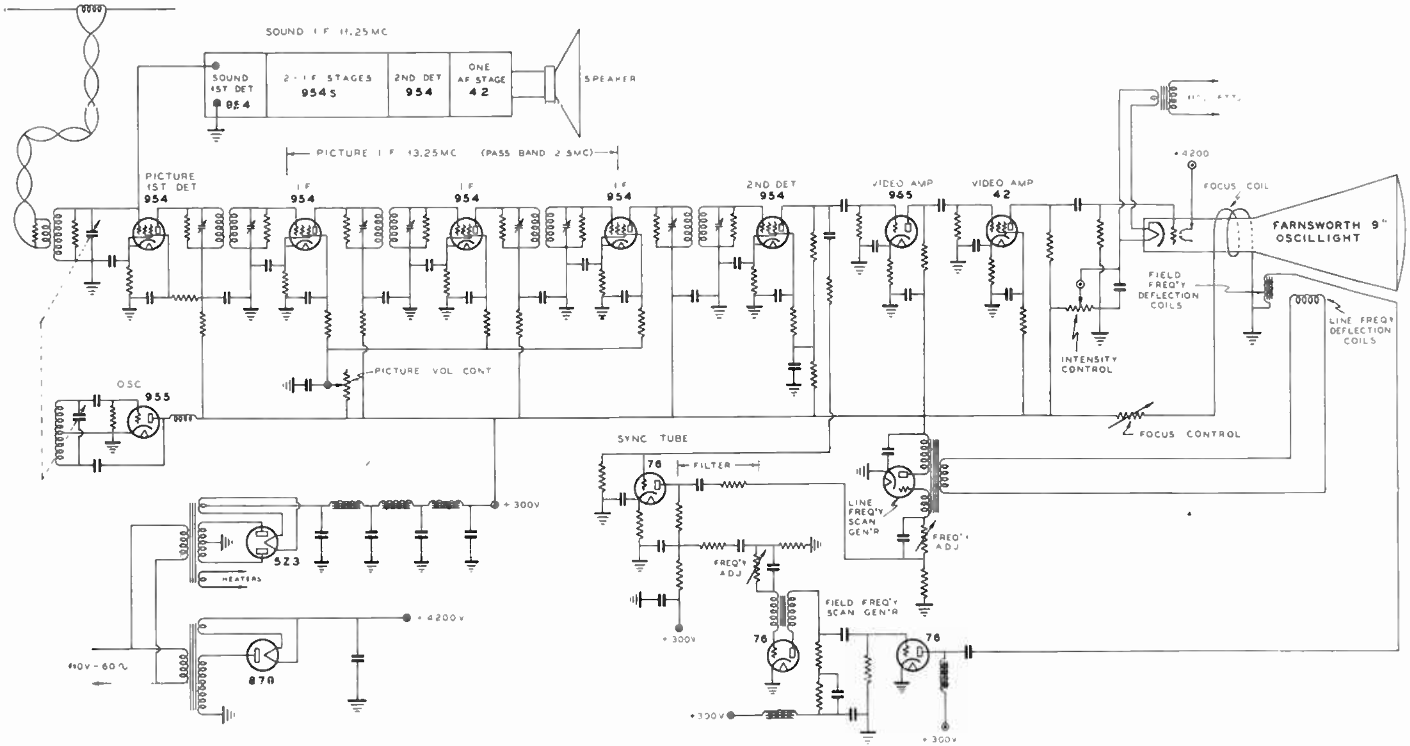
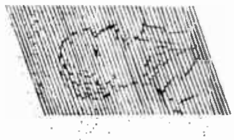


FIG. 8

Farnsworth Television Receiver Circuit

(Courtesy "Radio Engineering")



● An evacuated glass tube, funnel-shaped, containing an electron gun, two pairs of deflecting plates, and a fluorescent screen, is mounted on a base to which control voltages are applied. The electron gun consists of an electrically-heated cathode, a negatively-biased grid, and two perforated anodes with a higher positive voltage on the second than on the first. The gun produces, focuses, and projects a narrow beam of high velocity electrons on the screen where the point of impact becomes visible as a spot of light whose intensity is proportional to the number of electrons in the beam, as determined by the bias of the grid to which the received picture currents are applied. The spot of light is regularly deflected so as to trace a series of closely-adjacent parallel lines by means of saw-tooth voltage waves applied to the vertical (1-2) and horizontal (3-4) deflecting plates to which the received synchronizing pulses are also applied. The result is a motion picture on the fluorescent screen.

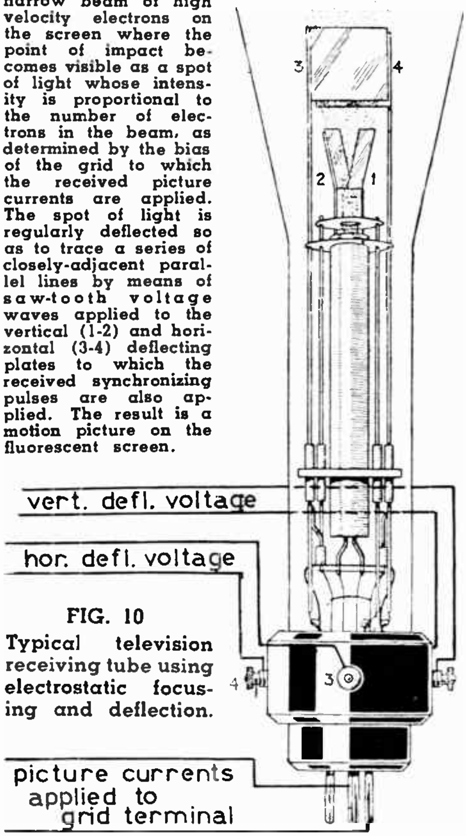


FIG. 10

Typical television receiving tube using electrostatic focusing and deflection.

operation being the same as that employed in the pick-up tube. As a consequence, prior to the application of the picture currents, the entire coating glows uniformly.

Meanwhile the picture currents, as received on the aerial, are amplified and applied to the grid, which is situated between the filament and the positive plate in the tube. When a strong voltage is applied to the grid, corresponding to a bright spot in the scene, more electrons pass through the grid than when a weak voltage is applied, corresponding to a dim spot in the scene. The cathode ray is thereby caused to vary in strength in accordance with the intensity of the light from various parts of the scene. As the brilliance of the fluorescent glow depends upon the strength of the cathode-ray which strikes the screen at any instant, the various elementary areas in the screen reproduce the variations in light and shade in the scene of action. The cathode ray thus acts like a pencil in drawing a motion picture on the fluorescent screen. The present pictures are in black and white, as in a photograph, though eventually they may be reproduced in natural colors.

A complete television receiver comprises both a sound and a picture reproducer. The sound reproducer may be a conventional ultra-short-wave superheterodyne, including first detector, two RF stages and second detector, all using 955 tubes, and a one-stage AF amplifier with a 42 tube. The same aerial (see Antenna Chapter for design) and a heterodyne oscillator using a 955 tube suffice for reception of both sound and picture signals on adjacent channels. They are readily separated because of the fact that the oscillator beats with the two carriers to produce different I.F. Any possibility of interference between sound and picture currents is obviated by rejector circuits. The schematic circuit diagram of a Farnsworth receiver in Fig. 9 shows 11.25 mc as the I.F. for sound and 13.25 mc as the I.F. for pictures. Selectivity can be enhanced by two preliminary RF stages not shown in the diagram.

In the picture reproducer the image appears on the screen of a cathode-ray tube which may be regarded as taking the place of the speaker in a sound reproducer. The amplified picture-current voltages are applied to the grid of this tube so as to modulate the slender beam of high-velocity electrons from the heater-type cathode to the screen. These varying voltages produce corresponding variations in the intensity of the fluorescence of the screen due to the impingement of electrons thereon. The tube is provided with a means for deflecting the beam horizontally and vertically and for focusing it. Farnsworth's oscillight employs magnetic focusing and deflection. Zworykin's (RCA) kinescope uses electrostatic focusing and magnetic deflection. This account is confined to Farnsworth's equipment for the simple reason that the details are more readily available to the author.

As shown in the circuit diagram, the picture current amplifier is a superheterodyne with 954 tubes in the first detector, three I.F., and second detector stages, with a 955 tube in the first video stage and a 42 tube in the second video stage. The I.F. stages are designed to pass a 2.5 mc band, which is ample for a 300-line picture with sequential scanning, but insufficient for a higher-definition picture with interlaced scanning. The wide band-pass characteristic is obtained by winding the transformers with resistance wire and by adjusting the coupling between the primary and secondary windings to give a flat-topped response curve. Any experimenter who is familiar with the design and construction of the usual type of narrow-band receiver should have no difficulty in assembling this portion of the equipment.

The real difficulty arises in connection with the equipment for focusing and deflecting the beam. It is expected that the Farnsworth 9-in. oscillight and special coils in which it is housed may soon be available for experimental use from the Philadelphia laboratories. The focusing coil consists of 30,000 turns of No. 36 wire wound on a bakelite tube 4 in. long and 2½ in. outside diameter. This fits over the neck of the cathode-ray tube. The high-frequency (line deflection) coils are coupled through a special transformer, code No. SA-2551, to the output of an 802 oscillator tuned approximately to the transmitter's line deflection frequency, say 6000 cycles, and synchronized by the amplified signals from the 76 tube in the filter circuit connected to the second detector of the superheterodyne. This filter circuit also separates the synchronizing pulses for the low (field) frequency generator which furnishes deflecting currents to the field deflecting coils. The circuit diagram shows 76 tubes as amplifier and oscillator for furnishing 25 or 30 cycle slope-wave current, depending upon the number of picture repetitions per second with sequential scanning.

As Farnsworth, and likewise RCA, employ interlaced scanning at their transmitters, this circuit diagram is obsolete insofar as the field frequency scanning generator is concerned. Full details regarding the oscillator for interlaced scanning, together with all other constants for the complete circuit, will be published in supplements to the author's book on "Television with Cathode-Rays" as soon as the patent situation makes such publication possible.

The power unit consists of an 879 supplying 4200 volts to the anode of the oscillight and a 5Z3 tube supplying 300 volts for the plates of other tubes in the circuit. Care should be exercised in providing proper insulation to avoid accidental contact with the 4200-volt circuit.

Chapter 17

TEST INSTRUMENTS

● The technique of making electrical measurements and the use of measuring equipment encountered in the problems of amateur radio practice are outlined in this section.

Voltage Multiplier

● In practically all radio measurement work a 0-1 DC milliammeter has been found to be sufficiently sensitive for average amateur service. To use this instrument for the measurement of voltage requires that a resistor be placed in series with the meter, and the value of which depends upon the highest voltage to be measured and equals the range of the meter in milliamperes times the series resistance: expressed,

$$R = E_{max} / I_{max} \text{ and } E = IR$$

Current Shunts

● To increase the range of the above instrument up to say, 10 amperes, requires the use of a current shunt, whose function is to carry part of the total current thereby lowering the flow of current through the meter. For any current reading the value of the shunt resistance is found by dividing the resistance of the meter by the maximum range of the meter, minus 1.

Resistance Measurements

● Resistances can be measured with a precision comparable to that of the meter accuracy with the aid of the following resistance formula:

$$R_x = \frac{R_m (R_o + R_m)}{\frac{E}{I_m} - R_o}$$

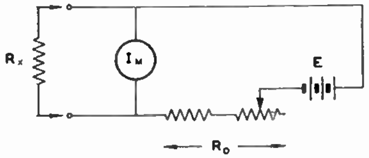


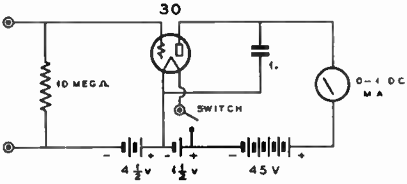
Fig. 1—Ohmmeter Circuit

where, in the diagram, R_x is the unknown resistance; R_m, the internal resistance of the meter; R_o, the limiting resistor; E, the battery voltage, and I_m, the current through the meter.

Simple Vacuum Tube Voltmeter

● This vacuum tube voltmeter will measure RF or AF voltages, indicating peak-values. It can be calibrated at 60 cycle input voltages and the same calibration curve will be satisfactory at radio frequencies. One purpose for this meter is in circuit alignment of a radio receiver in which the voltmeter is connected across an

Fig. 2—V. T. Voltmeter Mounted in Card-File Case



VACUUM TUBE VOLTMETER
Fig. 3

audio amplifier through an isolating 0.1 mfd. condenser, or it may be connected across the voice coil of a dynamic loudspeaker. The instrument will determine the audio response of an amplifier, a radio receiver, or the gain of an audio or radio-frequency amplifier; in addition, it can be made to measure the percentage modulation of a phone transmitter or indicate frequency characteristics. In conjunction with an auxiliary full-wave linear rectifier, the peak voltmeter herein described will measure both positive and negative modulation loops of a modulated carrier signal.

Only a few parts are required for building this useful V. T. voltmeter. It has a range of from 1 to 4 volts. A small 45 volt B battery, 4½ V. C. battery, and single 1½ volt dry cell supply power for the type 30 tube. A 0-to 1 DC milliammeter serves as an indicator. The complete unit with batteries can be built into a 4"x8"x6" card filing case, as illustrated in Fig. 2.

Fixed voltages of such value as to give approximate plate current cut-off are secured from the battery voltages indicated in the circuit diagram, Fig. 3. Since these voltages change somewhat with age, this V. T. voltmeter can not be accurately calibrated; its simplicity and general usefulness around a laboratory of either a service-man or radio amateur more than compensates for this deficiency. Most r-f and a-f measurements are comparative and thus they do not require extremely accurate voltage calibration.

The unit may be calibrated by using a potentiometer and a low-reading AC voltmeter across a filament winding of a transformer. The AC voltmeter reads r.m.s. values; consequently 2.5 volts r.m.s. equals 3.53 volts peak. The potentiometer can be employed to impress a known ratio of this voltage across the V. T. voltmeter. The actual impressed peak voltage should never exceed the bias voltage of about 4.5 volts.

This same method can be utilized with higher C-bias and plate voltage to read greater values of RF or AF voltage. In such cases, the micro-ammeter should have an opposing current network with a variable resistor arranged to allow a zero meter reading at the desired initial plate current.

Fig. 4

Ohmmeter

● A DC milliammeter can be connected in series with a resistor and battery for making resistance or continuity tests. The ohmmeter illustrated in Fig. 4 has a number of additional resistors and a rotary single pole switch in order to make it function as a DC voltmeter with ranges of 0-to-10, 0-to-

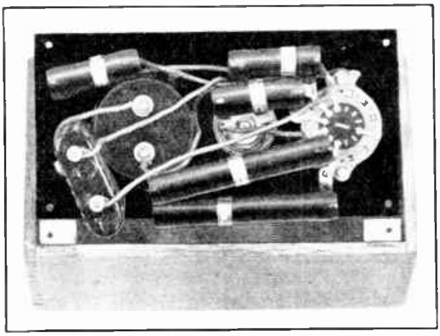
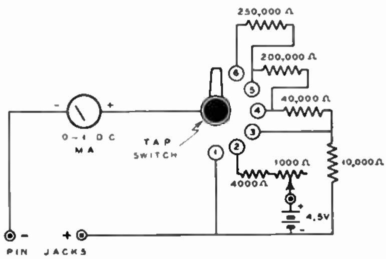


Fig. 5—Interior View of Ohmmeter, Showing Battery, Rotary Switch and Ohmite Resistors



OHMMETER — D C VOLTMETER

Fig. 6

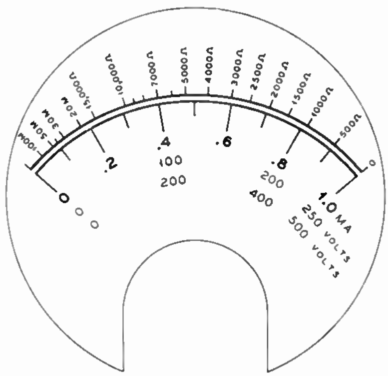


Fig. 7

Position 1 of Switch	**0- 1 M.A.**
Position 2 of Switch	**0-100,000 Ohms**
Position 3 of Switch	**0- 10 Volts**
Position 4 of Switch	**0- 50 Volts**
Position 5 of Switch	**0-250 Volts**
Position 6 of Switch	**0-500 Volts**

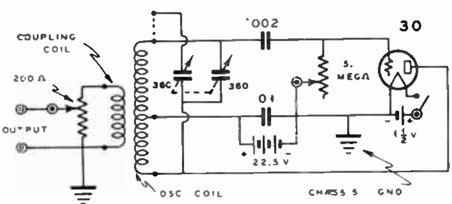
50, 0-to-250, and 0-to-500 volts. One position of the switch connects the meter as a 0-1 milliammeter. A box 4" x 8" x 3½" contains all parts which are mounted on a bakelite top panel, 4" x 8" x ⅛". The ohmmeter has a variable resistor in series with a fixed resistor for setting the meter to "zero" resistance when the test prods are short-circuited.

Ohmmeter scales for standard makes of milliammeters can be purchased from radio mail order houses, or the scale in Fig. 7 can be cut from this page, because it is of the correct size for a 2-inch Weston 0-1 milliammeter.

This device is a necessity for all radio servicemen, and equally useful for amateurs or experimenters.

All-Wave Test Signal Generator

● Any type of superheterodyne receiver can be easily aligned if a test or signal generator is available. This oscillator is easily constructed in its simpler forms, such as the one shown here. Either modulated or unmodulated test signals of any frequency from 150 KC 12MC are available from five plug-in coils. Harmonics can be used for higher frequencies. These coils plug into a 6-prong socket, and the coil is shielded by an aluminum can which is also "plug-in," fitting over a ring mounting on the top of the panel.



ALL WAVE TEST SIGNAL GENERATOR

Fig. 8

The circuit consists of a type 30 tube in a Hartley Oscillator with a 200 ohm potentiometer for a variable control of r. f. output. A variable grid-leak control provides unmodulated or self-modulated output for receiver testing. This resistor, at low values, provides an unmodulated signal and higher values produce a modulated tone due to blocking-grid action. A 1½ volt filament battery and small 22½ volt B battery supply power for the type 30 tube. A two-gang tuning condenser has its sections connected in parallel on the long-wave range by means of a link between two of the prongs of a 6-prong coil form. The condenser shown has a 2-to-1 reducing gear drive shaft.

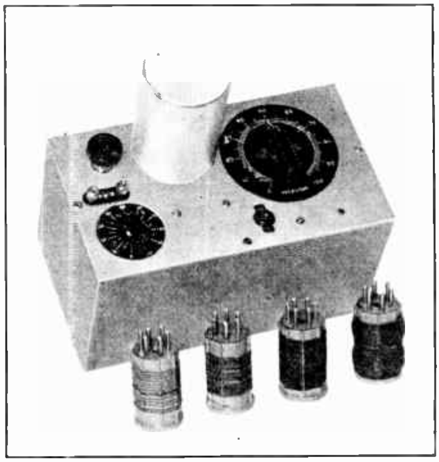


Fig. 9—All-Wave Test Signal Generator in Aluminum Shield Can. The coil is also shielded with a large coil-shield can, as shown

The entire unit, including batteries, is shielded. A 5" x 5" x 9" metal can contains the batteries and parts under 5" x 9" x 12" aluminum top panel. For intermittent use, the batteries will last from six months to a year. Battery supply occupies less space than AC power supply.

Calibration of this oscillator can be accomplished by means of a broadcast receiver. The high frequency range of the oscillator down to 550 KC can be calibrated by means of direct or beat-note reception of known frequency broadcast stations and the oscillator signal. The upper range may be roughly calibrated by extending the curve, or more accurately, by employing the second harmonic which will be audible in the broadcast range in the receiver. Dividing this reading in each case will give the fundamental frequency of the oscillator. The latter should tune to about 350 KC, which makes it useful to line up 450 KC superheterodyne receivers.

If a careful calibration of the fundamental frequency is made on the oscillator, the harmonics may be used to locate short wave stations, either amateur or broadcast. For example, if the shortwave station is listed at 6.01 megacycles, the oscillator can be set at 1502.5, 1202, 1001.66, 858.6 KC etc., which will all give harmonics on 6.01 MC. By checking at least two fundamental points, it is possible to ascertain which harmonic is heard in the short wave receiver. The fundamental of 1502.5 has an harmonic on 4.5 MC which may cause an error, but by swinging the oscillator setting over to 1202, the next fundamental having a 6.01 MC harmonic would give no harmonic at 4.5 MC.

Test Signal Generator Coil Data

Approx. Freq. Range	Secondary 1¼" Diam.	Coupling Coil (over center of sec.)
13 to 4.2 mc. (One tuning condenser)	15 turns No. 24 DSC, C. T., 1½" long (space-wound)	1 turn
5100 to 1600 kc. (One tuning condenser)	38 turns No. 26 DSC, C. T., 1⅜" long (space-wound)	2 turns
1800 to 530 kc. (One tuning condenser)	110 turns No. 30E, C. T., Close-wound	5 turns
550 to 150 kc. (Two tuning condensers)	285 turns No. 26 DSC, C. T., Jumble-wound over 1½" of winding length	10 turns

The frequency of a quartz-crystal (a component in a single signal receiver) can be determined very closely by setting the quartz plate on, or leaning it against the grid of the oscillator. At resonance the oscillator will suddenly change, as listened

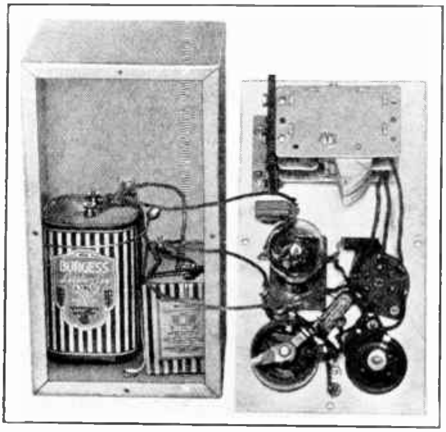


Fig. 10—Interior View of All-Wave Test Signal Generator, Showing Type 30 Tube, Dry Cells, Condensers and Resistors

to in a broadcast receiver tuned to the oscillator second harmonic. This test requires the manipulation of both the oscillator and the BCL receiver, but once the crystal frequency is found, the IF amplifier in the single signal receiver can be lined up to that frequency by means of the oscillator.

Note: Lining up an IF amplifier should always begin at the grid of the tube preceding the last stage of IF transformer. After that transformer is aligned (by ear or output meter), the next preceding stage may be lined up using less coupling to the grid of the next preceding stage. It is emphasized that one must always work with a fairly weak signal, because many sets have AVC which would introduce errors with a strong signal peaking, unless a meter is used.

This test signal generator could make an ideal piece of apparatus for radio clubs. The club members would have a useful piece of equipment for testing new receivers, or aligning old receivers. A few simple pieces of test equipment could be built from club funds and the apparatus could be loaned to members in the same manner as library books are made available to readers. The advantages of a club to its members could be greatly enhanced in this manner.

An AC Frequency Meter-Monitor

● The device here shown uses a type 24 tube as an electron-coupled oscillator, tuned over the 160 meter band. Harmonics of the 160 meter range are used in the 80, 40 and 20 meter bands, and the actual calibration curve shown in Fig. 14 was plotted for the 80 meter band. For 160 meter use, the curve readings would be halved, because frequency in kilocycles is used instead of meters of wavelength.

The oscillator circuit uses a small tuning condenser shunted by a large band-setting condenser. The latter is adjusted only when calibrating the frequency meter. The smaller condenser has a vernier dial which can be read accurately for frequency determination.

The 56 tube is used as a detector, beating the external signal against the 24 oscillator fundamental or one of its harmonics. A slight external coupling through a pin jack to the grid of the 56 can be used to pick-up low power transmitter signals. The same coupling can be used to provide a beat note

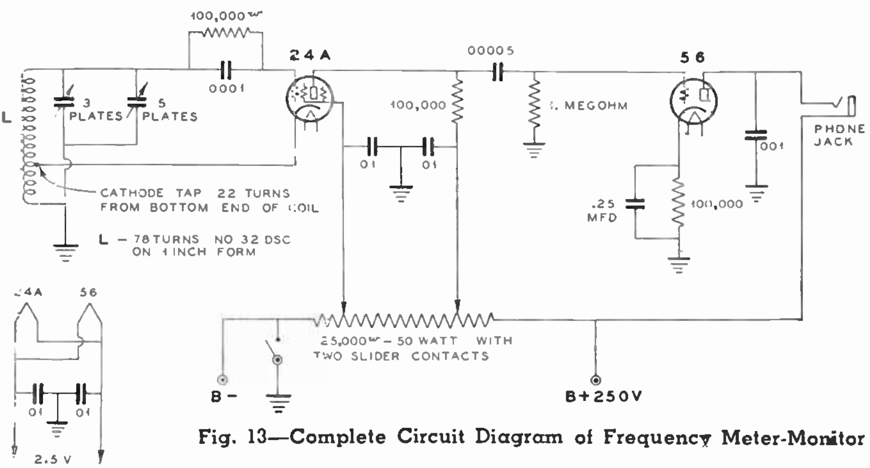


Fig. 13—Complete Circuit Diagram of Frequency Meter-Monitor

into a receiver for checking the frequency of received signals.

The pictures show the constructional details. Of paramount importance is good rigidity and well-soldered connections. The coil is made of 78 turns of No. 32 DSC wire, wound to cover about one-inch of space on a one-inch diameter bakelite tube. The cathode tap is made at a point 22 turns up from the ground end of the coil winding.

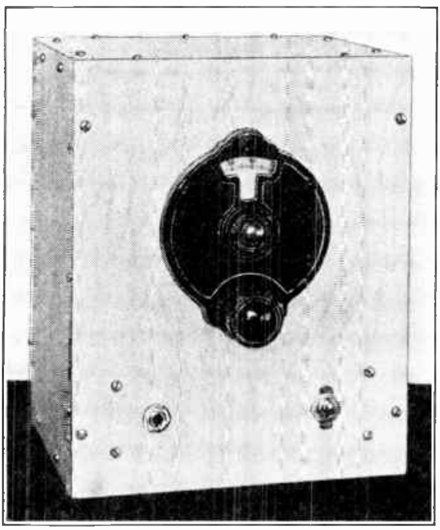


Fig. 11—Front View of Frequency Meter-Monitor

The filament and B supply can be taken from the receiver power supply. A switch is provided which opens the negative B lead to the frequency meter ground, making the instrument inoperative, when desired. The filaments or heaters should be turned on during all of the time the receiver or transmitter is to be operated. About a half-hour warm-up period should be allowed before calibration is made, in order to minimize frequency creepage.

