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UNITED STATES ARMY

(PROVISIONAL)

(IN FIVE PARTS)

PART III.

RADIO.

Prepared at the
HEAVY ARTILLERY SCHOOL, UNITED STATES ARMY,
ANGERS, FRANCE.

GENERAL HEADQUARTERS,
AMERICAN EXPEDITIONARY FORCES.
DECEMBER, 1918.

GENERAL HEADQUARTERS
AMERICAN EXPEDITIONARY FORCES
OFFICE OF THE CHIEF OF STAFF

FRANCE, *December* 13, 1918.

This Heavy Artillery Signal Manual *(Provisional) is published for the information and guidance of the American Expeditionary Forces.*

By command of General Pershing:

JAMES W. McANDREW,
Chief of Staff.

Official:
ROBERT C. DAVIS,
Adjutant General.

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HEAVY ARTILLERY SIGNAL MANUAL.

PART III.

Radio.

CHAPTER I.

THE THEORY UNDERLYING THE RADIO SYSTEM OF COMMUNICATION.

General Survey of the Field of Radio Communication.

Very soon after wire telegraphy became of practical usefulness, conditions were encountered in which the desirability of effecting electrical signalling without connecting wires became apparent. As a result of this need, a number of methods of telegraphing without wires were tried out, based on schemes of utilizing the conduction through the ground, magnetic induction, etc., as the means of sending the signals. All of these methods, however, were very limited as to range of transmission and were therefore of little importance and value as a system of communication.

Radio telegraphy. or the transmission of signals by means of unguided electric waves, was first introduced in 1896 by Marconi, after extensive experiments made by himself and with the help of the discoveries and research work of Hertz and others. In 1899 communication was established between Dover and Boulogne, a distance of 32 miles, and shortly after, information between ships was transmitted as far as 80 miles. The importance of radio communication was by that time universally admitted, and from this it has constantly grown and extended its field to commercial,

naval and military pursuits. From these early stages, the art has rapidly progressed until in 1916, Arlington Station could hear Japan working with Honolulu, the distance involved being approximately one half the circumference of the earth.

The application of radio to military uses is the one which will be particularly dealt with. In this application, its development has likewise been extremely rapid, and at the present time one of the most important means of communication between armies and units is by means of the unguided radio waves, this assuming greater importance as the intensity of destructive shell fire and hence the difficulty of maintaining wire communications increases.

An entire system of radio communication has been established to supplement the wire system for the forwarding of information between the various headquarters of the armies, divisions, brigades and even to and from the front line trenches. In an attack, when the infantry and the artillery move forward, one of the most difficult tasks is to maintain communication with headquarters. A certain element of time is involved in carrying forward wire communication systems and they are continually broken down by shell fire. The radio and ground telegraph apparatus, however, are much more simply carried forward and are usually operative unless destroyed by an almost direct hit. Of course, there are many times when the interference of the enemy and other of our own radio sets is so great as to make receiving of signals extremely difficult and at nearly all times the operator must be able to pick out his own signals from a number heard simultaneously.

Another system of radio communication is in existence between airplanes and artillery. This is called the fire-control system and it is perhaps the most extensive and complex of all the radio organisations in operation at the front. The firing of each battery of light, medium, heavy and superheavy artillery is directed to greater or less degree

by radio signals sent out from airplanes flying over enemy positions, particularly that of the last three named. This work is extremely important, and the number of airp anes used for the purpose is large. Great as is the value of the airplanes in extending the range of vision of the army, yet their effectiveness in directing artillery fire onto enemy targets is only made possible by the instantaneous means of communication between plane and battery afforded by the radio apparatus. In the early days of the war, even this scheme of communication was so slow, due to the cumbersome signals and natural sluggishness and difficulties incurred in developing and perfecting the practice, that the batteries were not kept busy enough to hold the interest of the men. The intervals between firing and receiving a range correction from the airplanes were so long that not much confidence was had in this method of directing fire. However, the signal system has been greatly simplified and otherwise improved, so that it is now effective in directing suitable battery fire on enemy gun positions and movements in such a manner as to frequently effectively silence the guns or destroy supply trains, etc.

Radio is also effectively used on reconnaissance and bombing airplanes, which sometimes are equipped with high power, long range sets. The radio telephone has found some use on battle planes and fighting machines, although this means of communication has not been extensively used up to the present time. It is now undergoing an intensive development and may come in for a more important part in the airplane and other radio work later on.

Not the least important use of the radio apparatus in military operations is that which the alert operator makes of it as a means of anticipating destructive shell fire on his own battery position. It frequently happens that he will hear a hostile plane sending down to the enemy batteries, the map co-ordinates of his position. He will then warn the battery commander not to fire for a period, as this would further prove the position to the hostile aircraft. Or

the operator may hear a shell burst at not great distance from his battery position and then hear the hostile plane send down a correction which denotes to the operator that his battery is the target at which the enemy is firing. A timely warning made to the battery commander under these circumstances has saved the lives of many artillery men.

The Electrical Units Pertinent to Radio.

Self and Mutual Inductance :—When an electric current is made to flow through a circuit, a magnetic field is established in the space surrounding it. The strength of this field at any g ven point is proportional to the current flowing in the circuit, and is dependent on the shape of the circuit and on the nature of the medium surrounding it. The value of the ratio of the field flux to the current in a given circuit is called its self-inductance (also called coefficient of self induction).

Thus,

$$\text{Self inductance} = \frac{\text{Electromagnetic Flux}}{\text{Current}}$$

The self inductance of a circuit therefore is the electromagnetic flux around the circuit when unit current is flowing through it.

If unit current is made to flow through one of two independent circuits A and B, (A for instance), the magnetic field due to that current extends around both circu ts A and B, if they are near enough together. That part of the flux due to A which interlinks with circuit B is called the mutual inductance of circuit A upon circuit B. This depends on the shape of each of the two circuits and on their relative position. Their mutual inductance is therefere greatest when the two circuits are closest together. Whenever a circuit reacts upon another, the two circuits are said to be coupled, the coupling being close or loose according to whether the mutual inductance is large or small.

As the magnetic field builds up around a wire carrying a current, it is possible to obtain a large inductance by winding the wire into a coil so that many turns will be concentrated in small space. By this means, a considerable flux may be produced through the summation of the fluxes due to each turn.

Capacitance.—If an insulated conductor is placed near a grounded conductor, and a charge is given to the former, its potential is found to be proportional to that charge, The value of the ratio of the charge to the potential of the conductor has been called the capacitance (electrostatic capacity) of that conductor. Thus,

$$\text{Capacitance} = \frac{\text{Electrostatic Charge}}{\text{Potential}}$$

A large capacitance may be obtained by placing two sheets of metal very close to each other and insulating them by means of some dielectric (air, mica, glass, etc.). Such a device is called a condenser. Condensers of large capacitance are built by combining a large number of sheets of metal foil separated by glass plates or sheets of mica. All even and all odd numbered sheets are connected together, respectively, each group forming one side of the condenser. The capacitance of a condenser is directly proportional to the area of the plates and inversely proportional to the distance between them.

Condensers of adjustable capacitance are also used. Several semi-circular metal plates are placed parallel and one above the other, and connected by means of metal rods extending through the plates at the two ends of the straight side, and held apart by blocks or washers, the whole group of plates making up one side of the condenser. The other side is made up of a set of similar plates having a semi-circular shape and mounted on a shaft at their centers. By rotating the shaft. the plate moves in or out between the stationary plates, and the capacitance of the condenser can thus be continuously varied.

Definitions of units.

Resistance:—The unit of resistance is the international ohm. It is the resistance of a column of mercury 106.3 cm. high, and weighing 14.4521 grams at a temperature of 0 deg. C.

Current:—The unit of current is the international ampere. It is that unvarying current which, when passed through a neutral solution of silver nitrate, will deposit silver at the rate of. 001118 grams per second.

Electromotive Force:—The unit of electromotive force is the international volt. It is the electromotive force which will cause one international ampere to flow through one international ohm.

Inductance:—The unit of inductance or of the coefficient of self-induction is the henry. It is the inductance of a circuit in which a current varying at the uniform rate of one ampere per second will induce an electromotive force of one international volt.

Capacitance:—The unit of capacitance is the farad. It is the capacitance of a condenser, such that a potential of one volt will cause the condenser to store a charge of one coulomb. (A coulomb is the quantity of electricity transported by a current of one ampere flowing for one second.

Electromagnetic Induction.

When a conductor is moved across a magnetic field so that it cuts lines of force, an emf. is generated in the conductor. If the conductor is part of a closed circuit, a current will flow in it due to this induced emf. As this induction effect is due to the cutting of lines of force by the conductor, it will be greatest at the instant of the highest rate of cutting the magnetic lines of force (greatest number of lines cut per second). This phenomenon has many practical applications, some of which are studied below.

Alternator:—Consider a loop of wire closed on an ammeter, and placed near a permanent bar magnet, Fig. I. If either

the magnet or the loop is moved, a current will be observed through the ammeter, the direction of the current depending upon the direction of motion and the polarity of the magnetic pole. If then the loop is held stationary and the magnet rotated around its axis aa, the direction of the magnetic

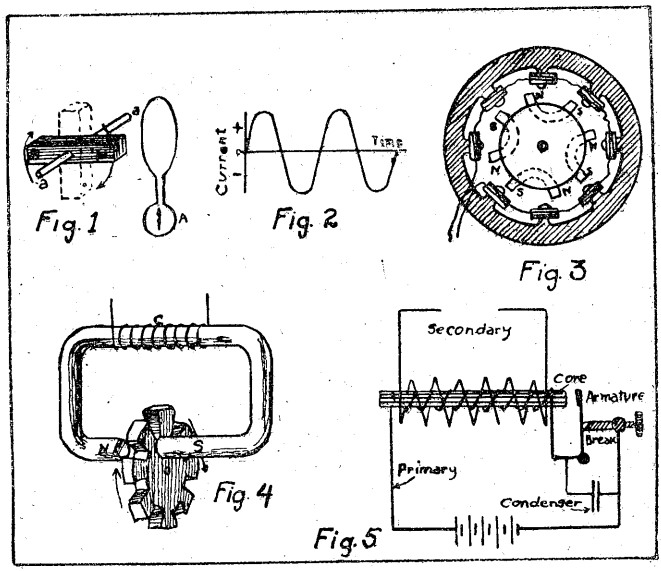


FIG. 1-5.

field through the loop will be alternately in opposite directions, and an alternating current will be generated in the stationary loop circuit.

As the current is a maximum when the number of magnetic lines of force cutting the wire per unit of time is greatest, this will occur when the magnetic pole passes directly in front of the loop. The current then decreases as the magnet pole is moved away, becomes zero for the position of the magnet shown in dotted lines, and increases again, but in the other direction, as the other pole of the

magnet revolves toward the loop. The duration of one complete cycle, that is, of one complete revolution of the magnet, is called the « period » of the alternating current, The number of periods per second is called the « frequency ».

A graphical representation of an alternating current may be obtained by plotting off the value of the current at each instant, time being counted on one axis, and current on the other. This produces what is known as a « sine » curve, as shown in Fig. 2. In order to obtain currents of higher frequency, it is simply necessary to rotate the magnet at a higher speed, or to use a number of magnets mounted on a frame locked to the shaft, Fig. 3. Also, rotating the magnet, Fig. 1, at higher speed, or increasing the number of magnetic fields cut through per revolution, Fig 3, increases the rate of cutting the lines of force and therefore produces higher voltage.

The permanent magnets may be replaced by electromagnets energized by a direct current derived from an auxiliary dynamo called an exciter, or from a battery. The field magnets, either permanent or electromagnets, may be stationary and the alternating current winding rotary.

The rotating portion of an alternating current generator is called the « rotor » and the stationary portion, the « stator ». The more common construction is to make the field windings (d. c.) rotary.

Inductor Type Alternator: — Another method of producing an alternating current is to wind a coil of wire C. Fig. 4, around a magnet of special shape, the two poles of which face each other and are separated by an air gap. A toothed iron disk is then made to rotate between the jaws of the magnet, so that the gap between the poles is alternately open and then practically closed with iron. The result is that the flux between the two poles, and hence the magnetic flux in the entire magnet, alternately increases and decreases. This periodically varies the number of magnetic lines of force inside the coil C. where an alternating emf. is

thus generated. This type of generator is called an « inductor type alternator ». It is quite widely used in supplying high frequency current to airplane radio apparatus. Instead of using a permanent magnet, it is of course possible to use an electromagnet energized by a direct current derived either from a storage battery or from a separate exciter dynamo.

Induction Coil :— Another form of electromagnetic induction is that involved in the operation of the ordinary induction coil, Fig. 5. This consists essentially of an iron core on which are wound two coils of wire. These are called the primary and secondary windings and the latter usually has a much larger number of turns of wire than the primary coil. Inserted in the circuit of the primary coil is a vibrator which, upon closing the circuit through the primary coil, is attracted toward the iron core of the coil, opening the circuit. It is then immediately released by the demagnetized coil and it returns to its former position to again close the circuit, the operation being very similar to that of the ordinary buzzer. The vibrator thus serves to very rapidly make and break the circuit through the primary coil.

In the induction coil method of producing current by induction, the coils remain stationary, but the function of the vibrator in alternately making and breaking the circuit through the primary, is to produce a rapid change in the number of lines of force resulting from the current in the primary coil. These lines of force also penetrate and surround the secondary coil and induce in it an emf, corresponding in magnitude to the rate of change of the number of lines of force produced by the primary coil. When the circuit of the primary coil is closed, the magnetic field rapidly builds up but is retarded from reaching its maximum value by the counter emf, due to the self-inductance of the primary coil. As this field increases, it induces an emf. in the secondary coil of higher voltage and in the opposite direction than that in the primary. When the current in

the primary has reached a certain value, the field becomes strong enough so that the vibrator armature is attracted toward the core, suddenly opening the primary circuit. This is followed by a rapid decrease in the number of lines of force cutting the secondary circuit, this change inducing an emf. of opposite polarity to the first, in the secondary

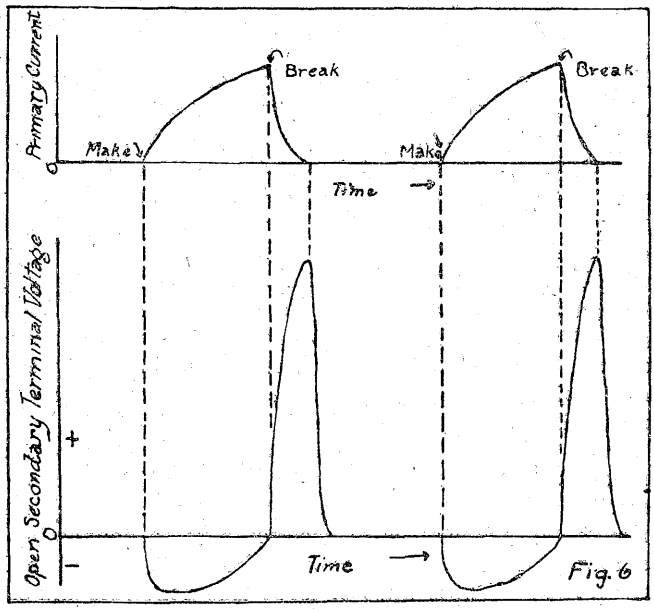


FIG. 6.—Current and Voltage Relations in Primary and Secondary of an Induction Coil.

coil. It is important to note that the opening of the primary circuit by the vibrator introduces a condenser in the primary circuit which serves the purpose of causing the primary current to fall to zero value with great rapidity. This is accompanied by a correspondingly high rate of decrease in the magnetic field, with the result that a very much higher emf. is generated in the secondary coil upon opening the

primary circuit than upon closing it. This is clearly illustrated by the curves of Fig. 6 where primary current and secondary voltage are plotted against time.

Transformer :—The operation of the alternating current transformer is based on a very similar principle to that of the induction coil. The principal difference between the two is that an alternating current is fed into the primary winding of the transformer instead of a direct current, as in the induction coil, which is broken up by the vibrator to produce a pulsating current.

The current in the primary of the transformer is then periodically reversed in direction. This produces a magnetic field periodically reversing in direction through the primary circuit, and also through the secondary coil which is generally wound over the primary on a common iron core. The reversals of the magnetic field induce in the secondary winding an opposite emf., the polarity of which is reversed at each reversal of the field. If the secondary terminals are connected to some external circuit, an alternating current of frequency equal to that of the primary current will then flow through this circuit. The ratio of the emfs. at the terminals of the two windings (primary and secondary) is equal to the ratio of their number of turns. Thus, if the primary consists of 20 turns of wire and the secondary of 1200 turns, the secondary voltage will be 60 times the primary voltage. The current will be roughly 1/60 as large, assuming unity power factor, since the power induced in the secondary cannot be greater than the power input to the primary. On account of the relative currents carried, the low voltage winding is made of heavy wire, while the high voltage winding is generally made of much finer wire.

Transformers used in radio apparatus are generally for the purpose of transforming a low voltage alternating current into a high voltage alternating current. Such transformers are called « step-up » transformers.

Oscillatory Discharge of a Condenser.

As outlined above, currents may be induced in a circuit by another entirely independent circuit in which an alternating or pulsating current is made to flow. As the inductive effect is due to a change of the magnetic flux in the circuits, it increases with increasing rate of change. In other words, the greater the number of reversals of flux per second,

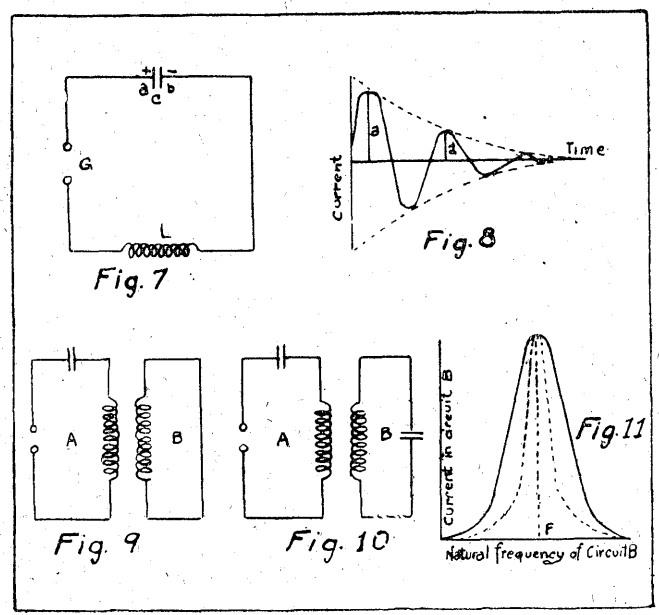


FIG. 7-11.

the greater the inductive effect at a given point, or the greater the distance through which this effect may be evidenced. In radio telegraphy, where these effects must be transmitted great distances, it is therefore necessary to generate alternating currents in the transmitting circuit of a very high frequency—something of the order of 30,000 to 3,000,000 cycles

per second. A number of methods have been used to attain this result, a very important one being the oscillatory discharge of a condenser. This is explained below.

Consider a condenser C. Fig. 7, with its plates connected to an inductance coil L and a spark gap G. The condenser is charged by some outside source of energy; that is, a difference of potential is established between the two plates, giving them opposite polarities. If this potential is made high enough, a spark will jump across the gap, momentarily short-circuiting the condenser through the inductance coil. The condenser will then discharge, and the quantity of electricity which had been accumulated on one of its plates will spread over the circuit in a tendency to equalize the charge on the two plates of the condenser. This will create a current in the circuit, flowing for instance from a to b in the direction aGLb. The effect of this current is to produce a magnetic field in the coil L. After a very short time, the condenser is entirely discharged, and there is no potential difference between its plates. There being no further charge on the condenser to maintain the current in the circuit, the latter will die out.

This is accompanied by the collapse of the electromagnetic field in the coil. This change of magnetic flux, however, generates a current in the coil, in the same direction as the discharge current of the condenser, so that the current in the circuit, instead of dying out suddenly at the moment the condenser is discharged, will continue to flow in the same direction for an instant and accumulate electricity on the condenser plate which was originally at the lower potential. When the current has ceased to flow, the condenser will be charged again, but with a polarity opposite to its original polarity. It will therefore start discharging in the opposite direction, the phenomena occuring as above described, but with the current flowing this time in opposite direction. A series of current reversals will thus take place, the initial energy which was stored in the condenser being alternately stored in the electrostatic and in the electromagnetic fields

of the circuit, this producing an alternating current of a frequency depending on the value of the inductance L and capacitance C, in the circuit. The relation between the frequency and the constants of the circuit is

$$f \text{ (cycles per second)} = \frac{159{,}200}{\sqrt{L \text{ (Microhenrys) } C \text{ (Microfarads)}}}$$

This frequency is called the " natural frequency " of the circuit.

This alternating current would maintain itself indefinitely if there were no energy losses during the cycle. However, the wires making up the circuit have resistance, in which a certain amount of the energy is dissipated in the form of heat. Also, there are heat losses in the spark gap, the radiation losses, and some other losses, generally of less importance, such as leakage losses in the condenser, etc. The result is that at each cycle, the intensity of the current grows less, until after a few cycles, the energy is practically entirely dissipated and the current is consequently " damped " out. These few cycles as a group are called a " train " of oscillations. In order to produce a new train of oscillations, it is then necessary to recharge the condenser by means of some outside source of potential. Such a train of oscillations may be represented as in Fig. 8, where current is plotted against time.

Decrement:—The number of cycles taking place in the circuit before the current is damped out is dependent on the resistance of the wire making up the circuit, being greatest for circuits of low resistance. The damping varies directly with the resistance of the circuit. The rate of damping of the current of such a discharge may be expressed mathematically by the ratio of the maximum amplitude of two consecutive cycles of a wave train. This ratio is a constant for a given circuit and is called the " arithmetic decrement " of the oscillation. Thus, the arithmetic decrement of the wave shown in Fig. 8, would be a/a'. The greater the value of this decrement, the more rapid the damping

of the oscillation. For a true, undamped alternating current, Fig. 2, the decrement is equal to 1.

In practice the arithmetic decrement is of little interest, and the term used most frequently to express the damping is the " logarithmic decrement " which is the Napirian logarithm of the arithmetic decrement. Hence the logarithmic decrement of an undamped oscillation is zero.

The frequency of oscillation of the condenser discharge may be very great—from 50,000 to 3,000,000 cycles per second, depending on the values of inductance and capacitance in the circuit. But the number of cycles in one train taking place before complete damping out is comparatively small. Hence, by recharging the condenser after each wave train, it is possible to produce a large number of trains of oscillations per second. This may be done by means of an induction coil or an alternator, and will be taken up later.

Phenomena of Resonance.

Due to the very high frequency of the discharge oscillations of a condenser through an inductance, the inductive effects are considerable. If an inductance coil B, Fig. 9, is placed near an oscillating circuit A, an alternating emf. is induced in coil B, exactly in the same way as in an ordinary transformer. If the coil is short circuited by means of a piece of wire, an alternating current will flow in the circuit. This will be of the same frequency as the current in circuit A, whatever that frequency may be, as determined by the values of capacitance and inductance in the generating circuit A. Circuit B is then said to be " aperiodic " as it has no natural oscillation period of its own.

If, however, instead of short circuiting coil B, a condenser is connected across its terminals, Fig. 10, phenomena of a somewhat different nature will take place, so-called resonance phenoma. The alternating current flowing in circuit A, at the natural frequency of that circuit, induces, as before, an alternating emf. of the same frequency. As a result of

this alternating current, the condenser of circuit B is charged every half cycle, and will therefore, independently of the current induced by circuit A, discharge through the inductance coil B at the natural frequency of circuit B. Two alternating currents of the natural frequencies of circuits A and B will thus flow in circuit B, and will combine, successively adding and subtracting their effects. If the two frequencies are made equal by a suitable adjustment of the natural period of circuit B, the two currents in that circuit will be in phase and will always add their effects to produce the maximum current in the circuit B. To obtain this condition, it is necessary that the product of the capacitance and inductance of one circuit equal that of the same constants of the other circuit. When this condition prevails, the two circuits are said to be " resonant ", or " in tune ". Circuit B may be tuned to circuit A by varying the capacitance of the condenser or the inductance of the coil B. Circuits which require a change in frequency are generally equipped with a variable air condenser or a multi-tap inductance coil, or both.

If the current in circuit B is plotted against the natural frequency of that circuit, a " resonance curve ", Fig. 11, is obtained which shows that the maximum current exists in B when its frequency is equal to that of circuit A. This curve may in some instances be of a very peaked shape (dotted curve), which means that under certain conditions, circuit A may produce an appreciable current in circuit B only when the latter is almost exactly in tune. Such a result may be attained by loosening the coupling of the two circuits; that is, by separating them so that the induced current in B will not react appreciably on circuit A. Also, the trains of oscillations in circuit A should be damped as little as possible, so that each train will act on circuit B for a comparatively great length of time. This object is attained by making the circuits of large size copper wire and consequent low resistance.

The fact that the current produced in circuit B by the

oscillations of circuit A is considerably greater when the two circuits are in tune, is used in radio telegraphy. as will be shown later, in order to make it possible to receive signals of a given frequency and practically eliminate those of other frequencies.

Propagation of Electric Waves.

The flow of electric current in any circuit is accompanied by the existence of interlinked magnetic and static fields which surround the conductors carrying the current and extend throughout space. Whenever the direction of current flow in the circuit is reversed, these fields reverse also. This reversal does not take place, however, throughout space instantaneously. The phenomenon is somewhat similar to the ripples taking place on the surface of water when a pebble is thrown into it. The disturbance gradually propagates itself at a uniform speed, keeping its shape and characteristics until it dies out due to friction losses. The disturbance or reversal in the electric field surrounding a conduetor propagates itself in much the same way, but at a speed of 300,000,000 meters (186,500 miles) per second. That is at a point 300,000.000 meters distant from the circuit under consideration, the reversal of the electric field will occur one second after the reversal of current has been made in the circuit. On account of the similarity with the ripples in the water, this phenomenon has been called an electromagnetic wave. Such waves, however, travel outward not only in one plane as the ripples on the surface of the water, but they radiate out into space in a spherical progression, The medium in which this propagation is assumed to take place is called the " ether ". This hypothetical medium is, for theoretical reasons, assumed to be present throughout space whether matter is present or not; it is the medium in which all electromagnetic disturbances, light waves and heat radiations occur.

If now a frequently reversed current or alternating cur-

rent is sent through a circuit, the interlinked magnetic and static fields will alternately reverse at the same frequency. This constitutes a series of waves progressing from the current carrying circuit outward into space in all directions. The length of the waves radiated is measured by the distance betwen two consecutive points at which the electric field has the same amplitude and direction.

This distance is therefore equal to 300,000,000 meters divided by the frequency of the alternating current.

Fluctuations of magnetic and static fields will produce electric currents in any metallic circuit which happens to be within the range of these fields, energy being thus dissipated in these circuits. As this energy is derived from the oscillating circuit, and conveyed to the various other circuits by the electromagnetic waves, the oscillating circuit is shown to " radiate " energy into space. An appreciable amount of energy is not radiated, however, at frequencies of less than about 10,000 cycles per second. The problem is then to generate high frequency alternating currents in a circuit of such shape as to radiate a large amount of energy and produce fields of sufficient strength that the changes in their intensity and direction may be intercepted at great distances. In the following chapter a study will be made of the application of these phenomena to radio telegraphy.

CHAPTER II.

DAMPED WAVE RADIO TELEGRAPHY.

Principles of Transmission.

From the previous study it has been seen that a radio transmitting set, that is, a set which will emit electromagnetic waves into space, may consist of an oscillatory circuit containing inductance and capacitance, in which trains of damped high frequency oscillations are produced in rapid succession by supplying a certain amount of energy to the system after each wave train. Such a set therefore comprises, in addition to the oscillating circuit, the necessary apparatus to produce the high voltage required for charging the condenser at the beginning of each train of oscillations. This auxiliary apparatus varies greatly with the various sets and is not exclusively applicable to radio work. It comprises ordinary power apparatus used for the production of high potentials and may be an induction coil, transforming the low voltage of a battery into a high pulsating voltage, or an alternator, generating low voltage alternating current which is then stepped up to a high voltage by means of a transformer. This will be studied in a later paragraph.

The oscillatory circuit, however, is a part of the set which is peculiar to radio work. It was seen that such a circuit is made up of an induction coil, the terminals of which are connected to the plates of a condenser; also, that there are two methods of starting oscillations in such a circuit, one being to introduce a spark gap, charge the condenser, and suddenly close the circuit by producing a spark across the gap, and the other being to couple a circuit without a gap to an oscillating circuit containing a gap. The first may be termed the " direct excitation " and the second, the " indirect excitation " method.

In radio telegraphy it is necessary, in order to increase the range of transmission, to arrange the oscillating circuit so that the electric field will be of suitable shape and of appreciable strength at great distances. This is accomplished by making either the inductance coil, or (more generally) the condenser of the oscillatory circuit of large physical dimensions. It is then called the " antenna " of the set.