This instrument can be calibrated either from standard frequency transmissions in the amateur bands, or by means of broadcast station transmissions. The latter are required by law to operate within 50 cycles of their assigned frequency, and most of the higher power or better stations operate within 10 to 15 cycles of their exact assignment. A broadcast receiver can be used to pick up these stations and a small oscillator using a B battery, a couple of dry cells and a type 30 tube can be used to "zero beat" any particular received broadcast station. An electron-coupled oscillator capable of tuning across the broadcast band will give stronger harmonics than a type 30 tube oscillator in this range, therefore a serviceman's test oscillator should be used if possible. The local oscillator with zero beat to a station on 880 KC, for example, will have a second harmonic on 1760 KC in the 160 meter band. The fourth harmonic would be 3520 KC in the 80 meter band, the 8th harmonic on 7040 KC in the 40 meter band, and the 16th harmonic, if audible, on 14,080 KC in the 20 meter band. The frequency meter is used to beat-note against this frequency and at zero beat, as heard in the broadcast band receiver and also in the frequency meter. An exact calibration point can be obtained. Several broadcast stations can be used to provide "harmonics" in this manner for several calibration points of the frequency meter.

Graph paper with 10 divisions to the inch, both horizontally and vertically, (100 squares to the square inch) is used for drawing the curve. Fig. 14 shows a typical 75-80 meter (3500 KC to 4000 KC) curve as plotted

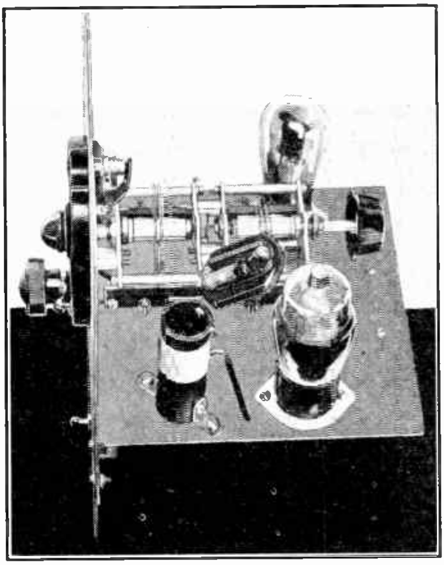


Fig. 12—Interior View of Frequency Meter-Monitor. Note Placement of Grid Condenser and Wide Spacing of Coil from Metal Chassis

from the frequency meter here described. The horizontal line at the bottom of the graph denotes the tuning dial scale divisions from 1 to 100, but marked only in units of 10 on the graph paper. The vertical portion of the graph is used to denote frequency in kilocycles, beginning with 3400 KC and ending with 4000 KC. Similar charts can be plotted for the other amateur bands.

The first requirement is to find a certain frequency, such as 3500 KC, so that the curve-plotting process can begin. Standard frequency transmissions are sent on the amateur bands at regular intervals.

When the standard frequency station announces (in telegraphic code) that it will transmit on 3500 KC, the receiver in the amateur station is then tuned to 3500 KC in such a manner that 3500 KC falls at the extreme end of the tuning dial . . . at the 100 degree scale indication on the dial. Then with the chart at hand, and the standard frequency of 3500 KC known, the amateur receiver is tuned to zero-beat. This found, the frequency meter dial is rotated until a point is found where the frequency meter also zero-beats with the receiver. The next step is to observe the setting of the frequency meter dial, also the setting of the amateur receiver dial. If the receiver dial is at 100° for 3500 KC, and if the frequency meter dial is at 80°, a dot is placed on the graph paper at a point where the vertical line which corresponds with No. 80 on the horizontal line crosses this line, as shown in Fig. 14. This point of intersection will be the 3500 KC point on the graph curve.

If a station asks you to check its frequency, you first zero-beat the signal on your receiver, then you zero-beat the frequency meter against the receiver. You next observe the setting of the frequency meter tuning dial and by means of the graph you can quickly find the frequency of the station which asks you for a frequency check. Suppose this signal is found at 600 on the frequency meter tuning scale; running your finger UP on the chart, you find that 60 on the horizontal line intersects with 3600 on the vertical line. Thus the frequency of the station you are checking is 3600 KC.

To check the frequency of your own transmitter, zero-beat the frequency meter against your transmitted signal and find the frequency from the curve.

Because there are 10 dividing lines for each unit of the graph, the frequency can be quite accurately shown, perhaps within 2 or 3 KC of the exact frequency. On the other hand, there are 100 points on the horizontal line, so that the entire dial sweep from 0° to 100° can be easily followed.

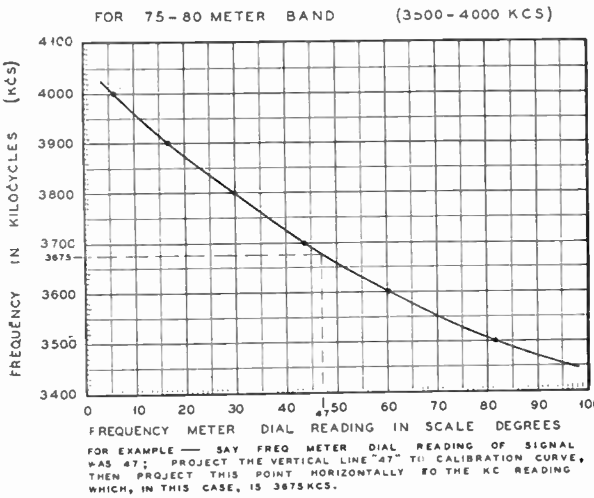


Fig. 14—Frequency Meter Curve

Schedule of Radio Emissions of Standard Frequency

● The National Bureau of Standards has a regular schedule of standard frequency emissions from its station WWV, Beltsville, Md., near Washington, D. C. These broadcasts are available to transmitting stations for adjusting their transmitters to exact frequency, and to the public for calibrating frequency standards and transmitting and receiving apparatus.

These broadcasts are given on three days a week on three single frequencies 5000, 10,000 and 15,000 KC. Those transmissions on 5000 KC are particularly useful at distances within a few hundred miles from Washington, those on 10,000 KC are useful for the rest of the United States, and those on 15,000 KC are useful in the United States and other parts of the world as well.

Each Tuesday, Wednesday and Friday (except legal holidays) three frequencies are transmitted as follows: noon to 1 p. m., Eastern Standard Time, 15,000 KC; 1:15 to 2:15 p. m., 10,000 KC; 2:30 to 3:30 p. m. 5000 KC.

The transmissions consist mainly of continuous, unkeyed carrier frequency, giving a continuous whistle in the phones when received with an oscillating receiver. For the first five minutes the general call (CQ de WWV) and the announcement of the frequency are transmitted. The frequency and the call letters of the stations (WWV) are given every 10 minutes thereafter.

The accuracy of the frequencies transmitted is at all times better than a part in five million. From any of them, using the method of harmonics, any frequency may be checked.

Making Zero-Beat Adjustments

● Methods for making accurate zero-beat adjustments between two oscillators or carrier frequencies are given herewith:

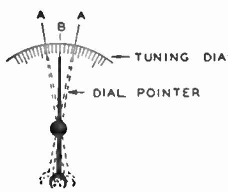


Fig. 15

"A-A" are the two sides of the signal having the same "beat note" (tone). "B" is the "zero beat" point (no tone).

To make a zero-beat adjustment between a transmitter and an oscillating receiver the first requirement is that a continuous wave (CW) signal be received, properly identified, then the receiver set to zero-beat. Second, the regeneration is reduced in the receiver until oscillation nearly stops. The receiver is next tuned slightly and the beat note heard (the strength of the note will be somewhat weaker) should be carefully reduced to zero frequency. When the condition is recognized, the receiver will be in EXACT zero-beat with the received signal. Unless a beat-frequency indicator is used, a telephone headset will match the two frequencies to within one cycle. Precaution must be exercised during an audible adjustment due to the fact that the zero state may be more than one cycle per second.

To zero-beat two carrier frequencies such as a local oscillator and transmitter signal, all that is required is the use of an oscillating receiver. First, the transmitter signal is picked-up and the oscillating receiver made to zero-beat with it. Next, the beat oscillator is turned on and made to zero-beat with the receiver. The frequency of the receiver is NOT varied during this procedure. Now, says J. K. Clapp in an issue of the I. R. E. Proceedings, "If the frequency of the oscillating receiver is moved away from the zero audible beat setting an audible beat tone of, say 1000 cycles is heard, the difference frequency between the signal and the local oscillator will be heard in the form of a waxing and waning audio-frequency tone. If the frequency of the receiver is varied slightly, thereby changing the audio-frequency, no change in the rate of waxing and waning occurs, showing that the beat is between the signal and the local oscillator. If the waxing and waning does *change* when the receiver frequency is varied, the beat note is between the wrong pair of oscillators, and the adjustment should be made again with more care—after the waxing and waning beat is heard, the oscillator may be readjusted to bring the rate of waxing and waning to one, or less cycles after which the two frequencies will be matched to within one cycle."

Absorption Type Wavemeter

● Known as "the old stand-by," this simple wavemeter is useful in every amateur station. It consists of a tank circuit which, when tuned to resonance, gives a visual indication of resonance by means of a glow from a flash light globe or neon lamp. Peak resonance is indicated by peak brilliance of the lamp. This wavemeter will not operate on harmonics or beats. The principle of operation is simple. Several methods of indicating devices and a suggested design for the wavemeter are seen in the diagram, Fig. 16.

A shows the tuned tank system with an aperiodic circuit (looped lamp). The lamp is lighted by means of RF induced in the tank circuit.

In *B* resonance is indicated by a flashlight globe shunted across approximately one inch of the lead. This is one of the best methods to use because it tunes very sharply and the indication of resonance is sharper on the condenser tuning scale than the system shown in *A*.

C is a variation of *B*, except that the coil is tapped instead of being of the plug-in type.

D uses a neon lamp as the medium of indication.

A RF meter can be substituted for the lamp in any of the systems shown.

The wavemeter can be calibrated by checking it against a frequency meter. Or the "click" method can be used. Couple the

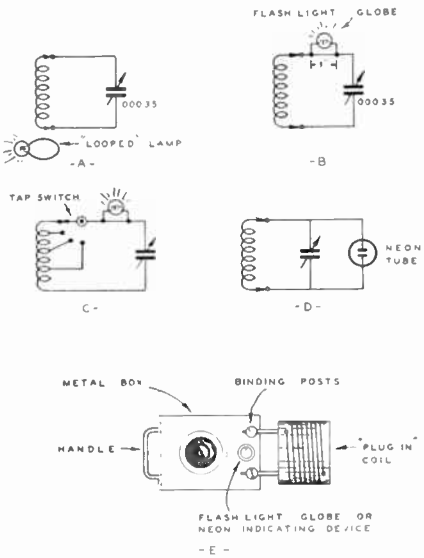


Fig. 16

wavemeter to the detector of a regenerative circuit, or to the oscillator of a superheterodyne and by tuning the wavemeter to resonance a distinct "click" is heard in the headphone connected to the receiver. There will be an error in the calibration due to the value of frequency of the IF amplifier used in the receiver. This value can be rechecked and a curve can be plotted, so that ultimately the wavemeter can provide calibration within 10 KC, depending upon the type of circuit used.

A high C tank is best for sharp tuning. With a .00035 mfd. condenser, the following coils will cover the amateur bands with fair accuracy:

160 Meters: 36 turns, No. 18, close wound on a 4-inch diam. form.

80 Meters: 18 turns, No. 18, spaced one diameter on a 4-inch diam. form.

40 Meters: 8 turns, No. 18, spaced ¼-inch between turns on a 4-inch diam. form.

20 Meters: 4 turns, No. 18, spaced ½-inch between turns on a 4-inch diam. form.

10 Meters: 8 turns, No. 14, spaced one diameter on a one-inch diam. form.

5 Meters: 4 turns, No. 14, spaced one diameter on a one-inch form and tuned with a 3-30 mmf. condenser.

The coil turns should be secured by applying small drops of household cement or "coil dope" to the turns. Clear lacquer is also suitable for this purpose. The wavemeter should be housed in a metal can and the variable condenser rotor should be grounded to the can. A wavemeter of this type for 5 and 10 meter operation can be made by winding a small coil of bare wire, "air-wound" and supported directly to a midget variable condenser. This unit is then mounted on a support strip and the variable condenser is equipped with a bakelite rod, about 1 foot long, with the control knob at the end farthest from the tuning unit. Another rod is attached to the support which holds the condenser and coil, so that the wavemeter can be held in one hand by means of this rod, the other hand being used to turn the long bakelite rod which varies the capacity of the tuning condenser. A 5 and 10 meter wavemeter of this type is *not* housed in a shield can.

Over-Modulation Indicator

● One of the Federal Communication Commission requirements is that every phone station is required to have a means for determining the limit of modulation. Thus, an over-modulation indicator must be in constant service when the phone transmitter is in operation.

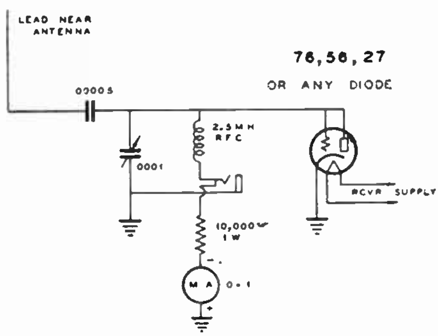


Fig. 17—Circuit Diagram of Overmodulation Indicator

The Linear rectifier shown in Figure 17 will indicate the slightest amount of carrier shift, which means over-modulation. The instrument is simply adjusted by varying the capacity of a small condenser; thus, the optimum meter deflection is obtained without resorting to coil-coupling schemes. The 50 mmfd. fixed condenser and 100 mmfd. variable condenser form a variable attenuator for RF voltage. The instrument is capacitively coupled to the antenna by running a line from the unit close to the antenna lead-in or feeder.

Fig. 18—A Piece of No. 12 Gauge Aluminum Is Bent in One Piece to Provide a Mounting Stand for the Overmodulation Indicator

The indicator is built into a 4" x 12" x 14" gauge aluminum strip, bent as shown in the photograph. The wiring details appear in the schematic. The RF choke is of the pie-wound type and is connected in the circuit so as to allow monitoring the modulated signal; monitoring CW signals will show up key-clicks in the headphones and the meter can be used to show relative radiation.

The needle on the meter should remain stationary at some fixed reading on the scale, such as half or two-thirds maximum deflection.

This form of over-modulation indicator cannot be used with controlled carrier modulated transmitters. For such transmitters, a 45 or 80-tube, or 879 should be connected in such a manner as to indicate negative peaks, and the transmitter monitored by a selective superheterodyne receiver with crystal filter, in order to test for voice transitions outside the channel in use. Such an indicator acts as a half-wave rectifier with its plate connected to the filament center-tap of the modulated class C stage and its filament connected through a 0-5 or 0-10 Ma DC meter and a 10,000 ohm resistor to the plate RF return circuit of the class C stage before it reaches the plate modulator.

A cathode-ray oscillograph is the best indicator for over-modulation. The trapezoidal figures readily show distortion and modulation capability even more clearly than the sine wave figures. The trapezoidal figure requires only a simple form of oscillograph.

Cathode-Ray Oscilloscope

● A sketch of a modern cathode-ray tube is shown in Figure 19. The device functions as follows: A filament heats a tube called a cathode, and negatively charged particles of electricity are emitted in all directions. These electrons are attracted by a positively charged plate called an anode. This anode has a perforation in its center and a stream of electrons shoots out through this opening and impinge upon a chemically treated surface (willemite or calcium-tungstate) called a screen, which is at the top end of the tube. Electrons striking this surface produce a glow or fluorescence which in turn varies with the intensity of the element controlling the flow of electrons. A negatively charged cylinder concentrates the electrons emitted by the filament so that practically all pass through the small hole in the anode. The percentage of electrons passing through the hole in the anode depends upon the size of the hole, the field between the cathode and the anode, the shape of the surrounding electrodes, electrical conditions about the anode, and other factors dependent upon the temperature of the anode which are too numerous to mention. Possibly the fraction passing through the hole can vary from one-ten millionth or less to possibly one per cent of the electrons. The energy given to the electron to pass to the chemically treated screen can only be approximated by direct experiment; however, the electrons gain their energy from the electrical accelerating field.

Sweep Circuits

● In order that the wave form of phenomena producing a vertical deflection may be viewed, a horizontal deflection is applied to sweep across the screen at a uniform rate. The linear time sweep may traverse the screen only once when observing a non-recurrent wave form, or it may be arranged to be returned rapidly to its starting position and to repeat the linear time sweep.

When the frequency of the wave form to be observed is a multiple of the repetition frequency of the linear time sweep, the wave form remains stationary on the screen.

The number of cycles of the wave appearing throughout the sweep on the screen shows the ratio of the frequency of the wave form to the frequency of the linear sweep voltage. Thus, a sweep frequency of 3,000 cycles per second shows four cycles of a 12,000 cycle per second wave-form.

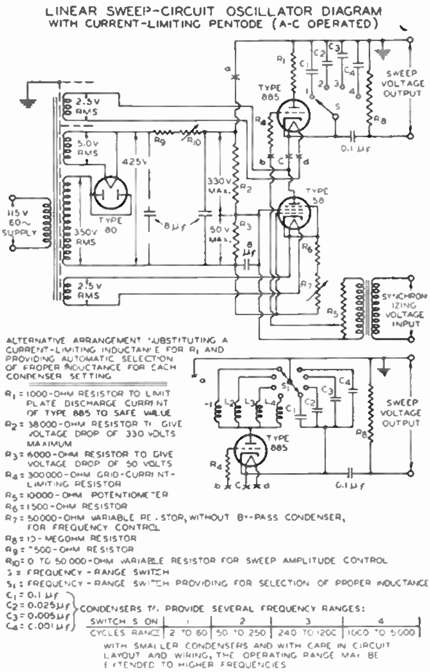


Fig. 19

A linear time sweep generator with good linearity, short-return sweep time, excellent frequency stability, and adjustable in frequency over the complete audio-frequency spectrum, is available with the present tubes. The type RCA-885 gas-filled triode tube was especially designed for this service. With suitable circuits, a sweep of 200 volts amplitude (or by special arrangements, 400 volts amplitude) can be obtained. The linear time sweep is generated by charging a condenser at a constant current rate. The constant current characteristic of the plate circuit of a pentode amplifier tube is used preferably as the constant-current controlling device. A diode operated at low filament voltage to produce saturation may also be substituted for this purpose. Another means consists in using only a small portion of the initial charging curve of the condenser.

Scanning or Deflecting the Cathode-Ray Beam

● The scanning of cathode rays upon the fluorescent screen is done by deflecting the beam of electrons vertically and horizontally, that is, in a zig-zag fashion until the whole surface of the screen has been irradiated.

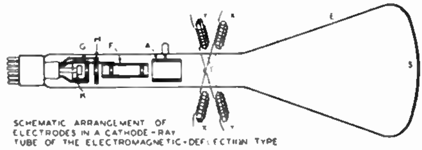


Fig. 20

The deflecting action may be accomplished by either electro-static or electro-magnetic fields. The fields must be at right angles to each other and must intersect at the tube axis. In practice, one field is controlled by the current or voltage under observation; the other is controlled by an alternating voltage to give a desired timing control. The field serves to spread the rays or tracing over the fluorescent screen. Whatever method is employed for deflecting the electronic beam, it need only be remembered that the rays are attracted or repelled by the charges in the electric field.

Notes

● An oscilloscope is easily affected by stray AC fields due to power transformers or filter chokes not being electro-magnetically shielded. This condition shows up as a curvature or ellipse of the straight line on the screen when an AC voltage is impressed on one set of the plates. Stray RF fields from a relatively high-powered buffer stage will sometimes prevent a thin line from appearing on the screen when preparations are being made to test a final amplifier stage. The best method is to amply shield the transmitter, although in some cases shielded leads and a separate ground connection will solve the problem.

Radiotelephone Transmitter Circuit Connection to Cathode-Ray Oscilloscope

● The diagrams show how to measure the modulated RF wave of a radiotelephone transmitter with the aid of an Oscilloscope. This connection does not measure the audio-frequency characteristic of the speech amplifier and modulator.

The RF coupling and audio output voltage to the Oscilloscope are adjusted to give the desired size of figure on the cathode-ray

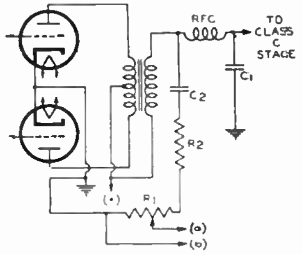


Fig. 21—Audio-Frequency Pick-up from Modulator for Connection to One Set of Oscilloscope Plates

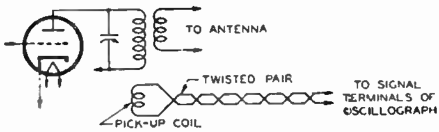


Fig. 22—R-F Pick-up for Connection to Plates of Cathode-Ray Oscilloscope

tube. The circuit connection here shown will provide trapezoidal figures for testing or monitoring the percentage of modulation.

Applications of Cathode-Ray Tubes

● Fundamentally, the cathode-ray tube may be regarded as an electron pointer or the movement of an uncalibrated electrical indicating device. The calibrating scales and circuit are provided by the user to suit the conditions under which measurements or indications are being made. Only a few practical applications are given here, others of more wider scope are found in treatises solely devoted to this phase of the subject.

One of the simplest uses of the cathode-ray tube is in the measurement of voltage. This is most conveniently done with the electro-static deflection type of tube. The displacement of the spot on the screen is directly proportional to the applied voltage. When a DC voltage is applied, the polarity as well as the magnitude is indicated by the displacement of the spot. When an alternating voltage is applied, the spot sweeps back and forth with an amplitude proportional to the peak-to-peak value of the applied voltage. For example, a 10-volt r.m.s. sine wave produces a sweep with an amplitude equal to 28-volts. At frequencies above 8 cycles per second, the sweep of the spot appears as a line, due to the persistence of vision. There is no error due to frequency until extremely high-frequencies are reached. Overvoltage on the deflecting plates, which is not excessive merely sweeps the spot off the screen. Thus, the cathode-ray tube, being rugged, having a high-impedance, and being independent of frequency, is useful as a peak voltmeter.

Since the electron beam can respond to several deflecting fields simultaneously or in rapid succession, the cathode-ray tube can be admirably applied to time or frequency comparisons. The feature of being able to combine in the cathode-ray tube the effects of two or even more factors makes it possible to obtain graphical results directly on the screen.

Application Notes

● The high voltage anode of the cathode-ray tube requires 1000 volts DC for proper operation. Also DC voltages are required for the amplifier. The RCA-879 tube (rectifier) is used in a half-wave rectifying circuit for providing the necessary anode voltages for the RCA-906. The 80-type tube, connected in a full-wave rectifying circuit is used for both rectifiers, individual filter circuits are provided. The transformer is oversize to prevent stray magnetic leakage that would otherwise affect the operation of the cathode-ray tube.

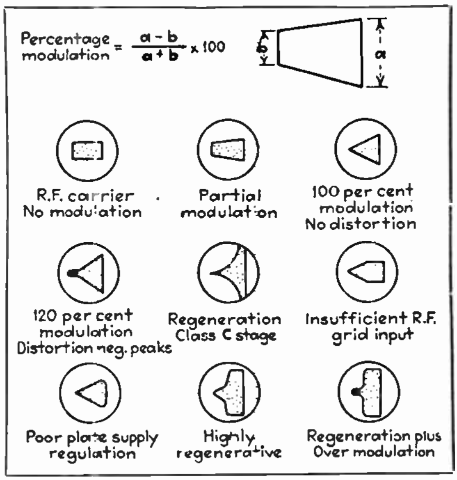


Fig. 23—Oscilloscope Chart, Showing Typical Trapezoidal Readings of a Phone Transmitter when Sweep Circuit Is Not Used

In application involving extremely accurate measurements, the current to anode (2) should be reduced to the minimum value consistent with the desired brilliance of pattern. Where brightness is an important consideration, it may be obtained by increasing the voltage applied to anode (2) up to the maximum value. This practice, however, is not always desirable since the greater acceleration of the electrons in the beam causes reduced deflection sensitivity.

It should be noted that the beam produc-

FIG. 1—Phase relation between two AC voltages in an audio amplifier system.

FIG. 3a—400 cycle audio waveform.

FIG. 3b—Grid Modulation—ideal condition.

FIG. 3c—Grid Modulation—over modulated.

FIG. 3d—Grid Modulation—with too much RF grid excitation.

FIG. 3e—Grid Modulation—partially modulated.

FIG. 3f—Grid Modulation—To much positive grid current.

FIG. 3g—Grid Modulation—100% modulation.

FIG. 3h—Grid Modulation—Final tank circuit detuned from resonance.

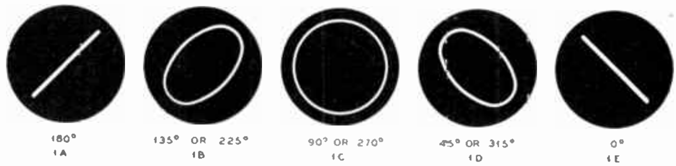
FIG. 4a—Grid Modulation—Same adjustment as FIG. 3g.

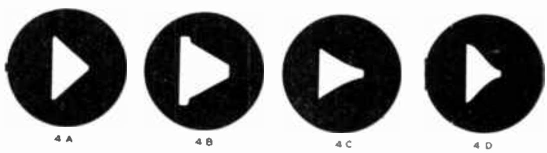
FIG. 4b—Grid Modulation—Typical adjustment, heavily modulated with excessive RF excitation and output.

FIG. 4c—Grid Modulation—Same as 4b with no grid current when unmodulated.

FIG. 4d—Grid Modulation—RF excitation very low and over-modulated.

FIG. 4e—Grid Modulation—about 50% modulated.





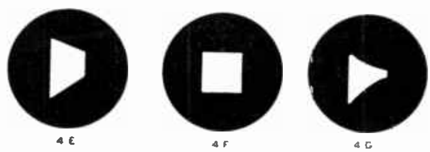


FIG. 4f—Grid Modulation—Zero per cent modulation.

FIG. 4g—Grid Modulation—Same as FIG. 3h plate tank detuned.

FIG. 24—Oscilloscopic Patterns for Grid-Modulated Phone Transmitter.

ing a spot of high intensity will burn the fluorescent screen if it is allowed to remain stationary even for a short interval. Such operation may cause excessive heating of the glass with resultant puncture. To prevent this possibility, it is recommended that the beam be kept in motion. It is well to apply controlling voltage to the deflecting system before permitting the electron stream to flow. Stopping of the electron beam may be accomplished by removing the voltage on anode (2) or by increasing the bias on the control electrode to cut-off.

Users of cathode-ray tubes are cautioned to strictly observe the technical information printed on bulletins packed in the tube cartons. Emphasis must also be stressed on the fact that extremely high voltages are applied to the tube and every precaution must be observed to keep from coming in contact with these potentials—fatalities can occur.