The dimensions and shape of the antenna vary greatly in practice and a number of types, some of which are described below are in use at present.

Types and Characteristics of Antennæ.

In the very great majority of cases, it is the condenser of the radio circuit which is made the antenna, the inductance coil being wound inside the set box. One reason for this is that such a condenser antenna is much more simply installed or repaired under emergency conditions. The simplest type considered here is the so-called " L " type antenna, Fig. 12. This consists of a horizontal wire, called the " aerial " which forms one side of the condenser. This is connected to one side of the inductance of the oscillating circuit. The other side of the condenser is made of a similar wire which is stretched out underneath the aerial wire, either slightly above or laid on the ground. Or the ground itself, if not too dry may be used as the counterpoise side of the condenser. This ground side of the condenser is connected either directly or through a spark gap to the inductance coil, according to the method of excitation used. This is explained below. The connecting wires used to connect the coil and gap to the aerial and the counterpoise (or ground) are called the " lead-in wires ". In some cases, no inductance coil is provided with the set, the self inductance of the antenna wire being sufficient.

A very important feature of the antenna is its " direction-

al effect ". When the antenna circuit is made to oscillate, the intensity of its electric field and hence the range of transmission is distinctly greater in the direction of the end at which the lead-in wires are connected (direction of the arrow in Fig. 12). Advantage is taken of this characteristic when using such an antenna, by pointing the aerial wire toward the location of the receiving station with which it

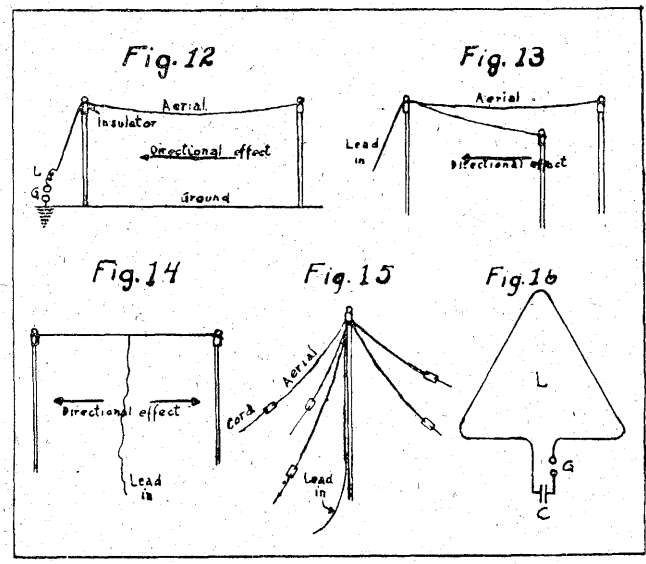


FIG. 12 to 16.

is desired to communicate, the lead-in wire being connected to that end of the aerial which is nearest the receiving station. It is very important to remember this, since the range of transmission in the other direction is considerably less.

Another type of antenna is the " V " antenna shown in Fig. 13. The aerial consists of two diverging horizontal wires and the lead-in wire is connected at the apex of the

" V ". If a counterpoise is used, it is generally made of two wires laid on the ground or stretched between masts above ground and underneath the branches of aerial. The directional effect of this antenna is toward the point of the " V ".

The " T " shaped antenna, Fig. 14, consists of a horizontal wire at the center of which the lead-in wire is connected. The directional effect is in either direction in the vertical plane of the antenna.

The " umbrella " type antenna consists of a number of interconnected wires suspended from the top of a mast and insulated from ground, spreading around the mast like the ribs of an umbrella frame. The free ends are fastened to the ground by means of insulators and ropes, Fig. 15. There is no directional effect with this antenna, the electric waves being radiated with equal strength in all directions.

There are a number of other types in use, but they are generally too difficult to set up in the field for common use. A very important consideration in using antennae is to always well insulate the aerial and lead-in wires from the ground in order to avoid any leakage path which would of course greatly reduce the range and might even completely prevent any radiation.

As was pointed out in the preceding chapter, the resistance of the oscillating circuit should be as low as possible in order to reduce the heat losses and resulting damping. The lead-in wires connecting the counterpoise and antenna to the set should be made as direct and as short as possible. This will also eliminate any superfluous inductance due to possible turns in these wires. If the set is under shelter, the wires should be run through ebonite tubes where they pass through the wall. If these are not available, a bottle may be used, the bottom of which has been broken out.

The ground connection should be made by driving a few metal rods into the ground and interconnecting them, and then connecting them to the set. A ground mat may also be used. This is a small metal netting which is placed on the

ground underneath the aerial and connected to the set. It is very useful when the station has to be set up in a short time, and is indispensable when the ground is dry or rocky.

An important use of the counterpoise is to be found on airplane sets where the aerial is generally a single wire let out from a reel on the airplane through an insulating tube, and the counterpoise is all the metallic parts of the airplane motor, gasoline tanks, stay wires, etc., electrically bonded together.

As mentioned before, the antenna sometimes consists of the inductance coil of the set instead of its condenser. The latter is then of small physical size and is mounted within the set box, while the antenna is a loop of wire, Fig. 16, of suitable size and of very few turns, frequently of only one turn, supported on a wooden frame. Such antennae, called "loop antennae", are generally used for short range radio telegraphy and for radiating very short wave lengths — 30 to 100 meter waves. They are directional in their plane. This type of antenna is somewhat delicate to repair and is not used very much in the field.

Direct Excitation Transmission.

With the direct excitation method of sending radio waves, the radiating oscillatory circuit comprises the aerial and ground (forming the condenser), an inductance coil L, and a spark gap, Fig. 17. The two electrodes of the spark gap are connected to the secondary (high voltage) terminals of a transformer, in the primary of which an alternating current may be made to flow by closing the key placed in series with it. When the key is closed, the primary low tension alternating current induces a high alternating voltage in the secondary of the transformer, and an alternating difference of potential is thus established between the aerial and the ground which causes a storing of energy in the antenna. If this potential is high enough when the maximum of the cycle is reached, the air gap breaks down and the antenna dis-

charges the stored energy through the inductance L, and a high frequency oscillation is created as explained previously.

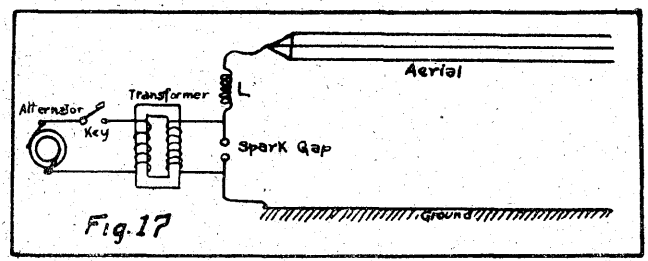


FIG. 17.

This is shown in Fig. 18. The upper curve shows the voltage variation in the secondary circuit of the transformer. It rises from zero to the breakdown potential e of the gap,

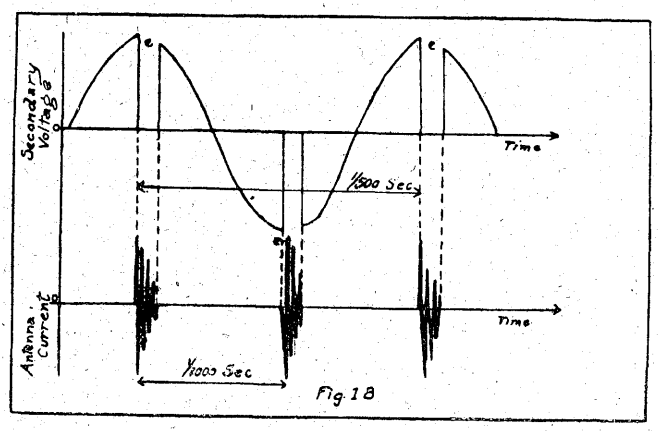


FIG. 18.

when the condenser discharges and suddenly equalizes the potential of its two electrodes. When the resistance of the gap breaks down, the voltage of the tranformer secondary drops practically to zero and a high frequency current oscil-

lates in the antenna circuit, as indicated in the lower curve. When the oscillations have been damped out due to heat losses in the spark, the resistance of the circuit, and the energy losses by radiation, there being no current flow through the gap, the latter opens again, and the voltage of the antenna follows again the cycle of the alternator until the negative maximum is reached, when the same phenomenon takes place. In this way for every half cycle of the alternator, a high frequency discharge of the antenna takes place which sets up in space, a train of high frequency oscillations (wave train). The frequency of successive wave trains is thus equal to twice the frequency of the alternator. This, for reasons seen later, is called the " audio " or " wave train " or " spark frequency ". The frequency of the oscillations of each individual train is called the " radio frequency " and is entirely independent of the frequency of succession of the sparks or wave trains, as it is determined by the constants (inductance and capacitance) of the antenna circuit. The value of the radio frequency can therefore be regulated by inserting capacitance or inductance in the antenna circuit. Thus placing an inductance coil in series with the aerial will increase the wave length (decrease the frequency), while a condenser inserted in series with the aerial decreases the wave length (increases the frequency). The frequency of the alternator in practice is of the order of 500 to 1,200 cycles per second.

Instead of using an alternator and transformer, an induction coil may be used. This supplies a high pulsating voltage at its secondary terminals instead of a high alternating voltage. The operation is the same in principle, the advantage being that such a set is readily portable, and easily set up. However, the wave trains may occur at slightly irregular intervals as the armature does not vibrate regularly as a rule.

The presence of a spark gap in the oscillatory circuit has the disadvantage of introducing quite a high resistance, so that the oscillations are rapidly damped out, and the interval

of time between two wave trains, although of the order of 1/1,000 second, is very much longer than the duration of the various wave trains. The result is that such sets are of low power and small range, as a great part of the energy of the oscillations, instead of being radiated into space, is wasted away as heat in the antenna circuit. Also, due to the rather

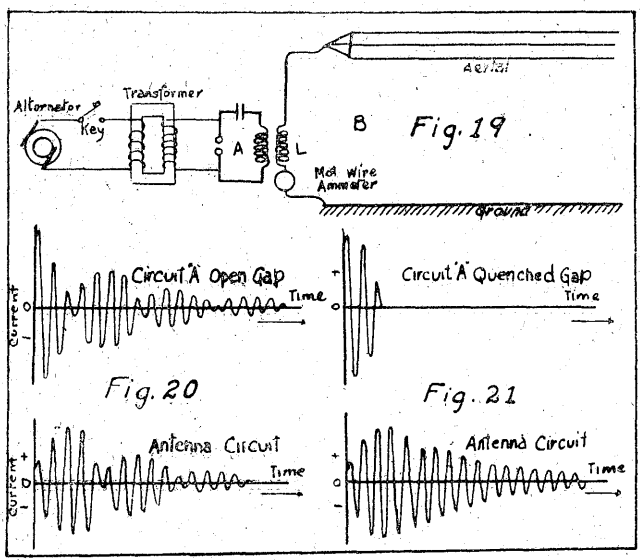


FIG. 19-21.

high decrement, tuning of the receiving set cannot be made very sharp. For long range sets, this method is then replaced by the indirect excitation method of transmission.

Indirect Excitation Transmission.

By this method, oscillations are started in an oscillatory circuit A, Fig. 19, exactly as with the direct excitation method, only this is a so-called closed oscillatory circuit; that is, both

the condenser and the inductance coil are of small physical dimensions.

Coupled to this circuit is the antenna circuit, comprising the large aerial-ground condenser and inductance through which the coupling to circuit A is made. Oscillations are set up in circuit A, as described above, each train of oscillations being rapidly damped out. Through the transformer action of the two inductance coils, these oscillations induce similar oscillations in the antenna circuit. When the oscillations in circuit A have been completely damped out, the antenna circuit, containing no high resistance such as the spark gap, will continue to oscillate for some time, so that for the same power input a greater amount of power will be radiated by using this method of exciting the antenna. For the proper operation of such a set it is of course necessary that the antenna circuit be tuned to the period of the closed oscillator circuit A. This is generally done as follows: Circuit A is first given the desired natural period by properly setting its variable condenser and variable inductance. The key is then closed and the antenna circuit adjusted by changing its constants until it is in resonance with circuit A. This condition is indicated by the maximum reading of the hot-wire ammeter inserted in the antenna for this purpose.

As in the previous case, many different arrangements of the circuits are possible. Instead of the alternator and transformer, use may be made of an induction coil. In some sets, the coupling of the closed oscillating circuit A to the antenna is made by means of one coil only, Fig. 22. This is called " conductive coupling ". The inductance of circuit A is then that part of the coil comprised between the points *a* and *b*, the portion of the coil included in the antenna circuit being that between *m* and *n*. It will be noticed that this arrangement of one or two inductance coils for effecting the transfer of energy from one circuit to another is, in principle, the same as an ordinary transformer, the only difference being the absence of an iron core. From this similarity, the arrangement has derived the name, " oscillation transformer ".

Some auxiliary phenomena take place when indirect excitation is used for setting up oscillations in the antenna. When a train of oscillations is started in a closed oscillatory circuit by the breaking down of the gap, the oscillations quickly damp out, mainly due to energy losses (resistance, gap, etc.) in the circuit itself. However, when such a circuit is coupled to some other oscillating circuit, such as in the case of Fig. 19, the closed oscillator, in addition to wasting away its energy in the usual internal losses, gives up at every cycle a part of it to the other oscillating circuit. So that its damping will be much greater. When the oscillations in the first circuit have died out, the second circuit has then stored a large part of the energy, and high frequency oscillations take place in that circuit. These react on the closed circuit and induce in it an emf. which causes the oscillations to start anew, due to the fact that the conducting gases in the gap were not given time after transfer of energy from the local to the radiating circuit to de-ionize or escape, and open the circuit. The second oscillating circuit thus gives back energy to the first, until it has returned all of it, at which time the first circuit is again in full oscillation. The phenomena then repeat in the same sequence. The result is a series of " beats " in each circuit, as represented in Fig. 20. The practical result is that the antenna circuit, instead of oscillating freely and radiating all its energy into space, feeds back and wastes some of it in the local oscillating circuit A.

To avoid this waste and secure the maximum radiation, it has been found necessary to prevent the transfer of energy back to the closed oscillating circuit, and a number of methods have been devised, all based on the same principle. The general principle consists of making the spark gap non-conducting after the circuit A has given up all of its energy; that is, after the oscillations taking place in it have been once damped out. If this is done, circuit A is open and an emf. induced back into that circuit by the antenna circuit will be unable to produce any current in it. Excitation by

this method is called " impact excitation ". This gives conditions shown in Fig. 21, from which it will be seen that after all the energy has been transferred from A to B, it is all spent in circuit B in free oscillations of low damping.

One method of making circuit A non-conducting consists in blowing out the spark in the gap by means of a violent stream of air produced by a blower of some sort. Such an

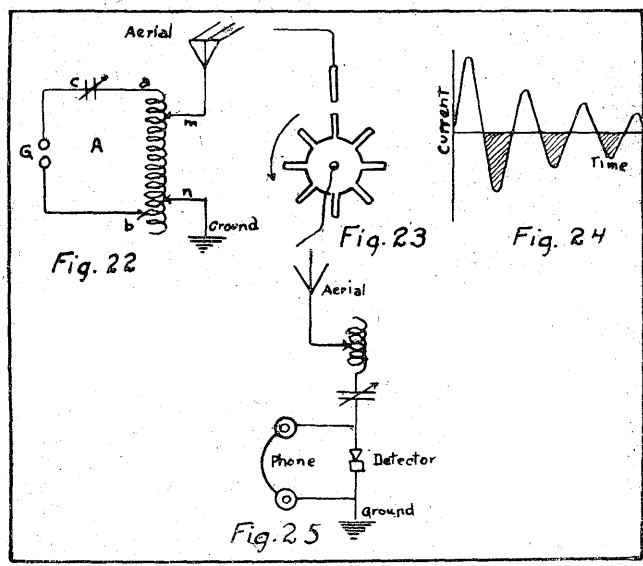


FIG. 22-25.

arrangement is called an air blast spark gap. Another method is the use of the " quenched gap, " in which the spark occurs in an air tight space between cooled electrodes made of metals such as zinc, aluminum or silver, all of which tend to prevent the spark from maintaining itself after the first energy transfer. A third method, used on a number of airplane transmitters, is the " rotary spark gap, " in which one of the electrodes of the gap is a stationary

metal post, at a small distance from wich is rotated a toothed metal disk forming the other electrode, Fig. 23. The disk is rotated at high velocity and a spark takes place every time one of the teeth of the disk passes in front of the stationary electrode. Each spark is extinguished very rapidly on account of the increased length of gap as the tooth turns away from the stationary electrode. There are two kinds of rotary gaps, called the " synchronous " and the " non-synchronous " gap. In the former, the disk is driven at such a speed, and has such a number of teeth, that there will be one spark for every cycle of the alternator. In the latter, the disk is driven at a different speed so that there will be more than one spark per cycle, or else one spark in every few cycles. The adjustment of such gaps is somewhat delicate and is not taken up here. While quenched gaps are of use in indirectly excited sets, they should be avoided in directly excited sets, as in this case the oscillations take place only in the antenna circuit and hence want to be prolonged as much as possible.

Principles of Reception.

In the previous paragraphs, a study has been made of the production in an antenna, of high frequency damped oscillations. These oscillations, it was pointed out, produce reversals of the electric field throughout space, and if the antenna is of suitable shape, of greater strength in certain directions than in others. Thus a damped oscillation in the antenna will produce a train of electric waves travelling from the source outward. When such a train of wave sweeps over any conductor, it will induce in this conductor an alternating emf. of proportional amplitude and of the same frequency as the oscillations of the train. If a circuit containing inductance and capacitance is acted upon by the oscillations, the alternating current set up in it will be a maximum when the natural freqnency of the circuit is equal to the frequency of the oscillations, or in other words, when the

circuit is tuned to the waves received, which means resonant with the transmitting circuit. A radio receiving set then comprises a circuit containing adjustable inductance and capacitance, so that it may be tuned to any frequency within certain limits. As it is of advantage that the receiving set intercept as much as possible of the energy of the incoming waves, it is made to cover as large an area as possible. This is accomplished by giving large physical dimensions to either the inductance coil or the condenser, in other words, by using an antenna. In such a circuit, for each wave train passing over the antenna there will be induced a train of high frequency oscillations. In order to perceive these oscillations, it is necessary to insert in the circuit some sensitive device which will respond to the extremely small currents induced in the antenna. The telephone receiver forms a very convenient device for this purpose because of its great sensitiveness and ruggedness. Reception of radio telegrams is thus almost universally done by sound.

As the frequency of the oscillations is far beyond the vibration frequency of the telephone receiver diaphragm, no sound would be produced by the latter under the influence of the alternating current induced in the receiving antenna. It is therefore necessary to rectify this current by means of a special device called a " detector ". This will conduct electric current fairly well in one direction, but practically not at all in the other. If such a detector is then connected in series with the telephone receivers, a wave train passing over the antenna will induce an alternating current in the circuit, but all the half cycles in one direction will be cut off by the detector, so that instead of a damped alternating current passing through the telephone, a series of unidirectional half-cycle impulses will flow, Fig. 24. As these impulses occur in such rapid succession that the receiver diaphragm will not respond to them their effect is added, giving one deflection of the diaphragm for each train of waves. When the train of oscillations is damped off, the telephone diaphragm falls back in place until the next wave train arrives at

the receiving station. If these trains arrive at a rate (for best results) of 500 to 1,200 per second, the successive vibrations of the telephone diaphragm will produce a sound in the operator's ear which will be of a very pure and steady note if the trains arrive regularly. which means that the spark of the transmitting set is occuring at very regular intervals, as determined by the vibrations of the induction coil vibrator.

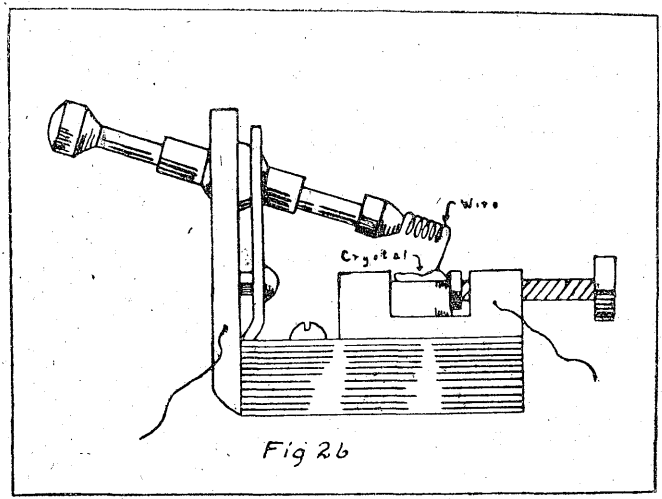
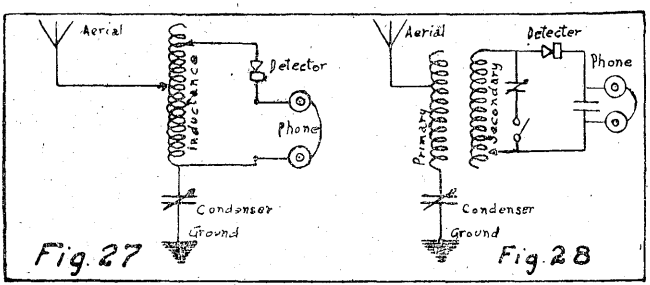


FIG. 26.

or by the alternating current frequency of the alternator. This wave train frequency is therefore called " audio frequency ", as was already pointed out, since it is of a frequency to which the telephone receiver and the ear will respond. The limits of audible frequencies are about 20,000 and 16 cycles per second.

There is quite a large variety of detectors. One used very widely on account of its simplicity is the crystal detector, a sketch of which is given in Fig. 26. It consists of a crystal of galena (lead sulphite) or iron pyrite (iron sulphite) held in

a special support. A fine metal wire is then maintained in position so that its point will rest with a light pressure against a spot of the crystal's surface. Certain points of the crystal surface give better results than others and almost completely stop the current flow in one direction. Such a spot is found by touching the wire point at various points of the surface, until the sound in the telephone receiver is great enough to be readily heard. This adjustment does not have to be repeated often if not disturbed by mechanical vibration. The selection of a good detecting spot on the



Damped Wave Receiving Circuits. FIG. 27-Inductively and Conductively Coupled. FIG. 28-Inductively Coupled.

crystal may be made by exciting the set by means of a small testing buzzer provided for the purpose.

From the previous paragraphs, it may be seen that a receiving set may be constructed by connecting an aerial to ground through an adjustable inductance and condenser, and a telephone receiver shunted by a crystal detector, fig. 25. The set is tuned by adjusting the inductance and the condenser until maximum response is obtained in the telephone. The high frequency alternating current induced in the antenna will then flow through the receiver in one direction (one half cycle), and through the detector in the other. Such a set, although very simple, has the disadvantage that the detector introduces a high resistance in the antenna, which prevents the latter from oscillating at maximum amplitude.

A better arrangement is therefore obtained by coupling the telephone and detector circuit to that of the antenna. This coupling may be inductive or capacitive. In case of the former, one of two coils may be used, just as in the case of sending sets. Such sets are shown in fig. 28. With circuits of this kind, the antenna circuit oscillates freely under the influence of the incoming waves, and induces the high frequency currents in the telephone circuit.

Tuning.

The waves emitted by transmitting stations are propagated in all directions, so that a receiving station may hear not only the signals of a particular station, but also those of all sets working within a good distance of it. It is evident that the reading of telegraphic signals would be absolutely impossible if it were not possible to weaken or eliminate all of the disturbing signals and on the other hand amplify the ones desired. If the disturbing signals are of wave lengths differing from that of the signal to be received, this selection of signals can be made by proper tuning of the receiving set.

When the resonance is very sharp, the receiving station may be sharply tuned. Reception by coupled circuits is almost always employed on account of the good tuning it affords, due to the possibility of double tuning both the antenna and the local oscillating circuits.

Coupling.

To maintain good tuning, it is necessary to avoid too close coupling, that is to say, to avoid bringing the two coupling coils too near together since in that case, the mutual reaction between the antenna and the oscillating circuits distorts the waves and decreases the sharpness of the tuning.

Care must be taken in the use of radio apparatus, not to put any metallic mass in the vicinity of the coils as this would be the seat of induced currents, the production of

which would take energy from the oscillating circuit and damp the oscillations.

Sources of trouble.

It has just been seen that tuning allows the elimination or the weakening of the effect of transmitted waves different in length from the ones to be received. For waves of nearly the same length, this elimination of interference will only be possible when the tuning is very sharp. This depends not alone on the receiving station. If the waves received have high damping, each incoming wave train is made up of only a few oscillations, and does not act very long on the receiving antenna. Sharp tuning requires the rhythmic repetition of the effects of a large number of successive oscillations. Oscillations of the lowest damping should therefore be used when sharp tuning at the receiving station is desired.

If two oscillations have the same or very nearly the same wave length, tuning cannot separate them, but receiving of either is nevertheless possible if the two sending stations have clearly defined tones. This depends on the difference in spark frequency (audio frequency) of the two transmitting sets, the higher this frequency, the higher the pitch of the note heard at the receiving station.

Other causes of serious trouble are electrical atmospheric disturbances, aurora borealis, the passage of electrified clouds, hail storms and drops of electrified rain. The atmospheric electrical discharges produce oscillating currents in the antenna, and the telephone receives them giving a series of mixed sounds. These noises are generally a series of impulses of low tone with the result that the high pitched musical signals are the least disturbed by atmospheric interference. This is often very troublesome in long distance receiving from powerful stations which work with long wave lengths. Although less intense on small field antenne, the atmospheric disturbances sometimes cause serious trouble in reading signals.

Influence of Ground Contour.

On a great plain, the waves are propagated normally in all directions from an antenna. In hilly regions, on the contrary, steep slopes form screens and deflect the waves. Near the foot of a steep hill, there is a region of shadow which is not reached by the waves coming from the opposite side. The waves reflected from the two slopes of a narrow valley, follow the valley. As it is necessary to avoid placing the receiving antenna in a region of shadow, an exposed position is sometimes preferable.

Telegraph lines and metallic conductors used in the construction of houses absorb the waves and their proximity is usually detrimental. In forests, an antenna receives and transmits badly because the sap of the trees conducts electricity and may be the seat of induced currents. When an antenna must be hidden in a wood it should be placed as close as practical to the edge from which the waves are coming, or in the middle of a glade. If possible, it is advantageous to install it above the trees. Interference with the waves by trees and houses is greater, the shorter the waves.

It is also necessary to choose a position for the ground connection where the ground is damp and conducting. An antenna in a position not entirely exposed may be good for transmitting and receiving waves in one direction, but not for another.

CHAPTER III.

UNDAMPED WAVE RADIO TELEGRAPHY.

The fact that the efficiency of the transmitting sets is greater, and that the tuning of the receiving sets is sharper for the waves having the smallest damping, gives rise to the desirability of using waves that are not damped at all. This means that an alternating current of constant amplitude and of radio frequency must be generated in the transmitting antenna. The use of alternators for this purpose presents very considerable difficulties, and is absolutely impracticable for portable sets such as are needed for military purposes. However, a new method of generation of undamped wave oscillations has come in for a very extensive application, consisting in the use of the three electrode vacuum tube.

Vacuum Tubes in Radio Communication.

Upon gaining a general idea of the newer apparatus used in the transmission and reception of communications by radio, one soon becomes impressed with the importance of the vacuum tube, as it occurs in nearly all of the principal types of modern radio apparatus. The same tubes may be used to transmit, to receive, to detect, to amplify, to modulate and to serve other important functions necessary to radio communication as it is now known. Their practical application to these numerous uses is an accomplishment of the last few years and the possibilities for further application are by no means exhausted. In fact, the whole field of radio work has been greatly influenced by the development of vacuum tubes, and by virtue of this it is now possible to effect radio communication through greater range with lower power and with greater selectivity than was formerly possible. Also, the tube has enabled the construction of appa-

ratus for these uses, which is readily portable—a most important feature in connection with military communication systems.

How these tubes work and how they can be made to serve such a multiplicity of purpose, are the questions which most naturally arise in the mind of every student. Answer to these two questions involves much highly theoretical discussion and more than one way of explaining the action in some instances. The following paragraphs, however, are intended to give an explanation general enough to be easily understood, while avoiding dual explanations of any particular action.

Electron Flow in Vacuum Tubes.

The electron flow in a vacuum tube will first be studied in a bulb containing two metal electrodes; one, a filament which may be heated by a local battery A, and the other, a flat piece of metal, called the plate, Fig. 29. If a battery B is connected across the tube with its negative pole to the filament and its positive pole to the plate, no current will be indicated on the ammeter I inserted in the circuit. However, if a current is passed through the filament by means of a battery A, bringing the filament to a red heat, a current of a few millamperes will be shown by the ammeter to flow in the circuit BFPIB. Thus, the heating of the filament causes a current to flow across the open space of the bulb. This may be accounted for as follows.