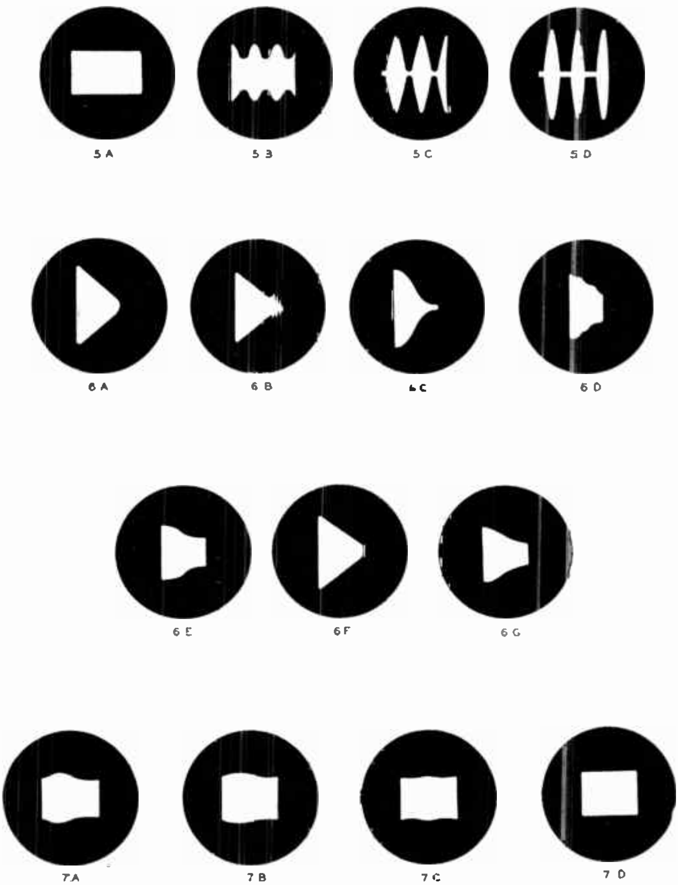


FIG. 5a—Plate Modulation—Carrier only.

FIG. 5b—Plate Modulation—Partially modulated.

FIG 5c—Plate Modulation—100%.

FIG. 5d—Plate Modulation — Over modulated.

FIG. 6a—Plate Modulation—100%.

FIG. 6b—Plate Modulation — Best adjustment obtainable with insufficient Class B audio by-pass condenser (only 2 mfd).

FIG. 6c—Plate Modulation — Over modulated before reaching normal 100% condition.

FIG. 6d—Plate Modulation—Same as 6c at point of best modulation obtainable. Regeneration, lack of RF shielding, Class B trouble and too heavy antenna loading.

FIG. 6e—Plate Modulation—Maximum modulation with Class B greatly mismatched to Class C load.

FIG. 6f—Plate Modulation—Maximum modulation with too heavy antenna load.

FIG. 6g—Plate Modulation—With insufficient grid RF excitation.

FIG. 7a—CW carrier with one section filter on final stage and saturated choke.

FIG. 7b—CW carrier with one section using larger choke.

FIG. 7c—CW carrier with two section filter, both filter chokes too small.

FIG. 7d—CW carrier 2 section filter with large chokes.

Fig. 25
Oscilloscopic Patterns for Plate-Modulated Phone Transmitter

Oscilloscopic Studies of Grid and Plate Modulation

● Interesting comparisons between grid and plate modulation can be revealed through the medium of the cathode-ray oscilloscope. The tracings accompanying these paragraphs portray the conditions under which the average phone transmitter operates.

In general, both grid and plate modulation systems can be made to produce nearly 100 per cent distortionless modulated output. The difficulties encountered are about equal; for the average amateur station, grid modulation is more easily adjusted for 20-meter operation, and plate modulation is easier adjusted on 80 and 160 meters, due to excitation problems. A correctly adjusted plate modulated phone presents a number of problems, the magnitude of which can be verified by listening-in to several radio-telephonic transmissions.

Notes For Test Records and Data

Chapter 18

POWER SUPPLIES

● A source of high voltage direct current must be applied to the plate electrode of a vacuum tube in order that the tube may properly function. The power is usually obtained from the AC mains. It is then transformed, rectified and filtered to produce a uni-directional current.

All vacuum tubes are rectifiers in principle and can be used for converting alternating currents into direct currents. In general, there are two types of rectifiers known as the half-wave and full-wave types. In a half-wave rectifier, the tube passes one-half of the wave of each alternation and blocks the other half; thus current flows for half the time and drops to zero the other half of the time. This causes a very uneven voltage output, because it varies from zero to maximum 60 times per second. Half-wave rectifiers produce a pulsating unidirectional current having a large undulatory DC characteristic.

To minimize the pulsations, and to make the current flow in a more continuous manner, a full-wave rectifier is used. This type of rectifier consists of two tubes, each connected to one end of the secondary of a transformer with a grounded center-tap connection. When one end of the transformer winding is going through the most positive part of the cycle, with respect to the center-tap, the other end of the transformer is most negative. Therefore, when one tube is conducting, the other is inoperative (plate negative with respect to the cathode); one-half cycle later, the other tube conducts and the first is non-conducting, such is the process of full-wave rectification. The output voltages from the tubes are connected together through a common rectifier tube filament circuit, and thus the tubes alternately supply current to the output circuit which is connected between the filament winding of the tubes, and the center-tap of the high voltage transformer. The rectifier filaments are always positive in polarity.

Full-wave rectifiers deliver a direct current pulsation 120 times per second instead of one pulsation for each cycle, therefore, the variation in output voltage is less. However, the pure direct current required for the amplifier tube is not yet available, so that some form of a low-pass filter must be placed between the rectifier and load.

A low-pass filter is a device which selects and passes certain types of electric currents and rejects and by-passes other unwanted types. It should be remembered that a pulsating DC voltage might be considered as that of a pure DC voltage which has a somewhat smaller alternating voltage superimpressed on it. In other words, the combination of the two voltages is, in every respect, exactly similar to the pulsating DC voltage output of the rectifier.

All filters and filter operations are designed to select and reject alternating currents. The characteristic of the alternating current which enables the filter to function in the aforesaid manner is its frequency. A low-pass filter offers little impedance to the passage of alternating currents of low frequency, but materially impedes the flow of such currents of high frequency. DC can also be considered as AC of zero frequency, thus passes straight on through a low-pass filter to the load with little or no impedance. On the other hand, the pulsations, or ripple consists of an AC current having a frequency of 120 cycles per second (twice the mains frequency) which the low-pass filter prevents from reaching the load where it would make its presence known as hum. A low-pass filter generally consists of two elements; an inductance, or choke coil, placed in series with the load, and one or more capacities (filter condensers) shunted across the load. An inductance or choke coil is a device which resists any change in that current that flows through it, and it offers a relatively high resistance to the flow of a varying current. The more variations there are per second, the more resistance it offers to the flow. Because it is in series with the load, the AC component (or ripple) passes with only the greatest of difficulty.

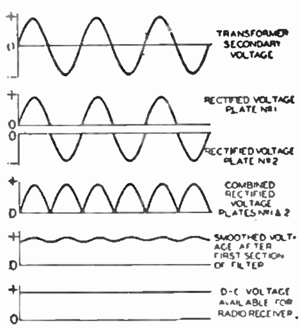


FIG. 1—Showing effects of rectification and filtering of an AC current.

On the other hand, a capacity (or condenser) is a device which has exactly the opposite action to that of a choke. It offers a relatively low impedance path to the flow of alternating or pulsating current and yet represents a very high or often an infinite resistance to the flow of direct current.

Electricity always follows the path of

least resistance. Thus the DC will choose to travel through the choke and back to ground through the load serving the useful function of attracting electrons from the filament over to the plate of the amplifier tube on its way. The AC component, or ripple, on the other hand, faces a high resistance in the choke, but a very easy path back to ground, where it seeks to go, through the condenser. It also chooses the path of lowest resistance, and consequently is by-passed directly to ground. The choke prevents the AC ripple from reaching the plate circuit of the amplifier tube, where it would cause undesirable hum.

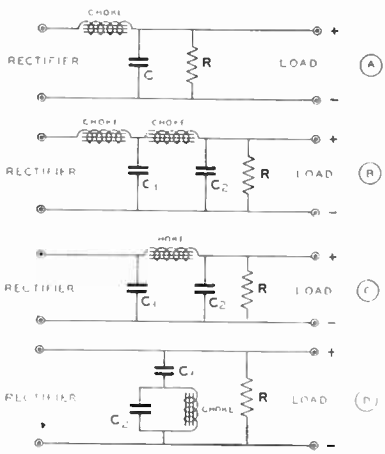


FIG. 2—Common types of filter circuits.

The first three circuits, a, b, and c, indicate parallel types of filters, and d, indicates the resonant filter connected across the supply line direct from the rectifier. On account of the effectiveness of the filter it is rather bulky and requires large values of inductance and capacity for successful operation. The resonant-type choke requires much less equipment, yet more accurate adjustment. Its application is generally limited to high power equipment, or to installations where proper equipment is available to determine effective filtering efficiency. For simple amateur installations, the "brute force" filter in some of its many forms will prove to be highly practicable.

For amateur applications, the ripple voltage must not exceed about 1 per cent for radio telephone service, in the audio and preliminary amplifier stages. With crystal-control the power supply to the final stage (often isolated) should have no more than 5 per cent ripple, and preferably much less. The simplest way to determine ripple voltage is to measure it with a voltmeter, and from reliable reports from other stations, as to whether or not the "carrier" is pure DC.

The diagram, Figure 3, shows a simple scheme for measuring the ripple voltage with the aid of a fixed condenser (about ¼ to 1 mfd.) and a high-resistance copper-oxide alternating current voltmeter. To make the measurement, connect the apparatus as shown. AFTER THE TRANSMITTER IS IN OPERATION, insert the voltmeter plug in the jack and read the voltage. This will be the approximate RMS ripple voltage (ap-

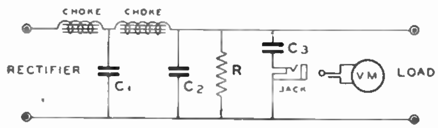
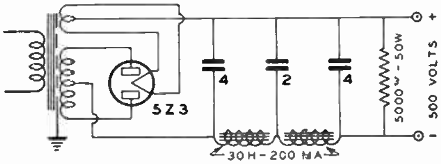


FIG. 3—Measuring ac-ripple.

proximate because it may be altered by the wave shape, and condenser capacity to a certain extent). Before turning off the plate current *remove the voltmeter* from the circuit. If this precaution is not observed when the transmitter is started or stopped, the rush of current caused by the condenser charging or discharging may burn-out or damage the meter. The meter must be connected in the circuit in such a way that it is on the low potential or negative side of the condenser. *Contact with the high voltage can cause a fatal shock!*

Generally, an input filter system, such as shown in Figure 2b, is advisable, especially with mercury-vapor tubes. The choke absorbs energy, similar to a fly-wheel. Due to the high inductance it resists any change in the current flowing through it. The choke coil selected should be large enough to carry the maximum direct current load without heating, and without losing too much inductance. Any coil wound on an iron or steel core has a certain amount of inductance, determined by the size of the core and the size and number of turns of wire wound on the core. The direct current which is impressed on it magnetizes the core, and this reduces the value of inductance. It is quite possible to raise the direct current up to magnetic saturation, in which case the core will cease to exist magnetically, and the effect will be that of a pure resistance. Closed magnetic circuits of steel or iron will saturate quite easily. All cores on properly designed chokes are fitted with a break in the magnetic circuit. Usually this is in the form of a piece of fibre, bakelite, or other material which is inserted between the ends of the laminations; any method of breaking the magnetic continuity will suffice. This gap is commonly called an "air-gap," but for mechanical reasons it is better to use a non-magnetic substance, instead of air as the spacing. Magnetic saturation can be avoided in chokes by liberal design, and by the use of plenty of copper and iron. Iron core material is often cheaper and easier to obtain than the employment of a large number of turns of wire; therefore, chokes should be designed with large cores, the dimensions of which should be kept within certain limits for practicability.

Choke coils are easily built as they contain only a single winding. Care, however, must be exercised in insulating the windings from the core as the winding must often stand the full plate voltage, plus the "peak," or 1.41 times the output voltage which is delivered from the rectifier system.



Standard full-wave rectifier using 5Z3 tube. This tube handles more current than the 80.

The other portion of the "filter" is the capacity, or condenser. The latter consists of two types, paper and electrolytic. Paper condensers consist of two strips of tinfoil, separated by high-voltage waxed-paper, and are available in capacities up to about 2 mfd. for voltages up to nearly 5000 volts. The electrolytic types are available in several voltage ranges of about 450 to 600 volts, maximum, per section, which is usually about 8 mfd. capacity. The action of an electrolytic condenser is dependent upon the fact when pure aluminum is immersed in a solution of sodium borate (other solutions are also used) a very thin film of oxide is formed on the surface of the metal. This film, which is apparently of molecular dimensions, forms the dielectric of the condenser. Because the capacity of any condenser is inversely proportional to the thickness of the dielectric, and directly proportional to the dielectric constant, it will be seen that the very thin film of dielectric will give remarkably high capacities for extremely small areas of aluminum.

Electrolytic condensers have the following disadvantages: single units cannot be made for operation at more than about 450 volts; they draw an appreciable current (a few milliamperes), and, after a few years of service often break down. On voltages higher than 350 to 450 volts, it is necessary to connect several condensers in series, or in series-parallel to obtain increased capacity. Under these conditions it is sometimes necessary to connect an equalizing resistor across each condenser as shown in Figure 4.

Some types of paper condensers are impregnated with wax, and some with oil, especially the higher voltage types. The oil type is most desirous, although more expensive than the ordinary wax impregnated types. Paper condensers are rated for "flash" and "normal operating voltage" test ratings; the first refers to a test, usually about twice

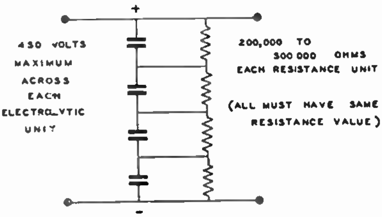
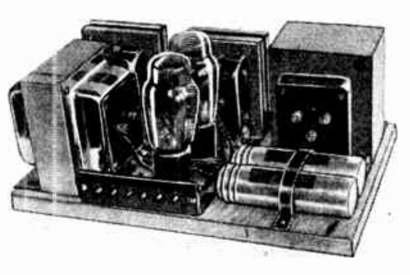


FIG. 4—Electrolytic condensers connected in series plus to minus, with 500,000 ohm, 1 watt, resistor connected across each condenser in order to equalize the leakage and to prevent excessive strain on any one section of condenser.

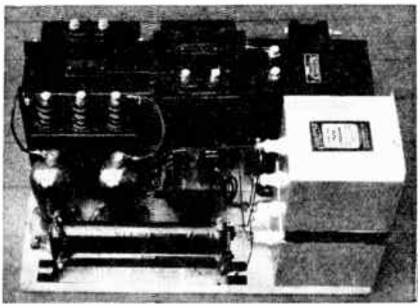
or three times the normal operating voltage of the condenser, and is only a manufacturers' test rating. The normal operating voltage, or working voltage, is the maximum voltage the condensers will be required to stand in service; this value is often the square root of 2, or 1.41 times the direct current voltage. For reasons of safety, it is good practice to use condensers of at least 1.5 times the normal working or operating direct current voltage as read on the output voltmeter across the filter terminals.

All mercury-vapor tubes are rated by their "maximum peak" current and "maximum inverse peak voltage." The "maximum peak" current rating is a measure of the ability of a tube to stand extemely high transient currents. This rating is intended to form a basis for set design in limiting the abnormal currents that occur during short circuit conditions or with certain types of filters. In addition to this rating can be included the "maximum average plate current," this is



Typical low voltage power supply.

based upon tube heating. It is the plate current as measured on a DC meter and represents the highest average current which can be continuously carried through the tube.

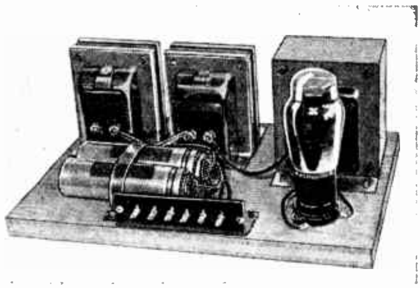


High voltage full-wave power supply using 866 or 866A rectifier tubes.

The "maximum peak inverse voltage" is the highest instantaneous voltage that a tube will safely stand in the direction opposite to that which it is designed to pass current. In other words, it is the safe arc-back limit with the tube operating within the specified temperature range. The relations between peak inverse voltage, the direct voltage, and the r.m.s. value of alternating voltage depend largely upon the individual characteristics of the rectifier circuit and the power supply. The presence of line surges, keying surges, or any other transient wave form distortion may raise the actual peak voltage to a value which is higher than that calculated from the sine wave voltages in the transformer. It should, therefore, be emphasized that the maximum rating of the tube refers to the actual inverse voltage and not to the calculated values. A cathode-ray oscillograph or spark gap connected across a tube is useful in determining the actual inverse peak voltage. In single-phase circuits, the peak inverse voltage on a rectifier tube is approximately 1.4 times the r.m.s. value of the plate voltage applied to the tube. In poly-phase circuits the peak inverse voltage must be determined vectorially.

Clarifying some points in the above paragraph it can be said that the maximum inverse peak voltage depends for its value on the peculiar qualities of alternating currents, where the usual type of thermo-couple, dynamometer, or similar common types of meters actually give the "square root or mean square," or r.m.s. value of the current, or voltage in a circuit. This means that ordinary meters read the effective current or voltage, or that which would cause the same heating effect by an equivalent direct current. In an AC circuit the maximum peak voltage or current is the square root of 2, or 1.4 times that indicated by the meter reading. In other words, in an AC circuit, with say 100 volts indicated, the actual peak voltage is 141 volts. In a simple half-wave rectifier system, therefore, with 1000 r.m.s. volts across the transformer secondary, there will be 1,410 volts peak voltage, and a single half-wave rectifier tube would have this voltage impressed on it, either positively when the current flows, or "inverse" when the current does not flow. The inverse peak may be twice this value if condenser input filter is used in a half-wave rectifier. With a full-wave system with a center-tap transformer, the voltage across the entire secondary will be twice that of a similar half-wave system, or 2,000 volts, applying the above example. The maximum peak inverse voltage across each tube when not conducting (negative half of the cycle) will be 2,000 x 1.41, or 2,820 volts. Obviously, care must be taken in the choice of rectifier tubes and associated equipment, because it is the peak voltage which breaks down the insulation and causes failure.

In the rectifier output circuit the two half-waves combine to form pulsating direct current, and the peaks of this current are also 1.41 times the indicated, or average value. This means that all units, such as condensers, etc., must be arranged to withstand this voltage.



Power supply for c-w operation. Low capacity filter condensers are used.

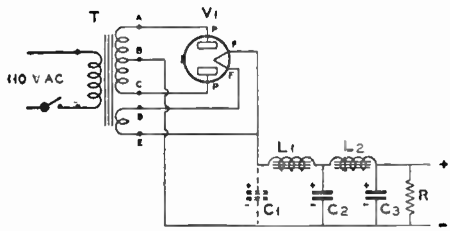
The voltage regulation of a rectifier and filter system must be given careful attention in the design of a power supply. It depends on the selection of a power transformer of substantial size and a reasonable overload capacity; the secondary should be of low resistance, and the transformer so designed that the voltage will not drop appreciably when the secondary load is increased. The selection of the proper chokes, of low resistance and high inductance and of low saturation, all contribute to the maintenance of good regulation in the power supply unit. The use of the so-called "swinging choke" which changes its inductance with variation in load, is also a help in this direction.

A heavy-duty resistor should be connected across the filter output so as to draw an appreciable load. This "bleeder" resistor should normally draw about 10 per cent of the full-load current. The resistor places a load on the system so that a chance open-circuit will not allow the condensers to build up to the full 1.4 times the normal voltage which, obviously, would place a strain on the entire system. A bleeder resistor must be wire-wound, preferably of the 50 or higher-watt dissipating variety. This resistor also helps keep the voltage constant, and to prevent "chirpy" signals when keying a CW or telegraph transmitter.

Technical Note

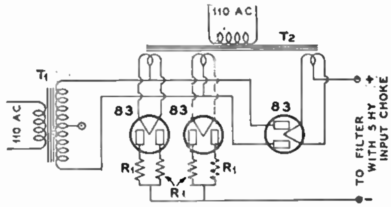
● Bleeder resistors must be mounted so as to allow free circulation of air, and placed as far away as possible from transformers, condensers, and other equipment, or the latter may be damaged from the heat radiated. Ohmic values are given in the table below for bleeder resistors satisfactory for most any amateur transmitter power supply.

Output Voltage	No. of Units in Series	Resistance Ohms	Current Ma
500	1	25,000	20
1000	2	50,000	20
1500	3	75,000	20
2000	4	100,000	20
2500	5	125,000	20
3000	6	150,000	20



When "C1" is connected in the circuit, the filter is termed "Condenser Input." If "C1" is omitted, the filter is called "Choke Input."

A further method of obtaining good voltage regulation is to use choke input to the filter. This is essential for all types of circuits having mercury-vapor tubes. If a condenser is connected directly across the output of a mercury-vapor rectifier system (except in some form of voltage doublers where a condenser is necessary) the condenser will draw nearly the peak 1.4 times the normal current from the rectifier at all times, and will also change the output voltage considerably; thus regulation will be poorer. Except in small units, vacuum type rectifiers with choke input to filters is strongly recommended, both for increased tube and condenser life, and for better regulation. A fuse placed in the power supply system may save a tube, condenser, or other piece of equipment, which costs many times the value of the fuse. It is desirable to mount the chokes in a position of minimum inductive field of the power transformer.



Bridge rectifier suitable for 1000 volt supply. R1 are equalizing resistors, 100 ohms each, 10w.

Plate Supply Circuits and Ratings

● Inasmuch as practically all amateur transmitter plate supplies use mercury-vapor rectifier tubes, the data compiled herein concern this type of tube only. Tubes of this type are rated on the basis of peak inverse voltage, and peak plate current.

Condenser Input

● Where a filter circuit is used having condenser input, the peak plate current per tube in a full-wave circuit may rise to values as

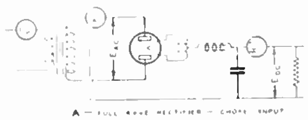


FIG. 1

E_{DC}-435 V
I_{DC}-100 MA
E_{AC}-1100 V
I_{AC}-71 MA
I_{PRI}-.6 MA

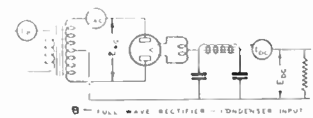


FIG. 2

E_{DC}-675 V
I_{DC}-100 MA
E_{AC}-1100 V
I_{AC}-103 MA
I_{PRI}-.9 MA

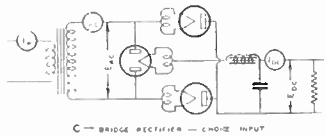


FIG. 3

E_{DC}-860 V
I_{DC}-100 MA
E_{AC}-1100 V
I_{AC}-96 MA
I_{PRI}-1.1 A

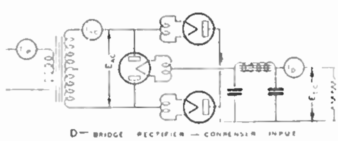


FIG. 4

E_{DC}-1200 V
I_{DC}-100 MA
E_{AC}-1100 V
I_{AC}-148 MA
I_{PRI}-1.65 A

Typical voltage and current readings in various types of power supplies.

great as four times the DC load current depending on the value of input capacitance. This naturally results in poor tube economy. In the case of 866 tubes, for example, the peak plate current of .6 ampere might be reached when the DC output obtained is only .15 ampere. A second factor which limits the application of condenser input filters for amateur work is the poor regulation obtained in such circuits.

Choke Input

● With a filter circuit having a choke input, the peak plate current per tube in a full-wave circuit will generally be about 50 per cent greater than the DC. With a saturated reactor this peak current will be increased as the load current is increased to as high as 2½ times the DC.

With the knowledge of the peak inverse voltage, and the peak plate current of the rectifier tubes, it is apparent that the proper tube or tubes and associated components can be readily determined for any plate supply output. These values for given tubes are enumerated below:

Tube Type	Peak Inv. Volts	Peak Plate Current (amp.)
82	1,400	.40
83	1,400	.80
66	7,500	.6
66A	10,000	.6
72	7,500	2.5
72A	10,000	2.5
869	20,000	5.0

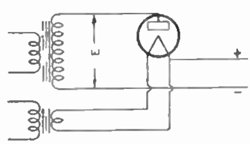
Standard Rectifier Circuits

● Figures 1 to 6 on the facing page illustrate typical rectifier circuits applicable to amateur use. The single-phase half-wave circuit of Figure 1 is not very popular due to the fact that the ripple is of greater magnitude and being of lower frequency than other systems is more difficult to filter. With choke input, the DC voltage will be approximately .45 that of the r.m.s. voltage E. Figure 2 illustrates the full-wave single-phase circuit which every amateur is familiar with. Figure 3 is identical in nature with Figure 2, except that four tubes (more if desired) are used to obtain higher current output. The resistors shown in the plate circuits of these tubes are very essential, otherwise one tube will generally take most of the load with the natural result that the tube life is greatly decreased; a drop of about six volts across these resistors will insure stability. Figure 4 shows a bridge circuit with four tubes, its advantage is that high DC voltages can be secured without expensive (high peak inverse voltage) tubes and with low voltage transformers. For full-wave rectification the DC voltage can be increased by using the entirè secondary output of the plate transformer, in fact, the voltage will be exactly doubled; of course, this halves the current output due to the transformer current carrying limitations. Figures 5 and 6 are similar to that of Figure 2, except that they apply to three-phase circuits. In the circuit of Figure 5, each tube carries current for one-third cycle. The circuit of Figure 6 is very commonly employed in high power transmitters where three-phase power is available due to the high DC output voltage attained. This circuit has the added advantage that the ripple frequency is high, being six times the supply frequency, allowing simple filtering.

Analyzing these rectifier circuits have given the values indicated above as the maximum operating and output values for any of the tubes described.

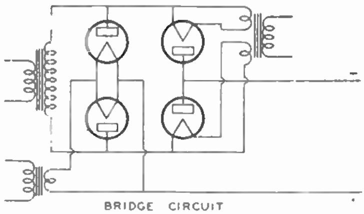
As an example in applying these figures to the 866 tube, it is found that in a full-wave circuit (Figure 2), the maximum transformer voltage E, each side of the center-tap is .35 x 7500, or 2650 volts. This gives a DC voltage at the input to the filter of 2650 $\times$ .9, or 2400 volts. The maximum DC output is .66 times the peak plate current of .6 ampere, or 400 MA. Hence, voltages and currents lower than these values can be used. With a saturated input reactor, the allowable DC is reduced. However, as these saturated reactors are normally used in conjunction with a class B amplifier load, the high DC and peak plate currents are normally of short duration, reducing the tube life by an amount which is not excessive.