The explanation of phenomena observed in a great number of experiments has led to the assumption that there exists extremely small non-material particles having a definite negative charge of electricity. These particles are called electrons. They move in great numbers between the atoms of any metal. At ordinary room temperatures, they do not escape out of the metal, in most cases, but when the metal is heated, the material atoms vibrate about their mean position of equilibrium with a speed and amplitude which

increases with the temperature. The electrons, which follow the atoms in this thermal agitation, likewise acquire increasing speed as the temperature of the metal is raised. When it becomes red hot, the speed of the electrons is so high that they leave the metal, This phenomenon is illustrated by the experiment described above, wherein the filament was made red hot and an electrostatic force was present, due to the

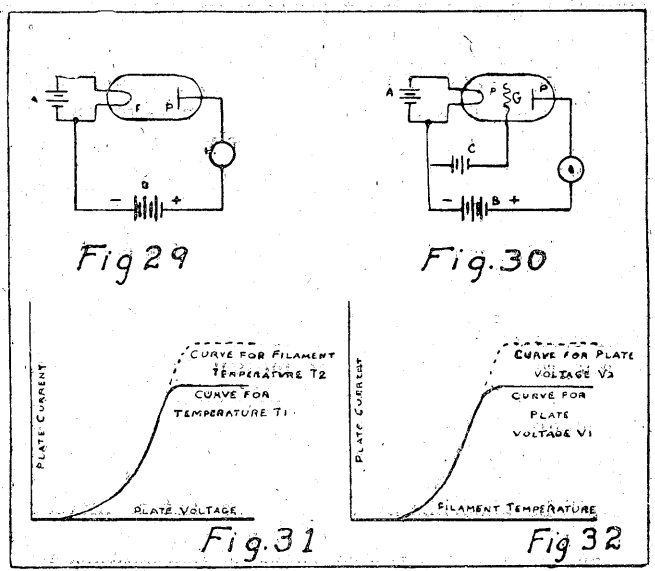


FIG. 29, 30 and 31-Two-Electrode Vacuum Tube and Characteristic Curves
FIG. 32-Three-Electrode Vacuum Tube.

connection of the B battery in the plate circuit, which tended to move the negative electrons from the filament to the plate by repulsion from the filament and attraction by the plate. Under these conditions, the electrons travel from the filament to the plate at a speed which may attain tens of thousands of miles per second, and transport negative charges across the space in the bulb from filament to plate. The passage

of electrons, each carrying its charge of electricity from filament to plate, constitutes a flow of electricity which is an electric current. It should be noted that the electron flow is from the negative filament to the positive plate, while the electric current flow is just the opposite from the positive plate to the negative filament. This is not difficult to explain, as the direction of flow of the electric current from positive to negative poles is a mere assumption which was made before the discovery of the electron flow, and could just as well have been assumed to be in the opposite direction.

If the polarity of the B battery, Fig. 29, is reversed, no electric current will flow through the ammeter, as the plate will be negative and will repel the negatively charged electrons and thus prevent any flow of electricity across the tube.

Operation of Two-Electrode Tubes under Various Conditions.

The two electrode vacuum tube is very frequently called a valve. For a given filament temperature, T_1, a definite number of electrons is emitted per unit of time. The number of electrons per second which will travel across the tube and reach the plate is the measure of the current in the plate circuit, and it varies within limits approximately as the square of the voltage across the space between plate and filament. As this voltage is increased, a certain value will be reached at which all electrons emitted by the filament will be absorbed by the plate, so that no increase of current will take place for higher values ot the plate voltage. This is shown in Fig. 30, curve for temperature T_1. In order to increase the plate current, it is then necessary to raise the filament temperature to some higher value, T_2, when the current curve will rise to a new value before bending over to the horizontal position.

Now, if the plate voltage is kept at a constant value, V_1, and the filament temperature raised by increasing the current from the battery A, the number of electrons emitted by the filament will vary approximately as the square of the filament temperature figured above the red heat tempera-

ture (1600° absolute for tungsten filament) until a point is reached where the electrostatic field, due to the negative charge of the electrons in motion in the tube, will exactly counteract that due to the positive charge of the plate. This condition is called the « space charge effect ». Any further increase of filament temperature would then tend to increase the number of electrons in the tube, and therefore the space charge. The latter then outweighing the charge of the plate, would repel some of the electrons back into the filament. A state of equilibrium is thus reached whereby the current remains constant independently of further increase of filament temperature, and the current curve will bend over and remain at a constant value of plate current, Fig. 31. If there is no potential difference between the filament and the plate, the space charge effect will prevent the flow of electrons to the plate.



FIG. 33.—French Audion Bulb.

To increase the current, it is then necessary to increase the plate voltage to some higher value, V_2. The upper limit to this voltage increase is that which prevails when a blue glow is observed around the plate. On old and defective tubes, this blue glow may appear at normal operating voltages, and then it is an indication of poor vacuum. It causes a hissing noise in the telephones and prevents good operation of the tubes.

The Three-Electrode Vacuum Tube.

The three-electrode tube, or audion bulb as it is also known, see Fig. 33, is a highly evacuated bulb containing a filament and a plate like the two-electrode tube already described, but in addition having a grid or wire screen support midway between the plate and the filament. The filament is made of some material, usually tungsten, or platinum coated with oxide, which when heated liberates a quantity

of electrons from its surface. The plate electrode is placed near to and usually encloses the filament.

It may take various forms, such as two flat plates, a cylinder, a cone, etc. The grid is made up of a network of metal wires, sealed into the tube and supported in such a manner as to be interposed between the filament and the plate so that any passage of electrons or current between these electrodes must pass through the grid.

If the plate is made positive with respect to the heated filament, a flow of electrons will take place from the filament to the plate, as explained in connection with the two-electrode tube. In their flow, the electrons must pass through the wire mesh of the grid, which can be made to have a controlling influence on the electrostatic field in the tube. Thus the rate of flow of electrons from filament to plate may be regulated by changing the potential of the grid with respect to the filament. If the grid is given a potential slightly negative to the filament, which may be done by a battery C, Fig. 32, it will repel some of the electrons emitted from the filament, but many of them, due to their high velocity, will pass through the mesh of the grid and reach the plate. Now, as the potential of the grid is made more negative, Fig. 34, the plate current will gradually decrease until the negative grid potential will be great enough to prevent all electrons from leaving the filament, thus stopping the plate current flow entirely. This is due to the action of the field created by the grid which has neutralized that created by the plate.

If the grid is made positive instead of negative, more electrons will be attracted toward the plate than would pass without the influence of the grid potential, and the plate current will be increased until saturation of the tube occurs. This saturation may be explained as follows: As the grid is made more and more positive, the plate current increases at a greater rate than the grid voltage, Fig. 34, so that a grid potential will be reached at which the space charge due to the negative electrons passing across the tube

will exactly counteract the influence of the positive grid potential. When this condition prevails, the maximum plate current is obtained. Further increase of grid potential tends to increase the plate current and therefore the space charge, but the latter, increasing at a greater rate, overbalances the influence of the grid and the plate current thus remains practically constant up to a certain grid voltage, beyond which the plate current slowly decreases. The limitation of plate current is due not only to the space charge effect, but also to the absorption of electrons by the grid in increasing numbers as its positive potential is increased. This absorption gives rise to a current flow in the circuit FGCF, called the grid current.

From the last two paragraphs it can be seen that if the grid is made alternately positive and negative, the plate current will be accordingly increased and decreased about its normal value in the absence of the grid. By means of a small dry battery it is possible to fix the mean potential of the grid at any point on the characteristic curve. The value of this mean potential (which is the grid potential existing when no oscillations are taking place) determines the operation of the tube as a rectifier or as an amplifier. The variations of grid potential modify the plate current, and the tube thus acts as a relay controlled by the very small variations of grid potential.

The electrostatic capacity of the grid being very small, the variations of its charge involve correspondingly small amounts of energy. It is therefore very sensitive, and having no inertia, it is able to follow the extremely rapid oscillations encountered in radio telegraphy-oscillations of frequency far beyond the range of mechanical or more common electrical devices.

Detector Action of Vacuum Tubes.

A simple connection of the three-electrode tube as detector is shown in Fig. 35. When a train of damped oscillations strikes the antenna, it produces an alternating voltage

in the antenna circuit as represented in Fig. 36-A. This voltage induces a similar voltage in the secondary coil, ab, of the receiving tranformer connected in the grid circuit, which is superimposed on the normal grid potential given

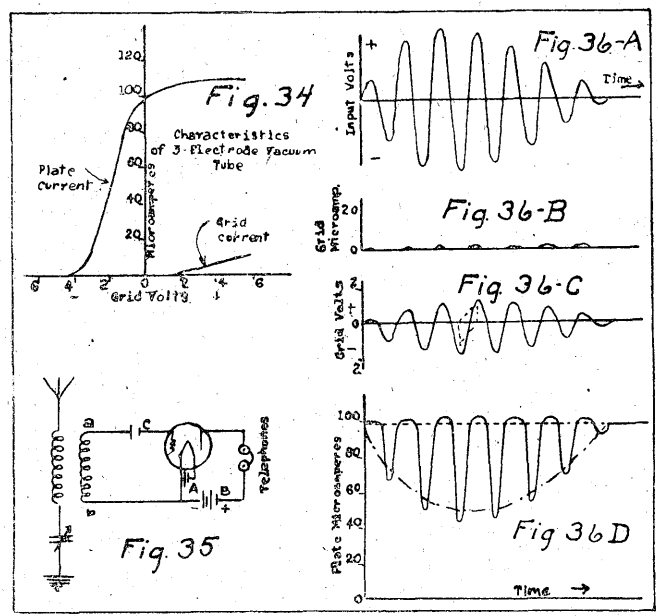


FIG. 34-Characteristics of Three-Electrode Vacuum Tube. FIG. 35-Three-Electrode Tube Used as Detector. FIG. 36-Analysis of Detector Action; (A) Input Voltage Due to Incoming Waves; (B) Resulting Grid Current; (C) Grid Voltage Resultant of Induced and Counter EMF.; (D) Current in Plate and Telephone Circuit.

by the battery C. The component of the grid current due to the alternating voltage will flow only during the positive half cycle of the oscillation, as seen from the grid current characteristic curve, Fig. 34, and indicated in Fig. 36-B. This current flow from grid to filament has a tendency to equalize the potential difference between them, so that the

actual grid voltage, instead of following a symmetrical curve similar to the antenna voltage, will be asymmetrical, the amplitude of the negative half of the wave being greater than that of the positive half, Fig. 36-C, as no current is then flowing.

Referring to the grid current characteristic curve, Fig. 34, again, it will be seen that an asymmetrical change in plate current will result from this asymmetrical change in grid potential, Fig. 36-D.

When flowing through the telephone receivers, this plate current will be smoothed out by the inductance of the telephone into a single unidirectional impulse; and such an impulse being produced for every wave train, a sound will be produced in the telephones at a frequency corresponding to that of the frequency of the trains. The operation of the tube as a detector will be best when the normal grid potential is near the upper bend of the characteristic curve, and will gradually become less effective as this potential is brought nearer to the lower bend, until a point is reached when rectification does not occur and where the asymmetrical variations of grid voltage produce symmetrical variations of plate current, Fig. 37. This particular part of the curve is used for amplification, as will be explained in a later paragraph. Beyond this point of no detector action, however, the rectifying properties of the tube reappear, so that it may be used as a fair detector on the lower bend of the characteristic curve (1).

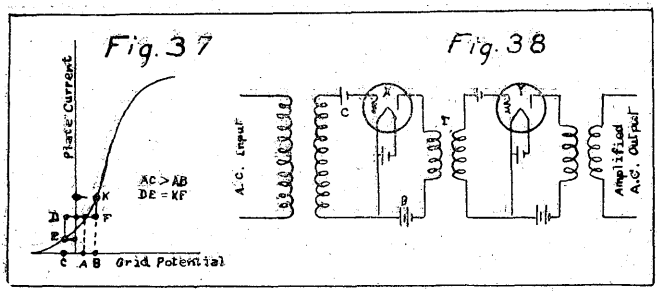
Grid Condenser Connection for Detector Action. — If the C battery, Fig. 35, is replaced by a small condenser (0005 mfd.), the detector action of the tube is different from that described above. During a period of no oscillations, the plate current assumes a certain value determined by the B battery and the filament temperature. If now an oscillation strikes the antenna, the grid will be made alternately positive and

(1) The curves of Fig. 36-B, 36-C and 36-D should lag about 180° behind the voltage curve of Fig. 36-A. This has not been shown because of its tendency to confuse.

negative. When it is positive, it attracts electrons, and being insulated from the filament, it retains these electrons and acquires a negative charge which lowers the plate current. The negative charge of the grid is then caused to leak off either through the condenser dielectric or through a high resistance shunting the condenser, so that by the time the next train of waves arrives, the grid is again at its normal potential.

Amplifier Action of Vacuum Tubes.

The energy of a signal wave at the receiving station is very often so extremely weak that it is necessary or advantageous to amplify the signals to make them more easily read. In radio telephony, this amplification has a special



Three-Electrode Vacuum Tube Used as Amplifier. FIG. 37-Point on Characteristic Curve Giving Symmetrical Amplification. FIG. 38-Connection for Cascade Amplification.

importance. The problem consists in producing changes in the telephone receiver current which are exactly proportional to the amplitude of the incoming waves, and without distortion. As outlined in the explanation of the detector action of the tube, a symmetrical oscillation in the primary (input) circuit induces an asymmetrical oscillation in the secondary or grid circuit, the voltage amplitude being less for the positive half cycle than for the negative. A point

may be found on the characteristic curve of the tube, Fig. 37, where the asymmetrical variation of grid potential produces symmetrical variation of plate current, so that the variations of the plate current will reproduce exactly those in the antenna without distortion. Furthermore, the very slight energy of the wave acting on the grid, produces very large variations of plate current because of the relay action of the tube, and this explains the amplification of the antenna oscillations.

To separate the amplified alternating current from the steady direct current in the plate circuit, the pulsating plate current is passed through a transformer, Fig. 38, which delivers the amplified alternating current at its secondary terminals. A second tube may be used to further amplify this wave if necessary, as tube Y, Fig. 38. When this is done, the process is called cascade amplification.

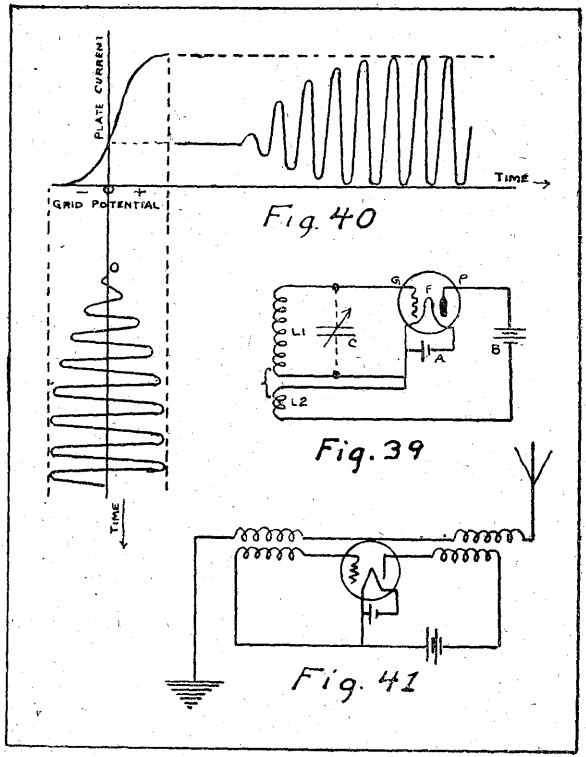
Oscillator Action of Vacuum Tubes. — Undamped Wave Transmission.

As the vacuum tube can be used as an energy amplifier, it can be made to generate and sustain oscillations by feeding back upon the grid circuit the energy amplified in the plate circuit. This can be done by electromagnetically or electrostatically (or both) coupling the grid circuit to the plate circuit. Such an arrangement is shown in Fig. 39, where the grid circuit GL_1FG is coupled electromagnetically to the plate circuit PL_2FP by means of the inductances L_1 and L_2.

If now a small change is produced in the potential of the grid, a change in plate current involving a greater amount of energy will result. This plate current, flowing through L_2 will in turn induce an emf. in L_1 of greater magnitude than the original potential change in the grid circuit. This produces a new change in the potential of the grid so that oscillations continue to increase in this manner until the amplitude of the plate current reaches the bends of the characteristic curve of the tube. At this point the oscillations

will have reached their final constant amplitude. Fig. 40 is a graphical representation of this phenomenon.

To produce oscillations, it is of course necessary that the values of inductance and capacitance, and the coupling, be



Vacuum Tube Used as Oscillation Generator. FIG. 39-Connection for Undamped Oscillation Generation. FIG. 40-Analysis of Generator Action. FIG. 41-Example ot an Undamped Wave Transmitting Set.

chosen of such values that the emf. induced in the grid circuit will be in phase with the alternating component of the plate current. To generate oscillations of any given

frequency, it is simply necessary to tune the oscillatory circuit by means of the condenser *c*, for instance. The circuit L_1C will then oscillate at its natural frequency, and these oscillations will be sustained by the plate current. The oscillator can then be coupled to an antenna and made to induce undamped oscillations in it which will be radiated into space. Such a circuit is shown in Fig. 41, but there are any number of connections which will enable the use of the three electrode tube as an oscillation generator. To use such a set as a radio transmitting set, it is simply necessary to insert a sending key at some point of the circuit. Then whenever the key is depressed, the antenna will radiate undamped waves.

Reception of Undamped Waves.

The reception of such signals is different from that of damped wave signals. The principle of damped wave reception is that every wave train, after being rectified, deflects the diaphragm of the telephone receiver, which then between two wave trains, springs back in place.

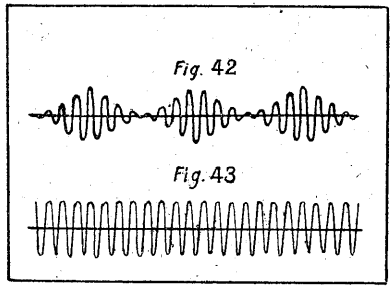


FIG. 42-43.

The succession of wave trains then sets the diaphragm into vibration at the spark frequency of the transmitting set.

In undamped wave telegraphy, the oscillations are not divided into wave trains: they are emitted without interruption, and with a constant amplitude, Fig. 42. Hence, the telephone diaphragm is deflected at the beginning of the signal, and so remains until the end of the signal, for the succession of the individual waves is so rapid that the diaphragm will not respond to the corresponding high rate of

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vibration. There is consequently no audible vibrations of the diaphragm. However, audible vibrations in the receiver may be obtained by several different methods.

One method consists in utilizing a mechanical interrupter called a " tikker " which is connected in the circuit at the receiving station, in such a way that it periodically interrupts the current through the telephone receivers—the current induced by the incoming radio waves — and thus breaks it up into current-off-and-on periods of a low frequency to which the diaphragm will respond. This method has the disadvantage that all the energy received by the antenna during the current—off periods is lost.

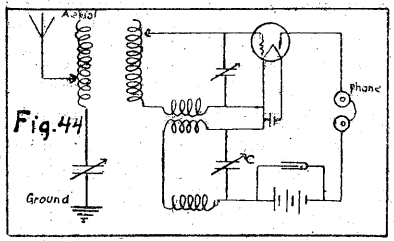


FIG. 44.—Schematic Circuit of an Autodyne Receiving Set.

A more recent and better method consists of a scheme for transforming at the receiving station, the continuous waves of constant amplitude into waves the amplitude of which varies periodically, Fig. 43. This end is attained by the application of the phenomenon, familiar in the study of sound wave propagation, called "beats". This is called the " heterodyne " method of reception.

The receiving set is tuned to the frequency of the incoming waves by means of its adjustable inductance coils and condensers. Then, undamped waves of slightly different frequency are generated locally at the receiving station and superimposed upon the oscillations in the detector circuit due to the incoming waves. The result is that the two rectified alternating currents add together algebraically to produce beats in the amplitude of the current through the telephones, of a frequency equal to the difference between the frequencies of the two currents.

Such a set may be constructed by modifying the receiver circuit shown in Fig. 35. It is simply necessary to couple the plate circuit of the detector tube to the grid circuit. The tube then acts simultaneously as a detector for the incoming waves and as a generator for the local undamped oscillations, Fig. 44. Such an arrangement of circuits is called an "autodyne" receiving set. The frequency of the local oscillations, may be changed by adjusting the setting of the condenser C for instance, and this will change the beat frequency and therefore the pitch of the sound in the telephone. A very pure note of any pitch may thus be obtained at the will of the receiving operator. The use of such sets allows exceedingly sharp tuning and practically eliminates all interference from other sending stations.

CHAPTER IV.

RADIO TELEPHONY.

The vacuum tube or audion bulb may be used for radio telephonic communication within limited ranges. The principles involved are the same as for undamped telegraphic transmission with sustained waves by means of the tube or audion, except that the sending key is replaced by a device for varying the intensity of the energy radiated, thus producing sounds at the receiving station corresponding to the inflections and modulations of the voice.

Several simple schemes have been evolved for producing these variations, the features of each being arranged in accordance with the conditions under which it is to be used. In all of them, however, the microphone by its variations of resistance under the influence of the voice acts upon the amplitude of the continuous sustained waves set up in the antenna by the vacuum tube and coil arrangement used in undamped telegraphy.

At the receiver, after detection, without the use of the heterodyne, the mean current in the telephones follows the variations of intensity of the waves received and reproduces the words spoken into the microphone at the transmitting station.

Microphone in low frequency circuit.

A simple means of causing the microphone to act upon the amplitude of waves emitted by an antenna consists in causing the variations of resistance in the microphone to modify the grid potential of the transmitting bulb. A battery P, a microphone, and the primary of a transformer are placed in series, and the secondary of the transformer is inserted in series with the grid so that the emf. of this secondary acts on the grid, see Fig. 45. When one talks into the

microphone the point of operation of the tube is thus shifted along its characteristic curve and a modification of the amplitude of the plate current and hence of the radiated wave results. The secondary of the transformer is shunted by a small condenser c which allows the high frequency currents to pass without traversing the secondary.

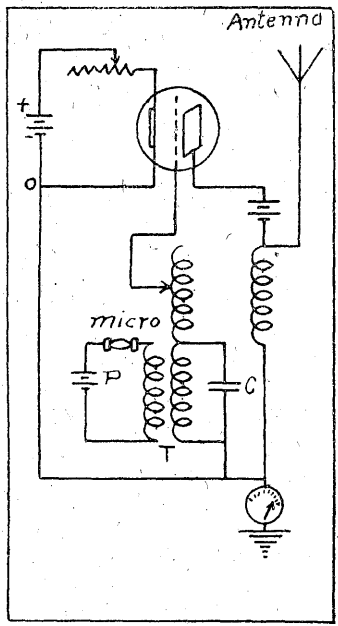


FIG. 45. — Microphone in low frequency circuit.

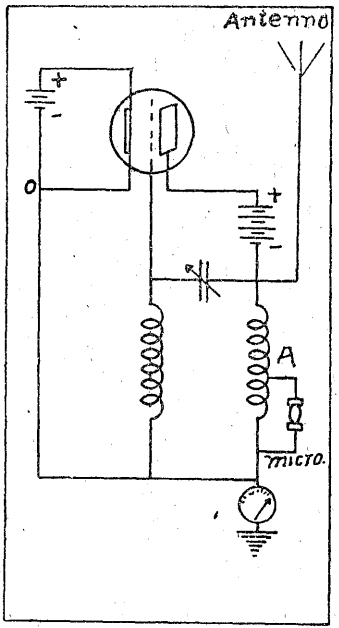


FIG. 46. — Microphone in high frequency circuit.

If the grid variations resulting from this arrangement are too feeble, a valve amplifier may be used to amplify the variations of current in the microphone and the amplified variations are then impressed on the grid resulting in a correspondingly greater variation in the radiated wave amplitude.

Microphone in high frequency circuit.

Another quite simple arrangement consists in shunting the microphone directly across several turns of the inductance or plate coil in the transmitter as in Fig. 46.

When the heating current is turned on, the transmitter sends out continuous sustained oscillations. When the microphone is used in speaking the variation of resistance therein furnishes a shunt of varying resistance across the several turns of the plate coil. This produces a greater or less resistance in the filament-plate circuit as well as in the open oscillating circuit composed of the antenna, inductance coil A, and ground, in accordance with the modulation of the voice. The effect of an increase in the plate circuit resistance is to decrease the amplitude of the current flowing from the battery to energize the antenna, and the amplitude of the oscillation is also directly decreased since there is a slight increase of resistance in the open oscillating circuit itself. The combined effect then is a considerable reduction in the amplitude of the transmitted wave. The effect of a decrease in resistance in the microphone and hence in the plate and oscillating circuits is the reverse and evidently results in an increase

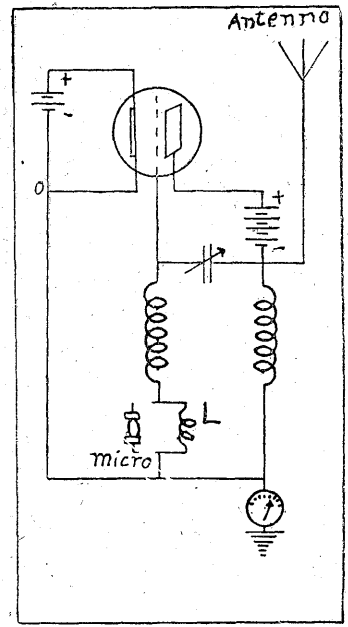


FIG. 47. — Microphone in series in grid cicruit.

in amplitude of the transmitted wave. This scheme is used in several of the French field sets designed primarily for sustained wave telegraphy, and gives excellent results within limited ranges. The E 10 and E 3 series are examples of this type. When the sets are of higher power, and the current intensity becomes greater than that allowed in the ordinary microphone it is necessary to use a special design of microphone. However, the common telephone transmitter gives good results with the sets above mentioned.

For more powerful sets a different arrangement makes it possible to obtain great variations of amplitude in the antenna while admitting only small high frequency currents into the microphone. A transmitter of the audion type is used, and the grid is given a sufficiently high self-inductance so that the adjustment which corresponds to the wave to be emitted necessitates only an extremely small capacity of the condenser. The microphone is placed in series in the grid circuit, being then traversed by a very small current. It has, however, a very noticeable action on the antenna current. The circuit consisting of the grid inductance and the coupling condenser, has a free period of oscillation less than that of the antenna. The variations of resistance in the microphone act upon the phase difference betwen the current in its oscillations and the difference of potential between its extremities, thus producing changes in the grid potential.

These changes in grid potential produce corresponding changes in the amplitude of the antenna oscillations with the effect already described. Ordinarily an inductance L is placed in parallel with the microphone so as to avoid the disturbance of tuning which might result from a complete cutting of the grid circuit by the microphone. See Fig. 47.

Microphone in an independent circuit which absorbs energy.

Still another method of producing the fluctuations in radiated amplitude is found in the arrangement shown in

Fig. 48. A high frequency alternator is connected directly into the antenna, and sets up oscillations of constant amplitude therein. Inductively coupled to the antenna is the plate circuit of a three-electrode vacuum tube, or audion, the grid of which is maintained at a considerable negative potential with respect to the filament by means of a battery C.

The current passing through the antenna coil A, induces an emf. in the plate coil B coupled to it and therefore a potential difference between the filament and the plate of the tube or audion, but on account of the strongly negative potential of the grid, this emf. produces a very small current in the plate circuit, i. e. the energy transferred from the antenna circuit to the plate circuit is very small. If the grid is made less negative, the same induced emf. in the plate circuit will produce a larger current, so there will be a larger transfer of energy from the antenna circuit to the tube. The tube will have absorbed power so to speak from the antenna circuit. The result of this absorption is that the normal output of the generator is divided between the two circuits in proportion to their impedances so that part only of the energy normally radiated without the reaction of the plate will now be radiated. The more positive the grid of the tube, more freely will current flow in the plate circuit, and the greater will be the power absorbed by the tube and therefore the less the amount of energy radiated. This variation of grid potential

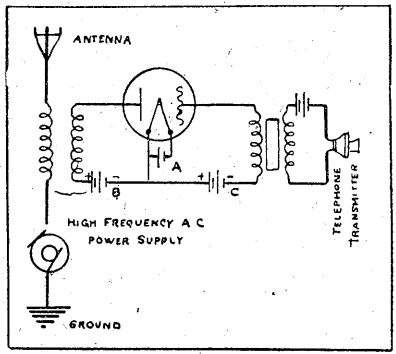


FIG. 48.
Microphone in independent circuit.

is brought about, as in the first method described above, through the use of a telephone transmitter coupled to the grid filament circuit through a transformer, as shown. The voice inflections and modulations result in varying potential impressed on the grid, and proportional variations in the energy radiated are produced, as described. The high frequency alternator may be an audion bulb or vacuum tube.