Figure No.	Transformer Volts "E"	DC Output Volts at Input to Filter	DC Output Current in Amperes
1	.7 x Inv. Pk. Vtg.	.45 x E	1.33 x Pk. Plate
2	.35 x Inv. Pk. Vtg.	.9 x E	.66 x Pk. Plate
3	.35 x Inv. Pk. Vtg.	.9 x E	1.32 x Pk. Plate
4	.7 x Inv. Pk. Vtg.	.9 x E	.66 x Pk. Plate
5	.43 x Inv. Pk. Vtg.	1.12 x E	.83 x Pk. Plate
6	.43 x Inv. Pk. Vtg.	2.25 x E	1.0 x Pk. Plate



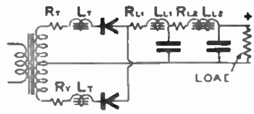
SINGLE PHASE HALF WAVE

FIG. 1



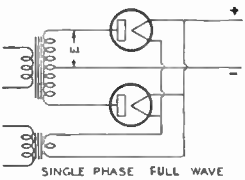
BRIDGE CIRCUIT

FIG 4



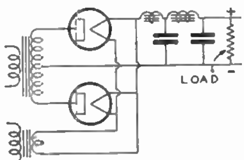
SIMPLIFIED FORM FIG 7

FIG. 8



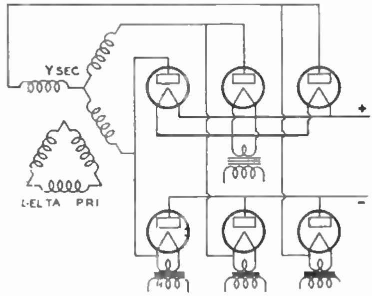
SINGLE PHASE FULL WAVE

FIG. 2



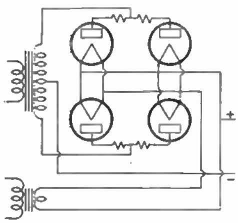
TYPICAL PLATE SUPPLY

FIG. 7



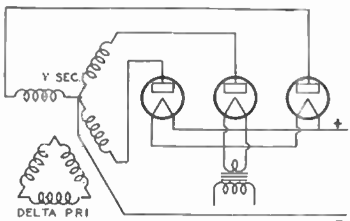
FULL WAVE THREE PHASE

FIG 6



FULL WAVE PARALLEL TUBES

FIG. 3



HALF WAVE THREE PHASE

FIG. 5

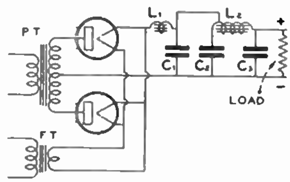
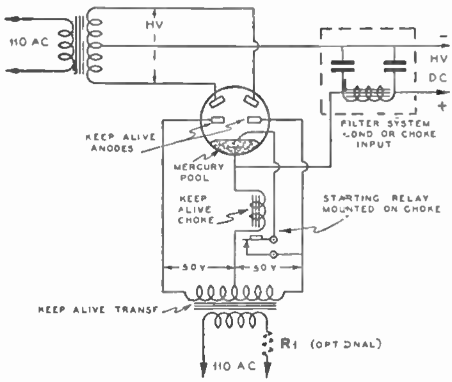
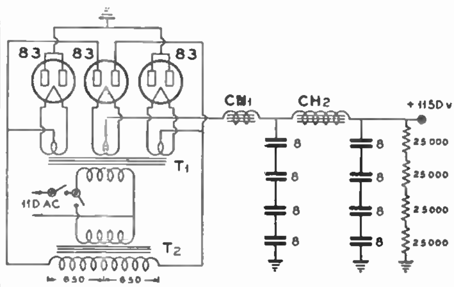


FIG. 9

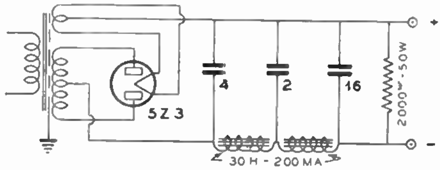


2C MULTI-ARC

Circuit diagram showing Multi-Arc starting, keep-alive circuit and filter supply. The Mercury Arc is capable of rectifying extremely high voltages and currents. Its normal operating life is long; its cost is not excessive.



Bridge rectifier using inexpensive parts. Output 1150 volts at 250 MA. Ordinary 8 mfd. 450 working-volt electrolytic condensers are connected in series, as shown.



C-BIAS FOR FONE WHEN FINAL AMP USED AS A LINEAR

Predetermining DC Voltage

● An examination of Figure 7 will show that it can be reduced to the more simpler form of Figure 8. Here, the ratio of transformation is such that E volts are induced in the transformer secondary. From the theoretical DC output which is .9 × E, and subtracting all the voltage drops, which include the drop across R_t (the transformer resistance), across L_t (the transformer leakage inductance, across V (the tube drop), across RL1 and RL2 (the choke resistances) it will be found that the output voltage can be accurately estimated. If the transformer regulation is known, a value of E can be obtained which already incorporates the transformer losses. The DC output is then (.9 × E) minus 15 (the normal voltage drop) across a mercury-vapor tube, minus I_{dc} x (RL1 plus RL2). This gives a definite means of predetermining the DC output voltage from a rectifier using a choke input filter.

Notes on Operating Mercury-Vapor Rectifier Tubes

● In respect to the operation of the tube it is considered good practice to allow the filament of the tube to come up to full temperature before the plate voltage is applied. Otherwise, the active material may be knocked off the filament. The precaution given is merely this: that the space charges around the cathode reduce the fall of potential at the surface of the cathode so that the positive ions which are drawn to the hot cathode or filament do not have energy enough when they strike the filament to knock off the active material. It is the positive ions of mercury accelerated in the high field around the filament when there is a large space charge that is attracted to the negative filament and injure its surface.

Every precaution should be taken to keep the mercury tube out of intense radio-frequency fields, because radio-frequency oscillations introduce potentials into the gaps between the cathode and the anode of the tube which, superimposed upon conditions already existing, leads to ionization and changes of current when they are not wanted. If the mercury tube is operating critically, it takes little to produce the necessary ionization which is needed for its operation. This added potential introduced by means of RF currents playing between the electrodes is sufficient to start ionization that is not desired. The tube should likewise be kept out of magnetic fields as such fields have the effect of changing the energies of the electrons in the atoms of mercury-vapor by distorting their hypothetical orbits and making certain direction of motion easier than others. Much difficulty in filtering the output of the rectifier may be eliminated by isolating the power supply from the transmitter and shunting the power supply with a fairly high mica condenser preceded by an adequate RF choke. A condenser of .002 mfd. may be used advantageously for 40 meter operation.

Power Supply Components

● The design of a good power supply is as equally important as the design of the transmitter or receiver; too much emphasis cannot be placed upon the proper selection of the various electrical components going into the power supply assembly. The design specifications and other complementary features are outlined in the subsequent paragraphs.

Transformer Design

● A common problem in radio and allied work is to determine how a transformer can be built to supply certain power requirements for a particular application, or how to calculate the windings needed to fit a certain transformer core which is already on hand. These problems can be solved by a small amount of calculation.

The most important factor in determining the size of any transformer is the amount of core material available. The electrical rating, as well as the physical size, is determined almost entirely by the size of the core. The core material is also important, but the present practice is to use high-grade silicon-steel sheet. It will be assumed that this type of material is to be employed in all contruction herein described. Soft sheet-iron, or stovepipe iron is sometimes substituted, but transformers made from such materials will have about 50 to 60 per cent of the power rating, pound for pound of core, as those made from silicon-steel. The core size determines the performance of a transformer because the entire energy circulating in the transformer (except small amounts of energy dissipated in resistance losses in the primary) must be transformed from electrical energy in the primary winding to magnetic energy in the core, and reconverted into electrical energy in the secondary. The amount of core material determines quite definitely the power that any transformer will handle.

Transformer cores are often designed so that if the losses per cubic inch of core material are determined, these losses can be used as a basis for calculating the rating of the transformer. These losses exist in watts, and are divided between the eddy current loss and the hysteresis loss. The eddy current loss is the loss due to the lines of force moving across the core, just as if it were a conductor, and setting up currents in it. Induced currents of this type are very undesirable and they are merely wasted in heating the core, which then tends to heat the windings, increase the resistance of the coils and reduce the overall power handling ability of the transformer. To reduce such losses, transformer cores are made of thin sheets, usually about No. 29 gauge. These sheets are insulated from each other by a coat of thin varnish, shellac, or japan, or by the iron-oxide scale which forms on the sheets during the manufacturing process, and which forms a good insulator between sheets.

"Hysteresis" means "to lag," and hysteresis in an iron-core means that the magnetic flux in the core lags behind the magnetizing force that produces it, which is, of course, the primary supply. Because all transformers operate on alternating current, the core is subjected to continuous magnetizing and demagnetizing force, due to the alternating effect of the AC field. This force heats the iron, due to molecular friction caused by the iron molecules reorienting themselves as the direction of the magnetizing flux changes. The higher the field strength, the greater the heat produced. A condition can be reached where a further increase in magnetizing flux does not produce a corresponding increase in the flux density. This is called "saturation" and is a condition which would cause considerable heat in a core. In practice, it has been found that all core material must be operated with the magnetic flux well below the limit of saturation.

Core losses manifest themselves as heat and these losses are the determining factor in transformer rating. They are spoken of as "total core loss," generally used as a single figure, and for common use a core loss of from .75-watts to 2.5-watts per pound of core material can be assumed for 60 cycles. The lower figure is for the better grades of thin sheet, while the higher loss is for heavier grades. About 1-watt per pound is a very satisfactory rating for common grades of material. This rating is also dependent on the manner in which the transformer is built and mounted, and in the ease with which the heat is radiated from the core. Transformers with higher losses may be used for intermittent service.

The transformer core loss can be assumed to be from 5 to 10 percent of the total rating for small transformers. Thus, if the core loss is known, the rating of the transformer can be easily determined. If the figure of 1-watt per pound is assumed, the problem is further simplified. To determine the rating of the transformer, weigh the core. If, for example, the core weighs 10 pounds, the transformer will handle from 100 to 200-watts. Such a transformer core can be assumed to have about 150-watts nominal rating. If the weighing of the core is inconvenient, the weight can be calculated from the cubic contents, or volume. Sheet-steel core laminae weigh approximately one-fourth pound per cubic inch.

Transformer cores are generally made of two types, shell and core. The shell-type has a center leg which accommodates the windings, and this is twice the cross-sectional areas of the side legs. The core-type is made from strips built-up into a hollow like affair of uniform cross section. For the shell-type core, the area is taken as the square section of the center leg, in this case 2¼ in. x 4½ in. and in the core-type, this area is taken as the section of 1 leg, and is also 2¼ in. x 4½ in., or an actual core area in both cases of 10.1 square inches, which is large enough for a comparatively large transformer.

To determine the number of turns for a given voltage, apply the following formula:

$$E = \frac{4.44\ N\ B\ A\ T}{10^8}$$

Where E equals the volts of the circuit; N, the cycles of the circuit; B, the number of magnetic lines per square inch of the magnetic circuit; A, the number of square inches of the magnetic circuit; and T, the number of turns.

The proper value for B, for small transformers, and for ordinary grades of sheet-iron, such as are now being considered, is 75,000 for 25 cycles and 50,000 for 50 or 60 cycles.

Rewriting the above formula:

$$T = \frac{E \times 10^8}{4.44\ N\ B\ A\ T}$$

and since N and B are known

$$T = \frac{10^8}{4.44 \times 60 \times 50{,}000} \times \frac{E}{A}$$

from which

$$T = 7.5 \times \frac{E}{A}$$

That is, for a transformer to be used on a 60 cycle circuit, the proper number of turns for the primary coil is obtained by multiplying the line-voltage by 7.5 and dividing this product by the number of square inches cross-section of the magnetic circuit.

On a 25 cycle circuit, the 7.5 becomes 12, and on 50 cycles it becomes 9.

Tentative Design

● Assume a transformer core that is to be used on a 115 volt, 60 cycle circuit for supplying power to two rectifier tubes, each of which takes 1,000 volts on the plate. The rectifier is of the full-wave type. The core measures 2½ inches x 4½ inches; hence,

$$T = \frac{7.5 \times 115}{2.25 \times 4.5} = 85 \text{ (to the nearest turn).}$$

SECONDARY WINDINGS (Turns for Voltages Given)

HIGH-VOLTAGE WINDING

WATTS	Section of Core (inches)	Area of Core (Square inches)	Primary Turns	Primary Wire Size	Turns per Volt	2.5 volts	5.0 volts	6.3 volts	7.5 volts	10 volts	250 volts	300 volts	350 volts	400 volts	450 volts	500 volts	600 volts	700 volts	800 volts	900 volts	1000 volts	1250 volts	1500 volts
10	½ x ½	.25	3500	31	32	80	160	205	240	320													
10	½ x ⅝	.31	2800	31	24.2	61	122	147	182	242													
12	½ x ¾	.37	2300	30	20.0	50	100	126	150	200													
12	⅝ x ⅝	.38	2280	30	19.6	48	96	124	147	196													
15	⅝ x ¾	.46	1875	29	16.1	42	84	105	124	161													
22	⅝ x 1	.62	1400	28	12.2	31	61	77	92	122													
20	¾ x ¾	.55	1570	28	13.6	34	68	86	102	136													
25	¾ x 1	.75	1150	27	10.0	25	50	63	75	100	2620	3150	3700	4200	4750	5250							
30	¾ x 1¼	.93	930	26	8.1	21	42	52	62	81	2100	1500	3140	3400	3800	4200							
50	¾ x 1½	1.12	770	24	6.7	17	34	43	50	67	1860	2100	2500	2840	3150	3500	4200	5000					
50	1 x 1	1.0	860	24	7.5	19	38	48	57	75	1950	2400	2700	3150	3600	3900	4700	5500					
60	1 x 1¼	1.25	690	23	6.0	15	30	38	45	60	1600	1900	2200	2500	2800	3150	3800	4400					
65	1 x 1½	1.50	575	23	5.0	13	25	32	38	50	1300	1575	1850	2100	2400	2650	3150	3700					
75	1 x 1¾	1.75	490	22	4.2	11	21	27	31	42	1100	1320	1550	1750	2000	2200	2650	3150	3800	4000	4400		
110	1 x 2	2.0	430	21	3.7	9	18	23	28	37	980	1170	1370	1550	1750	1960	2300	2750	3100	3500	3900		
105	1¼ x 1¼	1.56	550	21	4.8	12	24	31	36	48	1260	1510	1770	2050	2240	2510	3050	3500	4100	4500	5020		
100	1¼ x 1½	1.87	460	21	3.8	9	19	25	29	38	1000	1200	1400	1600	1800	2000	2400	2720	3200	3560	4000		
120	1¼ x 1¾	2.18	400	20	3.5	9	18	21	26	35	920	1100	1315	1470	1650	1840	2200	2560	2940	3300	3700	4620	5500
140	1¼ x 2	2.5	350	19	3.2	8	16	20	24	32	840	1020	1180	1340	1510	1680	2050	2350	2680	3000	3380	4200	5050
125	1½ x 1½	2.25	380	20	3.3	8	16	21	25	33	870	1040	1210	1400	1560	1730	2100	2420	2800	3120	3500	4400	5250
150	1½ x 1¾	2.64	330	18	2.9	7	14	19	22	29	760	910	1130	1220	1360	1530	1840	2100	2450	2750	3050	3800	4650
200	1½ x 2	3.0	290	17	2.42	6	12	15	18	24	630	765	890	1020	1150	1265	1522	1780	2050	2380	2350	3200	3840
300	2 x 2	4.0	215	15	1.87	5	9	12	14	19	490	590	690	780	880	980	1180	1360	1570	1760	1950	2350	2940
400	2 x 2½	5.0	175	14	1.52	4	8	10	12	15	395	470	550	640	710	790	950	1110	1265	1420	1590	1980	2400
500	2 x 3	6.0	145	13	1.26	3	6	8	9	12	330	395	455	530	595	660	790	920	1060	1200	1330	1650	2000

and the volts per turn equals

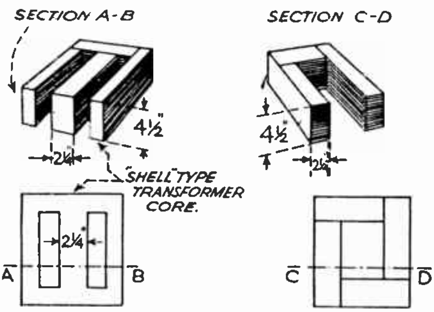
$$\frac{115}{85} = 1.353 \text{ which is the same for all coils.}$$

Now, the secondary coil must have two windings in series, each to give 1,000 volts, and with a middle-tap. The secondary turns

will be $\frac{2000}{1.353} = 1478$ with a tap taken out

at the 739th turn.

Allowing 1,500 cm per ampere, the primary wire should be No. 12. The size of the wire on the plate coils may be No. 22 or 24 for a 400 to 300 ma. rating.



Types of transformer cores.

To determine the quantity of iron to pile up for a core, it is well to consider 1 to 1.5 volts per turn as a conservative range. For trial assume 1.25 volts. Then by transforming the first equation:

$A = 7.5 \times \frac{E}{T}$ or, the area required is 7.5

times the volts per turn: in this case, $7.5 \times 1.25 = 9.38$ sq. in.

The magnetic cross section must be measured at right angles to the laminations that are enclosed by the coil; the center leg when the core is built up around the coil; and either leg where the core is built up inside the coil, that is, between the arrows in the sketches shown above.

It should be kept in mind that there is a copper, or resistance loss in all transformers. This is caused by the passage of the current through the windings, and is commonly spoken of as the "IR" loss. It manifests itself directly as heat, and varies as the load is varied: the heavier the load, the more heat is developed. This heat, as well as other heat losses, must be removed, or the transformer will burn up. Most transformers are so arranged that both the core and windings can radiate heat into the surrounding air, and thus cool themselves. Large transformers are mounted in oil, for cooling, and also for the purpose of increasing the insulation factors.

In any transformer, the voltage ratio is directly proportional to the turns ratio. This means that if the transformer is to have 110 volts input, and 250 turns for the primary, and if the output is to be 1,100 volts, 2,500 turns will be needed. This may be expressed as:

$$\frac{E_p}{E_s} = \frac{T_p}{T_s}$$

It is often more convenient to take the figure obtained for the primary winding, and by dividing by the supply voltage the number of turns per volt is calculated. This accomplished, the number of turns for any given voltage can be calculated by simple multiplication.

Radio transformers are generally of small size. The matter of power factor can therefore be disregarded, more especially because they work into an almost-purely resistive load. In the design of radio transformers, the power factor can be safely assumed as unity, in which case the apparent watts and the actual watts are the same. Admittedly this is not always a correct assumption, but it will suffice for common applications.

The size of the wire to be used in any transformer depends upon the amperage to be carried. For a current of 1-ampere as a continuous load, at least 1,000 circular mils per ampere must be allowed. For transformers which have poor ventilation, or intermittent heavy load service, or where price is not the first consideration, 1,500 circular mils per ampere will suffice. If, for example, a transformer is rated at 100-watts primary load on 110-volts, the current will be

$$I = \frac{W}{V} = \frac{100}{110} = 0.90 \text{ amperes,}$$

and if the assumption is 1,000 circular mils per ampere, it will be found that this will require $1.000 \times .90$, or 900 circular mils. The wire table on page 14 shows that No. 20 wire for 1,200 mils, is entirely satisfactory. If it is desired to use 1,500 circular mils, instead of 1,000, this will require $1,500 \times .90$ or 1,350 mils, which corresponds to approximately No. 19 wide. The difference seems to be small, yet it is large enough to reduce heating and to improve overall performance. Assume, for tentative design, a 600-volt, 100MA high-voltage secondary; a 3-ampere 5-volt secondary; and 2.5-volt 7.5-ampere secondary. Simple calculation will show a 60-watt load on the high-voltage secondary; 15-watts on the 5-volt winding; and 16-watts on the 2.5-volt winding, a total of 91-watts. The core and copper loss is 10-watts. The wire sizes for the secondaries will be for 100 mils current. No. 30 wire, 3-amperes at

Choke Table for Transmitter Power Supply Units

Current M.A.	Wire Size	No. Turns	Lbs. Wire	Approx. Core (Area)	Air Gap	Wt. Core
200	No. 27	2000	1.5	1½"x1½"	3/32"	4 lbs.
250	No. 26	2000	1.75	1½"x2"	3/32"	5 lbs.
300	No. 25	2250	2	2"x2"	⅛"	6 lbs.
400	No. 24	2250	3	2"x2½"	⅛"	7 lbs.
500	No. 23	2500	4	2½"x2½"	⅛"	10 lbs.
750	No. 21	3000	6	2½"x3"	⅛"	14 lbs.
1000	No. 20	3000	7.5	3"x3"	⅛"	18 lbs.

NOTES: These are approximately based on high-grade silicon steel cores, with total airgaps as given. Airgaps indicated are total of all gaps.

The use of standard "E" and "I" laminations is recommended. If strips are used, and if an ordinary square core is used, the number of turns should be increased about 25%. Choke coils built as per the above table will have an approximate inductance of 10 to 15 henrys. Because considerable differences occur due to winding variations, allowable flux densities of cores, etc., the exact inductance cannot be stated; these chokes will, however, give satisfactory service in radio transmitter power supply systems.

The wire used is based on 1000 circular mils per ampere; this will cause some heating on long runs, and if the chokes are to be used continuously, as in a radio telephone station in continuous service, it is good practice to use the next size larger choke shown for such loads.

5-volts, No. 15 wire; No. 11 wire for the 7.5-ampere secondary.

For high voltage secondary windings, a small percentage should be allowed to overcome the resistance of the small wire used, so that the output voltage will be as high as anticipated. The figures given in the table include this percentage which is added to the theoretical ratio of turns, and consequently the number of turns shown in the table can be accepted as the actual number of turns to be wound on the core of any given transformer.

Allowance should always be made for the insulation and size of the windings. Good insulation should be provided between the core and the windings, and also between each winding and between turns. Numerous materials are satisfactory for this purpose; varnished paper or cloth, called "empire," or paper is very satisfactory, although costly. Good bond paper will serve well as an insulating medium for small transformer windings. Insulation between primary and secondary and to the core must be exceptionally good, as well as the insulation between windings. Thin mica, or "micanite" sheet is very good. Thin fibre, commonly called "fish paper" is also a good insulator. Bristol Board, or strong, thin cardboard may also be used. In all cases, the completed coil should be impregnated with insulating varnish, and either dried in air or baked in an oven. Common varnishes or shellac are unsatisfactory on account of the moisture content of these materials. Air-drying insulating varnish is practical for all-around purposes; baking varnish may be substituted, but the fumes given off are inflammable and often explosive. Care must be exercised in the handling of this type of material. Collodion and banana oil lacquer is positively dangerous, and in the event of a short-circuit of transformer burn-out, a serious fire may result.

If it is desired to wind a transformer on a given core, it is much better to calculate the actual space required for the windings, then determine whether there is enough available space on the core. If this precaution is not observed, the designer may find that only about half the turns can actually be wound on the core, when the work is about three-fourths finished. From 15 to 40 per cent more space than is actually required must be allowed. The winding of transformers by hand is a space consuming process. Unless the builder is an experienced coil-winder, there is every chance that a sizable portion of the space will be used-up by insulation, etc., not sufficient space remaining for the winding. Calculate the cubical space needed for the total number of turns, and allow from 15 to 40 per cent additional space in the core "window." Thereby much time and labor will be saved.

Filter Chokes

● A choke is a coil of high inductance. It offers an extremely high impedance to alternating current, or to current which is substantially alternating, such as pulsating DC delivered at the output of a rectifier.

Choke coils are used in power supplies as part of the complete filter system in order to produce an effectively-pure direct current from the pulsating current source, that is, from the rectifier. The size of the choke must be such that the current flowing through it does not cause an appreciable voltage drop due to the ohmic resistance of the choke; at the same time sufficient inductance must be maintained to provide ample smoothing of the rectified current.

Smoothing Chokes

● The function of a smoothing choke is to discriminate as much as possible between the

AC ripple which is present and the desired DC that is to be delivered to the output. Its air-gap should be large enough so that the inductance of the choke does not vary materially over the normal range of load current drawn from the power supply.

Swinging Chokes

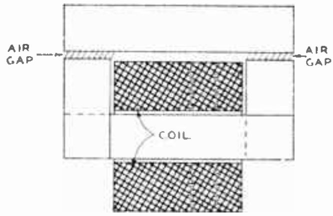
● In certain radio circuits the power drawn by a vacuum tube amplifier can vary widely. Class B audio amplifiers are good examples of this type of amplifier. The plate current drawn by a class B audio amplifier can vary a thousand per cent, or more. It is desirable to keep the DC output voltage applied to the plate of the amplifier as constant as possible, and the voltage should be independent of the current drawn from the power supply. The output voltage from a given power supply is always higher with a condenser input filter than with a choke-type input filter. When the input choke is of the *swinging* variety, it means that the inductance of the choke varies widely with the load current drawn from the power supply. Thus, at low load currents the inductance of the swinging choke is high and the filter acts as a choke input filter, with a relatively low output voltage. When the load current increases, the inductance of the swinging choke decreases and the filter circuit begins to act more and more like a condenser input filter. This causes the output voltage to rise somewhat, although the rise is usually adjusted so that it just offsets the voltage drop caused by the transformer and choke resistance, plus the drop across the rectified tubes. A swinging choke does not have much smoothing effect, but it is valuable in improving the voltage regulation of the power supply. The use of a swinging choke is desirable in a CW transmitter to reduce keying thumps which occur when a condenser input is used.

Design and Construction of Chokes

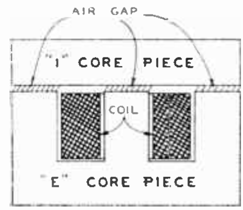
● A choke is made up from a silcon-steel core which consists of a number of thin sheets of steel, similar to a transformer core, but wound with only a single winding. The size of the core and the number of turns of wire, together with the air-gap which must be provided to prevent the core from saturating, are factors which determine the inductance of a choke. The relative sizes of the core and coil determine the amount of DC which can flow through the choke without reducing the inductance to an undesirable low value due to magnetization.

The same core material which is used in ordinary radio power transformers, or from those which are burned-out, is satisfactory for all general purposes.

In construction, the choke winding must



Two types of choke coil construction. The air-gap is approximately 1/32 inch.



The air-gap can be filled with non-magnetic material, such as brass, bakelite, etc.

be insulated from the core with a sufficient quantity of insulating material so that the highest peak voltages which are to be experienced in service will not rupture the insulation. It is good practice to operate chokes with the cores grounded; in addition, the choke may be placed in the negative high voltage lead, in order to minimize breakdown and to keep the filtering properties at high efficiency. If the choke is mounted on a breadboard, the core need not be grounded. In some cases where extremely objectionable hum is introduced it may be necessary to completely shield and ground the entire choke assembly.

Design of Voltage Dividers

● The calculation of the correct resistance values and the power ratings of voltage dividers can be determined by the following procedure:

Determine the voltage to be required at each tap and the current to be drawn from it. Vacuum tube manuals can be referred to for tube data.

Determine the bleeder current desired. This value will depend upon the total current drawn by all the tubes plus what the power supply can deliver without over-heating.