The vacuum tube, or audion may be used not only to modulate the a. c. power output of the high frequency alternator, as described, but to modulate the d. c. supply to that generator, thus accomplishing in another way the same final result,—the modulation of the antenna output. If the a. c. generator is an audion bulb, the modulator tube may be connected in parallel with the transmitting bulbs across the direct current supply, or plate battery, and the microphone or telephone transmitter is connected to the primary of a small transformer, the secondary of which is placed in the grid circuit of the modulator tube. As the resistance of the modulator tube is changed by the variation of grid potential due to the action of the voice on the telephone transmitter the amount of power to be transformed into oscillations by the oscillator tube will be correspondingly modulated.

Reception.

At the receiving station in radio telephony, the mean current variation due to the increase and decrease of amplitude of the intercepted wave brought about as above described, affects the telephone receiver after detection, and the disc vibrates exactly in accord with the inflections and modulations of the speaker's voice as in wire telephony. As stated, no heterodyne is used.

Since the oscillations set up in the receiving antenna are undamped, their syntony is good and it is possible to receive with a very loose coupling between primary and secondary.

The range is much less than that of the same set used for radio telegraphy, because the benefit of the heterodyne amplification is lost and also because the telegraphic key interrupts the wave entirely, while a telephonic transmitter only varies its amplitude.

Certain vowels, such as "a" or "o" produce large variations of the microphone resistance, while the vowel "i" produces smaller ones. If the action of the microphone has been so adjusted as to attain the maximum variation of amplitude for the vowels "a" and "o", the vowel "i" is less effective. As in order to understand spoken words it is necessary to detect all the syllables, the range is limited by the variations of amplitude (relatively small) of the less effective syllables. It is necessary to avoid too close a coupling for the microphone, for each strong syllable would reduce the intensity to zero in the antenna and would be badly reproduced.

This is also the reason why it is necessary to avoid loud tones in radio telephony, as in the ordinary telephone. When the transmitter is in an airplane the noise of the engine tends to make one speak too loudly. It is necessary to avoid yielding to this tendency.

CHAPTER V.

DESCRIPTION AND USE OF RADIO EQUIPMENT.

Transmitting set, Portable type N° 3 (French) — (Trench Set). General characteristics.

These portable sets, (see figure 49), are intended for use as near the front as possible, and in the immediate vicinity of the firing line, in order to allow liaison (transmission only) with a point situated behind the lines where a receiving set similar to the receiving set, Artillery Type A-I, is erected.

The equipment and design of these sets are such that they are very portable and rapidly and easily erected, relatively not very visible, and easily operated under all circumstances. Consequently, the sets are not very powerful and, on account of the limited capacity of the accumulators, cannot work for a very long period. They should be used only for very short messages.

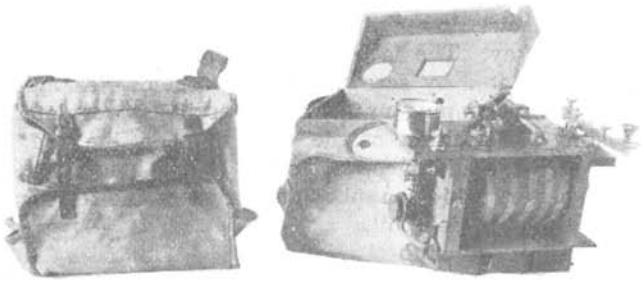


FIG. 49. — Transmitting Set, Portable Type-French.

The set, Type No. 3 belongs to the direct excitation of 30 watts nominal power. An induction coil supplied by a 10 volt set of accumulators supplies power through the primary to the secondary, antenna, and earth.

The primary current is interrupted by a breaking device operated electromagnetically by the core of the induction coil.

The antenna is a low, directive antenna supported by special supports at a height of about one meter above the ground; its length may be 25, 30, or 35 meters according to the wave length desired.

The frequency of the note emitted is about 100 vibrations per second.

The transmission limit of this set, with a receiving set similar to that used by the artillery, is, in certain regions, about 2 ½ miles. It may be considerably increased, if the antenna be placed higher.

Each set is packed, so as to be easily portable, in five separate parts, which include the transmitting box, accessories, antenna material and two storage batteries.

Description of the equipment.

The transmitting box (see figure 50) consists of an induction coil with a mechanical break in the primary. A condenser shunted across the break prevents sparking at the break contacts. In series with the primary coil is an ammeter and a key. The latter is of the plunger type, and its play is regulated by screwing the contact carrier tight by means of a clamping nut; the key spring is regulated by adjusting the position of the stop ring on the rod. By means of two binding posts, connection is made with the 10 volt battery which supplies power, when the key is pressed, to the induction coil.

The secondary of the induction coil is shunted by means of an unsymmetrical, adjustable spark gap, the electrodes of which are connected with two binding posts, respectively for ground and antenna connection.

All of the different parts are accessible. The main panel, on which the apparatus is mounted, may be removed by taking out the screws which hold it to the sides of the box

The method of adjustment is explained below. The adjustment of the breaking device is shown inside the cover of the box.

A canvas carrying case is provided for easy transportation.

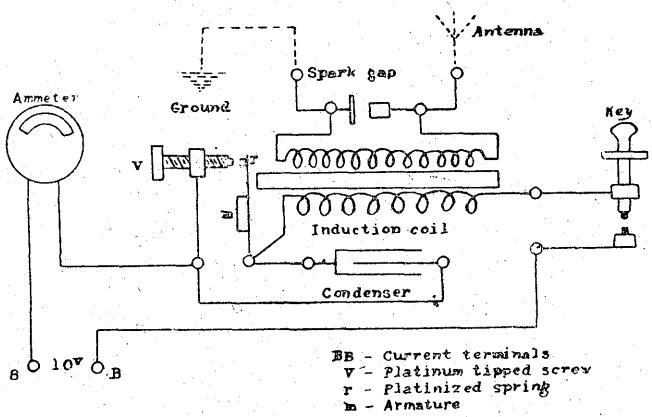


FIG. 50. — Transmitting Set, Portable Type No 3.

Equipment for ground connection and antenna.—The antenna equipment is composed of two hinged wooden supports with accessories for mounting, and the necessary antenna wire. Both arms of the supports are constructed so that they may be folded up for transportation : the upper section is provided with an insulator to which the antenna is fixed by means of a snap-hook. Each support is provided with guy rope and iron peg. The pull of the wire is balanced by the guy rope attached to the peg driven into the ground. The wooden supports are given suitable inclination, and the antenna may be lowered by relaxing tension on one of the guy ropes during intervals between transmission.

The connection between the antenna and the lead-in wire is obtained by twisting both wires together, or by means of a plug and socket.

The ground connection consists of a strip of wire mesh, or ground mat, soft enough to make good contact with the ground: it is provided with two terminals for connecting to the wire coming from the station. A ground stake permits improvement of the ground connection.

Each set is provided with two sets of antenna and ground connection material. (One as spare).

Accumulators. (*Storage batteries*).—Each set is provided with two 10-volt, 16 ampere hour batteries, provided with a shoulder strap for carrying purposes. Care must be taken that they are not upset when placed on the ground. In place of these batteries, two storage batteries of 10 volts, 20 ampere hours were formerly supplied and in some cases may still be sent out.

Accessories and spare parts.—Each set is provided with accessories contained in a canvas case, which may be attached to the belt. According as may be ordered in the field, these accessories may be taken to the first line, with the station, or left behind with the second set of antenna material and the second battery.

Adjustment of the equipment.

The adjustment of the equipment (except that of the spark gap) must be made in advance. This adjustment is very stable and is not easily changed but would be very difficult to make under fire of the enemy.

The adjustments necessary are the following:

Adjustment of the breaking device.

Adjustment of the antenna.

Adjustment of the spark gap.

Adjustment of the breaking device.—The only part of the breaking device which it is necessary to adjust is the platinum tipped screw. This is operated by a large milled red fibre knob and a lock nut fitted with a milled ebonite head. This allows the platinum tipped screw to be properly adjusted (it must be turned from right to left until it touches the head of the screw).

The platinum tipped screw must be adjusted so that when the coil is connected to a 10 volt battery, the ammeter will indicate about three amperes.

The breaking device must be forcibly set into motion instantly the coil is connected, care being taken that the distance between the core and the blade is not more than one or two millimeters. The screw which secures the core is placed on the left flange of the coil and must be tight.

Adjustment of the antenna.—The length of the antenna wire must be adjusted to one of three lengths — 25, 30 or 35 meters corresponding to the approximate wave-lengths desired, 100-120-150 meters.

Adjustment of the spark gap.—The longest spark-length of which the coil is capable should be found. This test must be made with the average antenna after it has been unwound and insulated from the ground. Under these conditions the spark is not very regular. Reduce the sparking distance in order to obtain a regular fat spark. The sparking distance will then be about two-thirds of the maximum sparking distance.

Operation of the set.

Transportation of the set.—The minimum personnel required to transport the set is three men.

The first one, who is in charge of the party, carries the transmitting box on his back and sometimes the accessory bag on his belt. The second carries the battery by means of a shoulder strap. The third one carries, over his shoulder, the bag containing the different parts of the antenna. Other men will carry, if necessary, the spare parts (battery and antenna). No special precaution is necessary while transporting the different parts of the set, except for the battery which must not be upset.

When the set is to be used for some time in a quiet area it should be installed in a shelter. During an attack the station is roughly set up, the connection between antenna

and transmitting box should be very short. The ground mat may simply be laid on the ground.

Setting up the set.—On arrival at the appointed place, *the first radio operator* sets the transmitting box on the ground, opens it and takes out the connecting wires that are inside.

He connects the transmitting box to the battery which the second man has placed on the ground, taking care to make connections with proper polarity.

He makes the ground and antenna connections by means of the plugs and fastens the ground connection cable to the terminal of the strip of wire mesh.

As the antenna is to be stretched in the opposite direction to the antenna of the corresponding receiving station, radio operator No. 1 indicates the direction to his aids by using, if necessary, the compass placed in the case containing the accessories.

Radio Operator No. 2.—Places the battery near the transmitting box.

He helps operator No. 3 get a hammer and a support with its attached guy rope and peg out of the case. He then sets the peg by means of a hammer, at the place indicated by the man in charge, and then sets up the support.

He afterwards stretches the strip of ground mat in the direction of the antenna, burying it, if practicable, and connects the leading-in wire to the antenna, as near the insulator as possible; he lays the wire on the support.

Radio Operator No. 3.—Removes the antenna material from its case. He fastens the end of the antenna to the insulator of the support, which has been placed by radio operator No. 2 and takes the reel in his left hand; in his right hand he carries the second support and the hammer.

He walks in the direction indicated by the man in charge and unrolls the antenna wire; when he gets to the end, he sets the second support up after having fastened the antenna to it, sets the peg and stretches the antenna.

He then brings the hammer and reel back to the station.

Transmission.—Radio Operator No. 1 operates the set and

sends the telegrams. The operator must work slowly, working the key to its extreme positions through a distance of one millimeter.

While working, always look at the ammeter; it must always work properly; the operation of the spark gap may be seen through the glass cover.

The second radio operator, writes the messages in the sen-

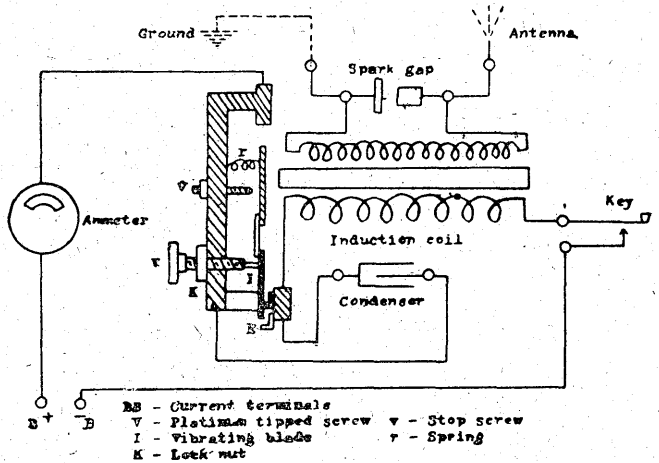


FIG. 51. — Transmitting Set, Portable Type No. 4.

ding book and takes the place of the first one, if necessary.

The third radio operator watches the antenna and repairs it if occasion requires.

Dismounting the set.—The three men reverse the order of the operations described above.

Transmitting Set. Portable Type No. 4 Model R. M. 1917.

Portable set No. 4 is a modification of set No. 3 and it differs from the latter only by a few alterations and improvements of the transmitting box, especially in regard to the make and break device and the key. See figure 51.

The make and break device of No. 4 set is of the vibrating type having its armature separated from the vibrating spring. It can be adjusted in three different ways :

1. Adjustment of the platinum screw V, (which is locked by turning the milled nut K).

2. Adjustment of the stop screw v (also locked by means of a nut).

3. Adjustment of the vibrating spring socket by means of a slide piece E.

Owing to the combination of the three adjustments described above, the make and break device may produce variable notes. Working on low pitch note is particularly satisfactory. The set is delivered adjusted for operating on low pitch notes and it is advisable to make all further adjustments only by means of the platinum screw. The key is an ordinary lever key which can be folded for transportation.

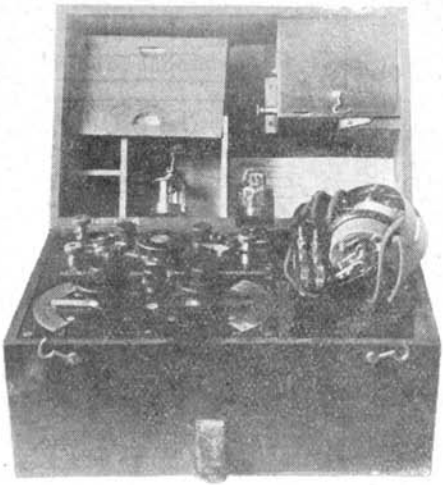


FIG. 52. — Receiver Type A-1.

The set operates on four amperes at 10 volts. The inductance coil (core, primary and secondary windings), is identical with that of set No. 3, the spark gap is also the same, except that it can be adjusted so as to give longer sparks (this being necessitated by the lower frequency of the spark).

The general arrangement of the transmitting box is similar to that of No. 3 set, the outside dimensions being, however,

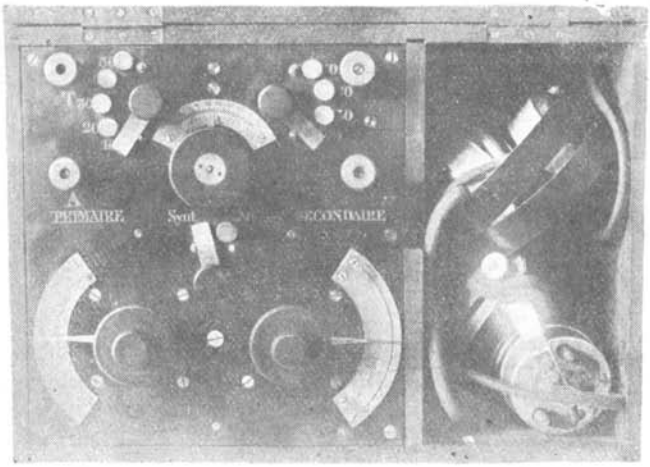


FIG. 53. — Receiver Type A-I. Face View.

slightly greater. The side handles are replaced by a leather strap.

The transmitting box is also transported in a leather bag. Accessories, storage batteries, antenna and ground material are the same as those delivered with set No. 3.

Receving Set. Type A-1.

The type A radio receiver, model Telegraphie Militaire 1915, Fig. 52 used for receiving damped wave signals of wave

lengths between 100 and 600 meters sent by aeroplanes, is made up as follows :

The primary circuit is composed of a 50 turn coil with take-offs every 10 turns (switch P) (Fig. 54) in series with a

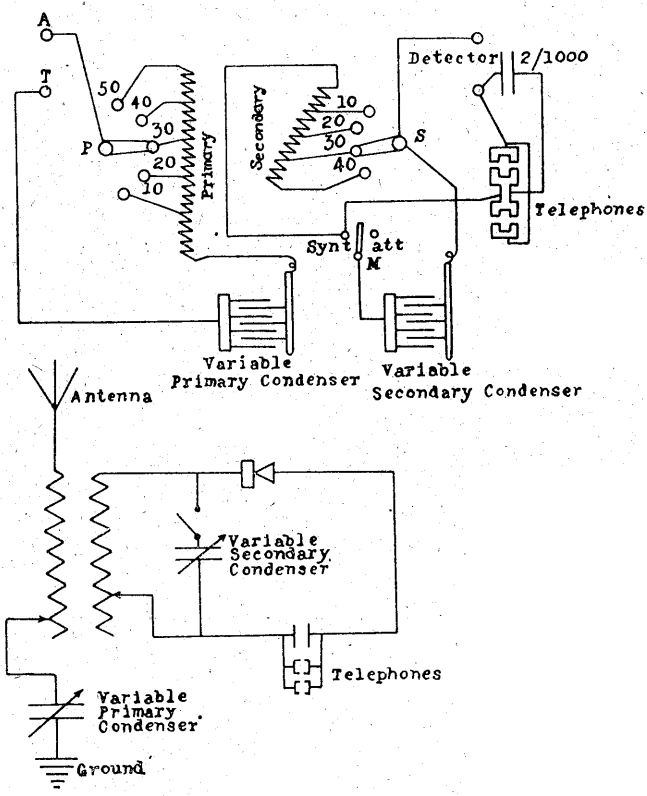


FIG. 54. — Circuits of Receiver Type A-1.

0.0005 microfarad variable air condenser. The minimum capacity is obtained when the index is on 0 of the scale, the maximum capacity when the index is on 90.

The secondary circuit is composed of a coil with 4 take-offs (switch S), and a variable air condenser, similar to that of the primary circuit. The coupling between the primary and secondary may be varied by turning the secondary coil on an axis perpendicular to that of the primary coil. The position of this secondary coil is shown by the index moving on a dial marked « Max-Couplage-Min » and scaled from 0 to 90. When the index is on Max and 90, both coils are parallel, i e., the coupling is a maximum; when on Min and 0, both coils are perpendicular, i. e., the coupling is a minimum. The first of these positions should be used when listening in for signals; the second position should be approached as closely as possible for tuning, as will be further explained.

The detector circuit is connected with the terminals of the secondary coil; it is composed of a crystal detector and telephone receivers. In parallel with the receivers is a small fixed stopping condenser with 2/1000 microfarad capacity. The secondary circuit may be, at will, aperiodic or tuned to the wave length being received. In the first case, the small switch M should be placed on the point « Att » and in the second case on the point « Synt ». This last position places the variable condenser in parallel with the secondary coil, while the first position leaves the condenser out of circuit.

Directions for use.

1st. Connect the antenna to the terminal marked A and the ground to the terminal marked T and find a sensitive point on the detector crystal. A small high frequency buzzer placed in the top of the Type A receiver is used for this purpose. This test buzzer has one exterior binding post which should be connected to the ground terminal. When the push button switch is closed the buzzer emits damped waves by which the detector point may be adjusted.

2nd. To tune the primary, place the small switch on the point marked « Att », the switch of the secondary coil S on

the point 40 and the adjustable coupling index on the point marked « Max ». Then place the switch of the primary coil, P, on the points marked 10-20-30-40-50 successively. With each position of the switch turn the primary condenser from one side of the scale to the other. Stop the switch condenser on the positions that give the best reception. Better results are obtained when the coupling is loose, so that the next step is to decrease the coupling by moving the index to the right, stopping it at the nearest position to « Min » which gives clear signals. This usually necessitates a slight readjustment of the primary coil and condenser.

3rd. To tune the secondary, place the small switch on the point marked « Synt » leaving the coupling at the position obtained in tuning the primary, usually between 10 and 20. Then place the switch S of the secondary coil successively on the points 10-20-30 and 40, and with it in position, turn the secondary condenser from one side of its scale to the other. Stop the switch and condenser index on the positions that give the best results. Again decrease the coupling moving the index as near « Min » as possible. As in the case of adjustment of the primary circuit, this will usually necessitate slight readjustment of the coil and condenser. The secondary tuning being obtained, increase the sound, if necessary, by slightly turning the coupling index towards the higher divisions. To avoid a close coupling, which will not prevent interference from foreign sendings, the index must not be turned too much.

Calibration of the secondary.

If the wave length of the sending station is known, the tuning of the secondary is made easier by using the calibration table given here and usually placed in the cover of the box, which shows, for each take-off of the secondary coil, both limits of the wave lengths obtained by varying the condenser from minimum to maximum. The values are approximate and vary a little with each instrument.

CALIBRATION TABLE
(For Standard Antenna).

SECONDARY COIL No. of turns	SECONDARY CONDENSER (Wave length limits when varied from 0° to 90°)	
	0°	90°
10	100	210
20	130	360
30	160	470
40	200	595

Amplifier Type 3-ter.

Description. The type 3-ter amplifier (see Fig. 55), is contained in a convenient carrying case, so arranged that it may be used, in the field without removal from the case.

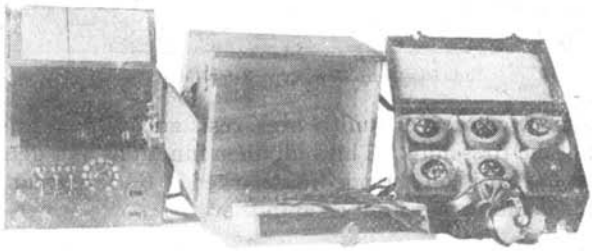


FIG. 55.—Amplifier, Type 3-*ter*.

The apparatus itself has a small wood housing about 27 cm wide by 26 ½ cm deep by 11 cm thick. On the front is an ebonite panel on which are mounted the control devices. In the lower left corner are three terminals marked L_1, L_2 and L_3.

Terminals L_1 and L_2 are used, (see Fig. 56), for radio telegraphy (T. S. F.), and if used with the type A receiver, should be connected to a plug inserted in the headset plug socket of the type A: or to the terminals of the type A

detector support according to whether it is desired to use the apparatus as an amplifier only, or as a detector and amplifier. Terminals L_2 and L_3 are used for ground telegraphy (T. P. S.).

The three blade double-throw switch S when placed on the position marked H. F. (high frequency) connects a small

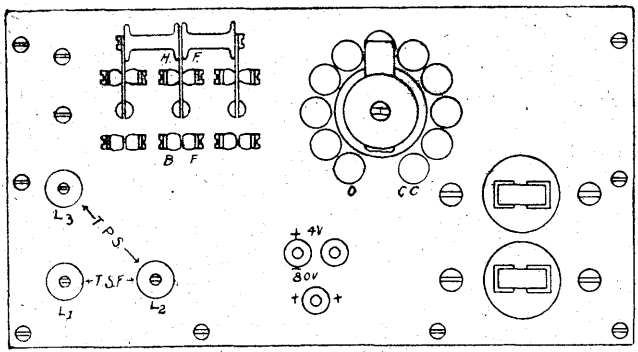


FIG. 56.—Amplifier Type 3-*ter*-Face View.

0003 m. f. condenser and a high resistance to the grid circuit of the first bulb. This bulb then functions as a detector. If the switch is on the position marked B. F. (low frequency) all three lamps are used as amplifiers.

Turning the eleven point rheostat R clockwise increases the current used to heat the filament in the bulbs. The extreme left and point, marked 0, is a dead contact, which allows the battery circuits to be broken.

Battery connections are made by means of four flexible conductors provided with the amplifier. These conductors are connected to a three pole hard rubber contact socket, the negative pole of the 80 or 40 volt battery and the positive pole of the 4 volt battery being connected to the same receptacle. This socket fits onto the three pins at the bottom of the panel marked with voltage and polarity signs. The pins are spaced so that only one position of the socket is

possible, and this is indicated by two arrows on its top edge. However, great care must be exercised in connecting the other ends of the flexible conductors to the battery terminals. Both voltage and polarity are clearly indicated for each conductor, and they should be carefully noted. Never connect the *4-volt flexible conductor terminals to the terminals of the 80 volt battery, and see that the minus* (—) *terminals of the conductors are connected to the negative poles of the batteries and the plus* (—) *terminals of the conductors are connected to the positive poles of the batteries.*

The bulbs used in the 3—ter amplifier are inserted in receptacles placed on a panel of ebonite which is suspended on two heavy rubber elastics to protect the bulbs from excessive shock.

The spacing between the pins of the bulbs is arranged so that it is impossible to make wrong connections. The letter G, indicating the grid pin, should be toward the front, thus giving an indication of the proper connection. The pins should be completely inserted, and good contact assured. If a pin fails to make good contact, the defect may be remedied by inserting a knife blade in the split and spreading it slightly.

Use of the amplifier.

When it is desired to use the apparatus as an amplifier only, the three pole switch, S, in figs 57 and 58 is placed on the position marked B. F. When the switch is placed thus, the low frequency current from the galena crystal, or other similar rectifier, is carried through the primary of a small transformer T_1, the secondary of which is in the filament-grid circuit of the first bulb. The filament-plate circuit of the first bulb contains the primary of a second transformer T_2, and the secondary of T_2 is in the filament-grid circuit of the second bulb. The connections of the third transformer T_3 and the bulb are the same as for T_2, and the second bulb, except that the plate-filament circuit of the last bulb contains the telephone headset sockets. It is seen, then,

that the rectified current received by the amplifier is successively amplified by the three bulbs, being finally passed through the headsets to operate the receivers. Each bulb amplifies about five times giving together with the effect of the transformers in all about 1.000 fold amplification.

In this first case the amplifier terminals L_1 and L_2 should

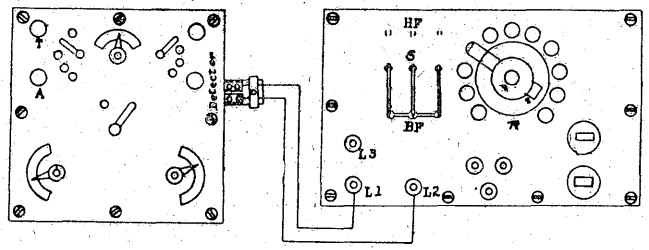


FIG. 57.—Amplifier used with Receiver Type A for Amplification solely.

be connected as stated, to a plug inserted in the headset plug socket of the type A receiver, if the amplifier is used with a type A. (See fig. 57.)

When it is desired to use the amplifier as a detector as well as an amplifier, the switch S is placed on the position

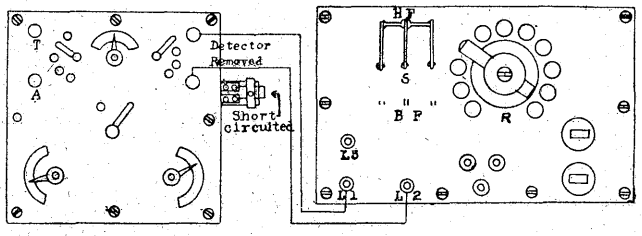


FIG. 58.—Amplifier Used with Receiver Type A for Detection and Amplification.

marked H. F., and the terminals L_1 and L_2 connected to the large binding posts on which the detector crystal is mounted, if used with the type A. The headset plug socket is then short circuited by means of a plug with wire con-

necting the two binding screws. (See fig. 58.) With this disposition the secondary circuit of the type A is connected on one side to the positive pole of the filament of the first bulb, and on the other side with the grid through an intermediate condenser C with imperfect insulation resistance, or shunted by a higher resistance of 1 to 5 meg. ohms. The

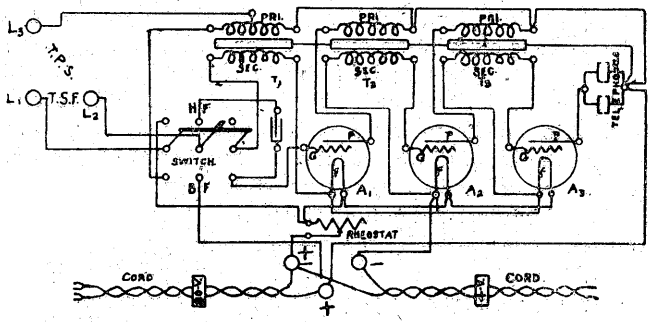


FIG. 59.—Circuits, Amplifier, Type 3 *ter*.

first bulb acts as a detector in the manner described above in the description of the audion as a detector and the second and third bulbs amplify the current in the plate-filament circuit of the first bulb.

Precautions to be observed with the 3-ter amplifier.

The apparatus must be carefully protected from mechanical vibration, though this feature is provided against in the later model 3-ter by means of the elastic band support for the ebonite bulb-base.

The instrument should be kept dry and free from dust at all times and for this reason should be kept in the carrying case provided.

In connecting the terminals L_1 and L_2 to the receiving circuit, be careful not to twist the wires or allow them to come in contact or even close proximity with each other, and they should not be allowed to touch the apparatus except

at the terminals. When the current is on and the bulbs are illuminated, none of the metal parts of the circuit should be touched. These precautions are necessary to prevent the howling of the amplifier. Often a howling noise can be heard even when these precautions are observed, and when this is the case, it may be stopped sometimes by reversing the plug in the Type A headset socket, thus reversing the connections to L_1 and L_2. This howling is due to reactance of the various circuits on one another, and often the capacity of the operator's body, if he touches any part of the circuit, is sufficient to set it up. For these reasons, as far as practicable, all the metallic parts exposed near the circuit, such as the case of the headset receivers, and the transformer cores are connected to the negative pole of the heating battery, which has the potential common to all circuits.

Bulbs may be tested by the use of a millammeter in the circuit of the 80 (or 40) volt battery. The current from filament to plate is shown by lighting each bulb in succession. Each should show not less than 2 milliamperes for 80 volts supplied. Should a bulb give no reading with a properly charged battery it may be due to the fact (1) that it is not completely pushed home; (2) that the connections between the pins and base are poor; (3) that it is burnt out; (4) that one of the connections inside the amplifier is broken. A current of over 10 milliamperes indicates a short circuit. Before deciding that the apparatus is out of order, at least two sets of bulbs should be tried.

E-10 Radio Sets.

The series of E-10 Sets used by the French, namely, the E-10, E-10bis, E-10 ter, and E-10 Artillery types, are all very similar in construction with slight modifications to adapt them to the needs of the particular conditions under which they are used. The most important of these to Heavy Artillery units is the Artillery type, which is constructed with a view to receiving the more or less feeble waves emitted by airplane sets.

E-10 Radio Set Artillery Type. — Description.

The French E-10 Artillery type radio set, (see fig. 60), was designed for use with undamped waves in transmitting, and for receiving either damped or undamped waves. Its wave length limits are approximately 550 and 750 meters. It is also possible to use it for radio telephony within limited ranges. The set is contained in a convenient field case, the dimensions of which are 57.5 centimeters wide, by 45 centi-

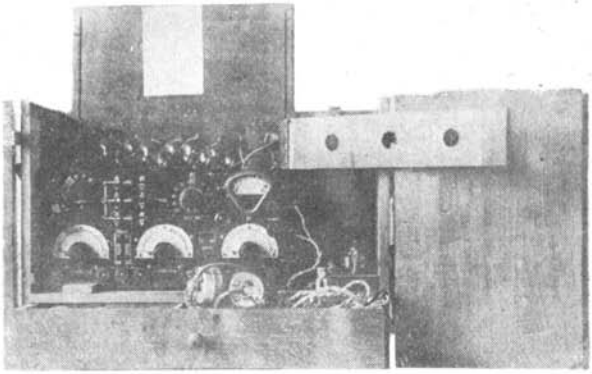


FIG. 60.—E-10 Set Artillery Type (French).

meters high by 33 centimeters deep, and the weight of which is 34 kilograms, (75 pounds). Inside the case is mounted the sending key: and an eight day clock, a stationery drawer and compartment for extra bulbs, headsets, battery leads, fuses, etc., are compactly arranged. Hinged doors on the front permit the use of the set in the field without removal from the case. It may, however, be removed when necessary by taking out the two wood blocks and sliding it forward.

The set itself is made up in a small cabinet 28.5 centimeters in height by 24 centimeters deep and 40.5 centimeters wide. The top and the upper section of the front are hinged,

giving easy access to the audion bulbs; and the front section has three holes through which it may be easily ascertained whether or not the bulbs are lighted. The lower part of the front is an ebonite panel on which are mounted the control devices. On the right or transmitting side are (see fig. 61).

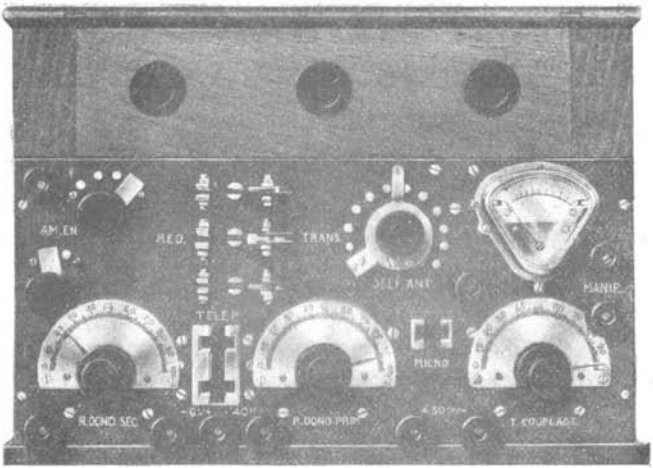


FIG. 61.—E-10 Set Artillery Type-Face View.

1. The antenna inductance switch; marked Self.-Ant; 2. Ammeter; 3. Small light which may be substituted for the ammeter, after adjustment, to indicate radiation; 4. The coupling condenser marked T. Couplage; 5. The telephone transmitter socket marked Micro; 6. The two binding posts for the key marked Manip; and 7. The binding posts for the 300 volt battery leads. On the left, or receiving side, are: 1′. The three blade double throw switch to shift from transmitting to receiving; 2′. The headset plug sockets marked Telep; 3′. The rheostat for the heating current marked Lampes; 4′. A small switch marked Am and En which permits shift from damped (AM) to undamped (EN) waves;

5′. The primary receiving condenser marked R. Cond. Prim; 6′. The secondary receiving condenser marked R. Cond. Sec; 7′. The antenna binding post A; 8′. The ground binding post T; and 9′. The 6 and 40 volt battery binding posts. The polarity of each is indicated and the positive (+) of the 6 volt battery and the negative (—) of the 40 volt battery are common. A description of the interior circuits is found later on page 84, it being thought advisable to show the principles of operation with simple diagrams first.

Antenna and ground.

The artillery set is designed to operate on the same wavelengths when connected to either of the following antenna systems. One type consists of two 60 meter lengths of antenna wire forming a V, the angle between them being 60 degrees. This antenna is supported 7, or preferably 12 meters above the ground upon coupled bamboo poles or upon steel masts. A more efficient antenna consists of two strands of antenna wire, each 80 meters in length, and supported 2 meters apart and 12 meters above the ground at the end farthest from the apparatus, and 7 or 12 meters above the ground at the other end. A wire 15 to 20 meters long leads from the point of the V or from the end of the antenna to the apparatus.

The ground should consist of four copper nets buried at least 45 centimeters, such as are supplied with the type A receiving sets, and the ground lead should be as short as possible.

Batteries.

The filament current of the transmitting and receiving bulbs is furnished by a 6 volt storage battery; the plate potential of the receiving bulbs by a 40 volt battery and the plate potential of the transmitting bulbs by a battery of from 300 to 320 volts. It is not possible to use one of the 40 volt transmitting batteries to supply the plate potential

of the receiving bulbs. The batteries are connected to binding posts on the front panel, as indicated on the posts, by the flexible leads which are supplied, and *care must be used to preserve* the polarity according to the signs on the binding posts. It is a good plan to insert a switch outside the set in the 300-V circuit; a fuse is already provided within the set.

Principles of operation.

The principles of the audion bulb and heterodyne are made use of for both sending and receiving, there being transmitting bulbs and three receiving bulbs mounted on an ebonite panel supported on thick rubber elastic to avoid excessive shock.

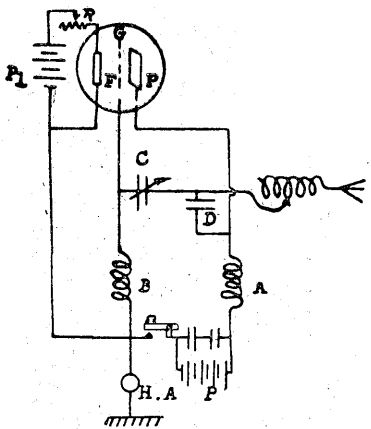


FIG. 62.—Schematic Transmitting Circuit E-10 Artillery Type.

Transmission.

A coil A (fig. 62) is placed in the plate circuit of the three transmitting bulbs connected in parallel, represented here by one bulb for simplicity. A battery P of 300 volts is connected so that the plate is positively charged through coil A. Coil B is placed in the grid circuit and these two coils are statically coupled by means of a variable condenser C. The filament circuit, the current for which is supplied by a 6 volt battery P_1 through a rheostat R, is also connected to the ground through a hotwire ammeter H. A. A key is inserted between the filament and plate circuits at M. The antenna is connected to the coil A through a fixed condenser D and also the coil B through the variable condenser C. The pur-

pose of the condenser D is to prevent condenser C and the antenna from being charged to the potential of the 300 volt battery P, thus avoiding possible rouble from a short circuit in C, or by means of a faulty or destroyed antenna.

Briefly the operation of the transmitter supplied by this arrangement of coils and audion bulbs is as follows. The plates being positively charged, when the key M is closed, negative electrons from the filament are attracted through the grid to the plate and a current flows in the plate-filament circuit. This current energizes the coils A and B and since both A and B are connected to the antenna on one side and to the ground on the other, oscillations are set up in the

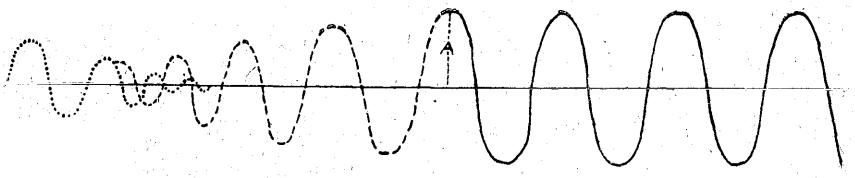


FIG. 63.

antenna. These oscillations would of course be damped except for the effect of the electro-magnetic coupling and the electrostatic coupling C between the coils A and B in the plate and grid circuits. In fig. 63 the wave represented by the dotted line may be considered as the resulting wave if there were no coupling between the grid and plate circuits. However, with the coupling present, from the first oscillation the grid receives a positive charge by electro-magnetic induction between A and B, and also electrostatically through the condenser C, the amount of which may be varied since C is a variable condenser. The potential of the grid being positive, an increased number of negative electrons is attracted from the filament and consequently an increased current flows in the plate-filament circuit. Therefore the amplitude of the second oscillation instead of being less than that of the first, is greater, and since a

greater amount of current flows in the plate-filament circuit each time, each successive oscillation will have a greater amplitude than the preceding one, as indicated by the broken lines in fig. 63. However a point is soon reached when the decrease in amplitude due to antenna losses which also increase in proportion to the increase of energizing current, equals the increase in amplitude supplied by the grid action, and then the sustained wave of constant amplitude, A, results. In any case a limit to the amplitude of the radiated wave is found in the maximum amplitude of the plate-filament current, where a further increase in grid potential no longer increases the plate current.

Receiving.

The receiving side of E-10 Artillery Type contains a fixed primary coil I (fig. 64), and a variable condenser C_1 in the antenna circuit, this being the same coil used as a variable inductance for transmission but so connected that it is not variable when used in the receiving circuit. The secondary receiving circuit is made up of two coils N and N_1, only N_1 being inductively coupled to the primary, and a variable condenser C_2. One side of the secondary circuit is connected to the grid of the first bulb L through a condenser C_3 of very small capacity across which is shunted a high resistance, R_3. On the other side it is connected to the positive end of the bulb filaments. The plate circuit of the first bulb contains a battery P_2 and the primary of a low frequency transformer. When oscillations are induced in the secondary circuit from the antenna, or primary circuit, this first bulb acts as a detector in the manner previously described in the explanation of the vacuum tube or Audion. Briefly, the plate-filament current is caused to pulsate by the variation of the grid potential and the resultant fluctuation of the plate potential is amplified through transformers and the two amplifying bulbs L_1 and L_2; and then affects the receivers, giving a signal. The frequency of the vibrations pro-

ducing this signal is determined by the frequency of the *wave train* emitted by the sending station.

By shifting the two point switch marked AM (damped) and EN (undamped) a small coil H is connected in or shunted out of the plate-filament circuit of the first bulb L, at

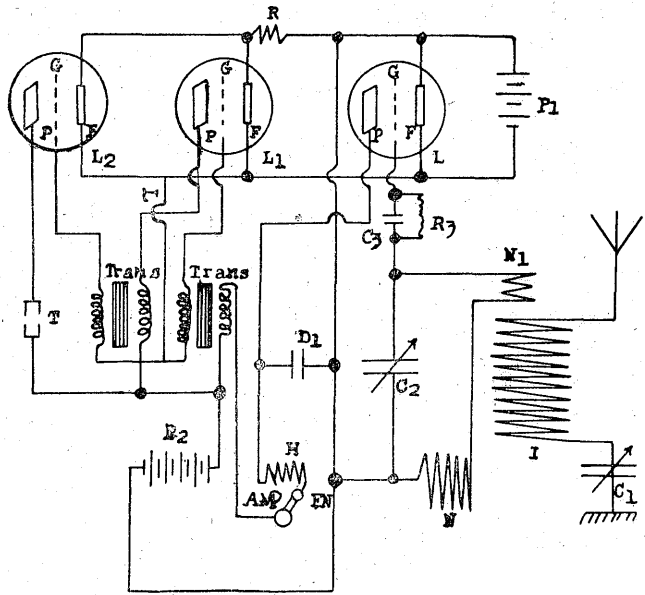


FIG. 64.—Receiving Circuits E-10 Set Artillery Type.

will. This coil is magnetically coupled to coil N of the secondary receiving circuit and when receiving undamped waves it is placed in the circuit by putting the small switch on the point marked EN (undamped). With this arrangement oscillations are set up in the plate-filament circuit which are superimposed on those received from the antenna in the same manner as with an independent heterodyne. The resultant wave varies the grid potential of L

through the condenser C_3 and resistance R_3. This causes the plate-filament current to pulsate as with damped waves; and the pulsation after having been amplified affects the receiver diaphragms in the same manner as in damped reception.

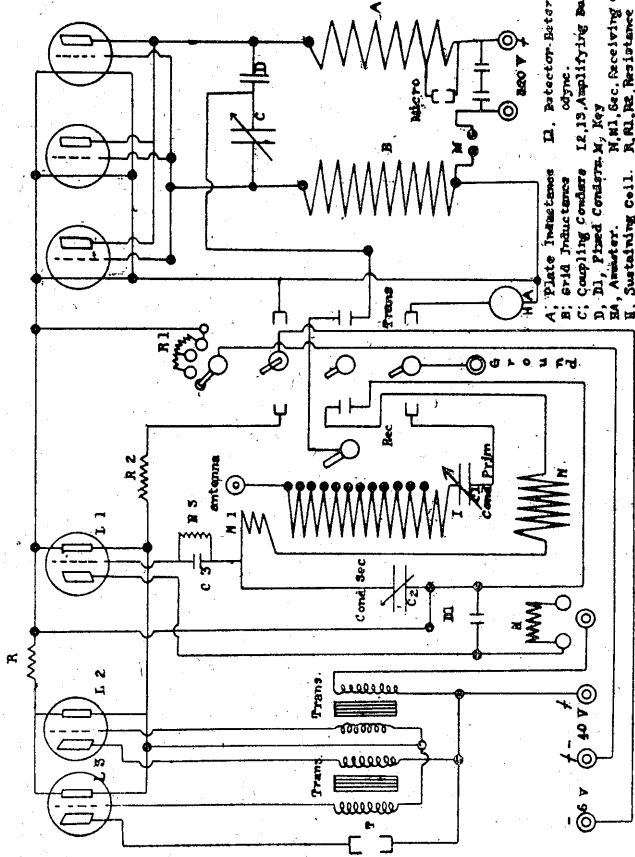


FIG. 65.—Circuits E-10 Set Artillery Type.

Mounting.

The parts composing the transmitting and receiving circuits are suitably mounted in a single box, as described. The connections are shown in fig. 65. The resistance shown at R_1 is controlled by the switch on the panel and constitutes the heating rheostat. The resistance shown at R_2 is provided to reduce the heating of the receiving bulbs as it need not be so great as that of the sending bulbs. A resistance R is also provided to reduce the heating of the amplifier bulbs still more.

The three blade double throw switch shown in fig. 65 changes from transmission to receiving and vice versa, *no further adjustment* being necessary. The upper blade shifts the heating current from the transmitting to the receiving bulbs and connects the resistance R_2 into the circuit.

When on the transmitting side, the second blade connects the antenna into the transmitting circuit, and when on the receiving side, it closes the secondary oscillating circuit, left open when transmitting so that it will not absorb any energy should it be in resonance with the wave length sent out. The bottom blade shifts the ground from the transmitting to the receiving side and vice versa.

The transmitting key is connected to the two binding posts on the right side of the ebonite panel, shown in fig. 65, marked M. When the telephone is used these binding posts are short circuited by screwing down the transmitting key, and the transmitter plug is inserted in the socket marked Micro.

The small pilot light on the front ebonite panel should be substituted for the ammeter HA, by means of a shifting contact inside the ebonite panel behind the ammeter. The glow of the light gives a satisfactory indication of resonance and its use saves the delicate wire in the ammeter.

A small condenser D_1 between the plate and filament circuits of the first bulb eliminates « howling » and aids reception.

Adjustment and operation of the set.

Having connected the 300 volt, the 6 volt and the 40 volt batteries to their proper binding posts, and having fastened the ground and aerial leads to T and A respectively the method of tuning is as follows :

1. Transmission. Throw the three blade double throw switch to the right on the point marked Trans. Switch the heating current on and commence working the key. Then modify the capacity of the coupling condenser C to set up oscillations in the antenna circuit. Measure the emitted wave length with the small wave meter provided, by placing the latter on top or near the set and, having switched on the small wave meter light, turning the dial until the increased brilliancy of the glow indicates resonance with the transmitted wave, the length of which is then indicated by the graduation opposite the pointer on the left of the face of the meter. (For a description of the T_1 wave meter see page 88 of this pamphlet.) If a greater wave length is desired increase the antenna inductance by turning the inductance switch clockwise. If a smaller wave length is desired lessen the amount of antenna inductance by turning the switch counter-clockwise ; the wave meter being used to determine the wave length resulting from the change. Having obtained the approximate wave length desired, more exact and finer adjustment may be made by means of the condenser C. The small wave meter battery should be switched off when not actually in use.

It is essential to have the radiated oscillations sufficiently stable, and to see by means of the ammeter, the small light, or the wave meter, that they are set up each time the key is closed. If they are not stable enough for reception the coupling should be made tighter. Decrease the antenna inductance by one point, and this will necessitate an increase in capacity of the condenser C i. e., a tighter coupling.

While working the key in transmission it is necessary to watch the small pilot light to see that oscillations are set up continuously.

2. Receiving. Throw the switch on the left side marked REC. If the wave length of the sending station is known the wave meter may be used to tune the receiving circuits to that wave length. Set up oscillations by turning the small switch on the front of the wave meter on point marked V first having set the indicator at the graduation corresponding to the desired wave length. Using successive positions of the primary condenser vary the secondary condenser until the point which gives loudest reception from the wave meter, in the headsets, is found. The two circuits will then be in resonance and adjusted to the wave length emitted by the wave meter and hence the sending station. If the wave length of the sending station is not known, it is quite simple to tune it in, by placing the primary condenser in successive positions and varying the capacity of the secondary condenser. It should be remembered that the primary inductance is not variable when on the receiving side so that varying the antenna-inductance switch is without effect on the wave length. Having found the sending station a slight readjustment of the primary condenser will ordinarily better the reception. The adjustment is the same whether damped or undamped waves are received.

When tuning for undamped waves a noise, or click, is often heard just at the moment when the varying of the primary condenser creates resonance between the primary and secondary circuits. The noise is due to a sudden decrease in the amplitude of the oscillations owing to the fact that the antenna at that moment is in exact resonance with and takes part in the oscillation, thus absorbing some of the energy of the secondary. This indication of resonance between the two circuits simplifies tuning by enabling them to be kept nearly in resonance throughout the process. Better results are obtained if, after tuning, a slight decrease in the heating of the bulbs is made by means of the heating rheostat.

3. Receiving telephone communications. When receiving telephone communication the heterodyne coil H is

shunted out as when receiving damped waves, by placing the small switch on the position AM. The heterodyne is more sensitive and may be used to tune in the other station, and then switched out. It may be necessary to increase the secondary condenser a little after switching out the coil H, because the latter modifies the period of the secondary circuit.

The wave meter.

A simplified type of wave meter, usually model T_1, is issued with E-10 sets.

Description.

Wave meter model T_1, consists essentially of an oscillating circuit made up of a variometer Sv and a fixed condenser C (fig. 66.) A small incandescent lamp A with its metallic filament connected into the circuit serves as an indication of resonance. It is fed by a small dry battery P. An electro-magnet E operates an armature in such a way as to set up damped oscillations in the coil Sv. A switch M allows the battery P to be connected to the lamp A, or to the vibrator V, according to whether it is desired to measure oscillations in a sending set or to set up damped oscillations for adjusting a receiving set.

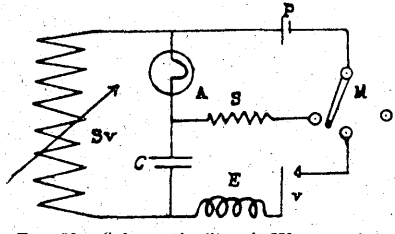


FIG. 66.—Schematic Circuit Wave meter Model T_1.

The wave meter is mounted in a wood box 135 m/m high by 125 m/m wide and 115 m/m deep, (fig. 67); the control devices are mounted on the front of an ebonite panel. The switch M can be placed on three points. The lowest is a dead contact, on which the switch must always be placed when the

apparatus is not in use. The second point marked V, connects in the vibrator, and the third point L connects in the small lamp placed on the upper left corner of the wave meter. The movable coil of the variometer is fastened to the knob B and the dial Q. The dial turns in its seat flush with the face of the ebonite panel. A mark R indicates the division on the dial Q which corresponds to the position of the movable coil and the wave length emitted or corres-

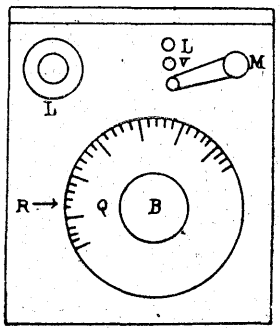


FIG. 67.—Wave meter Model T,.

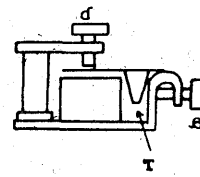


FIG. 68.—Vibrator Wave meter Model T,.

ponds to the position of the movable coil and the wave length emitted or received.

A small hinged shutter in the top of the box gives access to the battery and vibrator (fig. 68). The vibrator has two regulating screws a and b. The screw a controls the space between the armature and the magnet by means of a small v—shaped spring r. The normal space is a few tenths of a millimeter.

The contact point is of platinum or gold, and must touch the armature so that the vibrator starts when the switch M is placed on the point V.

The variometer Sv is made up of two parallel coils, the smaller turning inside the larger on an axis, in the plane of the turns. The two coils are in series and the total induc-

tion varies with their relative positions. The ratio between the maximum induction and the minimum induction obtainable by varying the position of the coils from parallel to perpendicular is approximately 3.5 to 1, and the wave length limits measurable with such an apparatus are in the ratio of 1.85 to 1 approximately. This type is graduated to read wave lengths from 550 to 1000 meters.

Method of use.

1. To measure wave lengths emitted from a local station: Place the meter near the transmitting set, and put the small switch M on the point marked L. The small lamp then glows, and when the wave meter circuit is in resonance with the radiated wave, the glow will brighten considerably. Resonance with the radiated wave length is obtained by regulating the variometer coils, i. e., by turning the knob B. When the lamp burns with maximum brilliancy resonance is indicated, and the wave length of the emitted wave may be read from the dial opposite the index R.

When used in the above manner the lamp acts as a thermal indicator. The battery circuit is through the lamp and the coil S, the resistance being so regulated that the lamp is only slightly reddened. When resonance is attained the oscillating current flows in this circuit with maximum intensity and not being able to cross the battery P, being stopped by coil S, the oscillations are added to the continuous current of the battery in such a way as to increase the brilliancy of the light.

It is necessary to adjust the coupling between the sending set and the wave meter, that is, the nearness of the latter to the sending set, in order to obtain precision. When they are too close together the exact point of resonance is not indicated. Also, if the transmitting set is powerful enough there is danger of burning out the lamp. When the wave meter is too far from the set, however, the lamp circuit will not be noticeably affected. With undamped sets the wave meter

should be a little removed, while with damped sets a closer position is necessary.

2. To measure received waves : The receiving set is first adjusted to resonance with the transmitted wave, the coupling which gives keenest reception being chosen. Keeping the headset on, the operator places the wave meter near the receiving set and starts the vibrator by placing the switch M on the point V. The wave meter oscillations are heard in the headset and by turning the knob B thus varying the relative position of the variometer coils, these oscillations may be brought in resonance with the circuits of the receiving set. Moving the wave meter up to or away from the set enables the sound to be regulated to a minimum volume and still be heard clearly and exact resonance is determined by further slight variation of the knob B. The wave length of the circuits of the receiving set and hence the received wave length is now read from the dial opposite the index R.

E—10, E—10 bis and E—10 ter Radio Sets.

These sets are all constructed on the same general plan and this plan is, as stated, practically that used in the E—10 Artillery type already discussed. There are a few points of difference, however, that should be noticed. The first of these is found in the arrangement of the transmitter, and though slightly different from the Artillery type the transmitter on all other E—10 sets is practically the same. A description of its arrangement follows.

Transmission.

In fig. 69 a coil AB is shown connected at one end to the plate of the transmitting bulbs, represented by one bulb, through the key M and a small condenser F. At the other end it is connected to the grid, and from an intermediate contact O to the filament. The antenna A and antenna inductance I are placed on the grid side, and the ground on

the plate side of this coil. A variable condenser C is placed across all except two turns of the coil and serves to vary the coupling between the grid and plate circuits. If P were connected directly to O, as in fig. 70, it is seen that a capacity between the battery P and the ground, or a defect in insulation causing a short circuit, would, due to the resistance of A, shunt out the coil and prevent oscillations in the antenna. To avoid this difficulty, the heating circuit from P is passed through a coil E wrapped around A and having the same number of turns and hence same resistance as A, shown in fig. 69 on the side of A for simplicity. This does not interfere with the high frequency oscillations in the antenna circuit. The small condenser F in the plate circuit allows high frequency oscillations to pass and does not shortcircuit the power terminals. The slight oscillations caused by the commutator action when a generator is used for the plate current are choked out and absorbed by the condensers at F_1 and the iron coils S_1 and S_2 (fig. 69).

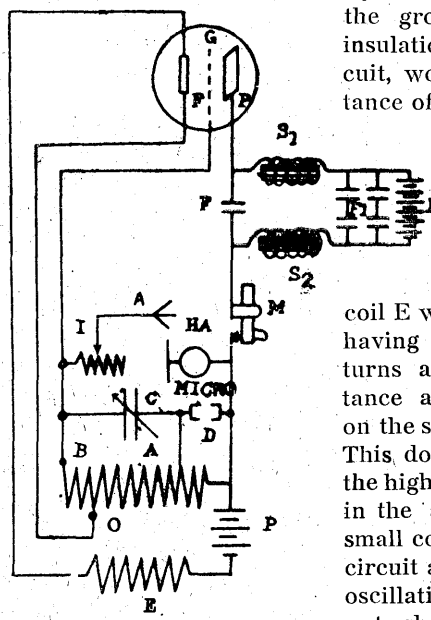


FIG. 69.—Schematic Circuits E—10 Set.

Adjustment.

The receiving circuits and the adjustment of both sending and receiving apparatus, are exactly the same as described for the Artillery type.

Special features.

E—10. The E—10 operates on waves from 550 to 750 meters in length, using a V—type antenna 30 meters in length, any other antenna of similar dimensions, or an airplane antenna.

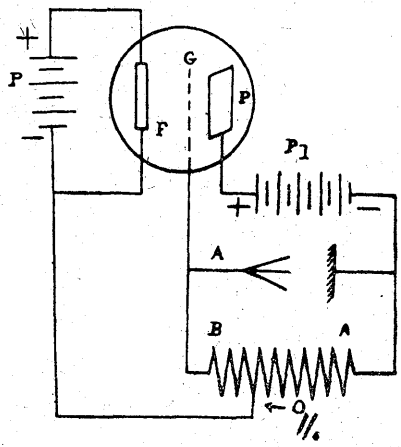


FIG. 70.

For transmitting waves from a ground station a 25 meter V—type antenna should be used.

E—10 bis. This set may be used with slightly longer wave lengths, its limits being 600 to 1000 meters approximately. For that purpose the receiving side has: (1) a switch with two points marked "petites ondes" and "grandes ondes" which allows the switching in of all or only a part of the antenna inductance I. (2) A second small switch marked "couplage" which allows the coupling of all or only a part of the secondary coil N_4 (fig. 65) to the primary. Different types of antennae used with this set give the following results:

1. Single wire antenna 45 meters long including 4 meter lead in. . . . . 600 to 1120 meters
2. Single wire antenna 40 meters long including 1 meter lead in: with buried ground nets. . . . . 600 to 1150 —
3. Single wire antenna 40 meters long including 1 meter lead-in: with one net laid out on top of the ground. . 590 to 1020 —.