Determine the current flowing in each section of the divider.

Calculate the resistance of each section by Ohm's law.

Determine the power rating from the equation:

$$\text{Watts} = \frac{I^2R}{1{,}000{,}000}$$
(I = Milliamperes)

The value I represents the highest current any section is required to carry. If the divider is to consist of several resistors the wattage of each section should be calculated separately and the actual current in that section used for the calculation.

Voltage dividers offer a common impedance to several circuits and so may give rise to regeneration and degeneration. These effects may be eliminated by employing by-pass condensers and extra filters in individual supply leads. (Hint: to constitute an efficient by-pass, the condenser reactance must be considerably lower than the circuit resistance, generally .1 ratio will suffice.)

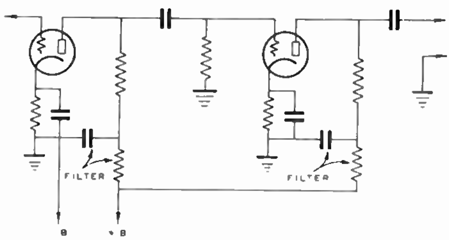


FIG. 10

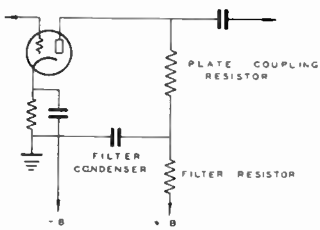


FIG. 11

Resistor-Capacity Filters

● Those excellent resistor-capacity filters that are featured in custom-built and very expensive equipment can be designed from very simple formula. In general, these filters function to stabilize, reduce hum and to prevent common coupling between stages. The effectiveness of the properties of an RC network is proportional to the ratio of the resistance to the reactance of the circuit; a resistive ratio of 50 to a capacitive ratio of 1 is satisfactory for all general purposes. In other words, the resistance in the filter must have a value about 50 times greater than the reactance of the condenser at the lowest frequency to be filtered.

Figures 10, 11 and 12 show how to connect RC filters. By-pass condensers such as those placed across C-bias resistors should have such a value that the impedance of the C-bias circuit is small in comparison to the ohmage of the resistor.

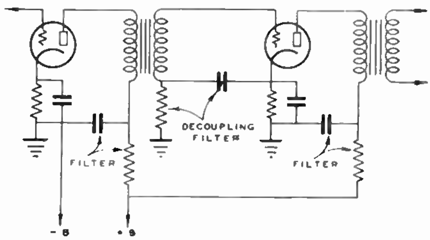


FIG. 12

Winding Turns Per Inch

B & S Gauge No.	D.C.C.	S.C.C.	Enamel	B & S Gauge No.	D.C.C.	S.C.C.	Enamel
6	5.44	5.60		26	39.90	45.30	57.00
7	6.08	6.23		27	42.60	49.40	64.00
8	6.80	6.94		28	45.50	54.00	71.00
9	7.64	7.68		29	48.00	58.80	81.00
10	8.51	8.55		30	51.10	64.40	88.00
11	9.58	9.60		31	56.80	69.00	104.00
12	10.62	10.80		32	60.20	75.00	120.00
13	11.88	12.06		33	64.30	81.00	130.00
14	13.10	13.45	14.00	34	68.60	87.60	140.00
15	14.68	14.90	16.00	35	73.00	94.20	160.00
16	16.40	17.20	18.00	36	78.50	101.00	190.00
17	18.10	18.80	21.00	37	84.00	108.00	195.00
18	20.00	21.00	23.00	38	89.10	115.00	205.00
19	21.83	23.60	27.00	39	95.00	122.50	215.00
20	23.91	26.40	29.00	40	102.50	130.00	230.00
21	26.20	29.70	32.00	41	112.00	153.00	240.00
22	28.58	32.00	36.00	42	124.00	168.00	253.00
23	31.12	34.30	40.00	43	140.00	192.00	265.00
24	33.60	37.70	45.00	44	153.00	210.00	275.00
25	36.20	41.50	50.00				

Rules of the Board of Underwriters Receiving Stations

● Owners of insured residences and buildings are compelled to comply to the following Underwriter's rules:

a—Outdoor antenna and counterpoise conductor sizes shall not be less than No. 14 if copper or No. 17 if of bronze or copper-clad steel. Antenna and counterpoise conductors outside of buildings shall be kept well away from all electric light and power wires or any circuit of more than 600 volts, and from railway, trolley or feeder wires, so as to avoid the possibility of contact between the antenna or counterpoise and such wires under accidental conditions.

b—Antenna and counterpoise where placed in proximity to electric light or power wires of less than 600 volts, or signal wires, shall be constructed and installed in a strong and durable manner, and shall be so located and provided with suitable clearances as to prevent accidental contact with such wires by sagging or swinging.

c—Splices and joints in the antenna span shall be soldered unless made with approved splicing devices.

d—The preceding paragraphs a, b, and c, shall not apply to power circuits used as receiving antenna, but the devices used to connect the light and power wires to radio receiving sets shall be of approved type.

e—Lead-in conductors, that is, conductors from outdoor antennas to protective devices, shall be of copper, approved copper-clad steel or other metal which will not corrode excessively and in no case shall they be smaller than No. 14, except that bronze or copper-clad steel not less than No. 17 may be used.

f—Lead-in conductors from the antenna to the first building attachment shall conform to the requirements for antennas similarly located. Lead-in conductors from the first building attachment to the building entrance shall, except as specified in the following paragraph, be installed and maintained so that they cannot swing closer to open supply conductors than the following distances:

Supply wires 0 to 600 volts........2 feet

Supply wires exceeding 600 volts. 10 feet

Where all conductors involved are supported so as to secure a permanent separation and the supply wires do not exceed 150 volts to ground, the clearance may be reduced to not less than 4 inches. Lead-in conductors on the outside of buildings shall not come nearer than the clearances specified above to electric light and power wires unless separated therefrom by a continuous and firmly fixed non-conductor which will maintain permanent separation. The non-conductor shall be in addition to any insulating covering on the wire.

g—Each lead-in conductor from an outdoor antenna shall be provided with an approved protective device (lightning arrester) which will operate at a voltage of 500 volts or less, properly constructed and located either inside the building at some point between the entrance and the set which is convenient to a ground, or outside the building as near as practicable to the point of entrance. The protector shall not be placed in the immediate vicinity of easily ignitable material, or where exposed to inflammable gases or dust or flyings of combustible materials.

h—The grounding conductor from the protective device may be bare and shall be of copper, bronze or approved copper-clad steel, and if entirely outdoors shall not be smaller than No. 14 if of copper nor smaller than No. 17 if of bronze or copper-clad steel. If wholly indoors or with not more than ten feet outdoors it need not be larger than No. 18. The protective grounding conductor shall be run in as straight a line as possible from the protective device to a good permanent ground. The ground connections shall be made to a cold-water pipe where such pipe is available and is in service connected to the street mains. An outlet pipe from a water tank fed from a street main or a well may be used, providing such outlet pipe is adequately bonded to the inlet pipe connected to the street water main or well. If water pipes are not available, ground connections may be made to a grounded steel frame of a building or to a grounding electrode, such as a galvanized pipe or rod driven into permanently damp earth or to a metal plate or other body of metal buried similarly. Gas piping shall not be used for the ground.

i—The protective grounding conductor shall be guarded where exposed to mechanical injury.

An approved ground clamp shall be used where the protective grounding conductor is connected to pipes or piping.

j—The protective grounding conductor may be run either inside or outside the building. The protective grounding conductor and ground, installed as prescribed in the preceding paragraphs h and i may be used as the operating ground.

It is recommended that in this case the operating grounding conductor may be connected to the ground terminal of the protective device.

If desired, a separate operating grounding connection and ground may be used, this operating grounding conductor may be either bare or provided with an insulated covering.

k—Wires inside buildings shall be securely fastened in a workman-like manner and except as provided in paragraph m of this section shall not come nearer than two inches to any electric light or power wire not in conduit unless separated therefrom by some continuous and firmly fixed non-conductor, such as porcelain tubes or approved flexible tubing, making a permanent separation. This non-conductor shall be in addition to any regular insulating covering on the wire.

l—Storage battery leads shall consist of conductors having approved rubber insulation. The circuit from a filament "A," storage battery of more than 20 ampere-hours capacity, NEMA rating, shall be properly protected by a fuse or circuit-breaker rated at not more than 5 amperes. The circuit from a plate, "B," storage battery or power supply shall be properly protected by a fuse.

Transmitting Stations

● The following paragraphs apply to amateur stations only:

a—Antenna and counterpoise conductors outside buildings shall be kept well away from all electric light or power wires or any circuit of more than 600 volts, and from railway, trolley or feeder wires, so as to avoid the possibility of contact between the antenna or counterpoise and such wires under accidental conditions. Antenna and counterpoise conductors when placed in proximity to electric light or power wires of less than 600 volts, or signal wires, shall be constructed and installed in a strong and durable manner, and shall be so located and provided with suitable clearances as to prevent accidental contact with such wires by sagging or swinging.

b—Antenna conductor sizes shall not be less than given in the following table:

Material	Stations to which power supplied is less than 100 watts and where voltage of power is less than 400 volts	Stations to which power supplied is more than 100 watts or voltage of power is more than 400 volts
Soft copper	No. 14	No. 7
Medium drawn copper	No. 14	No. 8
Hard drawn copper	No. 14	No. 10
Bronze or copper-clad steel	No. 14	No. 12

c—Splices and joints in the antenna and counterpoise span shall be soldered joints unless made with approved splicing devices.

d—Lead-in conductors shall be of copper, bronze, approved copper-clad steel or other metal which will not corrode excessively and in no case shall be smaller than No. 14.

e—Antenna and counterpoise conductors and wires leading therefrom to ground switch, where attached to buildings, shall be firmly mounted five inches clear of the surface of the building, on a non-absorptive insulating support, such as treated pins or brackets, equipped with insulators having not less than five inches creepage and airgap distance to inflammable or conducting material, except that the creepage and airgap for continuous wave sets of 1,000 watts and less input to the transmitter shall not be less than 3 inches.

f—In passing the antenna or counterpoise lead-in into the building, a tube slanting upward toward the inside or a bushing of non-absorptive insulating material shall be used, and shall be so insulated as to have a creepage and air-gap distance in the case of continuous wave sets of 1,000 watts and less input to the transmitter, not less than three inches, and in all other cases not less than five inches. Fragile insulators shall be protected where exposed to mechanical injury. A drilled window pane may be used in place of a bushing, provided the creepage and air-gap distance, as specified above, are maintained.

g—Adequate lightning protection either in the form of a grounding switch or suitable lightning arrester shall be provided. The grounding conductor for such protection shall be at least as large as the lead-in and in no case smaller than No. 14 copper, bronze, or approved copper-clad steel. The protective grounding conductor need not have an insulating covering or be mounted on insulating supports. The protective grounding conductor shall be run in as straight a line as possible to a good, permanent ground suitable for the purpose. The protective grounding conductor shall be protected where exposed to mechanical injury.

h—The operating grounding conductor where used shall be of copper strip not less than ⅜ inch wide by $\frac{1}{32}$ inch thick, or of copper, bronze or approved copper-clad steel having a periphery, or girth, of at least ¾ inch, such as No. 2 wire. and shall be firmly secured in place throughout its length.

i—The operating grounding conductor shall be bonded to a good, permanent ground. Preference shall be given to water piping. Other permissible grounds are grounded steel frames of buildings or other grounded metal work in the building, and artificial grounding devices such as driven pipes, rods, plates, cones, etc. Gas piping shall not be used for the ground.

j—The transmitter shall be enclosed in a metal frame, or grill, or separated from operating space by a barrier or other equivalent means, all metallic parts of which are effectually connected to ground.

k—All external metallic handles and controls accessible to the operating personnel shall be effectually grounded.

No circuit in excess of 150 volts should have any parts exposed to direct contact. A complete dead-front type of switchboard is preferred.

l—All access doors shall be provided with interlocks which will disconnect all voltages in excess of 750 volts when any access door is opened.

m—Under the conditions noted in paragraphs 1 and 2. below, wiring may be grouped in the same conduit armored cable, electrical metallic tubing, metal raceway, pull-box, junction box or cabinet.

1. Power-supply wires are introduced solely for supplying power to the equipment to which the other wires are connected.

2. Wires other than power-supply wires run in conduit, armored cable, electrical metallic tubing, metal raceways, pull-box, junction box or cabinet with power supply wires are insulated individually or collectively in groups by insulation at least equivalent to that on the power-supply wires or the power and other wires are separated by a lead sheath or other continuous metallic sheathing.

Conversion Table

Factors for conversion, alphabetically arranged

MULTIPLY	BY	TO GET
Amperes	X1,000,000,000,000	micromicroamperes
Amperes	X1,000,000	microamperes
Amperes	X1,000	milliamperes
Cycles	X1,000,000	megacycles
Cycles	X.001	kilocycles
Farads	X1,000,000,000,000	micromicrofarads
Farads	X1,000,000	microfarads
Henrys	X1,000,000	microhenrys
Henrys	X1,000	millihenrys
Kilocycles	X1,000	cycles
Kilovolts	X1,000	volts
Kilowatts	X1,000	watts
Megacycles	X1,000,000	cycles
Mhos	X1,000,000	micromhos
Microamperes	X.000,001	amperes
Microfarads	X.000,001	farads
Microhenrys	X.000,001	henrys
Micromhos	X.000,001	mhos
Micro-ohms	X.000,001	ohms
Microvolts	X.000,001	volts
Microwatts	X.000,001	watts
Micromicrofarads	X.000,000,000,001	farads
Milliamperes	X.001	amperes
Millihenrys	X.001	henrys
Millimhos	X.001	mhos
Milliohms	X.001	ohms
Millivolts	X.001	volts
Milliwatts	X.001	watts
Ohms	X1,000,000,000,000	micromicro-ohms
Ohms	X1,000,000,000	micro-ohms
Volts	X1,000,000	microvolts
Volts	X1,000	millivolts
Watts	X1,000,000	microwatts
Watts	X1,000	milliwatts
Watts	X.001	kilowatts

Radio Symbols

The following symbols are commonly used in radio work and many of these symbols are used in the pages of this book:

E_F	Filament (or heater) terminal voltage
E_B	Average plate voltage (DC)
I_B	Average plate current (DC)
E_P	AC component of plate voltage (effective value)
I_P	AC component of plate current (effective value)
E_C	Average grid voltage (DC)
I_C	Average grid current (DC)
E_G	AC component of grid voltage (effective value)
I_G	AC component of grid current (effective value)
E_{FF}	Filament (or heater) supply voltage
E_{BB}	Plate supply voltage (DC)
E_{CC}	Grid supply voltage (DC)
U	Amplification factor
r_P	Plate resistance
s_M	Grid plate transconductance (also mutual conductance, gm)
R_P	Plate load resistance
Z_P	Plate load impedance
DC	Direct Current (as adjective)
AC	Alternating Current (as adjective)
RMS	Root Mean Square
U.P.O.	Undistorted power output
C_{GK}	Grid-cathode (or filament) capacitance
C_{PK}	Plate-cathode (or filament) capacitance
C_{G1P}	Effective grid-plate capacitance in a tetrode (cathode [or filament] and screen grounded)
$C_{G1}(k+g_2)$	Direct interelectrode capacitance of grid to cathode (or filament) and screen
$C_P(k+g_2)$	Direct interelectrode capacitance of plate to cathode (or filament) and screen

Common Word Abbreviations

ABT	about	FR	for	ND	nothing doing	TR	there
AHD	ahead	GA	go ahead	NG	no good	TT	that
AHR	another	GM	good morning	NL	night letter	UD	it would
ANY	any	GN	good night	NM	no more	UL	you'll
BD	bad	GT	get, got	NR	number	V	from
BK	break	GG	going	NW	now	VB	very bad
BUG	speed key	HA	laughter	OB	old boy	VY	very
BN	been	HI	laughter-high	OL	old lady	WA	word after
B4	before	HR	hear—here	OM	old man	WB	word before
BI	by	HW	how	OP	operator	WD	would
BCUZ	because	HV	have	OW	old woman	WF	word following
BTWN	between	I	"ok"	PLS	please	WK	work
BIZ	business	IC	I see	PSE	please	WL	will—would
CK	check	K	go ahead	PX	press	WN	when
CN	can	LID	poor operator	R	ok	WL	wavelength
CUL	see u later	LIL	little	RI	radio inspector	WT	what
C	see	LST	last	SA	say	WX	weather
CW	continuous wave	LTR	letter	SS	single signal		
DE	from	MI	my	SIG	signal	X	interference
DX	distance	MA	milliamp.	STICK	pencil	XMTR	transmitter
DA	day	MSG	message	SKED	schedule	YF	wife
DH	dead-head	MILL	typewriter	TFC	traffic	YL	young lady
DC	direct current	MST	must	TKS	thanks	YR	your
ES	and	MNI	many	TNX	thanks	30	finish
FB	fine business	MI	my	TK	take	73	regards
FM	from	MK	make	TMW	tomorrow	88	love and kisses
		MO	more	TNK	think		

Q SIGNALS

Abbreviation	Question	Answer
QRA	What is the name of your station?	The name of my station is
QRB	What is your approximate distance from my station?	The approximate distance between our stations is
QRC	By what private company (or Government administration) are the accounts for charges of your station liquidated?	The accounts for charges of my station are liquidated by the private company (or by the government administration).
QRD	Where are you going and where do you come from?	I am going to and I am coming from
QRG	Will you indicate to me my exact frequency (or wavelength) in kc. (or m.)?	Your exact frequency in kc. (or wavelength in m.) is
QRH	Does my frequency (or wavelength) vary?	Your frequency (or wavelength) varies.
QRI	Is my note steady?	Your note varies.
QRJ	Are you receiving me badly? Are my signals weak?	I can not receive you. Your signals are too weak.
QRK	Are you receiving me well? Are my signals good?	I receive you well. Your signals are good.
QRL	Are you busy?	I am busy (or I am busy with). Please do not interfere.
QRM	Are you being interfered with?	I am being interfered with.
QRN	Are you bothered by static?	I am bothered by static.
QRO	Shall I increase power?	Increase power.
QRP	Shall I decrease power?	Decrease power.
QRQ	Shall I send faster?	Send faster.
QRS	Shall I send slower?	Send slower.
QRT	Shall I stop sending?	Stop sending.
QRU	Have you something for me?	I have nothing for you.
QRV	Are you ready?	I am ready.
QRW	Shall I tell you are calling him on kc. (or m.)?	Please tell I am calling him on kc. (or m.)
QRX	Shall I wait? When will you call me again?	Wait. (or Wait until I have finished communicating with) I shall call you at o'clock (or soon).
QRY	Which is my turn?	Your turn is number (or after every other call).
QRZ	Who is calling me?	You are called by
QSA	What is the strength of my signals (1 to 5)?	The strength of your signals is (1 to 5).
QSB	Does the strength of my signals vary?	The strength of your signals varies.
QSD	Is my keying accurate? Are my signals distinct?	Your keying is inaccurate. Your signals are bad.
QSG	Shall I transmit telegrams (or one telegram) at once?	Transmit telegrams (or one telegram) at once.
QSJ	What is the charge per word for , including your interior telegraph charge?	The charge per word for is francs, including my interior telegraph charge.
QSK	Shall I continue the transmission of all my traffic? I can use break-in operation	Continue the transmission of all your traffic. I shall break you if necessary.
QSL	Can you give me acknowledgment of receipt?	I give you acknowledgment of receipt.
QSM	Shall I repeat the last telegram I sent to you?	Repeat the last telegram you sent to me.
QSO	Can you communicate with directly (or through)?	I can communicate with directly (or through).
QSP	Will you relay to free of charge?	I will relay to free of charge.
QSR	Has the distress call from been attended to?	The distress call received from has been attended to by
QSU	Shall I transmit (or reply) on kc. (or m.) and or with waves of type A1, A2, A3, or B?	Transmit (or Reply) on kc. (or m.) and/or with waves of type A1, A2, A3 or B.
QSV	Shall I transmit a series of VVV ?	Transmit a series of VVV
QSW	Do you wish to transmit on kc (or m.) and or with waves of type A1, A2, A3 or B?	I am going to transmit (or I shall transmit) on kc. (or m.) and/or with waves of type A1, A2, A3 or B.
QSX	Do you wish to hear (call signal) on kc. (or m.)?	I hear (call signal) on kc. (or m.)
QSY	Shall I change to transmission on kc. (or m.) without changing the type of wave? or Shall I change to transmission on another wave?	Change to transmission on kc. (or m.) without changing the type of wave, or Change to transmission on another wave.
QSZ	Shall I send word or group twice?	Send each word or group twice.
QTA	Shall I cancel telegram number as if it had not been sent?	Cancel telegram number as if it had not been sent.
QTB	Do you agree with my word count?	I do not agree with your word count; I herewith repeat the first letter of each word and the first figure of each number.
QTC	How many telegrams have you sent?	I have telegrams for you (or for).
QTE	What is my true bearing relative you? or What is my true bearing relative to (call signals)? or What is the true bearing of (call signal) to ?	Your true bearing relative to me is degrees, or Your true bearing relative to (call signal) is degrees at o'clock, or The true bearing of (call signal) relative to (call signal) is degrees at o'clock.
QTF	Will you give me the position of my station based on bearings taken by radiocompass stations you control?	The position of your station as based on radiocompass stations that I control is latitude longitude.
QTG	Will you transmit your call signal for fifty seconds, ending with a dash of ten seconds, on kc. (or m.) so that I can take your radiocompass bearing?	I am going to transmit my call signal for forty seconds, ending with a dash of ten seconds, on kc. (or m.) so that you can take my radiocompass bearing.
QTH	What is your position in latitude and longitude (or according to any other indication?	My position is latitude, longitude (or according to any other indication).
QTI	What is your true course?	My true course is degrees.
QTJ	What is your speed?	My speed is knots (or kilometers) per hour.
QTM	Send radio signals and submarine sound signals so that I can determine my bearing and my distance	I am sending radio signals and submarine signals so that you can determine your bearing and your distance.
QTO	Are you leaving the dock (or the port)?	I am going to leave the dock (or the port).
QTP	Are you going to enter the dock (or the port)?	I am going to enter the dock (or the port).
QTQ	Can you communicate with my station by means of the International Signal Code?	I am going to communicate with your station by means of the International Signal Code.
QTR	What is the correct time?	The correct time is
QTU	What are the working hours of your station?	The working hours of my station are from to
QUA	Have you any news of (call signal of mobile station)?	The news of (call signal of mobile station) is
QUB	Can you give me, in this order, information concerning: visibility, height of clouds, and ground wind for (place of observation)?	Following are the weather details requested:
QUC	What is the last message received by you from (call signal of mobile station)?	The last message received by me from (call signal of mobile station) is
QUD	Have you received the urgency signal made by (call signal of mobile station)?	I have received the urgency signal made by (call signal of mobile station) at (o'clock).
QUF	Have you received the distress signal made by (call signal of mobile station)?	I have received the distress signal made by at o'clock.
QUG	Are you going to be forced to alight at sea (or on land)?	I am going to be forced to alight at sea (or on land) at (place).
QUH	Will you give me the barometric pressure at sea level?	The barometric pressure at sea level is (units).
QUJ	Will you give me the true head to follow, with no wind, for directing me to come to you?	The true head to follow, with no wind, for directing you to come to me, is from degrees at o'clock.

The signal series of QA, QB, QC, QD, QF and QG are reserved for special aeronautical codes.

Chapter 19

Laws and Regulations

General Information

● Any licensee receiving notice of violation of radio laws shall reply to said notice in writing to the FCC at Washington.

Requests for special call-letters will not be considered.

The person manipulating the telegraph key of an amateur station must be a duly licensed operator.

The original license shall be posted in the station or kept in the personal possession of the operator on duty, except when it has been mailed to an office of the FCC for endorsement or change before date of its expiration.

Amateur stations must not be used to handle messages for pecuniary interests, direct or indirect, paid or promised.

Amateur transmissions must be free from harmonics. Loosely-coupled circuits must be used, or devices that will result in giving equivalent effects to minimize keying impacts, clicks, harmonics and parasitics.

1KW power input to the stage which feeds the antenna is the maximum permissible power for amateur operation.

Amateur operators must transmit their assigned call letters at the end of each transmission, or at least once during each 15 minutes of operation. If an amateur transmitter causes general interference with reception of broadcast signals in receivers of modern design, that amateur station shall not operate during the hours from 8 p. m. to 10:30 p. m., local time, and on Sundays from 10:30 a. m., until 1 p. m., local time, upon such frequency or frequencies as cause such interference.

Each licensee of an amateur station must keep an accurate LOG of station operation, name of person operating the transmitter, with statement as to the nature of transmission. The call letters of the station, the input power to the stage which feeds the antenna, the frequency band used, the location of the station if portable operation is used, must all be entered in the station LOG. A copy of each message sent and received must be kept on file for at least one year. This information must be available on request by authorized representatives of the Government of the United States. The station may be operated only to the extent provided by the class of privileges for which the operator's license is endorsed.

Distress Signals

● The International Distress Signal is ...— — —... (three dots, three dashes, three dots) The distress signal is *NOT* SOS: it is an easily-recognized group of *characters* of three dots, three dashes, three dots. For radiotelephony distress calls the signal is *MAYDAY*. All communications must cease when a distress call is heard. Communication must not be resumed until it has been definitely determined that all is clear again. When you hear a distress call, notify the nearest source from which aid can be secured.

● It is unlawful to send fraudulent signals of distress or communications relating thereto; to maliciously interfere with any other radio communications. Distress calls have precedence over all others. Minimum power must be used to effect reliable communication. The use of profane language is prohibited. The contents or meaning of a message must be kept secret, except to an authorized agency which takes part in the forwarding of the message, or to the addressee or his agent, or upon the demand of a court of competent jurisdiction or authority.

Secrecy provisions do not apply to broadcasts for public use, or to distress calls. In the event of a national emergency the station can be ordered closed.

In the event of an emergency an amateur station is permitted to communicate with stations other than amateur.

"AR" denotes the end of a message. "SK" denotes the end of a communication.

● The penalty for violating the provisions of the Communications Act of 1934 is $10,000, or imprisonment not to exceed 2 years, or both, for each offense. The operator's license is liable to suspension for 2 years if a conviction is secured. The station license can also be revoked.

For violation of any of the regulations of the Federal Communications Commission a fine not to exceed $500 can be imposed for each day of such offense. If the convicted person is a licensed operator his license can be suspended for a period not to exceed 2 years. The station license can also be revoked. The penalty for not keeping a station log is the same as related above. For malicious interference with distress communications the maximum penalty of $10,000 and 2 years can be imposed. For malicious interference with other than distress communications the license can be suspended for up to 2 years. An amateur who accepts material compensation for any services rendered by his station is subject to a fine of not more than $500 for each day of such offense. His license can also be suspended for as long as 2 years.

INDEX

TRANSMITTING AND SPECIAL PURPOSE TUBES

RCA Communication Equipment

Type	Amateur's Net Price	DESCRIPTION	Electrodes	Max. Plate Dissipation Watts	Cathode Type	Cathode Volts
203-A	$15.00	R-F Power Amplifier, Oscillator, Class B Modulator	3	100	Filament	10.0
204-A	97.50	Oscillator, R-F Power Amplifier, Class B Modulator	3	250	Filament	11.0
211	15.00	R-F Power Amplifier, Oscillator, A-F Power Amplifier, Modulator	3	100	Filament	10.0
800	10.00	R-F Power Amplifier, Oscillator, Class B Modulator	3	35	Filament	7.5
801	4.50	R-F and A-F Power Amplifier, Oscillator, Modulator	3	20	Filament	7.5
802	3.90	R-F Power Amplifier Pentode	5	10	Heater	6.3
803	38.50	R-F Power Amplifier Pentode	5	125	Filament	10.0
804	15.00	R-F Power Amplifier Pentode	5	40	Filament	7.5
805	18.00	R-F Power Amplifier, Oscillator, Class B Modulator	3	125	Filament	10.0
807	3.90	Transmitting Beam-Power Amplifier	5	21	Heater	6.3
830-B	10.00	Class B Modulator, R-F Power Amplifier, Oscillator	3	60	Filament	10.0
831	265.00	Oscillator, R-F Power Amplifier	3	400	Filament	11.0
834	12.50	R-F Power Amplifier and Oscillator	3	50	Filament	7.5
837	8.50	R-F Power Amplifier Pentode	5	12	Heater	12.6
838	16.00	Class B Modulator, R-F Power Amplifier, Oscillator	3	100	Filament	10.0
840	6.00	R-F Pentode	5		Filament	2.0
841	3.25	R-F Power Amplifier, Oscillator A-F Voltage Amplifier	3	15	Filament	7.5
842	3.25	A-F Power Amplifier, Modulator	3	12	Filament	7.5
843	12.50	Power Amplifier, Oscillator	3	15	Heater	2.5
844	18.00	Screen-Grid R-F Power Amplifier	4	15	Heater	2.5
845	16.00	Modulator, A-F Power Amplifier	3	75	Filament	10.0
849	160.00	Modulator, A-F Power Amplifier, R-F Power Amplifier, Oscillator	3	400	Filament	11.0
850	37.50	Screen-Grid R-F Power Amplifier	4	100	Filament	10.0
851	350.00	Modulator, A-F Power Amplifier, R-F Power Amplifier, Oscillator	3	750	Filament	11.0
852	16.40	Oscillator, R-F Power Amplifier	3	100	Filament	10.0
860	32.50	Screen-Grid R-F Power Amplifier	4	100	Filament	10.0
861	295.00	Screen-Grid R-F Power Amplifier	4	400	Filament	11.0
864	1.60	Amplifier (Low Microphonic Design)	3	—	Filament	1.1
865	12.75	Screen-Grid R-F Power Amplifier	4	15	Filament	7.5
868	5.00	Phototube	2	—	—	—
917	6.00	Phototube (High-Vacuum Type)	2	—	—	—
918	5.00	Phototube (High Sensitivity)	2	—	—	—
919	6.00	Phototube (High-Vacuum Type)	2		—	—
920	7.00	Twin Phototube	4		—	
954	5.80	Detector, Amplifier Pentode (Acorn Type)	5	—	Heater	6.3
955	3.75	Amplifier, Detector, Oscillator (Acorn Type)	3		Heater	6.3
956	5.80	Super-Control R-F Pentode (Acorn Type)	5	—	Heater	6.3
991	.90	Voltage Regulator	2	—	—	—
1602	2.75	Amplifier Triode (Low-Microphonic Type)	3	15	Filament	7.5
1603	2.25	Amplifier Pentode (Low-Microphonic Type)	5	—	Heater	6.3

Type	Amateur's Net Price	RECTIFIERS	Electrodes	Max. Peak Inverse Volts	Cathode Type	Cathode Volts
217-A	20.00	Half-Wave, High-Vacuum	2	3,500	Filament	10.0
217-C	20.00	Half-Wave, High-Vacuum	2	7,500	Filament	10.0
836	11.50	Half-Wave, High-Vacuum	2	5,000	Heater	2.5
866	1.75	Half-Wave, Mercury-Vapor	2	7,500	Filament	2.5
866-A	4.00	Half-Wave, Mercury-Vapor	2	10,000	Filament	2.5
872	14.00	Half-Wave, Mercury-Vapor	2	7,500	Filament	5.0
872-A	16.50	Half-Wave, Mercury-Vapor	2	10,000	Filament	5.0
878	11.00	Half-Wave, High-Vacuum for Cathode-Ray Tubes	2	20,000	Filament	2.5
879	3.00	Half-Wave, High-Vacuum for Cathode-Ray Tubes	2	7,500	Filament	2.5
885	2.00	Gas-Triode for Cathode-Ray Sweep-Circuit Control	3	300	Heater	2.5

Type	Amateur's Net Price	HIGH-VACUUM CATHODE-RAY TUBES	Electrodes	Max. Anode No. 2 Volts	Cathode Type	Cathode Volts
903	97.50	9 in., Electromagnetic Deflection, High-Vacuum	5	7,000	Heater	2.5
904	52.50	5 in., Electrostatic-Magnetic Deflection, High-Vacuum	5	4,600	Heater	2.5
905	45.00	5 in., Electrostatic Deflection, High-Vacuum	4	2,000	Heater	2.5
906	18.00	3 in., Electrostatic Deflection, High-Vacuum	4	1,200	Heater	2.5
907	48.75	5 in., Electrostatic Deflection, High-Vacuum, Short Persistence Screen	4	2,000	Heater	
908	21.00	3 in., Electrostatic Deflection, High-Vacuum, Short Persistence Screen	4	1,200	Heater	
909	49.00	5 in., Electrostatic Deflection, High-Vacuum, Long Persistence Screen	4	2,000	Heater	2.5
910	21.25	3 in., Electrostatic Deflection, High-Vacuum, Long Persistence Screen	4	1,200	Heater	2.5
911	22.50	3 in., Electrostatic Deflection, High-Vacuum, (Electron gun of low-magnetic material	4	1,200	Heater	2.5
912	163.40	5 in., Electrostatic Deflection, High-Voltage, High-Vacuum	4	15,000	Heater	2.5

Prices effective Oct. 19, 1936. Prices subject to change or withdrawal without notice.

CONDENSER REQUIREMENTS..

TYPE TJ DYKANOL TRANSMITTING CAPACITORS

Developed after many years of laboratory research and study, the C-D line of Dykanol impregnated and filled transmitting condensers are accepted as standard by all technicians in the radio industry. Their extreme compactness, sturdy construction and proven dependability make them most desirable where utmost satisfaction is demanded.

Cap. Mfd.	Cat. No.	List Price	H	W	D
Working Voltage 600 V.D.C.—440 R.M.S. Rect. A.C.					
1	TJ-6010	$2.75	2 1/8	1 13/16	1 1/16
2	TJ-6020	3.50	2 7/8	1 13/16	1 1/16
4	TJ-6040	4.50	3 7/16	2 1/2	1 9/16
Working Voltage 1000 V.D.C.—660 R.M.S. Rect. A.C.					
1	TJ-10010	$3.00	2 1/8	1 13/16	1 1/16
2	TJ-10020	4.50	4	1 13/16	1 1/16
4	TJ-10040	7.00	4 13/16	2 1/2	1 9/16
Working Voltage 1500 V.D.C.—1000 R.M.S. Rect. A.C.					
1	TJ-15010	$3.75	4	1 13/16	1 1/16
2	TJ-15020	6.25	4 5/16	2 1/2	1 9/16
4	TJ-15040	9.00	4 13/16	3 3/4	1 1/4
Working Voltage 2000 V.D.C.—1500 R.M.S. Rect. A.C.					
1	TJ-20010	$5.25	3 7/16	2 1/2	1 9/16
2	TJ-20020	8.00	4 1/16	3 3/4	1 1/4
4	TJ-20040	11.00	4 1/16	3 3/4	2 1/4

Cap. Mfd.	Cat. No.	List Price	H	W	D
Working Voltage 3000 V.D.C.—2200 R.M.S. Rect. A.C.					
1	TJ-30010	$18.00	4 1/16	3 3/4	2 1/4
2	TJ-30020	23.00	4 5/16	3 3/4	3 3/16
4	TJ-30040	30.00	4 13/16	3 3/4	4 9/16
Working Voltage 4000 V.D.C.—2750 R.M.S. Rect. A.C.					
1	TJ-40010	$26.00	5 1/16	3 3/4	2 1/4
2	TJ-40020	30.00	5 1/16	3 3/4	4 9/16
Working Voltage 5000 V.D.C.—3300 R.M.S. Rect. A.C.					
1	TJ-50010	$30.00	4 5/16	3 3/4	4 9/16
2	TJ-50020	34.00	6 1/16	3 3/4	4 9/16
Working Voltage 6000 V.D.C.—4400 R.M.S. Rect. A.C.					
1	TJ-60010	$63.00	9 1/16	5 1/8	3 1/2

TYPE 86 Hermetically sealed in glazed porcelain containers, the Type 86 Mica Transmitting condensers are entirely impervious to the most severe temperature and humidity conditions. By the use of Mica as a dielectric, it has been possible to reduce the loss of power flowing through the capacitor to 1/20 that of ordinary flint glass dielectric condensers. Supplied with heavy terminals and convenient mounting feet, this capacitor is the ideal transmitting condenser for use in tank, plate blocking, grid, and antenna coupling circuits.

Cap Mfd.	Maximum D.C. Voltage	Cat. No.	List Price	Maximum Current in Amps. 15,000 K.C. 20 M.	7500 K.C. 40 M.	3750 K.C. 80 M.	1875 K.C. 160 M.
.00005	12,500	45A-86	$3.75	3	2.5	1.5	1
.0001	12,500	31A-86	3.75	5	4	3	2
.00025	12,500	325A-86	3.75	7	6	6	4
.0005	7,000	35C-86	3.75	7	8	6	4
.0005	12,500	35A-86	4.25	8	9	8	7
.001	7,000	21C-86	4.25	8	9	10	8
.001	12,500	21A-86	5.00	9	10	11	12
.0015	7,000	215C-86	4.75	9	9	10	8

Cap. Mfd.	Maximum D.C. Voltage	Cat. No.	List Price	Maximum Current in Amps. 15,000 K.C. 20 M.	7500 K.C. 40 M.	3750 K.C. 80 M.	1875 K.C. 160 M.
.0015	12,500	215A-86	$5.50	9	10	11	12
.002	7,000	22C-86	5.25	8	9	10	10
.002	12,500	22A-86	6.50	9	12	13	15
.003	7,000	23C-86	6.00	9	10	10	10
.005	7,000	25C-86	7.00	9	11	12	11
.005	10,000	25B-86	9.50	10	13	14	15
.01	3,500	11D-86	7.00	10	13	14	14
.01	7,000	11C-86	9.50	10	13	15	15

Type 9 and 4 Moulded Mica Transmitting Condensers. Only the finest of raw material, subjected to most severe laboratory tests is employed in the construction of these capacitors. Extensively utilized in aircraft, marine, and submarine transmitters because of their high degree of dependability and exceptional adaptability.

These, and other transmitting capacitors completely detailed and listed in Catalog No. 133A supplied free on request. Available at all C-D authorized distributors.

MICA • DYKANOL • WET & DRY ELECTROLYTIC • PAPER

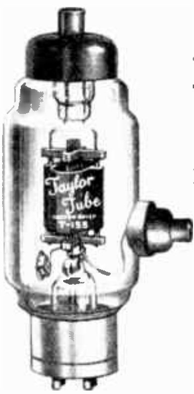
Taylor CUSTOM BUILT Tubes

T-200

T-55

More Watts Per Dollar
with
Taylor Carbon Anode Tubes

Over 50,000 satisfied users proves TAYLOR TUBES are superior. Pick a TAYLOR TUBE to serve your purpose.



T-155

866

Type	Use	Plate Dissipation Watts	Price
T55	H. F. General Purpose Tube	55	$ 8.00
T-200	Osc. & RF Amplifier	200	21.50
T-155	H.F. Osc. & RF. Amplifier	155	19.50
822	RF. Amp. & Class "B" Mod.	200	18.50
814	Osc. & RF. Amp.	200	18.50
HD-203-A	General Purpose Tube	150	17.50
203-A	General Purpose Tube	100	12.50
845	Audio Amp.	100	12.50
211	General Purpose Tube	100	12.50
211-C	H.F. Osc. & RF Amp.	100	12.50
203-B	Class "B" Mod.	50	7.50
841-A	General Purpose Tube	50	7.00
756	General Purpose Tube	40	4.95
825	General Purpose Tube	40	4.95
866	Mercury Half Wave Rectifier 2½ volts 5 amps.		1.65
866-B	M.W.M.V. Rect. 5 volts 5 amps.		3.00
872	H.W.M.V. Rect. 5 volts 10 amps.		12.00

841-A

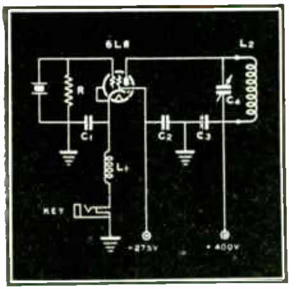
756

FULLY GUARANTEED

TAYLOR TUBES, INC.
2341 Wabansia Ave.
Chicago, Illinois

IF YOU WANT MORE OUTPUT

Use C and S Crystals In Your Jones Exciters



Jones 6L6 Oscillator

• You can operate a crystal oscillator on its fundamental frequency, as well as on its harmonics, in the new Jones All-Band Oscillator circuit shown above. Try this new circuit . . . and a C-&-S Crystal at the same time. The performance of both will surprise you.

C and S Holders, $1.00

I. C. A. Holders............$1.00
The new C-&-S Holder
Is Illustrated Above.

C and S Crystals Insure Success

YOU can not realize the full benefits from the new Jones Oscillators or Exciters unless you use a GOOD crystal. If the crystal has two "humps" or "peaks," it is worthless for harmonic operation. C-and-S has a de-luxe crystal for the Jones Harmonic Oscillator; it is conservatively priced and it has the endorsement of Frank C. Jones.

Prices:

C-&-S CUT K-96. A low-drift, high activity 40, 80 or 160 meter MOUNTED crystal........................$2.75

Same Crystal as above, but unmounted. 80 or 160 meters only $2.00

THICK C-&-S CUT. An extremely thick cut crystal. Low drift, high activity. Supplied mounted only. 7,000 KC Band......$3.50 14,000 KC Band......$6.00

100-KC Standard Frequency Bars, X-cut, mounted....$9.50

SS Super IF Filter Bars, X-cut, mounted, 450-520 KC....$4.50

Special Crystal Grinding and Cutting for Wholesalers.

Prices on Request.

We solicit orders for single frequency networks, Army, Navy and Traffic Nets. These crystals are available at regular prices, if for 80 or 160 meter operation.

• **Commercial and Police-Frequency Crystals.**

SUPER-THICK C-&-S CUT. For Commercial and Police Radio Only. Attractive Prices on Request.

C&S Quality

C and S XTALS

836 E. Weber Ave. Phone 8279W Stockton, California

JEFFERSON *Radio* Transformers

JEFFERSON RADIO PRODUCTS

AUDIO
PP INPUT
INTER-STAGE
DRIVER
OUTPUT
POWER
MODULATION
FILAMENT
PLATE
MICROPHONE
CHOKES
LINE
AUTO
MIXING
FIELD SUPPLY

FILAMENT TRANSFORMERS

You Can Depend On

Typical of the values in the Jefferson line of fourteen Filament Transformers are the following:

Cat. No. 464-201—Pri. 115 volts 60 cycles—Sec. 2½ volts CT. @ 12 Amps. Secondary insulation tested at 7500 volts—**Your cost $1.20.**

Cat. No. 464-321—Pri. 115 volts 60 cycles—Sec. 7.5 volts CT. @ 6.5 Amps. Secondary Insulation tested at 2000 volts—**Your Cost $1.80.**

The above units are also available completely shielded.

PLATE SUPPLY TRANSFORMERS

Unusual values in all popular size plate supply transformers are listed in the complete Jefferson catalog. The following are representative:

Cat. No. 465-18 delivers 1000 or 1250 volts DC at 300 milliamps. Weighs 30 pounds—**Your cost $13.80.**

Cat. No. 465-211 will deliver 1000 volts DC 400 MA with conventional full wave rectifier or 2000 volts DC—200 MA with bridge type rectifier—**Your cost $15.00.**

MODULATION TRANSFORMERS

A Complete Jefferson Line

A line of 11 modulation transformers listed to take care of all popular requirements. The following is outstanding:

Transformer No. 467-526 for coupling PP 6L6's in Class AB_2 to Class C load—60 watts capacity. Pri. 3800 ohms. Secondary: 7200 ohms with 120 MA DC or 3000 ohms with 200 MA DC for single 03A or two 800's—**Your cost only $5.40.**

SWINGING and SMOOTHING CHOKES

Conservatively rated swinging and smoothing chokes in carrying capacities up to 500 MA are listed in the Jefferson catalog.

Swinging Choke No. 466-360 has capacity of 170 to 500 MA,—Inductance 15 to 5 henries,—Resistance 60 ohms. **Your cost $9.00.**

Smoothing Choke No. 466-370—with capacity of 500 MA,—Inductance 15 henries, Resistance 100 ohms,—**priced at $10.20.**

SEND for COMPLETE CATALOG and AMPLIFIER CIRCUIT DIAGRAMS—FREE

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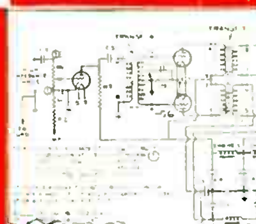
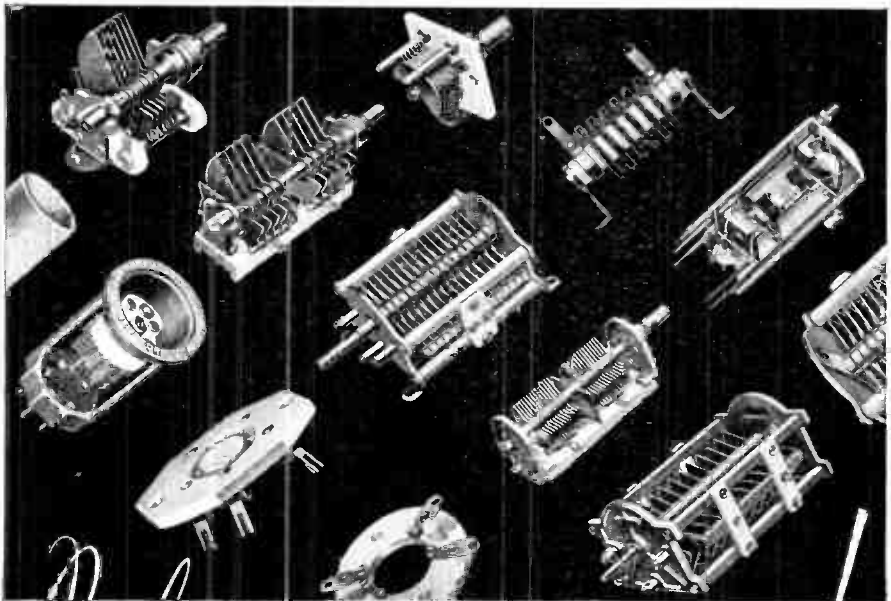


JEFFERSON ELECTRIC COMPANY

Bellwood (Suburb of Chicago) Illinois

Canadian Factory, [illegible] College St. Toronto



Priceless PRECISION IN EVERY UNIT!

TWENTY-FIVE years ago, the first HAMMARLUND precision products made their appearance to the applause of the radio engineering world. Their dominant superiority became a by-word in laboratories, industrial plants, homes, and schools the world over. Today, specialists show an even greater approval of the distinctive and extensive line of HAMMARLUND parts with *priceless precision built into every unit!* They are specified for every conceivable type of radio instrument.

Every feature of HAMMARLUND products is designed for peak electrical and mechanical efficiency. Wide capacity ratios; vibration-proof construction; noise-free operation; quality insulation; selected metals —all with an eye to dependable trouble-free, long-lasting service.

A wide variety of stock models is available. Above are shown a few popular HAMMARLUND products—single and split-stator midget and micro condensers, transmitting condensers, acorn and standard Isolantite sockets, transmitting chokes, Isolantite coil forms, XP-53 plug-in coils, air-tuned I.F. transformers.

The new HAMMARLUND "37" catalog completely describing all HAMMARLUND products with numerous illustrations, curves and mechanical drawings, has just been released. A copy will be rushed to you free of charge upon request. Just mail the coupon below.

MAIL COUPON NOW!

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Please send me new HAMMARLUND "37" Catalog.

Name ....
Address ....
City .... State .... RH 37

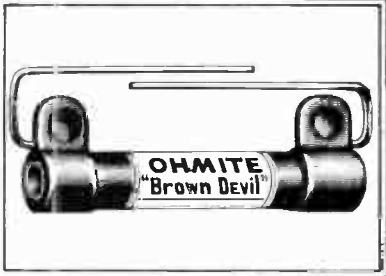
HAMMARLUND'S 25TH YEAR

OHMITE

FIXED AND ADJUSTABLE RESISTORS

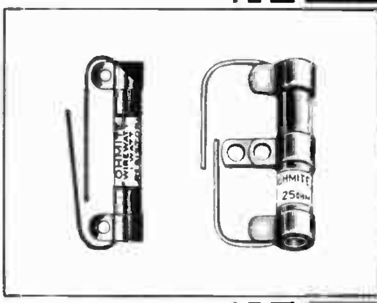
OHMITE "Brown Devil"

These are vitreous enameled resistors, made in both 10 watt and 20 watt sizes; resistance values from 1 ohm to 100,000 ohms. A cement coated resistor, the famous "Red Devil," is also made by us—long a favorite with amateurs and radio service men. The "Red Devils" have a five-to-one factor of safety and will not fail even when they get red hot. The 10 watt size has resistance values of from 1 to 25,000 ohms and the 20 watt size from 25,000 to 100,000 ohms.



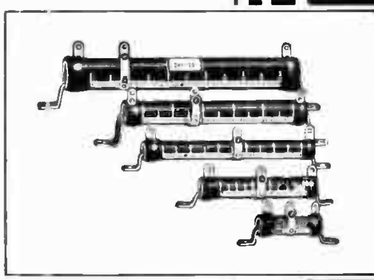
OHMITE "Wirewatt" and Center-Tap Resistors

Ohmite "Wirewatt" is a small wire-wound, vitreous enameled resistor of one watt rating. In stock values of from 100 to 25,000 ohms. This is the finest small resistor that money can buy. Center-tapped resistors can be furnished in either the "Wirewatt" or "Brown Devil." They are chiefly used to secure electrical centers of tube filament circuits.



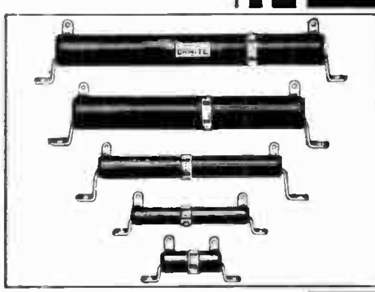
OHMITE "Dividohms"

Voltage-divider resistors of high quality. Where closer adjustment than can be provided by a tapped unit (Ohmite "Multivolt") is desired, this resistor is recommended. "Dividohms" are wire-wound, vitreous enameled units of the very finest grade of construction to be obtained anywhere. An adjustable lug with a "ball point" permits adjustments to varying resistance values.



OHMITE Fixed Resistors

These are the standard vitreous-enameled fixed resistors. Get your copy of the OHMITE AMATEUR HANDBOOK which describes these and many other items in the OHMITE LINE—with circuits, tables and other interesting information. Ten cents at your dealers or sent postpaid on receipt of 10 cents.



OHMITE

MANUFACTURING CO.

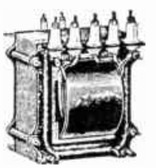
4842 Flournoy St. Chicago, Ill.

A NEW KIND of CATALOG

The "RED BOOK of AMATEUR RADIO"

Mid-West Quality Maintained
Write for Your Free Copy!
Here are just a few typical
Money Saving Values for You

PLATE SUPPLY TRANSFORMERS



3000 - 2000 - 0 - 2000 - 3000 Volts at 350 MA. thru-filter. 110V. Pri. Dim: h. 9¼"; w. 7¼"; d. 6¾". 1 KW.

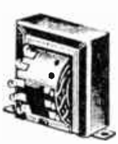
NET PRICE **$18.95**

Thordarson Plate and Filament Transformer

600-0-600 Volts at 200 MA. thru filter. 7½V. at 2½ Amp. 5V. at 3 Amp. 2½ V. at 5 Amp. 110 Pri. Dim.: h. 5"; w. 3¾"; d. 4⅜".

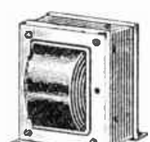
NET PRICE **$2.45**

FILTER CHOKES



Height 3"; width 2½"; depth 2½". Mounting centers 3". Smoothing choke 30 henry 100 MA. DC Resistance 150 ohms.

No. B11187—Type A.
NET PRICE................**95c**



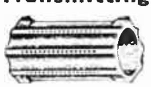
C2 — Height 4⅞"; width 3⅜"; depth 3" mounting centers 2¾" — 2⅞". C3 — Height 4⅞"; width 3⅜"; depth 2⅜"; mounting centers 2⅜" — 2⅞".

Smoothing choke 30 henry 200 MA. DC Resistance 150 ohms.
Type C3.
NET PRICE........... **$1.25**

Smoothing choke 30 henry 300 MA. DC Resistance 95 ohms.
Type C2.
NET PRICE........... **$1.95**

All the Leading Communication
RECEIVERS AT LOW PRICES
RCA
NATIONAL
HAMMARLUND
HALLICRAFTERS
BRETING 14

Mid West Transmitting Coil Forms



Special ceramic forms for winding transmitting inductance. Adaptable for 20, 40, 80 and 160 meters. Threaded for winding any size wire up to No. 10. Holes in ends for mounting insulators in plugs.

No. A7583—2½" O.D.x5" long. SPECIAL NET PRICE, EACH........................**59c**

No. A7584—4" O.D.x6½" long. SPECIAL NET PRICE, EACH........................**99c**

Transmitting Antenna Insulators

Constructed of white glazed, wet process porcelain. Combine remarkable strength with very low loss. Have high dielectric strength. For transmitting or receiving aerials. All 1" diameter.

7 IN. NET EACH..................**18c**
12 IN. NET EACH..................**26c**
20 IN. NET EACH..................**34c**

STEEL STANDARD RACK PANELS

Supplied in ⅛" thickness completely slotted and finished in a black crackle.