4. Airplane antenna 80 to 100 meters long . . . . . 600 to 1000 meters
5. V—type antenna with 50 meter branches and 15 meter lead-in . . 900 to 1420 —

The secondary receiving circuit can, however, only be tuned in to receive wave lengths of 450 to 1150 meters.

E—10 ter. The dimensions of the transmitting coil are slightly longer in this set than in the E—10 bis, it being designed for use with a short antenna, usually about 14 meters long, and installed on tanks. Its wave length limits are 600 to 1000 meters.

E-3 Radio Set. — Description.

The French type E—3, E—3 bis and E—3 ter set can be used for any undamped wave communication of the wave range indicated.

Use.

All three sets transmit sustained wave signals, either telegraphic or telephonic, by means of oscillations set up by the standard French amplifier lamps of the transmitting box, with 320 volts on the plates and 6 volts on the filaments. Four lamps connected in parallel are used, putting 0.6 to 0.8 ampere into the antenna. The antenna used with the E-3 set is horizontal, V-shaped, 50 meters on each side, 60° angle, supported 7 meters above the ground on bamboo poles. A wire 15 meters long leads from the apparatus to the point of the V. Connected to this antenna the E-3 set transmits wave-lengths between 600 and 1050 meters, to a distance of about 60 miles for telegraphic and 10 miles for telephonic transmission. The E-3 bis set, connected to an antenna similar to that described above, with a supplementary antenna loading coil, transmits wave lengths between 1,000 and 1,400 meters and has the same range as the E-3 set. It may also be used with the antenna of the E-3 ter set,

which has 3 horizontal branches each 80 meters long, making angles of 40° with each other, and a lead wire to the point of the angle, 20 meters long, and is supported 7 meters above the ground on bamboo poles. Connected to this antenna without the supplementary antenna loading coil the E-3 bis set emits wave lengths between 1,000 and 1,500 meters. These sets receive both damped and sustained waves, of a range of wave-lengths somewhat greater than that for trans-

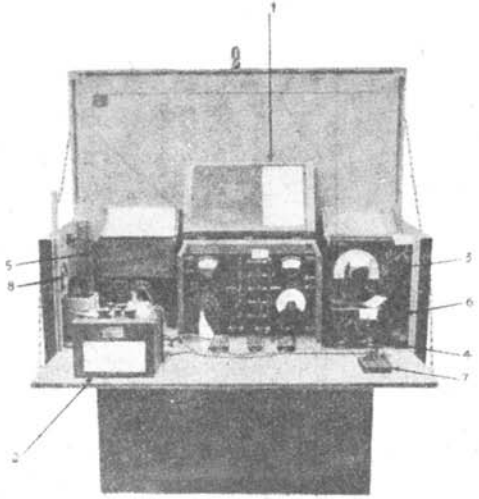


Fig. 71.—Set, Radio Type E—3 French.

mission. The transmitting box circuit with one amplifier lamp operating, is used as a heterodyne for receiving sustained waves and a Type 3-ter amplifier for detecting and amplifying the signals received, damped or sustained. The full set (see fig. 71) includes (1) an antenna inductance or loading coil of 130 turns; (2) A Type E-3 Sending apparatus and heterodyne; (3) An E-3 Receiving apparatus, similar to the Type A set; (4) A Type 3-ter Amplifier; (5) one 4 volt battery for the amplifier, one 6 volt battery for the hetero-

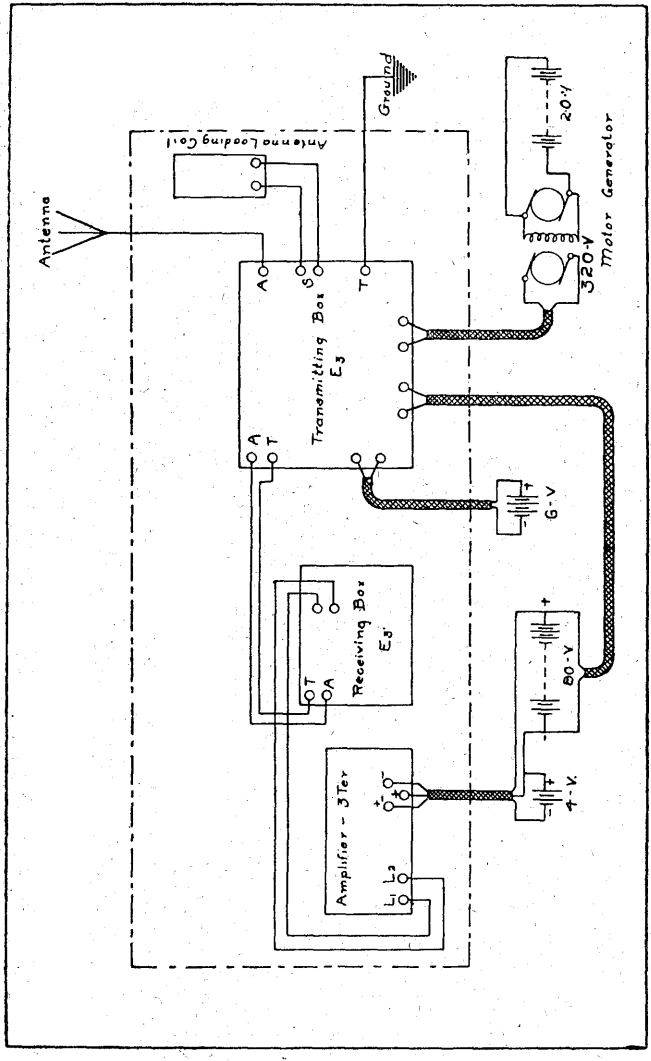


FIG. 72.—Exterior Connections Radio Set Type E—3.

dyne, one 40 volt battery for the amplifier and heterodyne, and eight 40 volt batteries (320 volts) for the transmitter. (A 320 volt direct current generator is sometimes used in the place of the eight 40 volt sending batteries); and (6) a wave meter. The exterior connections of these elements are shown in Fig. 72.

Loading coil.

The loading coil of 130 turns is controlled by 2 eleven point switches. One of these is adjustable turn by turn up

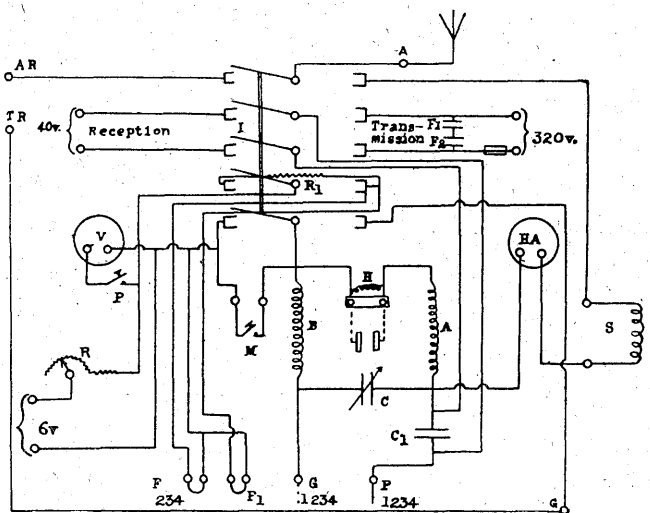


FIG. 73.—Transmitting Box and Heterodyne Set Radio Type E—3.

to ten turns, while the other adjusts by ten turns. With this coil in the antenna circuit, wave lengths from 600 to 1000 meters may be sent.

The E—3 sending apparatus and heterodyne.

Fig. 73 shows its interior circuits. A 6 volt battery connected at the terminals indicated in the figure is used to

heat the bulb filaments and the current is varied by the rheostat R. The 320 volt battery (or generator) is connected to the terminals as shown.

Receiving.

When using the E-3 to receive undamped waves, only one bulb of the apparatus remains in circuit, and it functions as a heterodyne. A simplified diagram of the set under these conditions is shown in figure 74. The connecting and disconnecting of the various circuits for transmitting and receiving is simplified by the use of a five pole double throw switch. For receiving, the switch shown in fig. 73 at I disconnects the 320 volt and connects the 40 volt batteries. It also cuts three bulbs out and puts a resistance R_1 in series with the bulb that is left in, and remains lighted. The sending key M is also short circuited, and the plate coil is disconnected from the ground, allowing the bulb and coils to operate as an independent heterodyne.

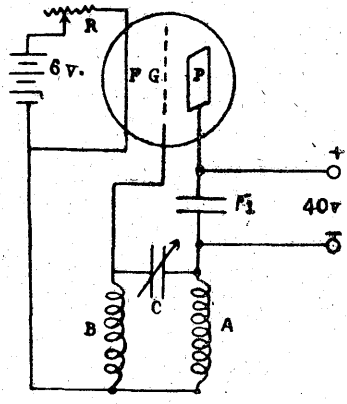


FIG. 74.—Schematic Receiving Circuits Set Radio Type E—3.

Transmission.

For transmitting, a special double commutator direct current dynamo is sometimes furnished with the E-3 and so there are two condensers F_1 and F_2 of 2 m. f. each in series across the power terminals, as shown in fig. 75, to prevent variation of the plate potential due to small fluctuating currents from the generator commutators. A fixed condenser

C_4 of .0005 m. f. capacity is placed in parallel with these two condensers and in the plate circuit. It allows current to flow from Coil A to plate P by reason of its small capacity, and together with Coil S and condensers F_1 and F_2 completely suppresses the slight commutator fluctuations. A fuse is usually placed in the positive side of the 320 volt circuit. A large variable condenser C furnishes a static coupling between the plate and grid coils. The key is inserted in the

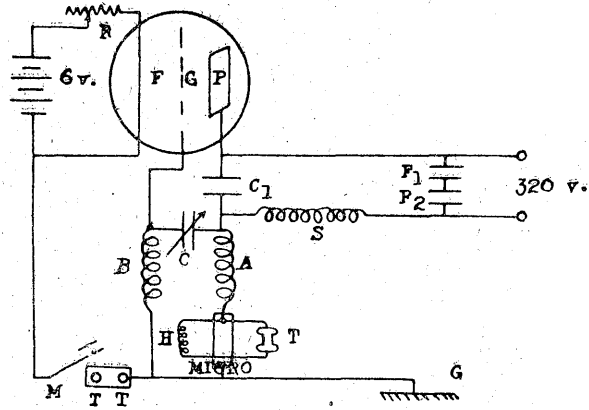


FIG. 75.—Schematic Transmitting Circuits Set Radio Type E—3.

plate circuit at M, and the microphone for telephonic transmission at T.

E—3 Receiving apparatus.

This apparatus is very similar to the Type A receiver previously described but will receive wave lengths from 500 to 1000 meters, and is especially designed to receive undamped waves. The primary coil has 79 turns tapped by a 5 point switch at the 30th, 38th, 47th, 61st, and 79th turns. A small fixed mica condenser and a variable air condenser are in parallel with each other, and in series with the primary coil. Minimum capacity is afforded with the variable condenser

index at 0, and maximum capacity with it at 90. The secondary coil has 108 turns tapped by a 4 point switch at the 33rd, 54th, 81st, and 108th turns. It revolves inside the primary, affording a variable coupling, a strong coupling being used to pick up stations, and a weaker coupling to cut out undesired stations. A variable air condenser is in parallel with the secondary coil. The detector, headset plug sockets and fixed stopping condenser are arranged as in the Type A set. Also the secondary variable condenser may be switched in or out by means of a small switch marked ATT, and SYNT., the former position leaving the secondary free to oscillate in any period; or the latter making it dependent upon the amount of capacity inserted with the variable condenser.

Calibration of receiver.

The following calibration table for primary and secondary holds for the prescribed V-type aerial with 50 meter branches, and with a 15 meter lead-in; and the prescribed ground composed of five nets buried in a V as near the set as possible, the fundamental wave length of this antenna being 325 meters and its capacity .0004 microfarad.

Primary coil	Condenser reading 0 to 90	Wave length
Step 1. 30 turns	0 to 90	450 to 570
— 2. 38 —	— — —	520 to 660
— 3. 47 —	— — —	590 to 740
— 4. 61 —	— — —	680 to 880
— 5. 79 —	— — —	820 to 1050
Secondary coil		**Wave length**
Step 1. 33 turns	0 to 90	190 to 530
— 2. 54 —	— — —	235 to 760
— 3. 81 —	— — —	240 to 1000
— 4. 108 —	— — —	230 to 1180

The amplifier.

A 3–ter amplifier is used and may be connected to serve as a detector and amplifier, in which case the first bulb

acts as a detector and the other two as amplifiers; or all three bulbs may be used as amplifiers. The connections are the same as when 3-ter is used with the Type A, which are shown in figures 58 and 57 of this pamphlet. One of the 40 volt batteries used in transmitting may also be used to furnish the plate potential, and a separate 4 volt battery is used for the filament current.

The wave meter.

Wave meter Type No. 1 range 100 to 1100 meters is supplied with the E-3 set; wave meter Type No. 5 range 500 to 2000 meters with the E-3 bis and E-3 ter sets. A description of these wave meters is given later.

Use of the set for transmission.

The five pole double throw switch on the E-3 Transmitter being on the transmitting position marked T, light the bulbs by turning the rheostat handle. Depress the key and vary the condenser until maximum reading on the ammeter is obtained. Then make a series of dots and dashes and see if the ammeter functions properly. The variations of the condenser should be very slight and, when adjusting, vary the heating of the filament, being careful not to burn the filament out. For wave lengths up to 800 meters the ammeter should not read more than .7 to .8 ampere; and .6 to .7 ampere for wave lengths up to 950 meters; and .5 ampere for 1,000 meters. The reason for a decrease in output of current for greater wave lengths is that the loading coil has an inductance much greater than the plain antenna. For larger wave lengths the small coil H, (Fig. 75) may be placed in circuit by removing the brass bar from the binding posts marked "Micro". Signals must be sent slowly, and be sure to notice the ammeter readings and see that it functions properly when each dot and dash is made.

Calibration of transmitted waves. — The wave meter is placed near the loading coil of the set to be tuned and its

vibrator set in motion. The variable condenser of the meter is set on the desired wave length on its scale. Then depress the key of the transmitter and note the sound in the wave meter telephones. If the set is not in resonance, vary the loading coil until the transmitter is in resonance with the calibrated circuit. When this is true the loudest sound will be heard in the telephones. With the adjustments of the instrument at this point of maximum sound the wave length of the transmitter may be read on the scale of the wave meter. The set should be so tuned that the least variation of the condenser will decrease the sound in the wave meter telephones.

Use of the set for reception.

Calibration of the heterodyne. It is best to have the heterodyne calibrated so that changes may be made readily from one wave length to another. To make this calibration, place the wave meter near the set containing the heterodyne. The 5 pole double throw switch of the set being on the receiving side, start the heterodyne. Adjust the wave meter to proper wave length; start its vibrator, then adjust the variable condenser of the set under test until the loudest sound is heard in the telephones of the wave meter. Then the corresponding wave length can be read from the scale on the wave meter.

Receiving transmitted signals.— The heterodyne having been calibrated it is set on the proper wave length, the primary of the receiver is then tuned; with the condenser switch of the secondary off, i. e., on ATT. The secondary switch should be on point 4, and the coupling as loose as possible. The primary switch is moved successively over points 1, 2, 3, 4 and 5. While it is on each point the condenser is moved slowly over its entire scale and back to the zero position. When the maximum sound is obtained during these operations the setting should be noted. Then the condenser switch must be placed on "Synt" and the secondary tuned in the same way as the primary, leaving

the coupling between primary and secondary as loose as possible in order to assist in weeding out interference from damped waves. The heterodyne will prevent interference from undamped signals. When tuning to obtain resonance with the transmitted wave it is necessary to vary the heterodyne condenser slightly to verify its setting. It is best to have the receiver calibrated so that ready changes may be properly made. As soon as a distant station is properly tuned on the receiving set its wave should be calibrated by measuring both the heterodyne and the receiving set.

Calibration.

As soon as a station is installed the following work should be attended to and properly recorded :

1. Calibrate the loading coil for various wave lengths.
2. Calibrate the receiver for various wave lengths.
3. Calibrate the heterodyne for various wave lengths.

Wireless telephony.

Connect the microphone by removing the brass short-circuiting bar from the posts marked " Micro " on the set ; short circuit the key. The apparatus is then adjusted for the proper wave lengths as in radio telegraphy. Speak loudly, distinctly and directly into the microphone at the same time having the mouth piece in a vertical plane. Wireless telephone signals are received just the same as damped telegraph signals, and therefore the heterodyne circuit must be broken by the rheostat used to furnish current to the filament of its bulbs.

Use of interrupter when transmitting.

For shorter ranges the E-3 set when equipped with the small direct current dynamo, may be used to send waves that can be received as ordinary damped waves. This is made possible by the use of an interrupter, placed in series with the key, that makes and breaks the sending circuit. Bin-

ding posts on the key (which are ordinarily short circuited) permit easy installation of the interrupter. The interrupter is a toothed disc mounted on the shaft of the dynamo. Every other sector of the disc is insulated, which causes the transmitter current to be broken, giving the effect of ordinary damped waves.

Wave Meters.

At the front great care must be taken to see that all radio sets are properly adjusted for wave lengths assigned to the station. This is due to the fact that so many sets operate in a small zone simultaneously. Without correct tuning, interference would cause confusion, and inefficient work would result. The necessary adjustment is accomplished by means of a wave meter. The importance of its use is greatly increased with the increased use of undamped waves, for the highly selective qualities of tuning possessed by sets using such waves enable many sets to be used simultaneously on waves differing only slightly in length, and wave meters must be used te accomplish this fine tuning.

Types T_1 and T_2.

The simplified Type T_1 wave meter issued with E-10 sets and its use in tuning these sets for sending and receiving have already been described. The Type T_2 is constructed and used in exactly the same manner as the T_1 the only difference being that it is calibrated to read wave lengths from 1000 to 1800 meters instead of 550 to 1000 meters.

Types no. 1 and no. 5.

These wave meters (see Fig. 76) are issued with the E-3 series of radio sets. They may be used in conjunction with any other radio sets of corresponding range of wave lengths. They are identical in size and external appearance differing only in the range of wave lengths for which they are

adapted. Wave Meter Type No. I (see Fig. 76). has a range from 100 to 1,100 meters; Type No. 5, a range from 500 to 2,000 meters.

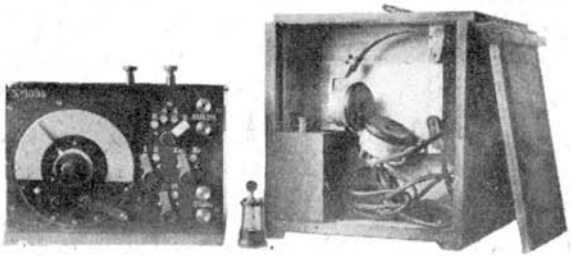


FIG. 76.—Wave Meter Type No. 1.

The wave meters may be used:

1. To measure the wave length emitted by a station.
2. To measure the wave length received by a station.
3. To adjust the station in advance for the reception of a given wave length.
4. To measure the natural wave length of an antenna.
5. To measure the capacity of a condenser.
6. To measure an inductance.
7. To measure the effective capacity and the inductance of an antenna.
8. To receive strong signals.

Description.

Fig. 77 shows the circuits of the small tyne wave meter.

A is the calibrated oscillating circuit.

B is an auxiliary coil.

C an impulse excitation circuit.

D a receiving circuit.

The oscillating circuit A consists of a variable condenser F and two coils R and M. The condenser has an inner and an outer scale. When the lever E is on point I, waves may

be measured from 100 to 350 meters, using the inner scale of condenser F. When lever E is on point 2, waves from 250

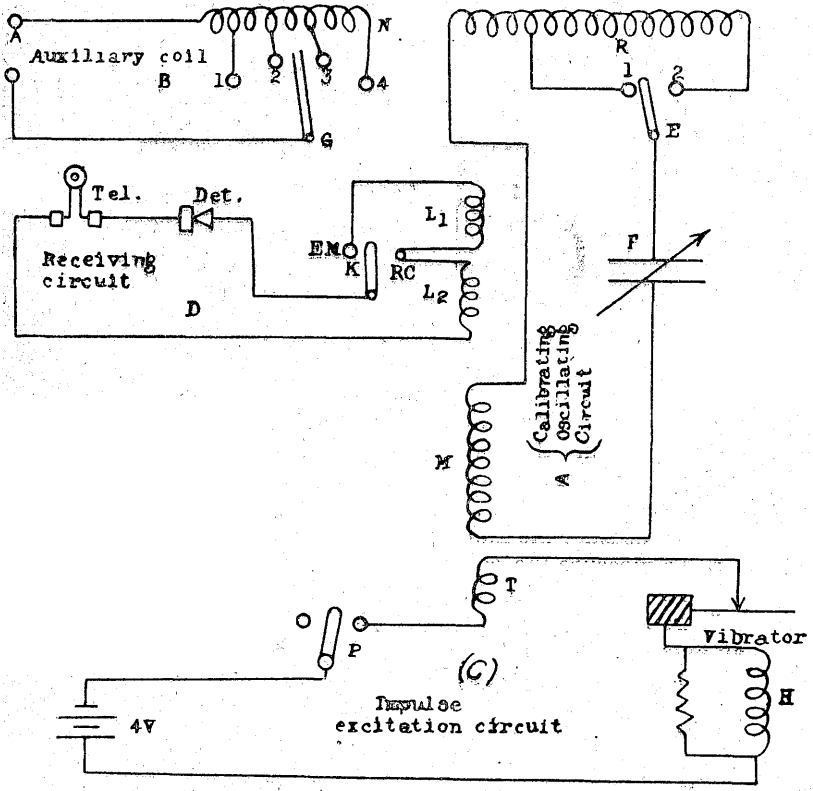


FIG. 77.—Circuits : Wave Meter Type No. 1 and Type No. 5.

to 1,000 meters may be measured, using outer scale of condenser F.

The Auxiliary Coil B is made up of 8 turns and by using the letter G it is adjustable by two turns on each contact point. The impulse excitation circuit C is made up of a coil

T and a vibrator H, the latter acting as a quenched spark gap. The variations of current set up by the vibrator H, acting through coil T will induce currents in circuit A through coil M. The coil M being in the circuit A, will set up oscillating currents with a wave length corresponding to the adjustments of the variable condenser F and the inductance controlled by switch E. The circuit D is the receiving circuit and is sensitive to any oscillation set up in the calibrated oscillating circuit A. Circuit D contains two coils L_1 and L_2. They are in series but are wound in opposite directions, each coil having the same number of turns. The circuit also contains a telephone receiver and detector.

Use of the meter to measure the wave length of a transmitting set.

Place the wave meter at a distance from the transmitter of which the wave length is to be measured, this distance varying with different powered sets. The stronger the emissions the further away the meter must be placed. Next put on the telephone head set and in the usual way adjust the detector. Place the lever K on the point marked EM. When on this position start the transmitter to be measured and press the key. The emisssions will only effect the receiver circuit D through the calibrated oscillating circuit, A. The reception of the emissions of the transmitter directly by circuit D is prevented because the coils L_1 and L_2 are made up of the same number of turns and wound in opposite directions. The coil M of circuit A is built closer to coil L_2 than to L_1 therefore oscillations in circuit A will effect coil L_2 more than coil L_1 : then this difference is readily heard in the telephones in the receiving circuit D. This being true we can adjust the calibrated circuit A until it is in resonance with the transmitter. This is done by listening in telephones of circuit D and adjusting condenser F and inductance E until the maximum sound is heard. Then by referring to the calibrated scale of the condenser we can read directly the wave length of the emissions from the transmitter under test.

Use of the meter to measure the wave length of signals received from a distant station.

The auxiliary coil B is inserted in series with the aerial and the receiving set of the local station. In coil N place adjusting lever G on contact I. This places two turns of coil N in series with the aerial. Next adjust the receiving set until you hear the maximum signals from the station to be measured, using as loose a coupling as possible. Next close switch P in circuit C which starts the vibrator H. Then T of this same circuit will induce a current in calibrated circuit A. Adjust condenser F and inductance coil, using lever E until the sound is heard plainly in the receiving set. Then the circuit A is in resonance with the signals that were sent from the station under measurement. If the circuit C fails to emit energy enough to let coil R induce into coil N audible signals, then the lever G must be placed on points 2, 3, or 4 of the coil N so as to insert more turns. The receiving set must be adjusted on the incoming signals when the lever G is moved before taking the reading of F. When these adjustments are made the scale on condenser F will give the wave length of the distant station. The measurements are more accurate when the least number of turns in coil N are used.

To calibrate a receiving set.

Place the wave meter in circuit as in measuring the wave length of signals received from a distant station. Then start the vibrator H by closing switch P. Adjust the circuit A for any desired wave length as shown by the scale on condenser A. Then adjust the receiving set under test until the maximum sound is heard using as loose a coupling as possible. Then receiver will be tuned to the wave length indicated by the scale on condenser F. Then by readjusting the circuit A and repeating the above process the receiving set may be calibrated for any desired wave lengths.

How to measure the wave length of an antenna.

Insert the auxiliary coil B in the antenna circuit of the receiving set. Then short circuit the condenser in the primary circuit of the receiving set and reduce the primary inductance to as small a value as possible. Then cut the condenser of the secondary out of circuit and reduce the secondary inductance until it shall be in resonance with that of the primary circuit. Then close switch P which starts the vibrator M. Adjust the circuit A until maximum sound is heard in the receiving set under test. Then the wave length of the aerial may be read from the scale on condenser F. This will not give the exact wave length of the aerial as allowance must be made for the small inductance that was left in the primary of the receiving set.

The wave meter as a heterodyne.

When the auxiliary coil B is inserted in the aerial circuit of a receiver the meter can be used as a heterodyne by starting the vibrator and adjusting the calibrated circuit to approximately the same wave length as the signals to be received. The wave meter circuits then set up waves of approximately the same length as the incoming signals but the period will vary from that of the signal so that one instant it adds to their amplitude and at the next instant it decreases it, producing audible signals in the telephones of the receiver.

Other uses.

In addition to the uses already explained the wave meter can, as stated, be used to make numerous other useful measurements :

1. Capacity of a condenser.
2. Self inductance in a coil.
3. Capacity and inductance in an aerial.

These measurements give only approximate values and

are of no practical use to radio at the front so their description is omitted here.

Owing to an error in standards all TM wave meters

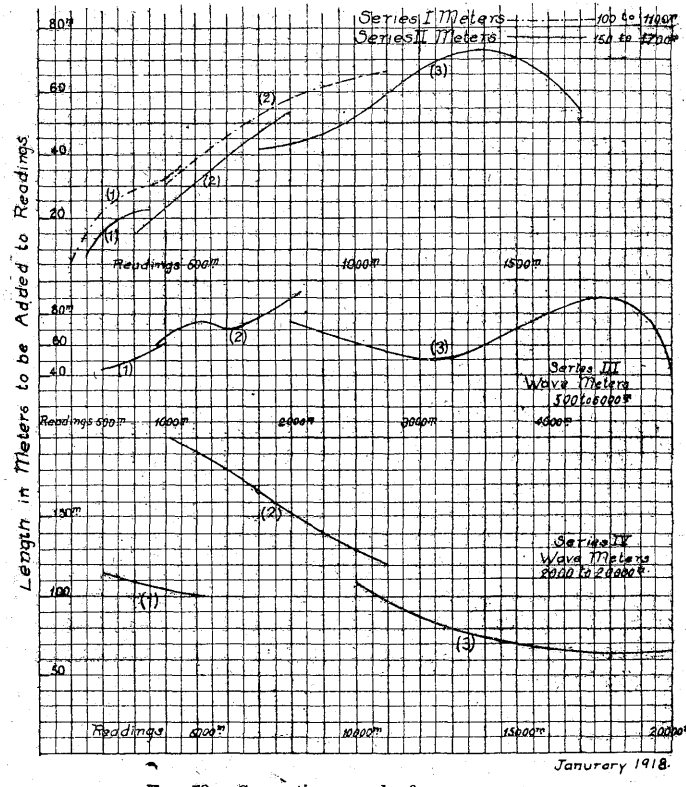


FIG. 78.—Correction graphs for wave meters.

issued previous to January 1, 1918 are incorrectly calibrated. Graphs giving the corrections to be applied to the readings made with these instruments Series I, II, III and IV are given in Fig. 78. It is necessary to add to the readings made from the scale, the length in meters indicated by the graph.

Example : The reading on scale 3 of a Series II wave meter is 1150 meters. The corresponding correction shown on the graph is 63 meters. The wave length corrected to accord with a 1918 scale, then, is :

$$1150 + 63 = 1213 \text{ meters.}$$

The number of the scale on the wave meter to which the curve applies is given in parenthesis near the curve. In the first set of curves the Series I wave meter corrections are indicated with a broken line thus : —.—.—.—. Series II wave meter corrections are indicated with an unbroken line thus : _____.