Cat. No.	Size	Net
B11187	1¾x19	$0.39
B11188	3½x19	.44
B11189	5¼x19	.49
B11190	7 x19	.54
B11191	8¾x19	.59
B11192	10½x19	.69
B11193	12¼x19	.79
B11194	14 x19	.89
B11195	15¾x19	.99
B11196	17½x19	1.09
B11197	19¼x19	1.19
B11198	21 x19	1.29

Blank Rack Chassis Crackle Finish

Designed to fit all Standard Relay Racks. Made with inverted flanges for mounting bottoms as protection against dirt. Welded corners.

7" W. x 17" L. x 3" H.........75c
10" W. x 17" L. x 3" H.........79c
13" W. x 17" L. x 3" H.........89c

BLANK CHASSIS Cadmium Plated

These chassis and bases are made of cold rolled specially annealed steel, cadmium plated with welded corners.

B11202	10 x12 x3	69c
A7555	10 x17 x3	75c
B11203	10 x23 x3	89c
A7553	7 x12 x3	65c
B11204	7 x17 x3	75c
B11205	7 x23 x3	85c
A7552	7 x 9½x3	59c
A7551	7½x11 x2½	65c
A7554	11 x10 x2½	69c
A7550	9½x 5 x1½	35c
A7549	8½x 4¾x1½	35c

MID-WEST RADIO MART 520 SO. STATE STREET, CHICAGO, ILL.


The Veteran Amateur Demands
UTAH PARTS
There's a reason for this preference by veteran amateurs and service men in all parts of this country. For 15 years Utah has been constantly striving toward perfection, earning the favor of the radio amateur by superiority in quality, by a painstaking and never-ending search for better design, and the ready adoption of refinements based on years of sound experience.
The Radio Amateur knows that Utah parts in his "rig" are an assurance of dependable performance and satisfactory operation of the equipment he builds so carefully.
Demand Utah parts from your dealer—it pays. If you haven't a copy of the latest Utah Amateur catalog—write for yours now.
UTAH SPEAKERS • VIBRATORS • TRANSFORMERS • VOLUME CONTROLS
TONE CONTROLS • JACKS • PLUGS • CHOKES • SWITCHES • RESISTORS
UTAH RADIO PRODUCTS COMPANY
TORONTO - CHICAGO - BUENOS AIRES
"15 YEARS OF LEADERSHIP"

MACHINE vs. SHORT WAVE RECEIVER for RADIO CODE

WHY WASTE valuable time trying to become an Operator by listening to your Short Wave Receiver alone. Few indeed, ever get beyond the scant Amateur stage by that method.

The "Instructograph Way" permits you to practice uninterruptedly on whatever kind of sending you wish or need. You may practice any time—day or night; good or bad weather; slow or fast as your advancement demands. You regulate the speed of sending as you wish.

No "fishing around" for some Amateur sending at your speed, and have him stop just about the time you get started to practice. No dividing your attention by "tuning" with one hand and trying to copy with the other. No weather or static interference with schedules.

So, if you are tired of trying to get a start, or are a "10 per" man, get the Instructograph and quickly get ALL the enjoyment of the AIR. To be limited to 13 or 20 words per minute on your Short Wave Receiver is about like it would be to have your Broadcast Receiver limited to "Bed-Time Stories." Get in the game right.

Read what a few of the boys say about the "Instructograph Way." We have hundreds of such letters from all sections of the Country.

CHAS. O. WEBER
321 W. GRAISBURY AVE., AUDUBON, N. J., SAYS:

"Boy, Oh Boy. Why I ever wasted about a year trying to learn to receive Code on my Short Wave Receiver, when I could buy an Instructograph, that would be willing to give me lessons whenever I was in the mood, for the small sum of $20.25—I do not know. You could not buy it back for many times the amount if you wished to do so.

"I have made wonderful progress in the past few weeks, and with the assistance of the Instructograph I am sure that I shall soon have all the speed I desire."

JOSEPH P. SKUTNIK
PINE ISLAND, NEW YORK, W2JWK, SAYS:

"In appreciation of the services the 'Instructograph' has rendered me, I wish to state that, in my opinion, there is no other machine on the market today that equals it when it comes to teaching the code.

"In my own case I could not pass the 8 word per minute mark after I had practiced four months by other methods. Today, after practicing with the Instructograph for a period of seven weeks, I can comfortably receive about 21 words per minute. On May 16th I took the Amateur examination and passed the code test with ease.

"You have my permission to reprint any of the above statements, to convince others that the Instructograph is just the machine to use in learning the code, or gaining speed."

JAMES W. DATES
17 SHERWOOD ST., WELLSBORO, PENNA., SAYS:

"As I intend to keep your machine for another month, I am enclosing a postal money order for $2.25.

"I am coming along very nicely, but require more time on numbers, so am keeping it for another month.

"I have a great deal of faith in your method of code instruction, as I have progressed further in one month with it than in five months listening on Short Wave."

MACHINES FOR RENT OR SALE

The "Instructograph" Code Machine is manufactured in two sizes. The "Standard," as illustrated above, includes a full set of ten tapes and the Book of Instructions. This machine may be rented at a nominal monthly rate, and the rental paid, may be applied on the purchase price, if it is desired to purchase after three months' trial, or sooner.

The "Junior" Model, similar in appearance to the standard machine, only smaller and with five tapes and the Book of Instructions, is not rented but may be purchased for $12.00—delivered to any point in the United States or Possessions. The small machine operates just as efficiently as the larger one—the difference being mainly in the size, weight and number of tapes supplied. Additional tapes, however, may be purchased at a reduced rate.

Send today for a detailed description of both machines, and the several renting propositions. A post card with your name and address is all that is necessary.

The Instructograph can also be used for American Morse (Wire) Code Instruction, for which tapes are available.

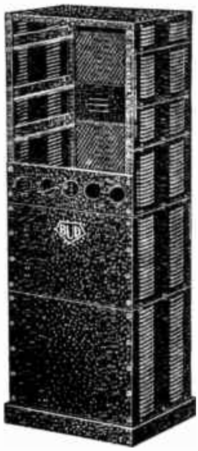
INSTRUCTOGRAPH CO.

916 Lakeside Place (*Dept. RBK*) **Chicago, Illinois**

Creators and Producers

of low loss, High Quality, Ruggedly Constructed

AMATEUR RADIO PARTS

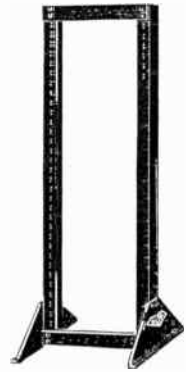


BUD SECTIONAL CABINET RELAY RACK

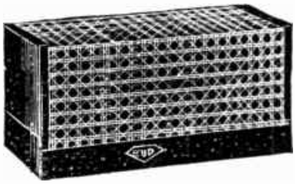
This new innovation in rack design, permits the building of a cabinet rack to your required height without having any waste space. The feature of this rack is that you can have a complete rack starting from 3½" high and progressing in height in multiples of 1¾" until any desired height is attained. Additional sections can be added at any time.

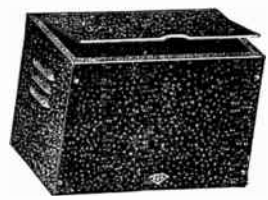
A screw driver is the only tool necessary for assembling (illustrated at left).

Other types and sizes of RELAY RACKS for any requirement, also rack panels and dust covers.



BUD METAL CABINETS AND CHASSIS BASES

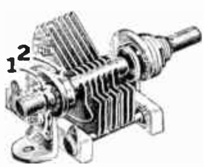




Made in numerous types and sizes. Ruggedly constructed, of heavy gauge sheet steel. Cabinets have black crackle finish. Chassis in black crackle and zinc coated finish.

MIDGET CONDENSERS

Note These Improved Features!

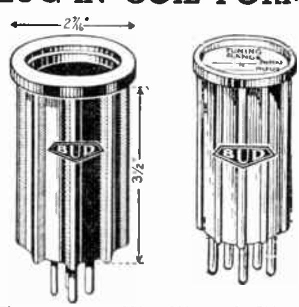


1. **New Positive Wiping Contact** on rotor shaft with adjusting screw, eliminates mechanical noise on high frequencies.
2. **Close Fitting Bearings** hold rotor calibration and smoothness of operation.
3. Insulated with **ISOLANTITE.** Soldered brass, plate assemblies, and heavy aluminum end plates make a precision built, ruggedly constructed condenser.

For S. W. Receivers and Xmitters. Numerous capacities in single and dual units with single or multiple spacing.

Bakelite

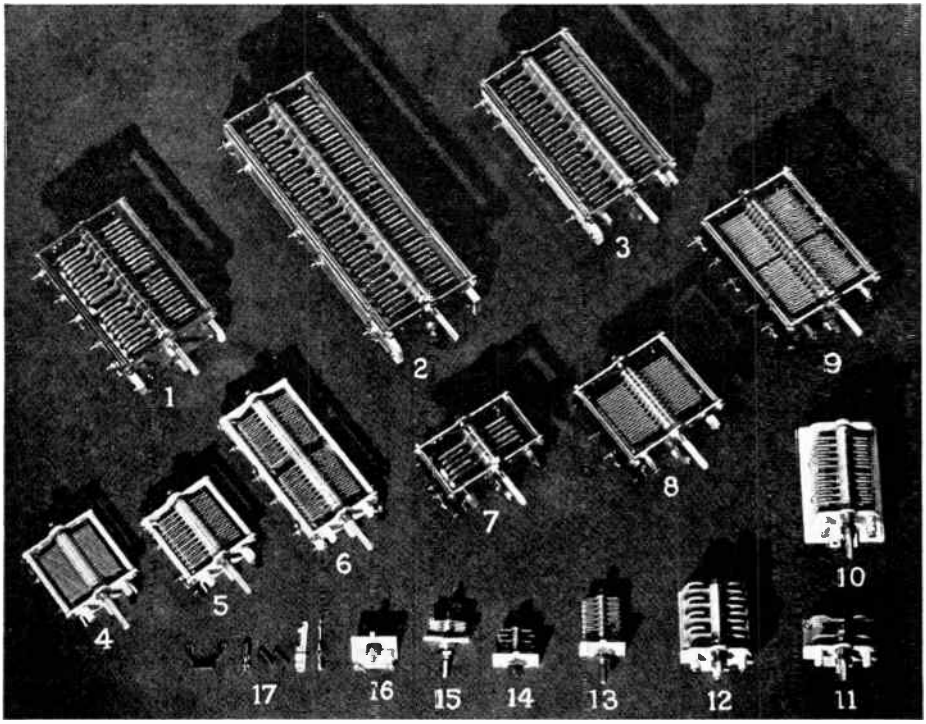
PLUG-IN COIL FORMS



Three sizes, 1¼, 1½ and 2¼ inch Dia. Made in 4, 5 and 6 prong units to fit standard tube sockets. Ideal form for receiver or Xmitter Inductances.

Listed above are but a few items of the complete line of amateur parts in the BUD line. A new catalogue which illustrates and describes hundreds of items used by every branch of the radio industry is Free for the asking. Write Dep't. RBH-37 for your copy.

BUD RADIO INC. • **1937 E. 55TH STREET CLEVELAND, OHIO**



YOUR FAVORITE CARDWELLS FOR 1936 LEAD THE FIELD FOR 1937

A survey of Cardwell sales to the amateur discloses 16 numbers so outstanding in popularity, we present them in a family group:

(1) **XG-50-KD** $10.00 list — Cap. 50-50 mmf. airgap .171 in., 5500 V. condenser for P.P. tanks—Mycalex insulation.

(2) **XC-75-XD** $17.00 list — Cap. 75-75 mmf. airgap .200 in., 7000 V. condenser for P.P. tanks—Mycalex insulation.

(3) **XC-100-XS** $11.50 list — Cap. 100 mmf. airgap .200 in., 7000 V. tank condenser—Mycalex insulation.

(4) **MR-365-BS** $3.30 list — Cap. 365 mmf. airgap .031 in., 1000 V. condenser. Compact unit for high "C" exciter units, buffer stages, etc.

(5) **MT-100-GS** $4.40 list — Cap. 100 mmf. airgap .070 in., 3000 V. For 500-1000 V. buffer stages.

(6) **MT-100-GD** $8.00 list — Cap. 100-100 mmf. airgap .070 in., 3000 V. Mycalex insulation. For P.P. plate modulated 10's.

(7) **XG-25-KS** $3.00 list — Cap. 25-9 mmf. airgap .171 in., 5500 V. neutralizer for 203-A's, 211's, etc.

(8) **XT-220-PS** $4.00 list — Capacity 220 mmf. airgap .070 in., 3000 V. For antenna net works and medium power tanks.

(9) **XT-210-PD** $8.00 list — Cap. 210-210 mmf., airgap .070 in., 3000 V. For P.P. medium power tanks.

(10) **NP-35-GD** $6.00 list — Cap. 35-35 mmf. airgap .084 in., 4200 V. H. F. condenser for 5-10M.

(11) **NA-4-NS** $3.60 list — Cap. and gap adjustable. Normally a 4 mmf. neutralizer for 800, 852's—Mycalex insulation. Rotor lock. Slotted shaft for screw driver adjustment.

(12) **NA-14-NS** $5.00 list — H. F. neutralizer for 805's, etc. Capacity 14-5, airgap .218 in., 7000 V. condenser.

(13) **ZT-30-AS** $1.85 list — Trim-air neutralizer, capacity 30-4 mmf., airgap .070 in., 3000 V. Isolantite insulation.

(14) **ZS-4-SS** $1.85 list — Trim-air Neutralizer—Cap. 4-1.5 mmf., airgap .150 in., 4500 V. buffed plates. For 35-T's, T-55's, etc.

(15) **ZR-25-AS** $1.40 list — Trim-air—Cap. 25-2 mmf., airgap .031 in., 1000 V.

(16) **ZR-15-AS** $1.25 list — Trim-air—Cap. 15-1.5 mmf. airgap .031 in., 1000 V.

(17) (L to R) — Trim-air mounting bracket, extension shaft, mounting posts, and 804-A Inductance clips (for No. 12 or No. 14 wire).

Write for our handy net price bulletin with all pertinent information on 100 quality variable air condensers for every purpose and power including 1 KW phone.

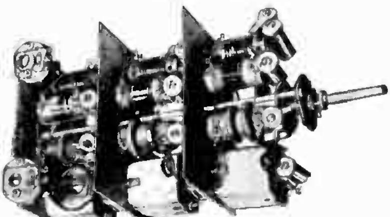
THE ALLEN D. CARDWELL MANUFACTURING CORPORATION

81 PROSPECT STREET, BROOKLYN, N. Y.

Meissner

Multi-Wave Assembly

Mono-unit construction



In answer to the constant demand for an "All Wave" coil assembly that will meet the demands of modern requirements, Meissner offers the coil and switch assembly as shown in the illustration.

The unit embodies all coils, range switch, shunt trimmers, series padders, A.V.C., by-pass condensers and necessary shielding. It is in fact the entire "Front End" of an all-wave set, exclusive of the gang condenser and tubes. Aligned and padded. No adjustments necessary. **ALIGN-AIRE (air dielectric) Trimming Condensers used on all bands,** except the ultra high frequency band. which requires no trimmers. The essential features of this assembly are listed below in condensed form.

1. Aligned and padded. Completely assembled and accurately balanced. Ready to work. No adjustments necessary. No testing equipment necessary. 2. Simple, efficient coil construction—individual coils for each band. 3. Essentially no leads from coils to switch (all coils except long wave, 2000 meters, supported by their lugs from switch. 4. No common grounds. Tuned circuit ground returns, connect directly to respective gang wipers. 5. All leads short and direct resulting in uniformity of all assemblies. 6. **ALIGN-AIRE** (air dielectric) trimming condensers used on all bands, except the ultra high frequency band which requires no trimmers. 7. Padding condensers—Variable mica on the long wave and broadcast and police bands, fixed mica on the 6 to 18 MC band and no pad on the ultra high frequency band. 8. **R.F.** stage is used on all bands except the ultra high frequency band. 9. The oscillator detector unit has circuit constants giving uniform oscillation voltage and optimum conversation conductance on all bands. 10. Simple compact chassis lay-out.

AVAILABLE IN FIVE DIFFERENT COMBINATIONS

For Use with 410 mmf. Condenser

5 Band	4 Band	3 Band
7.5 to 20 meters	7.5 to 20 meters	16.4 to 51 meters
16.4 to 51	16.4 to 51	48.5 to 177
48.5 to 177	48.5 to 177	167 to 555
167 to 555	167 to 555	
732 to 2140		
Model No. 7505—List $21.00	Model No. 7504—List $17.50	Model No. 7503—List $16.00

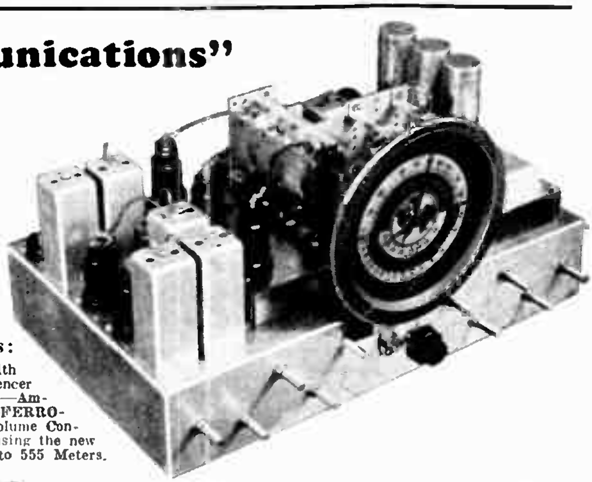
For use with 260 mmf. Condenser

5 Band	4 Band
3.8 to 9.9 meters	3.8 to 9.9 meters
9.7 to 25	9.7 to 25
24 to 68	24 to 68
67 to 200	67 to 200
190 to 555	
Model No. 7515—List $21.00	Model No. 7514—List $17.50

14-Tube "Communications" Receiver Kit

Utilizing the MEISSNER Completely Assembled Tuning Unit

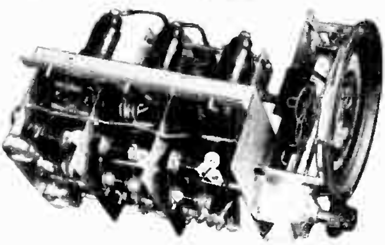
5 Bands—3.8 to 555 Meters



Especially designed for the Radio Amateur who wants a receiver to cover all the bands. The five, ten, twenty, forty, eighty, one hundred and sixty, and the broadcast band. Every "proven" development in circuit design is incorporated.

Some of the Outstanding Features:

Crystal Filter—Beat Frequency Oscillator with cut-out switch and pitch control—Noise Silencer Circuit—Variable Electrical Band Expansion—Amplified A.V.C.—Variable Sensitivity Control—FERROCART (Iron-Core) I.F. Transformers—Audio Volume Control—Fourteen New Metal Tubes—P.P. Output using the new "Beam" 6L6 Metal Tubes—Five Bands 3.8 to 555 Meters.



The complete Coil Kit consists of the following: Completely wired tuning unit as described above. Noise Silencer I.F. Transformer. Beat Frequency Oscillator Transformer. Matched Pair of Crystal Filter Transformers. FERROCART (Iron Core) I.F. Output Transformer. Band Expansion I.F. Transformer. FERROCART (Iron-Core). 6 Shielded R.F. Chokes. Complete set of diagrams and instruction sheets.

Kit No. 7502—Complete as described above..............List $50.00

Completely Wired Tuning Unit Only

The completely wired and accurately balanced and aligned tuning assembly, includes the Meissner multi-wave coil assembly, band-change switch, variable gang condenser, tube sockets for tuning unit (3), and a calibrated 6" Aeroplane dial with "Micromaster" mechanical band spread.

Model No. 7512..List $35.00

FREE Our complete catalog is ready. Everything in coils: I.F., R.F., Chokes, etc., as well as complete all wave and special short wave tuning assemblies and complete coil kits for sets from two to fourteen tubes. You need this guide to help you select the proper coil or coil assembly.

MEISSNER PRODUCTS ARE SOLD BY ALL LEADING JOBBERS

MEISSNER MFG. CO., MT. CARMEL, ILLINOIS

UTC

Most Complete Transformer Line in the World

QUALITY · RELIABILITY

Don't Forget . . . the NEW UTC VARIMATCH Modulation Transformer will Match ANY Modulator Tubes to ANY RF Load . . . .

The Varimatch transformer will not only match PRESENT available modulator tubes, but any tube that may be released at a FUTURE date.

All you have to decide is the DC input to your RF stage. Then just pick the VARIMATCH output transformer that will handle the maximum audio power required.

These transformers will also match the line impedance output of PA or similar amplifiers direct to the Class C tubes.

VM-1 Will handle any power tubes to modulate a 20 to 60 watt Class C stage. Maximum audio output 30 watts. Net to Hams....... **$4.80**

VM-2 Will handle any power tubes to modulate a 40 to 120 watt Class C stage. Maximum audio output 60 watts. Net to Hams....... **$7.50**

VM-3 Will handle any power tubes to modulate a 100 to 250 watt Class C stage. Maximum audio output 125 watts. Net to Hams..... **$12.00**

VM-4 Will handle any power tubes to modulate a 200 to 600 watt Class C stage. Maximum audio output 300 watts. Net to Hams..... **$19.50**

VM-5 Will handle any power tubes to modulate a 450 watt to 1 KW plus. Class C stage. Maximum audio output 600 watts. Net to Hams .. **$42.00**

The secondaries of all Varimatch transformers are designed to carry the Class C plate current.

The Varimatch Transformer Never Becomes Obsolete

NEW VARIMATCH INPUT TRANSFORMERS

PA-49 Pushpull 45, 59 or 6L6 plates to push pull 845A prime grids. PA-2. Net to Hams.................................. **$4.50**

PA-50AX Single 53, 56, 6C5, 6C6 triode, 6A6 to Class B 53, 6A6 or 6E6 grids or single 89 to Class B 89 grids. PA-1. Net to Hams.................................. **$3.30**

PA-51AX Single 46 or 6L6 to Class B 46 or 59 grids. Single 45, 59, 2A3 or 6L6 to Class B 46 or 59 grids. Single 49 to Class B 49 grids. Single 37, 76, 6C6 triode or 6C5 to Class B 19 or 79 grids. Single 30 to Class B 19 or 79 grids. Single 89 to Class B 19 or 79 grids. Single 2A5, 42, 45 triode plate to A prime 45's. 2A5's or 42's. PA-1. Net to Hams.................................. **$3.30**

PA-52AX Push pull 45, 59, 2A3 or 6L6 plates to 2-46 Class B grids. Push pull 45, 59, 2A3 or 6L6 plates to 4-46 or 59 Class B grids. Push pull 2A3's to 2-841 Class B grids. PA-2. Net to Hams.................................. **$3.90**

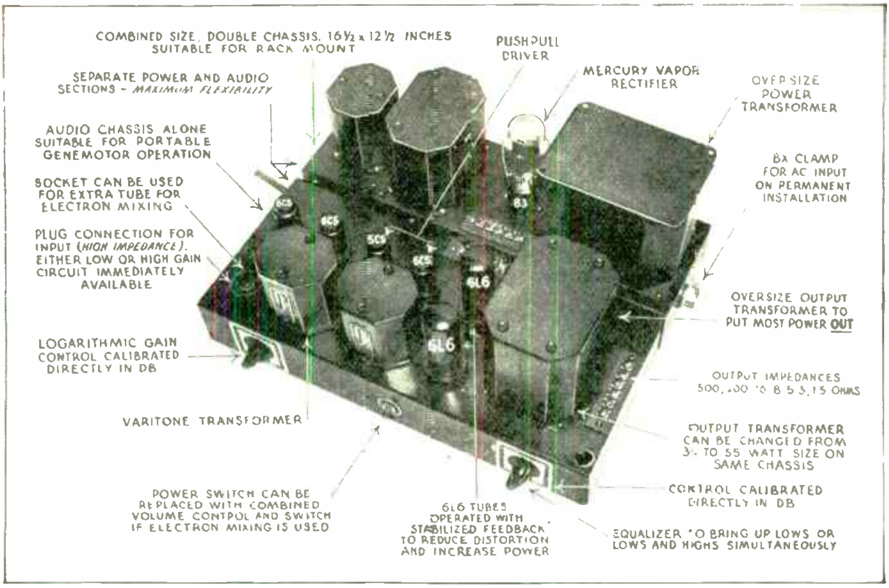
PA-53AX Push pull 42, 45, 50, 59, 2A3 or 6L6 plates to two 210, 801, RK-18, 35T or 800 Class B grids. Push pull 2A3 plates to two 838, 203A, 50T, 35T, 211A, 242A, 830B, 800, RK-18, 801 or 210 Class B grids. PA-2. Net to Hams.................................. **$4.50**

PA-59AX 500, 200 or 50 ohm line to two 805, 838, 203A, 830B, 800, RK-18, 801 or 210 Class B grids. Net to Hams.................................. **$4.50**

PA-238AX Push pull parallel 2A3, 45, 50, 59 or 6L6 to four 805, 838, or 203A Class B grids. Push pull parallel 2A3, 45, 50, 59, 6L6 or two 211A, 845 plates to Class B 204A, HF-300 or 849 grids. Push pull parallel 2A3, 45, 50 or two 50T, 211A, 845 plates to Class B 150T or HF-200 Class B grids. PA-3. Net to Hams.................................. **$10.50**

PA-512 500, 200 or 50 ohm line to two 150T, HF-300, HF-200, 204A or 849 Class B grids. PA-3. Net to Hams.................................. **$12.00**

New . . . UNIVERSAL BEAM POWER AMPLIFIER



PAK amplifier kits feature: Power output 35 watts self bias, 55 watts fixed bias; gain 118 DB, immediate change-over to 95 DB; separate power supply and audio decks; stabilized feedback; mobile operation with genemotor—20 watts output; provision for electron mixer or low impedance input if desired.

PAK-1 Complete 35 watt kit including all accessories and output transformer with line and voice coil impedances, type PAK-1, net price to hams.................... **$45.00**

PAK-1X 35 watt kit with modulation output transformer, type PAK-1X, net price to hams **$45.00**

PAK-2 amplifier same as PAK-1, but with 55 watts output transformer to line and voice coils, net price to hams........ **$48.00**

PAK-2X same as PAK-1, but with 55 watt modulation output transformer, net price to hams **$48.00**

NEW UTC TRANSFORMERS for use with 6L6 TUBES

PA-428 Power transformer for push pull 6L6 tubes, self or fixed bias primary, 115 v. a.c., 60 cycles. Secondaries 450-0-450 at 250 ma.; 6.3 VCT 4A, 6.3 VCT-2A tapped for 2½ volts-3A, 5 VCT 3-A. Net to hams..... **$8.40**

PA-233 Input transformer from two 56, 6C6 triode, 6C5, or similar tubes to 6L6's self bias. Net to hams.................... **$3.60**

PA-333 This input transformer is designed to operate from 6C5's or similar driver tubes to two 6L6's fixed bias.
Net to hams.......................... **$3.60**

PA-433 From 45 or 2A3 plates to two or four fixed bias 6L6 grids.
Net to hams.......................... **$3.90**

***PA-2L6** 6600 ohms. plate to plate. Will match 35-40 watts output. Secondary impedance, 500, 200, 16, 8, 5, 3, 1.5 ohms.
Net to hams.......................... **$6.00**

***PA-4L6** 3800 and 3300 ohms. plate to plate. Will match two 6L6's fixed bias, 60 watts output; four 6L6's self bias, 60-80 watts output. Secondary impedance, 500, 200, 16, 8, 5, 3, 1.5 ohms. Net to hams............... **$9.00**

**These transformers incorporate the new UTC Feedback (patent applied for) Winding which reduces harmonic distortion, increases available power and reduces plate resistance tremendously. No resistors or condensers are necessary.*

Ask your distributor for the new UTC BEAM POWER AMPLIFIER BULLETIN. This attractive book dicusses the operation of 6L6 Beam Power Tubes and includes circuit diagrams.

UNITED TRANSFORMER CORP.

72 SPRING STREET • NEW YORK, N. Y.

EXPORT DIVISION: 100 VARICK STREET NEW YORK, N.Y. CABLES: "ARLAB"

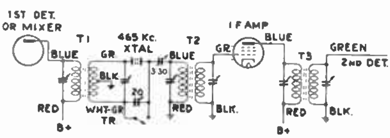
Aladdin REG. U.S. PAT. OFF. — Polyiron Mica-Tuned I-F's

Type A i-f Transformers

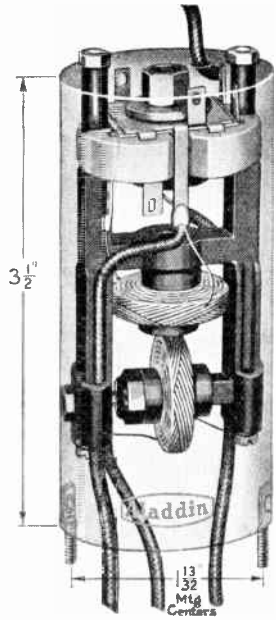
Adjustable coupling, as offered in the Type A ALADDIN Polyiron transformers, permits a desirable degree of circuit variation by the advanced radio technician. A lateral adjustment is provided for the lower coil to secure the exact degree of coupling required for any i-f circuit. In doing this the following procedure should be followed: Loosen the set screws in the bakelite supports, reached through the bottom of the shield; adjust the coupling by carefully turning the nut on the side of the unit. A clockwise rotation of two turns increases the selectivity as shown by A in the accompanying curves, but reduces the gain. A counter-clockwise rotation of two turns produces overcoupling, broadening the curve as shown in C and reducing the gain. B curve is the factory setting at optimum gain.

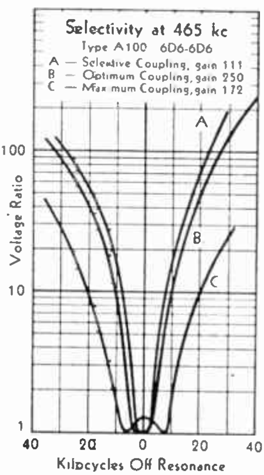
No factory replacements or adjustments will be made after the lateral coupling seal is broken.

The diagram and table below show three combinations of ALADDIN units for use in a crystal filter circuit.



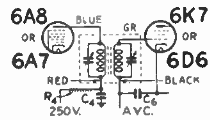
T_1 G101C or A100C or GA100C		
T_2 G101A	A100	GA101A
T_3 G201	A201	GA201 for Diode 2nd Det.
T_3 G101A	A100	GA101A for Triode 2nd Det.

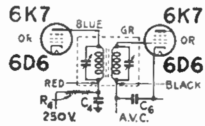




Applications

The selection of an ALADDIN transformer should be governed by the types of tubes employed and the gain which the circuit will handle. While 465 kc is the present established i-f frequency, a few transformers are listed for use at other frequencies. The accompanying circuits show tubes corresponding to the types recommended in the data.

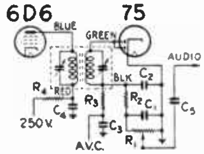




A resistor (1000-1500 ohms) by-passed by a condenser (0.1 u-f) appears in the plate circuits. This is recommended because the high gain of Polyiron transformers may cause oscillation if stray coupling exists.

Two stages (three transformers) are not advisable unless a crystal filter is used and then only in a carefully designed circuit. One stage of i-f amplification is ample for the finest receiver.

A typical diode stage (75, 6H6, etc.) shown on the left, working into a 0.5 meg. load (R_1) may have the following values: R_2, 0.05 meg; R_3, 0.5 meg; R_4, 1000 ohms; C_1, C_2, 100 uuf; C_4, 0.1 uf; C_3, C_5, 0.05 uf.



Specifications and List Prices

Alumnium Shield 1½" D. x 3½" high, 1 13/32" Mtg. Centers

Type	Frequency Range, kc	Factory Setting	Gain	Band-Width 2x	Band-Width 10x	Band-Width 100x	Between	Use	List Price
A101	440-480	465 kc	50	..	24	82	6A7-6D6	Converter	$3.00
A101M	440-480	465 kc	48	..	16	56	6A8-6K7	Converter	3.00
A100	440-480	465 kc	250	..	19	66	6D6-6D6	Interstage	3.00
A201	440-480	465 kc	110	13	31	..	6D6-75	Diode	3.00
A200M	440-480	465 kc	113	19	51	..	6K7-6H6	Diode	3.00
A100C	440-480	465 kc	...	..	..	..	-XTAL	XTAL Inp.	4.00
A200C	440-480	465 kc	...	..	..	..	6D6-75	F. W. Diode	4.00
A125	360-380	370 kc	49	..	16	53	6A7-6D6	Converter	3.00
A125	360-380	370 kc	220	..	15	47	6D6-6D6	Interstate	3.00
A225	360-380	370 kc	110	12	31	..	6D6-75	Diode	3.00
A150	250-270	260 kc	62	..	15	54	6A7-6D6	Converter	3.00
A150	250-270	260 kc	330	..	15	41	6D6-6D6	Interstage	3.00
A250	250-270	260 kc	120	11	31	..	6D6-75	Diode	3.00
A175	165-185	175 kc	54	..	11	50	6A7-6D6	Converter	3.00
A175	165-185	175 kc	300	..	9	30	6D6-6D6	Interstage	3.00
A275	165-185	175 kc	135	8	24	..	6D6-75	Diode	3.00
A185	105-125	115 kc	81	..	10	34	6A7-6D6	Converter	3.00
A185	105-125	115 kc	370	..	9	28	6D6-6D6	Interstage	3.00
A285	105-125	115 kc	145	6	18	..	6D6-75	Diode	3.00

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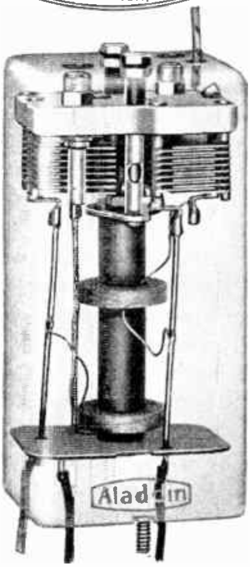
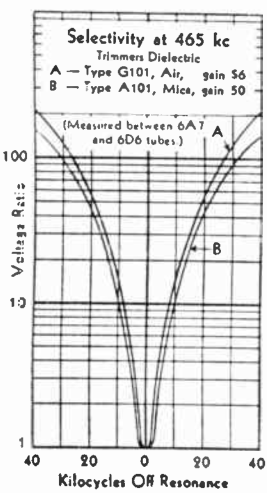
Polyiron Air-Tuned I-F's





Type G Fixed-Coupling i-f Transformers

An advanced design intended for precision amateur and commercial high-frequency communication receivers, Type G transformers use air-trimmed coils on Polyiron Cores.

The purpose of this design is to provide the utmost freedom from frequency drift in communication-type receivers. Normal temperature changes or variations in humidity have a negligible effect upon air-dieletric trimmers. Type G transformers may be used in circuits of the type shown on page 2.

The use of ALADDIN Polyiron results in a sharper resonance curve and a higher gain than is obtainable with air-core coils of the same physical dimensions.

The increased efficiency of the air trimmers over mica trimmers is evident in the adjacent curves.

Type GA Adjustable Coupling i-f Transformers

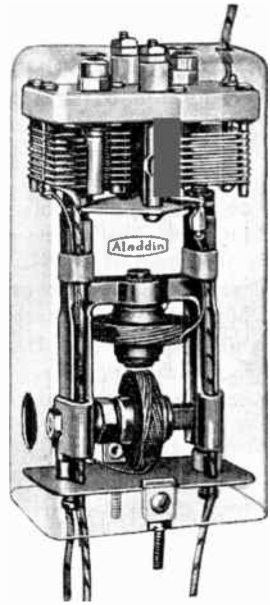
The adjustable coupling feature of popular Type A ALADDIN Polyiron core i-f transformers is now available with dual air trimmers, in Type GA, suitable for use in circuits shown on page 2.

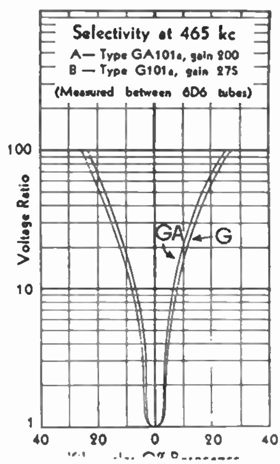
This design is particularly suited to the needs of the advanced amateur and designers of special equipment, wherein the utmost freedom from frequency drift must be maintained over long periods of time.

In the tabulations below, it may be observed that some items are listed twice with different gain figures. In each case the transformer is the same, the gain and band width changing with various tubes and circuits.

Type GH Band-Expansion i-f Transformer

Is an air-tuned three-tap band-expansion converter coupler for use in a circuit similar to that shown on page 5 for the H103, where high fidelity may be required for BCL use and extra selectivity for the congested short-wave channels.





Specifications and List Prices

Aluminum Shield 1 7/16" x 1⅞ x 4" high. 1 11/32" Mtg. Centers

Type	Frequency Range, kc	Factory Setting	Gain	Band Width 2x	Band Width 10x	Band Width 100x	Between	Use	List Price
			Type G Air-tuned Fixed Coupling						
G101	456-465	465 kc	56	..	15	57	6A7-6D6	Converter	$5.50
G101M*	456-465	465 kc	70	..	14	31	6A8-6K7	Converter	5.50
G101A	456-465	465 kc	275	..	17	53	6D6-6D6	Interstage	5.50
G101A	456-465	465 kc	180	..	21	71	6K7-6K7	Interstage	5.50
G201	456-465	465 kc	125	10	29	..	6D6-75	Diode	5.50
G201M†	456-465	465 kc	90	10	29	..	6K7-6H6	Diode	5.50
G208	456-465	465 kc	100	20	..	..	6K7-6H6	Silencer Diode	4.50
G101C	456-465	465 kc	...	..	..	..	-XTAL	XTAL Inp.	6.25
G175	170-180	175 kc	56	..	11	37	6A7-6D6	Converter	5.50
G175	170-180	175 kc	295	..	10	30	6D6-6D6	Interstage	5.50
G275	170-180	175 kc	140	7	19	..	6D6-75	Diode	5.50
			Type GA Air-tuned Adjustable Coupling						
GA101	456-465	465 kc	43	..	15	54	6A7-6D6	Converter	6.50
GA101M	456-465	465 kc	52		15	49	6A8-6K7	Converter	6.50
GA101A	456-465	465 kc	200	..	15	48	6D6-6D6	Interstage	6.50
GA101A	456-465	465 kc	146	..	17	57	6K7-6K7	Interstage	6.50
GA201	456-465	465 kc	100	13	35	..	6D6-75	Diode	6.50
GA201M	456-465	465 kc	92.5	14.5	42	..	6K7-6H6	Diode	6.50
GA100C	456-465	465 kc	...	..		..	-XTAL	XTAL Inp.	7.25
			Type GH Air-tuned High Fidelity Converter						
GH103	456-465	465 kc	A-52	..	16	52.5	6A7-6D6	Converter	6.50
			B-60	..	At the nose				
			C43.4	14.5	At the nose				

*G101M Formerly S2242A. †G201M Formerly S2242B. April, 1936 QST Page 22.

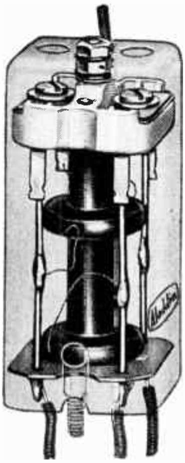
Aladdin
REG. U.S. PAT. OFF.

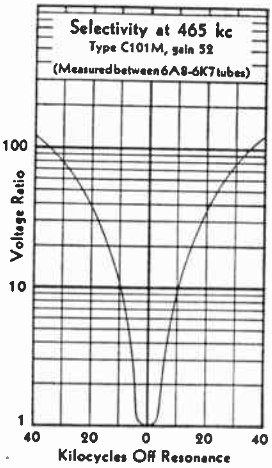
Polyiron Radio Components

Type C Midget i-f Transformers

Type C ALADDIN Polyiron i-f transformers are designed for auto, home and portable receivers in which space is limited. The Litz-wound coils and low-loss dual mica trimmers are contained in a small copper shield only 2½" high by 1⅛" square.

The gain of Type C transformers in circuits employing metal or metal-glass tubes averages better than the leading types of air-core coils, while the selectivity is distinctly better. Metal tubes have different inter-electrode capacitances from glass tubes; hence, for best performance, associated circuit components must be specifically designed to match these tubes. The results achieved with Type C i-f transformers in auto, home and portable receivers are proof of the value of this careful design in conjunction with metal tubes.

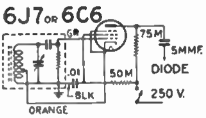




The accompanying performance curves and gain figures are made from average production samples, and are representative of the characteristics of these compact transformers. Circuits using metal tubes, as shown on page 2, right column are recommended for use with these ALADDIN Polyiron transformers.

Specifications and List Prices

Type	Frequency Range, kc	Factory Setting	Gain	Band Width 2x	10x	100x	Between	Use	List Price
C101M	440-480	465 kc	52	..	22	72	6A8-6K7	Converter	$2.50
C100M	440-480	465 kc	134	..	23	75	6K7-6K7	Interstage	2.50
C200M	440-480	465 kc	96	13	35	..	6K7-6H6	Diode	2.50
C350	440-480	465 kc	...	..	..	..	6J7 or 6C6	BFO	2.50

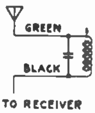


Beat Frequency Oscillator

Type C350 is a beat-frequency oscillator unit for use in connection with a 6J7 electron-coupled oscillator or an equivalent tube such as the type 6C6.

The accompanying circuit diagram illustrates the method of using the BFO Type C350 unit.

Aladdin Wave Trap



The ALADDIN wave trap is designed to be used in series between the aerial and antenna coil for the rejection of commercial interference at intermediate frequencies. The ALADDIN wave trap is tuned to the interfering signal by varying the inductance of the coil, accomplished by moving the Polyiron core with an adjusting screw.

Type	Frequency in kc	Size	List Price
R4563	440-510 Shielded	1¾"x1½" sq.	$2.00
R4560	440-510 Unshielded	1¾"x1"x⅞"	1.50

Aladdin Resonator

A flexible time saving alignment tool. When used with a reliable oscillator and output meter, misaligned circuits are immediately indicated, showing whether an increase or decrease in capacity is needed to align the circuit. Inserting the Polyiron end into a coil has the effect of adding capacity while the brass end has the effect of reducing the capacity. Proper alignment is indicated when both ends, upon being separately placed in the field of the coil, decrease the output of the receiver. List price with instructions, $1.00.

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6. Vibration dampener roll in machined slot for beautifully stutterproof sending.
7. Straight key changeover lever, locks rod for shipping and handling also.

$7.95

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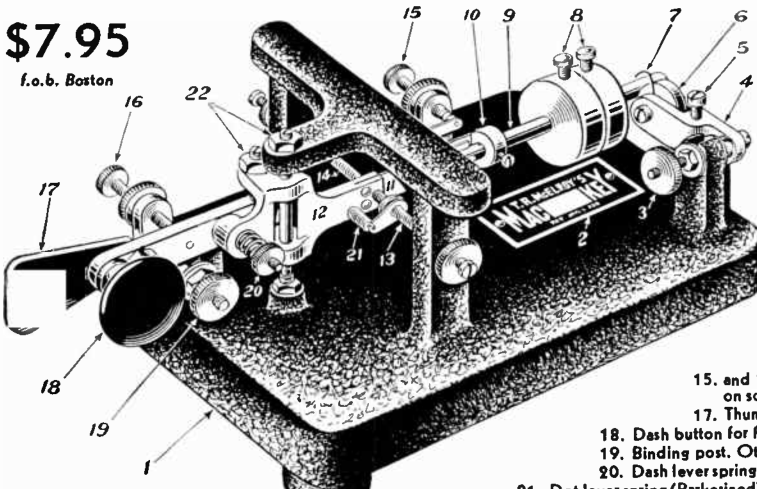


8. Speed governor weights. 5 wpm to 50 wpm.
9. Vibrating rod.
10. Dot U spring holding and adjusting collar. This U spring formed in a die out of highest quality Swedish blued steel of exact weight desired and then Parkerized for longevity.
11. Main spring also selected after exhaustive experimenting for correct weight and also Parkerized.
12. Main lever yoke casting which provides the excellent dash lever suspension.
13. Dot lever back stop screw.
14. Dot lever travel screw.
15. and 16. Dot and Dash contact screws on solid bar for perfect alignment.
17. Thumb paddle for dots.
18. Dash button for first and second fingers.
19. Binding post. Other post is number 3.
20. Dash lever spring (Parkerized) and adjustment nut.
21. Dot lever spring (Parkerized) and adjustment nut assembly.
22. Dash lever and Dot lever bearing adjustment screws.

FOR TELEGRAPH OPERATORS $10.00

I have a special model with circuit closer and my Mac Cord affixed to binding posts, which I've made up because so many telegraph operators wanted my key but needed these extras for use on telegraph wires.

MAC OSCILLATOR @ $3.95

(either AC or DC)

Tone control, 1000, 800, and 600 cycle note. Phone output 2000 ohms and 10 DB. Separate output 200 ohms — 30 DB. This oscillator is really a great asset in improving code. Uses 2 No. 76 tubes.

All Mac Items Stocked and Sold by Nearly All Distributors

AN OPEN LETTER TO THE OPERATORS

Writing an ad is an art itself and I haven't got it. As I've said many times I try to give every pennies worth of value possible in my items and it doesn't leave the extra dough to hire hifalutin' ad writers. So just read this as a kinda personal note from me to you fellers: —

I show a cut of my MAC KEY on the other page. Actually the ones I now ship are quite a lot better because when I had to make up special dies and jigs etc., to make extra special speed keys on an order from a certain government department (which, by the way, never purchased speed keys prior to my Mac Keys) — as I was saying, with these special tools, I was able to make an awful lot of improvements on the regular key.

DELUXE MODEL MAC KEY @ $15.00

No cut made, but just try to picture in your mind's eye the most beautiful instrument you ever thought of — that's my deluxe model. Huge 1/4 x 32 bronze screws, 3/16" contacts, completely and beautifully chromium plated — that's it. It's a honey.

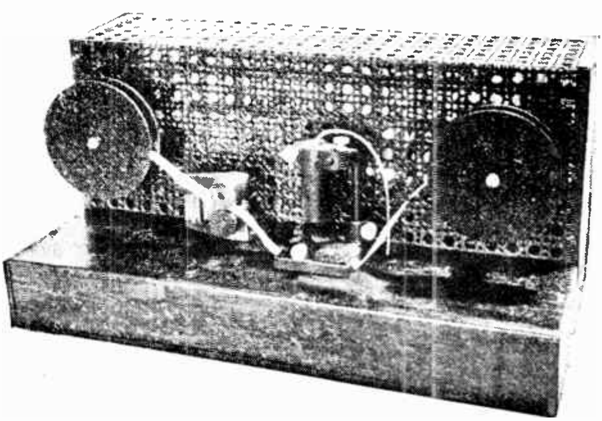
MAC AUTO @ $69.00

I think (and I hope!) that most operators throughout the world know by this time that I try to be truthful in describing my items. I therefore ask that you please believe me when I say that my MAC AUTO is so incomparably superior to any automatic ever heretofore built that it is about impossible to over-emphasize its excellence.

Uses either AC or DC 110V. Complete with all tubes.

Completely electrical. Not a single mechanical part except motor and even motor speed governed electrically.

Oscillator is built into it operating directly from photo-electric cell. No relays!



The first and the only automatic code machine using photo-electric cell.

The jobbers, who are your friends as well as mine, will sell this auto on time payments.

Entirely new in principle: it is completely electrical with no moving or mechanical parts excepting the motor and even the varying of motor speed is electrical, being accomplished by varying shunt windings juice. So far as I can determine from tests of my first working model, the speed is limitless!

MAC AUTO uses ordinary commercial recorder tape which means that the supply of tape is endless and the cost is but slightly more than the actual cost of the paper. *MOREOVER AND OF UTMOST IMPORTANCE* any code may be used — regular radio code (Continental Morse), telegraph code (American Morse) and other codes to which I do not care to refer in this ad, but will give information when it is sought.

The Mac Auto will probably be handled by Candler in connection with his courses, but it will also be sold by the radio distributors who've been such good friends of mine from the start and without whose support I just could not have lasted as long as I have. To them, now and publicly, my sincere thanks for their support. To the thousands of hams who've bought my stuff, written encouraging letters and boosted the key, my sincere thanks. Best wishes and good bye until we meet on these pages next year.

Mac.

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FINEST AMATEUR RECEIVERS

the Super Sky Rider—Unsurpassed for Design and Construction! Direct calibration tuning. 6L6 Beam Amplifier delivers 14 watts undistorted output. Cathode-Ray Field Strength Indicator. 11 tubes; 10 of them metal. Five bands cover 40 MC to 530 KC. Improved 10-meter performance. The receiver sensation of 1937!

Other Outstanding 1937 Sky Riders:

- **the Sky Rider Commercial**—11-tube Super-Het especially fitted for commercial service.
- **the Ultra Sky Rider**—the perfect receiver for Ultra High Frequency work.
- **the Sky Chief**—7-tube Super-Het with latest features of higher priced sets.
- **the Sky Buddy**—a 5-tube Communications Receiver at an astonishingly low price.

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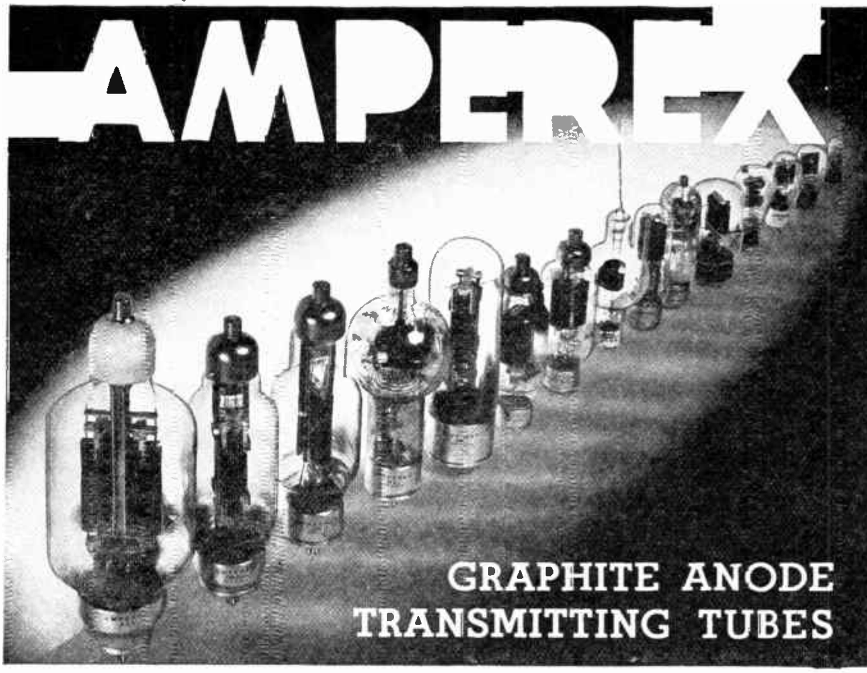

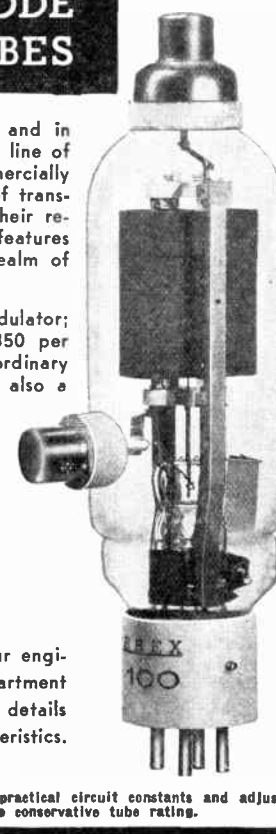

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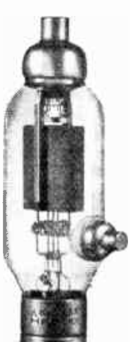

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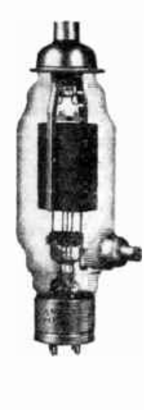

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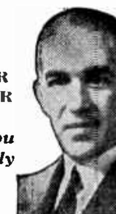

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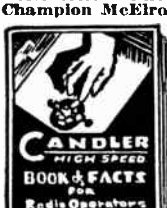

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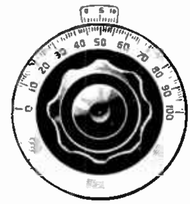

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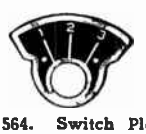

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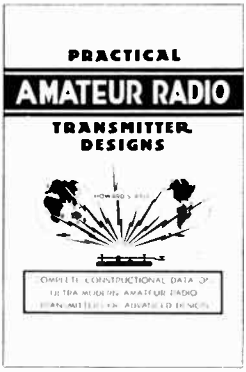

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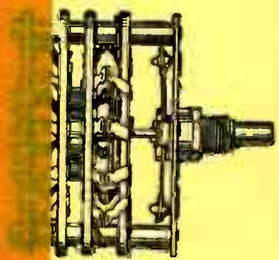

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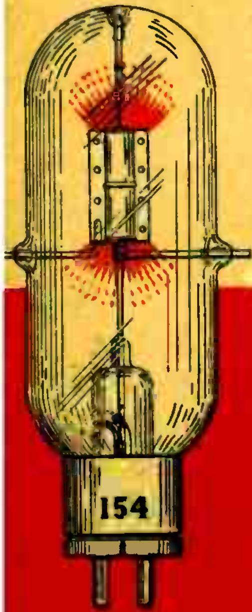

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