All French wave meters correctly calibrated are conspicuously marked " Longueurs d'ondes rectifiées 1918 " on the front panel.

Chapter VI.

RADIO IN THE FIELD.

Location of the Radio Receiving Station.

Several important points must be considered in determining upon the location of the Battalion Receiving Station for heavy artillery fire adjustment. Since it is necessary, or at least advantageous, that the Panel Station and the receiving station be close together in order to allow vocal communication between them, the selection of a location for the easy display of panels is an important feature. Positions on the reverse side of a gentle slope or in rear of a masking hedge or wood afford proper concealment from enemy aviators and do not give away the station location. This feature becomes of considerable importance when the large 9 × 9 meter panels are used as they are much more easily seen than the smaller 4 × 4 meter ones. In cases where it is found difficult to conceal the panels from the enemy as above, it is then necessary to separate the Panel Station and the Radio Receiving Station in order to protect the latter from bombardment attracted by the panels. Communication must then be maintained between the two by means of telephones.

The Receiving Station must also be placed so that the antenna wires will be free from danger of being grounded or knocked down by trees. Positions too close to active batteries or busy roads should be avoided, for the noise and vibration interferes with reception.

Dugout.

In places where it becomes necessary to locate the Radio Receiving Station in a dugout the dugout should be sufficiently large to accommodate the instruments and a table

large enough to insure their being well protected from the dampness of surrounding walls and affording sufficient writing space for two operators. Flooring should be provided to keep the operators' bodies insulated from the ground.

Care should be used to keep the antenna lead well insulated where entering the dugout; and to preserve as much air space between the antenna lead and walls ot the dugout as possible. A straight lead to the instruments is desirable. However, at the point of entrance to the dugout passage way, or through the insulator tube in the wall, a " drip loop " to prevent rain drops from coursing down the lead to the instruments should be provided. Sharp turns as well as unnecessary loops should be avoided. When it is necessary to go through wood or sand bags, tube insulators should be used.

Good results are usually obtained by burying the ground net, in the floor of the dugout, and placing the stakes in an out of the way location near the table, connecting the net and stakes to the instrument as described. Where the soil at the bottom of the dugout is of chalk or sand the ground net should be placed on the outside of the dugout in the surface soil which is a better conductor than the sand or chalk. The lead wire from the dugout to the ground net should be separated as far as possible from the antenna lead wire. If there are two doors to the dugout it is better to let the two leads come in different doors. If the ground net is not available, satisfactory results will be obtained by digging a narrow trench around the floor of the dugout next to the wall and burying eight or ten loops of bare copper wire, the ends of which are connected to the two stakes and the receiving set.

The Receiving Station should never be located near the telephone exchange or electric power lines; nor in dugouts or offices where other business is carried on. It is absolutely essential that nothing other than that connected with the radio station should occupy the radio dugout or quarters.

Erection of Antenna for Use with Type A Set.

The antenna most commonly used with the Type A radio set, previously described is a standard 50 meter V Type. It is composed of two 50 meter branches of special stranded tinned copper antenna wire, with a lead-in of 15 meters. usually mounted on double bamboo, or American lance poles spliced with iron coupling, so as to give a total height of 7 meters. The branches of the V should make an angle of approximately 30 with each other, and the V should be so placed that the bisector of this angle, if prolonged through the apex would pass approximately through the center of the target sector assigned to the battalion. This directional effect is important because it aids the strength of signals sent by an airplane operating in the direction of the target, thus permitting more selective tuning. With such an antenna the shortest wave length to be received with the Type A receiver is approximately 180 meters. If shorter wave lengths are desired the lengths of the two branches may be reduced to 35 meters.

The ground.

With the Type A sets a copper netting and two ground stakes are supplied for the establishing of a ground. Satisfactory results are obtained when this net is buried 10 or 15 inches and the two ground stakes placed at one end of the net, driven in the ground and connected to the binding posts on both sides of the net. The net should be buried as close to the receiving set as possible, in order to have a short ground lead. Directly under the antenna or in prolongation of it is the best position for the net.

Material.

To set up the above described antenna the following material is necessary :

100 meters stranded tinned copper antenna wire.
15 meters insulated wire for lead to set.
8 bamboo poles (2 extra).
1 shovel.
3 couplers, double; or 6 couplers, single.
3 guy ropes or wires, 18 meters long.
6 stakes for guys.
3 ebonite insulators for poles.
3 meters copper wire for ground connections.
1 copper net.
2 ground stakes.
2 hammers.

Duties prescribed for operators.

A systematic method of erecting the antenna is prescribed. In practice drills as well as in action, all electrical connections should be made mechanically secure as well as electrically secure. Care should be taken in fixing of guys, ropes, poles and other parts in the erection of the antenna to see that each part, and hence the whole, is well secured. For a personnel of 3 men the following routine is prescribed.

No. 1 selects two of the strongest bamboo or lance poles and couples them together with one double or two single iron couplings, on the spot where the apex of the V is to be placed and fixes one of the ebonite insulators to the top of the pole. He then splices the two antenna wires together and splices the lead-in to them. The antenna wires are then fastened to the insulator and the wire or rope guys fastened below the insulator. He then drives two stakes in the ground on a line perpendicular to the bisector of the V and 8 paces apart. His guys are then fastened to these stakes. He now indicates to Nos. 2 and 3 the direction they must go and unreel their branches of the antenna, allowing about 30° between the branches. Fig. 79.

No. 1 then erects the apex pole, allowing it to lean slightly against the strain of the guys in direction of the branches so that it will stand alone as shown in Fig. 80.

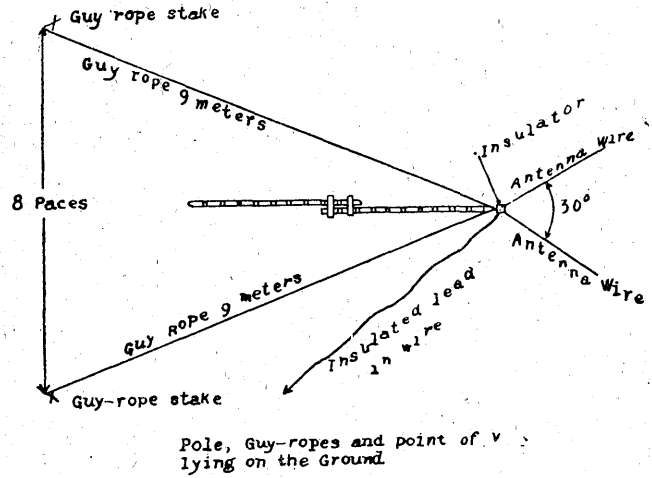


FIG. 79.— Erection of Antenna.

He then buries the ground net about 10 to 15 inches deep, connecting the ground lead to its binding posts. The two

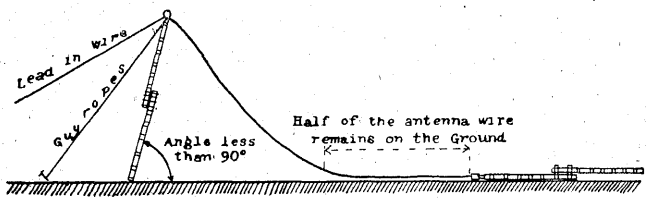


FIG. 80.—Erection of Antenna.

ground stakes are then driven in about half their length and connected with the net by means of the ground lead. No. 1

then connects the antenna and ground wires to the receiving set; and if the amplifier is to be used he also installs it.

No 2. also clamps two poles together, fixes an insulator to the top of the pole, fastens the guys below the insulator and having given the end of his branch of the antenna to No. 1, starts in the direction pointed out by No. 1, unreeling his branch of the antenna as he goes. He takes with him two coupling poles with the guys fastened on, two stakes, and a hammer. When he has unreeled the full length of his wire he fastens it to the insulator on top of the pole, lays the pole in prolongation of the wire so that half the length of his branch will remain off the ground, as shown by Fig. 80. His two 9 meter guys are then laid out on the ground at an angle of 60° to each other, and the guy stakes driven in at the end of the guys. The guys are then fastened to the stakes and the poles are lifted, carefully, against the strain of the guys. The guys should then be adjusted so that the antenna has a very slight sag, care being taken that the two branches are the same in this respect.

No. 3 erects the other branch of the antenna in exactly the same manner as No. 2.

The antenna branches should, of course, be measured to determine their proper length beforehand. This length should be, as stated, 50 meters for each branch. Small wood reels should be provided for reeling up the guys and antenna wires. Care should be taken, when ropes are used for guys, to prevent the shrinking and stretching of the ropes due to weather conditions from breaking antenna wires or lance poles.

Antenna for Receiving Press.

The large European stations used to send out otficial communiques and press messages operate on a wave length much higher than can be received with the Type A set used in Artillery fire control, the wave length limits of which are 180 to 550 meters approximately.

Eiffel tower may be received by means of a simple single wire antenna of a hundred or more meters in length and a crystal detector inserted in series with this antenna and a well established ground. Particular attention should be paid to the ground, a net buried ten or twelve inches and a stake at each corner all connected together will give satisfactory results. Buried shell cases have been used to replace the net satisfactorily. The telephone should be preferably the 2000 ohm type issued with Type A sets and the leads are attached to each side of the detector stand, thus simply shunting the detector with the telephones. Fig. 81.

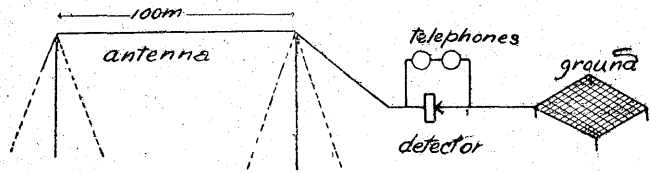


FIG. 81.—Simple Radio Receiver.

If a 3 ter amplifier is available the L_1 and L_2 terminals should be connected to each side of the detector and the head phones inserted in the amplifier in the regular manner. The signals will be greatly amplified then. Or, the amplifier may be used without a crystal detector using the first bulb as a detector, by inserting the L_1 and L_2 terminals in series with the ground, that is connecting L_1 to the antenna and L_2 to the ground (or vice versa) and placing the 3 pole double throw switch on H. F.

A simple constructed coil of the slide tuner Type may be made from material usually available in Heavy Artillery organizations. Its use in the antenna circuit above described or a similar antenna enables the tuning out of interferance and the receiving of stations of a greater wave length than can be received with the simple antenna circuit alone. Pyrene fire extinguisher tubes make excellent cores and a

sufficient number of turns of enamelled wire about No. 22 cover the full length of the tube give a wave length enabling the reception of most of the large European damped stations. Even the light field wire issued for telephone work may be used in constructing a coil of the type described. Such coils are known as " Auto transformers " or directly coupled receivers, for the same turns are used to form both primary and secondary circuit. The head phones and detectors issued with Type A sets are used in the secondary circuit. The connections used are shown in Fig. 82, P being the slide contact of the primary, S being the slide contact of the secondary and D and T being the detector and telephones.

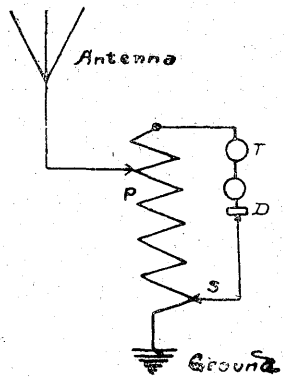


FIG. 8.
Circuit of simple slide Tuner.

Use of 3-ter amplifier as heterodyne.

For the reception of undamped or sustained waves, the inconvenience of not having an independent heterodyne may be overcome by a carefully executed change in wiring the first bulb of the 3-ter amplifier, by means of which the first bulb is made to oscillate as well as amplify, thus supplying the local sustained waves necessary for undamped wave reception. The change consists in simply inserting a variable capacity in parallel with the plate circuit of the first bulb, by means of a fine wire lead to the plate *pin* of the first bulb. The capacity may be supplied by two of the type A condensers connected in parallel or by the type wave meter condenser. This method of connecting a 3-ter amplifier gives excellent results, though great care must be used while making the connections not to interfere with the

circuits of the amplifier, or the type A. The receiving set used is connected to the amplifier in exactly the same manner as for damped reception,i.e. the telephone plug with two leads is inserted in the socket and the two leads connected to L_1 and L_2. The crystal detector is used, and its adjustment plays an important part in the success of the heterodyne.

Chapter VII.

MISCELLANEOUS.

Meteorological Data.

Meteorological information is supplied to artillery units from French Sounding Posts, sometimes by telephone but usually by means of Radio transmission. These sounding posts are of two kinds:

1. Army meteorological posts.
2. Army Corps sounding posts.

Army meteorological posts are distributed over the territory independent of the location of units. It is the information from these posts that is usually used by the heavy artillery. The data is transmitted by radio sets using damped waves of 500 meters, the messages of which can be received at 100 kilometers without amplification. It is sent out every four hours commencing at a specified initial hour. A table that is issued through G. H. Q., giving the list of Army meteorological posts with the initial hour of emission, should be obtained by the radio officers of all artillery units at the front.

Army corps sounding posts are established by army corps, the data therefrom being especially fit for light artillery. It is generally transmitted by telephone but in each army certain Army corps posts may let out their information by radio. The wave length used is variable and the hour of emission is regulated by Army headquarters.

The information is transmitted in a code of groups of 6 characters each.

1st Group: Consists of the index of the station transmitting in three letters sent twice.

2nd Group: Gives the character of the wind data sent; the altitude of the station; the temperature and pressure.

Following groups: Give the wind direction and velocity

at succeeding altitudes, at 0m, 200m, 500m, 1000m, 2000m, 3000 m, 4000m.

Second Group Code	1st Figure.	3 means sending ballistic wind.
	2nd —	Altitude in 100s of meters of meteorological post e. g.: 1 = 100 meters.
	3rd & 4th Figures.	Temperature in degrees (minus temperatures are indicated by adding 50 to their absolute value: 62 = 12° below zero).
	5th & 6th —	Pressure in millimeters at above altitude, cutting off the 7 e. g.: 56—Pressure at the Meteorological post altitude would be 756 millimeters.
Other Groups' Code	1st & 2nd Figures.	Altitude in 100 meters for which the ballistic wind is given: 05 means 500 meters.
	3rd & 4th —	Direction wind comes from at this altitude. A compass chart of 0 to 40 is used. 10 = East. 20 = South. 30 = West. 40 = North. 00 = Calm.
	5th & 6th —	Velocity of wind in meters per second with the addition of 50. Ex. 63 = 13 meters per second wind.

It is important that radio operators be able to receive and record meteorological data correctly. The meteorological stations always repeat the message and it should be record-

ed the second time by the operator, each figure being checked as it is put down. The following method of tabulation should be used:

Time 1.30 P. M.
21 October 1918.

MNSMNS	MNSMNS
311856	311856
023258	023258
053261	053261
103365	103365
203369	203369
303474	303474
403675	403675

Explanation of message:

MNS is the call letter of the Army Meteorological Post transmitting.

2nd group: 311856 indicates;

3—Ballistic wind;
1—100 meters Post altitude;
18—Temperature 18°;
56—Pressure at altitude of 100 meters (Post altitude) 756 millimeters.

3rd group: 023258 indicates;

02—Altitude 200 meters. (Above Post Altitude).
32—Wind direction at 200 meters high. (Above Post Altitude).
58—Velocity of wind 8 meters per second.

Transmission of Standard Time.

Every artillery unit equipped with radio should every day receive standard time from the Eiffel Tower. The tower

transmits standard time, on wave length of 2700 meters, damped, three times a day, i. e. at 10.00 A. M., 10.45 A. M. and 11.45 P. M. (Greenwich time, the time used by the Allied armies in France and by French railroads).

Commencing at 9.56 a. m. groups of three dashes are sent till 9.57, the end of the last dash indicating 9.57 exactly. Between 9.57 and 9.58 a series of dash, dot, dot, dash is sent and then three dashes, the end of the last one indicating 9.58 exactly, and so on until 10.00 a. m. The general scheme follows:

A. M.: 9.56 — — — — — — — — — — — — : 9.57 a. m.
: 9.57 — . . — — . . — — — — — — : 9.58 a. m.
: 9.58 — . — . — . — — — — : 9.59 a, m.
: 9.59 — — . — — . . — — — . — — — — : 10.00 a m.

Commencing at 10.44 a. m. a similar scheme is used, signals being given every two minutes with one dot being used to indicate exactly the odd minute:

A. M.: 10.44 — — — — — — — — — . : 10.45 a. m.
: 10.46 — . . — . . — . . . : 10.47 a. m.
: 10.48 — . . . . — . . . . — . . . . . : 10.49 a. m.

Time is transmitted at 11.45 P. M. in the same manner as at 10.45 A. M. Standard time should be received as follows:

While the Tower is sending preliminary signals, the radio operator on duty will adjust his receiving apparatus and carefully watch the motion of the split second hand of a stop watch.

Just as the Tower sends the signal indicating the precise time, he will carefully note down the time of the watch. By comparing the watch time with the transmitted time he will get the correction to be applied to the watch.

To avoid any mistake, do not attempt to time the reference watch itself.

The radio officer for infantry and artillery units, the local radio service for large unit staffs, are responsible for reception of standard time.

All advisable measures must be taken within the units to insure standard time transmission over the telephone to the most advanced units. The lists of units to receive daily time transmission should be posted in every telephone station.

For transmission of standard time over the telephone, the transmitting operator will call up the receiving station and announce:

"Am going to transmit standard time at (such) hours."

He then watches the split second hand of a stop watch, taking into account the required correction, warns his correspondent 10 or 15 seconds before the time announced by calling "Ready," and just as the split second passes on the required division he announces the time, calling, "Time." The receiving operator goes through the same performance as the radio operator when receiving from the Tower.

European stations.

The list on the next page gives the call letter, working time, wave length, and nature of message sent, of the more important European Stations.

Communiqués.

French official communiqués are sent out from Eiffel Tower, Paris, in French, at 3:00 p. m. and 11:50 p. m. and from Lyon, France in English at 12:00 noon. German official communiqués are sent out about 1:00 p. m. and 7:30 p. m. (time is variable) from Nauen, Germany.

NOTE. The schedules given above are based on standard European time, and consequently are subject to a one hour variation in accordance with the time plan of the French government adopted since the war. During the spring and summer all stations listed may be expected one hour later than the time given. For example, Eiffel Tower may be expected in the afternoon at 4:00 p. m.

DAMPED				
Time.	Call letters.	Name.	Work.	Wave length in meters.
3:50 a. m.	H B	Budapest, Austria.	Press	3500
9:56 a. m.	F L	Eiffel Tower, Paris, France.	Time	2700
10:44 a. m.	F L	Eiffel Tower, Paris, France.	Time	2700
11:00 a. m.	P O Z	Nauen, Germany.	Press	3900
12:00 Noon	T S R	Czarskoie Selo, Russia. .	Press	4500
12:30 p. m.	M P D	Pohldu, England.	Press	2800
1:00 p. m.	M C I	Carnavon, England. . . .	Press	11000
1:00 p. m.	P O Z	Nauen, Germany.	Press	3900
3:00 p. m.	F L	Eiffel Tower, Paris, France.	Press	2700
3:30 p. m.	I C I	Coltano, Italy.	Press	7000
5:30 p. m.	O S M	Constantinople, Turkey.	Press	2700
7:30 p. m.	P O Z	Nauen, Germany.	Official	3900
8:00 p. m.	V A	Mezieres, Austria.	Press	1500
8:00 p. m.	B U C	Roumanian Hdqrs	Press	3000
9:30 p. m.	E A C	Cadiz, Spain.	Press	2700
10:00 p. m.	P O Z	Nauen, Germany.	Press	3900
11:50 p. m.	F L	Eiffel Tower, Paris, France.	Press	2700
12:00 a. m.	M C I	Carnavon, England. . . .	Press	11000
3:00 a. m.	S D	Malta.	Press	2700
No fixed hour	L P	Leipzig, Germany. . . .	Press	4000
No fixed hour	E G C	Madrid, Spain.	Press	4000
No fixed hour	M P D	Pohldu, England.	Press	2800
UNDAMPED				
12:05 a. m.	B Y C	Naval Station, England. .	Press	10000
4:00 a. m.	Y N	Lyon, France.	Press	10000
4:00 p. m.	B Y C	Naval Station, England. .	Press	10000
8:10 p. m.	B Y C	Naval Station, England. .	Press	3500
No fixed hour	P O Z	Nauen, Germany.	Press	10000
No fixed hour	Y N	Lyon, France.	Press	10000

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UNITED STATES ARMY

(PROVISIONAL)

(IN FIVE PARTS)

PART III.

RADIO.

Prepared at the
HEAVY ARTILLERY SCHOOL, UNITED STATES ARMY,
ANGERS, FRANCE.

GENERAL HEADQUARTERS,
AMERICAN EXPEDITIONARY FORCES.
DECEMBER, 1918.

GENERAL HEADQUARTERS
AMERICAN EXPEDITIONARY FORCES
OFFICE OF THE CHIEF OF STAFF

FRANCE, *December* 13, 1918.

This Heavy Artillery Signal Manual *(Provisional) is published for the information and guidance of the American Expeditionary Forces.*

By command of General Pershing:

JAMES W. McANDREW,
Chief of Staff.

Official:
ROBERT C. DAVIS,
Adjutant General.

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HEAVY ARTILLERY SIGNAL MANUAL.

PART III.

Radio.

CHAPTER I.

THE THEORY UNDERLYING THE RADIO SYSTEM OF COMMUNICATION.

General Survey of the Field of Radio Communication.

Very soon after wire telegraphy became of practical usefulness, conditions were encountered in which the desirability of effecting electrical signalling without connecting wires became apparent. As a result of this need, a number of methods of telegraphing without wires were tried out, based on schemes of utilizing the conduction through the ground, magnetic induction, etc., as the means of sending the signals. All of these methods, however, were very limited as to range of transmission and were therefore of little importance and value as a system of communication.

Radio telegraphy. or the transmission of signals by means of unguided electric waves, was first introduced in 1896 by Marconi, after extensive experiments made by himself and with the help of the discoveries and research work of Hertz and others. In 1899 communication was established between Dover and Boulogne, a distance of 32 miles, and shortly after, information between ships was transmitted as far as 80 miles. The importance of radio communication was by that time universally admitted, and from this it has constantly grown and extended its field to commercial,

naval and military pursuits. From these early stages, the art has rapidly progressed until in 1916, Arlington Station could hear Japan working with Honolulu, the distance involved being approximately one half the circumference of the earth.

The application of radio to military uses is the one which will be particularly dealt with. In this application, its development has likewise been extremely rapid, and at the present time one of the most important means of communication between armies and units is by means of the unguided radio waves, this assuming greater importance as the intensity of destructive shell fire and hence the difficulty of maintaining wire communications increases.

An entire system of radio communication has been established to supplement the wire system for the forwarding of information between the various headquarters of the armies, divisions, brigades and even to and from the front line trenches. In an attack, when the infantry and the artillery move forward, one of the most difficult tasks is to maintain communication with headquarters. A certain element of time is involved in carrying forward wire communication systems and they are continually broken down by shell fire. The radio and ground telegraph apparatus, however, are much more simply carried forward and are usually operative unless destroyed by an almost direct hit. Of course, there are many times when the interference of the enemy and other of our own radio sets is so great as to make receiving of signals extremely difficult and at nearly all times the operator must be able to pick out his own signals from a number heard simultaneously.

Another system of radio communication is in existence between airplanes and artillery. This is called the fire-control system and it is perhaps the most extensive and complex of all the radio organisations in operation at the front. The firing of each battery of light, medium, heavy and superheavy artillery is directed to greater or less degree

by radio signals sent out from airplanes flying over enemy positions, particularly that of the last three named. This work is extremely important, and the number of airp anes used for the purpose is large. Great as is the value of the airplanes in extending the range of vision of the army, yet their effectiveness in directing artillery fire onto enemy targets is only made possible by the instantaneous means of communication between plane and battery afforded by the radio apparatus. In the early days of the war, even this scheme of communication was so slow, due to the cumbersome signals and natural sluggishness and difficulties incurred in developing and perfecting the practice, that the batteries were not kept busy enough to hold the interest of the men. The intervals between firing and receiving a range correction from the airplanes were so long that not much confidence was had in this method of directing fire. However, the signal system has been greatly simplified and otherwise improved, so that it is now effective in directing suitable battery fire on enemy gun positions and movements in such a manner as to frequently effectively silence the guns or destroy supply trains, etc.

Radio is also effectively used on reconnaissance and bombing airplanes, which sometimes are equipped with high power, long range sets. The radio telephone has found some use on battle planes and fighting machines, although this means of communication has not been extensively used up to the present time. It is now undergoing an intensive development and may come in for a more important part in the airplane and other radio work later on.

Not the least important use of the radio apparatus in military operations is that which the alert operator makes of it as a means of anticipating destructive shell fire on his own battery position. It frequently happens that he will hear a hostile plane sending down to the enemy batteries, the map co-ordinates of his position. He will then warn the battery commander not to fire for a period, as this would further prove the position to the hostile aircraft. Or

the operator may hear a shell burst at not great distance from his battery position and then hear the hostile plane send down a correction which denotes to the operator that his battery is the target at which the enemy is firing. A timely warning made to the battery commander under these circumstances has saved the lives of many artillery men.

The Electrical Units Pertinent to Radio.

Self and Mutual Inductance :—When an electric current is made to flow through a circuit, a magnetic field is established in the space surrounding it. The strength of this field at any g ven point is proportional to the current flowing in the circuit, and is dependent on the shape of the circuit and on the nature of the medium surrounding it. The value of the ratio of the field flux to the current in a given circuit is called its self-inductance (also called coefficient of self induction).

Thus,

$$\text{Self inductance} = \frac{\text{Electromagnetic Flux}}{\text{Current}}$$

The self inductance of a circuit therefore is the electromagnetic flux around the circuit when unit current is flowing through it.

If unit current is made to flow through one of two independent circuits A and B, (A for instance), the magnetic field due to that current extends around both circu ts A and B, if they are near enough together. That part of the flux due to A which interlinks with circuit B is called the mutual inductance of circuit A upon circuit B. This depends on the shape of each of the two circuits and on their relative position. Their mutual inductance is therefere greatest when the two circuits are closest together. Whenever a circuit reacts upon another, the two circuits are said to be coupled, the coupling being close or loose according to whether the mutual inductance is large or small.

As the magnetic field builds up around a wire carrying a current, it is possible to obtain a large inductance by winding the wire into a coil so that many turns will be concentrated in small space. By this means, a considerable flux may be produced through the summation of the fluxes due to each turn.

Capacitance.—If an insulated conductor is placed near a grounded conductor, and a charge is given to the former, its potential is found to be proportional to that charge, The value of the ratio of the charge to the potential of the conductor has been called the capacitance (electrostatic capacity) of that conductor. Thus,

$$\text{Capacitance} = \frac{\text{Electrostatic Charge}}{\text{Potential}}$$

A large capacitance may be obtained by placing two sheets of metal very close to each other and insulating them by means of some dielectric (air, mica, glass, etc.). Such a device is called a condenser. Condensers of large capacitance are built by combining a large number of sheets of metal foil separated by glass plates or sheets of mica. All even and all odd numbered sheets are connected together, respectively, each group forming one side of the condenser. The capacitance of a condenser is directly proportional to the area of the plates and inversely proportional to the distance between them.

Condensers of adjustable capacitance are also used. Several semi-circular metal plates are placed parallel and one above the other, and connected by means of metal rods extending through the plates at the two ends of the straight side, and held apart by blocks or washers, the whole group of plates making up one side of the condenser. The other side is made up of a set of similar plates having a semi-circular shape and mounted on a shaft at their centers. By rotating the shaft. the plate moves in or out between the stationary plates, and the capacitance of the condenser can thus be continuously varied.

Definitions of units.

Resistance:—The unit of resistance is the international ohm. It is the resistance of a column of mercury 106.3 cm. high, and weighing 14.4521 grams at a temperature of 0 deg. C.

Current:—The unit of current is the international ampere. It is that unvarying current which, when passed through a neutral solution of silver nitrate, will deposit silver at the rate of. 001118 grams per second.

Electromotive Force:—The unit of electromotive force is the international volt. It is the electromotive force which will cause one international ampere to flow through one international ohm.

Inductance:—The unit of inductance or of the coefficient of self-induction is the henry. It is the inductance of a circuit in which a current varying at the uniform rate of one ampere per second will induce an electromotive force of one international volt.

Capacitance:—The unit of capacitance is the farad. It is the capacitance of a condenser, such that a potential of one volt will cause the condenser to store a charge of one coulomb. (A coulomb is the quantity of electricity transported by a current of one ampere flowing for one second.

Electromagnetic Induction.

When a conductor is moved across a magnetic field so that it cuts lines of force, an emf. is generated in the conductor. If the conductor is part of a closed circuit, a current will flow in it due to this induced emf. As this induction effect is due to the cutting of lines of force by the conductor, it will be greatest at the instant of the highest rate of cutting the magnetic lines of force (greatest number of lines cut per second). This phenomenon has many practical applications, some of which are studied below.

Alternator:—Consider a loop of wire closed on an ammeter, and placed near a permanent bar magnet, Fig. I. If either

the magnet or the loop is moved, a current will be observed through the ammeter, the direction of the current depending upon the direction of motion and the polarity of the magnetic pole. If then the loop is held stationary and the magnet rotated around its axis aa, the direction of the magnetic

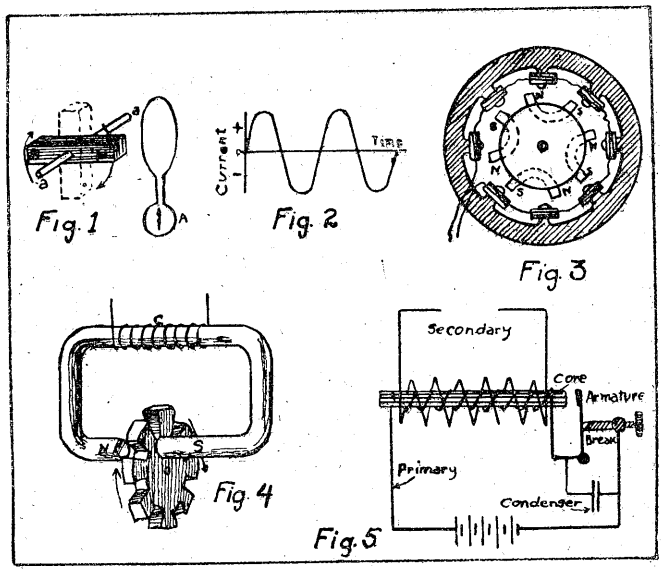


FIG. 1-5.

field through the loop will be alternately in opposite directions, and an alternating current will be generated in the stationary loop circuit.

As the current is a maximum when the number of magnetic lines of force cutting the wire per unit of time is greatest, this will occur when the magnetic pole passes directly in front of the loop. The current then decreases as the magnet pole is moved away, becomes zero for the position of the magnet shown in dotted lines, and increases again, but in the other direction, as the other pole of the

magnet revolves toward the loop. The duration of one complete cycle, that is, of one complete revolution of the magnet, is called the « period » of the alternating current, The number of periods per second is called the « frequency ».

A graphical representation of an alternating current may be obtained by plotting off the value of the current at each instant, time being counted on one axis, and current on the other. This produces what is known as a « sine » curve, as shown in Fig. 2. In order to obtain currents of higher frequency, it is simply necessary to rotate the magnet at a higher speed, or to use a number of magnets mounted on a frame locked to the shaft, Fig. 3. Also, rotating the magnet, Fig. 1, at higher speed, or increasing the number of magnetic fields cut through per revolution, Fig 3, increases the rate of cutting the lines of force and therefore produces higher voltage.

The permanent magnets may be replaced by electromagnets energized by a direct current derived from an auxiliary dynamo called an exciter, or from a battery. The field magnets, either permanent or electromagnets, may be stationary and the alternating current winding rotary.

The rotating portion of an alternating current generator is called the « rotor » and the stationary portion, the « stator ». The more common construction is to make the field windings (d. c.) rotary.

Inductor Type Alternator: — Another method of producing an alternating current is to wind a coil of wire C. Fig. 4, around a magnet of special shape, the two poles of which face each other and are separated by an air gap. A toothed iron disk is then made to rotate between the jaws of the magnet, so that the gap between the poles is alternately open and then practically closed with iron. The result is that the flux between the two poles, and hence the magnetic flux in the entire magnet, alternately increases and decreases. This periodically varies the number of magnetic lines of force inside the coil C. where an alternating emf. is

thus generated. This type of generator is called an « inductor type alternator ». It is quite widely used in supplying high frequency current to airplane radio apparatus. Instead of using a permanent magnet, it is of course possible to use an electromagnet energized by a direct current derived either from a storage battery or from a separate exciter dynamo.

Induction Coil :— Another form of electromagnetic induction is that involved in the operation of the ordinary induction coil, Fig. 5. This consists essentially of an iron core on which are wound two coils of wire. These are called the primary and secondary windings and the latter usually has a much larger number of turns of wire than the primary coil. Inserted in the circuit of the primary coil is a vibrator which, upon closing the circuit through the primary coil, is attracted toward the iron core of the coil, opening the circuit. It is then immediately released by the demagnetized coil and it returns to its former position to again close the circuit, the operation being very similar to that of the ordinary buzzer. The vibrator thus serves to very rapidly make and break the circuit through the primary coil.

In the induction coil method of producing current by induction, the coils remain stationary, but the function of the vibrator in alternately making and breaking the circuit through the primary, is to produce a rapid change in the number of lines of force resulting from the current in the primary coil. These lines of force also penetrate and surround the secondary coil and induce in it an emf, corresponding in magnitude to the rate of change of the number of lines of force produced by the primary coil. When the circuit of the primary coil is closed, the magnetic field rapidly builds up but is retarded from reaching its maximum value by the counter emf, due to the self-inductance of the primary coil. As this field increases, it induces an emf. in the secondary coil of higher voltage and in the opposite direction than that in the primary. When the current in

the primary has reached a certain value, the field becomes strong enough so that the vibrator armature is attracted toward the core, suddenly opening the primary circuit. This is followed by a rapid decrease in the number of lines of force cutting the secondary circuit, this change inducing an emf. of opposite polarity to the first, in the secondary

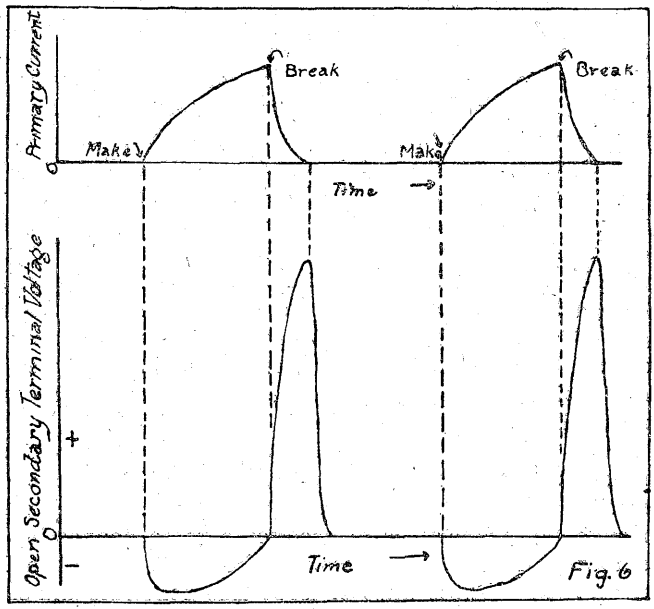


FIG. 6.—Current and Voltage Relations in Primary and Secondary of an Induction Coil.

coil. It is important to note that the opening of the primary circuit by the vibrator introduces a condenser in the primary circuit which serves the purpose of causing the primary current to fall to zero value with great rapidity. This is accompanied by a correspondingly high rate of decrease in the magnetic field, with the result that a very much higher emf. is generated in the secondary coil upon opening the

primary circuit than upon closing it. This is clearly illustrated by the curves of Fig. 6 where primary current and secondary voltage are plotted against time.

Transformer :—The operation of the alternating current transformer is based on a very similar principle to that of the induction coil. The principal difference between the two is that an alternating current is fed into the primary winding of the transformer instead of a direct current, as in the induction coil, which is broken up by the vibrator to produce a pulsating current.

The current in the primary of the transformer is then periodically reversed in direction. This produces a magnetic field periodically reversing in direction through the primary circuit, and also through the secondary coil which is generally wound over the primary on a common iron core. The reversals of the magnetic field induce in the secondary winding an opposite emf., the polarity of which is reversed at each reversal of the field. If the secondary terminals are connected to some external circuit, an alternating current of frequency equal to that of the primary current will then flow through this circuit. The ratio of the emfs. at the terminals of the two windings (primary and secondary) is equal to the ratio of their number of turns. Thus, if the primary consists of 20 turns of wire and the secondary of 1200 turns, the secondary voltage will be 60 times the primary voltage. The current will be roughly 1/60 as large, assuming unity power factor, since the power induced in the secondary cannot be greater than the power input to the primary. On account of the relative currents carried, the low voltage winding is made of heavy wire, while the high voltage winding is generally made of much finer wire.

Transformers used in radio apparatus are generally for the purpose of transforming a low voltage alternating current into a high voltage alternating current. Such transformers are called « step-up » transformers.

Oscillatory Discharge of a Condenser.

As outlined above, currents may be induced in a circuit by another entirely independent circuit in which an alternating or pulsating current is made to flow. As the inductive effect is due to a change of the magnetic flux in the circuits, it increases with increasing rate of change. In other words, the greater the number of reversals of flux per second,

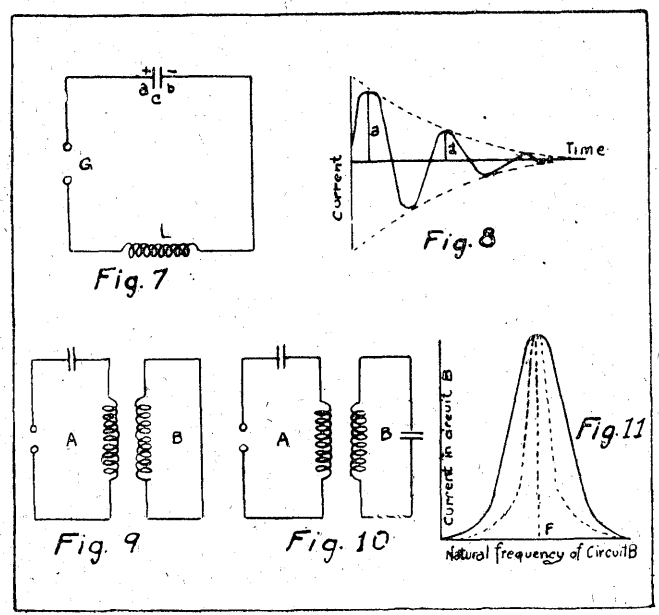


FIG. 7-11.

the greater the inductive effect at a given point, or the greater the distance through which this effect may be evidenced. In radio telegraphy, where these effects must be transmitted great distances, it is therefore necessary to generate alternating currents in the transmitting circuit of a very high frequency—something of the order of 30,000 to 3,000,000 cycles

per second. A number of methods have been used to attain this result, a very important one being the oscillatory discharge of a condenser. This is explained below.

Consider a condenser C. Fig. 7, with its plates connected to an inductance coil L and a spark gap G. The condenser is charged by some outside source of energy; that is, a difference of potential is established between the two plates, giving them opposite polarities. If this potential is made high enough, a spark will jump across the gap, momentarily short-circuiting the condenser through the inductance coil. The condenser will then discharge, and the quantity of electricity which had been accumulated on one of its plates will spread over the circuit in a tendency to equalize the charge on the two plates of the condenser. This will create a current in the circuit, flowing for instance from a to b in the direction aGLb. The effect of this current is to produce a magnetic field in the coil L. After a very short time, the condenser is entirely discharged, and there is no potential difference between its plates. There being no further charge on the condenser to maintain the current in the circuit, the latter will die out.

This is accompanied by the collapse of the electromagnetic field in the coil. This change of magnetic flux, however, generates a current in the coil, in the same direction as the discharge current of the condenser, so that the current in the circuit, instead of dying out suddenly at the moment the condenser is discharged, will continue to flow in the same direction for an instant and accumulate electricity on the condenser plate which was originally at the lower potential. When the current has ceased to flow, the condenser will be charged again, but with a polarity opposite to its original polarity. It will therefore start discharging in the opposite direction, the phenomena occuring as above described, but with the current flowing this time in opposite direction. A series of current reversals will thus take place, the initial energy which was stored in the condenser being alternately stored in the electrostatic and in the electromagnetic fields

of the circuit, this producing an alternating current of a frequency depending on the value of the inductance L and capacitance C, in the circuit. The relation between the frequency and the constants of the circuit is

$$f \text{ (cycles per second)} = \frac{159{,}200}{\sqrt{L \text{ (Microhenrys) } C \text{ (Microfarads)}}}$$

This frequency is called the " natural frequency " of the circuit.

This alternating current would maintain itself indefinitely if there were no energy losses during the cycle. However, the wires making up the circuit have resistance, in which a certain amount of the energy is dissipated in the form of heat. Also, there are heat losses in the spark gap, the radiation losses, and some other losses, generally of less importance, such as leakage losses in the condenser, etc. The result is that at each cycle, the intensity of the current grows less, until after a few cycles, the energy is practically entirely dissipated and the current is consequently " damped " out. These few cycles as a group are called a " train " of oscillations. In order to produce a new train of oscillations, it is then necessary to recharge the condenser by means of some outside source of potential. Such a train of oscillations may be represented as in Fig. 8, where current is plotted against time.

Decrement:—The number of cycles taking place in the circuit before the current is damped out is dependent on the resistance of the wire making up the circuit, being greatest for circuits of low resistance. The damping varies directly with the resistance of the circuit. The rate of damping of the current of such a discharge may be expressed mathematically by the ratio of the maximum amplitude of two consecutive cycles of a wave train. This ratio is a constant for a given circuit and is called the " arithmetic decrement " of the oscillation. Thus, the arithmetic decrement of the wave shown in Fig. 8, would be a/a'. The greater the value of this decrement, the more rapid the damping

of the oscillation. For a true, undamped alternating current, Fig. 2, the decrement is equal to 1.

In practice the arithmetic decrement is of little interest, and the term used most frequently to express the damping is the " logarithmic decrement " which is the Napirian logarithm of the arithmetic decrement. Hence the logarithmic decrement of an undamped oscillation is zero.

The frequency of oscillation of the condenser discharge may be very great—from 50,000 to 3,000,000 cycles per second, depending on the values of inductance and capacitance in the circuit. But the number of cycles in one train taking place before complete damping out is comparatively small. Hence, by recharging the condenser after each wave train, it is possible to produce a large number of trains of oscillations per second. This may be done by means of an induction coil or an alternator, and will be taken up later.

Phenomena of Resonance.

Due to the very high frequency of the discharge oscillations of a condenser through an inductance, the inductive effects are considerable. If an inductance coil B, Fig. 9, is placed near an oscillating circuit A, an alternating emf. is induced in coil B, exactly in the same way as in an ordinary transformer. If the coil is short circuited by means of a piece of wire, an alternating current will flow in the circuit. This will be of the same frequency as the current in circuit A, whatever that frequency may be, as determined by the values of capacitance and inductance in the generating circuit A. Circuit B is then said to be " aperiodic " as it has no natural oscillation period of its own.

If, however, instead of short circuiting coil B, a condenser is connected across its terminals, Fig. 10, phenomena of a somewhat different nature will take place, so-called resonance phenoma. The alternating current flowing in circuit A, at the natural frequency of that circuit, induces, as before, an alternating emf. of the same frequency. As a result of

this alternating current, the condenser of circuit B is charged every half cycle, and will therefore, independently of the current induced by circuit A, discharge through the inductance coil B at the natural frequency of circuit B. Two alternating currents of the natural frequencies of circuits A and B will thus flow in circuit B, and will combine, successively adding and subtracting their effects. If the two frequencies are made equal by a suitable adjustment of the natural period of circuit B, the two currents in that circuit will be in phase and will always add their effects to produce the maximum current in the circuit B. To obtain this condition, it is necessary that the product of the capacitance and inductance of one circuit equal that of the same constants of the other circuit. When this condition prevails, the two circuits are said to be " resonant ", or " in tune ". Circuit B may be tuned to circuit A by varying the capacitance of the condenser or the inductance of the coil B. Circuits which require a change in frequency are generally equipped with a variable air condenser or a multi-tap inductance coil, or both.

If the current in circuit B is plotted against the natural frequency of that circuit, a " resonance curve ", Fig. 11, is obtained which shows that the maximum current exists in B when its frequency is equal to that of circuit A. This curve may in some instances be of a very peaked shape (dotted curve), which means that under certain conditions, circuit A may produce an appreciable current in circuit B only when the latter is almost exactly in tune. Such a result may be attained by loosening the coupling of the two circuits; that is, by separating them so that the induced current in B will not react appreciably on circuit A. Also, the trains of oscillations in circuit A should be damped as little as possible, so that each train will act on circuit B for a comparatively great length of time. This object is attained by making the circuits of large size copper wire and consequent low resistance.

The fact that the current produced in circuit B by the

oscillations of circuit A is considerably greater when the two circuits are in tune, is used in radio telegraphy. as will be shown later, in order to make it possible to receive signals of a given frequency and practically eliminate those of other frequencies.

Propagation of Electric Waves.

The flow of electric current in any circuit is accompanied by the existence of interlinked magnetic and static fields which surround the conductors carrying the current and extend throughout space. Whenever the direction of current flow in the circuit is reversed, these fields reverse also. This reversal does not take place, however, throughout space instantaneously. The phenomenon is somewhat similar to the ripples taking place on the surface of water when a pebble is thrown into it. The disturbance gradually propagates itself at a uniform speed, keeping its shape and characteristics until it dies out due to friction losses. The disturbance or reversal in the electric field surrounding a conduetor propagates itself in much the same way, but at a speed of 300,000,000 meters (186,500 miles) per second. That is at a point 300,000.000 meters distant from the circuit under consideration, the reversal of the electric field will occur one second after the reversal of current has been made in the circuit. On account of the similarity with the ripples in the water, this phenomenon has been called an electromagnetic wave. Such waves, however, travel outward not only in one plane as the ripples on the surface of the water, but they radiate out into space in a spherical progression, The medium in which this propagation is assumed to take place is called the " ether ". This hypothetical medium is, for theoretical reasons, assumed to be present throughout space whether matter is present or not; it is the medium in which all electromagnetic disturbances, light waves and heat radiations occur.

If now a frequently reversed current or alternating cur-

rent is sent through a circuit, the interlinked magnetic and static fields will alternately reverse at the same frequency. This constitutes a series of waves progressing from the current carrying circuit outward into space in all directions. The length of the waves radiated is measured by the distance betwen two consecutive points at which the electric field has the same amplitude and direction.

This distance is therefore equal to 300,000,000 meters divided by the frequency of the alternating current.

Fluctuations of magnetic and static fields will produce electric currents in any metallic circuit which happens to be within the range of these fields, energy being thus dissipated in these circuits. As this energy is derived from the oscillating circuit, and conveyed to the various other circuits by the electromagnetic waves, the oscillating circuit is shown to " radiate " energy into space. An appreciable amount of energy is not radiated, however, at frequencies of less than about 10,000 cycles per second. The problem is then to generate high frequency alternating currents in a circuit of such shape as to radiate a large amount of energy and produce fields of sufficient strength that the changes in their intensity and direction may be intercepted at great distances. In the following chapter a study will be made of the application of these phenomena to radio telegraphy.

CHAPTER II.

DAMPED WAVE RADIO TELEGRAPHY.

Principles of Transmission.

From the previous study it has been seen that a radio transmitting set, that is, a set which will emit electromagnetic waves into space, may consist of an oscillatory circuit containing inductance and capacitance, in which trains of damped high frequency oscillations are produced in rapid succession by supplying a certain amount of energy to the system after each wave train. Such a set therefore comprises, in addition to the oscillating circuit, the necessary apparatus to produce the high voltage required for charging the condenser at the beginning of each train of oscillations. This auxiliary apparatus varies greatly with the various sets and is not exclusively applicable to radio work. It comprises ordinary power apparatus used for the production of high potentials and may be an induction coil, transforming the low voltage of a battery into a high pulsating voltage, or an alternator, generating low voltage alternating current which is then stepped up to a high voltage by means of a transformer. This will be studied in a later paragraph.

The oscillatory circuit, however, is a part of the set which is peculiar to radio work. It was seen that such a circuit is made up of an induction coil, the terminals of which are connected to the plates of a condenser; also, that there are two methods of starting oscillations in such a circuit, one being to introduce a spark gap, charge the condenser, and suddenly close the circuit by producing a spark across the gap, and the other being to couple a circuit without a gap to an oscillating circuit containing a gap. The first may be termed the " direct excitation " and the second, the " indirect excitation " method.

In radio telegraphy it is necessary, in order to increase the range of transmission, to arrange the oscillating circuit so that the electric field will be of suitable shape and of appreciable strength at great distances. This is accomplished by making either the inductance coil, or (more generally) the condenser of the oscillatory circuit of large physical dimensions. It is then called the " antenna " of the set.

The dimensions and shape of the antenna vary greatly in practice and a number of types, some of which are described below are in use at present.

Types and Characteristics of Antennæ.

In the very great majority of cases, it is the condenser of the radio circuit which is made the antenna, the inductance coil being wound inside the set box. One reason for this is that such a condenser antenna is much more simply installed or repaired under emergency conditions. The simplest type considered here is the so-called " L " type antenna, Fig. 12. This consists of a horizontal wire, called the " aerial " which forms one side of the condenser. This is connected to one side of the inductance of the oscillating circuit. The other side of the condenser is made of a similar wire which is stretched out underneath the aerial wire, either slightly above or laid on the ground. Or the ground itself, if not too dry may be used as the counterpoise side of the condenser. This ground side of the condenser is connected either directly or through a spark gap to the inductance coil, according to the method of excitation used. This is explained below. The connecting wires used to connect the coil and gap to the aerial and the counterpoise (or ground) are called the " lead-in wires ". In some cases, no inductance coil is provided with the set, the self inductance of the antenna wire being sufficient.

A very important feature of the antenna is its " direction-

al effect ". When the antenna circuit is made to oscillate, the intensity of its electric field and hence the range of transmission is distinctly greater in the direction of the end at which the lead-in wires are connected (direction of the arrow in Fig. 12). Advantage is taken of this characteristic when using such an antenna, by pointing the aerial wire toward the location of the receiving station with which it

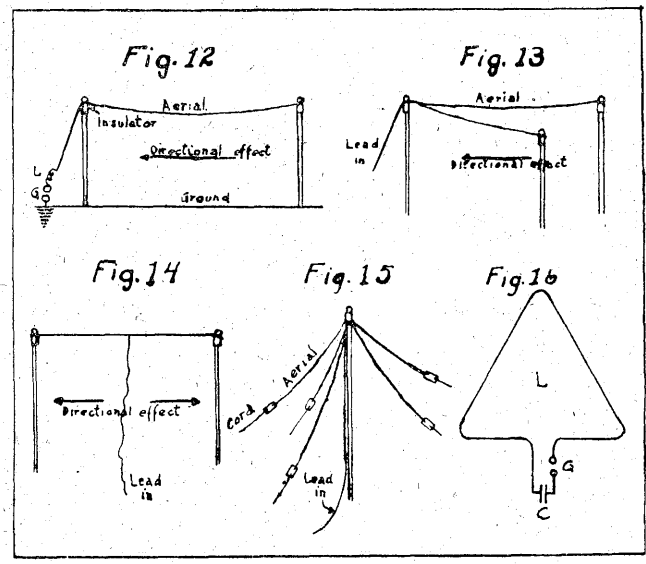


FIG. 12 to 16.

is desired to communicate, the lead-in wire being connected to that end of the aerial which is nearest the receiving station. It is very important to remember this, since the range of transmission in the other direction is considerably less.

Another type of antenna is the " V " antenna shown in Fig. 13. The aerial consists of two diverging horizontal wires and the lead-in wire is connected at the apex of the

" V ". If a counterpoise is used, it is generally made of two wires laid on the ground or stretched between masts above ground and underneath the branches of aerial. The directional effect of this antenna is toward the point of the " V ".

The " T " shaped antenna, Fig. 14, consists of a horizontal wire at the center of which the lead-in wire is connected. The directional effect is in either direction in the vertical plane of the antenna.

The " umbrella " type antenna consists of a number of interconnected wires suspended from the top of a mast and insulated from ground, spreading around the mast like the ribs of an umbrella frame. The free ends are fastened to the ground by means of insulators and ropes, Fig. 15. There is no directional effect with this antenna, the electric waves being radiated with equal strength in all directions.

There are a number of other types in use, but they are generally too difficult to set up in the field for common use. A very important consideration in using antennae is to always well insulate the aerial and lead-in wires from the ground in order to avoid any leakage path which would of course greatly reduce the range and might even completely prevent any radiation.

As was pointed out in the preceding chapter, the resistance of the oscillating circuit should be as low as possible in order to reduce the heat losses and resulting damping. The lead-in wires connecting the counterpoise and antenna to the set should be made as direct and as short as possible. This will also eliminate any superfluous inductance due to possible turns in these wires. If the set is under shelter, the wires should be run through ebonite tubes where they pass through the wall. If these are not available, a bottle may be used, the bottom of which has been broken out.

The ground connection should be made by driving a few metal rods into the ground and interconnecting them, and then connecting them to the set. A ground mat may also be used. This is a small metal netting which is placed on the

ground underneath the aerial and connected to the set. It is very useful when the station has to be set up in a short time, and is indispensable when the ground is dry or rocky.

An important use of the counterpoise is to be found on airplane sets where the aerial is generally a single wire let out from a reel on the airplane through an insulating tube, and the counterpoise is all the metallic parts of the airplane motor, gasoline tanks, stay wires, etc., electrically bonded together.

As mentioned before, the antenna sometimes consists of the inductance coil of the set instead of its condenser. The latter is then of small physical size and is mounted within the set box, while the antenna is a loop of wire, Fig. 16, of suitable size and of very few turns, frequently of only one turn, supported on a wooden frame. Such antennae, called "loop antennae", are generally used for short range radio telegraphy and for radiating very short wave lengths — 30 to 100 meter waves. They are directional in their plane. This type of antenna is somewhat delicate to repair and is not used very much in the field.

Direct Excitation Transmission.

With the direct excitation method of sending radio waves, the radiating oscillatory circuit comprises the aerial and ground (forming the condenser), an inductance coil L, and a spark gap, Fig. 17. The two electrodes of the spark gap are connected to the secondary (high voltage) terminals of a transformer, in the primary of which an alternating current may be made to flow by closing the key placed in series with it. When the key is closed, the primary low tension alternating current induces a high alternating voltage in the secondary of the transformer, and an alternating difference of potential is thus established between the aerial and the ground which causes a storing of energy in the antenna. If this potential is high enough when the maximum of the cycle is reached, the air gap breaks down and the antenna dis-

charges the stored energy through the inductance L, and a high frequency oscillation is created as explained previously.

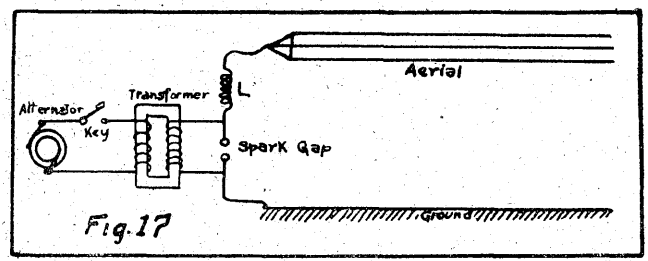


FIG. 17.

This is shown in Fig. 18. The upper curve shows the voltage variation in the secondary circuit of the transformer. It rises from zero to the breakdown potential e of the gap,

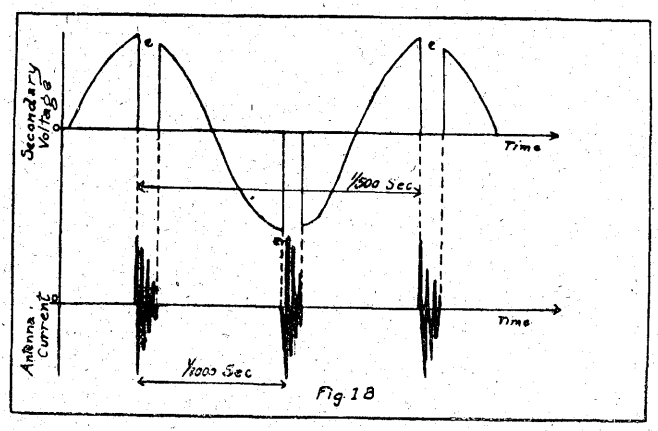


FIG. 18.

when the condenser discharges and suddenly equalizes the potential of its two electrodes. When the resistance of the gap breaks down, the voltage of the tranformer secondary drops practically to zero and a high frequency current oscil-

lates in the antenna circuit, as indicated in the lower curve. When the oscillations have been damped out due to heat losses in the spark, the resistance of the circuit, and the energy losses by radiation, there being no current flow through the gap, the latter opens again, and the voltage of the antenna follows again the cycle of the alternator until the negative maximum is reached, when the same phenomenon takes place. In this way for every half cycle of the alternator, a high frequency discharge of the antenna takes place which sets up in space, a train of high frequency oscillations (wave train). The frequency of successive wave trains is thus equal to twice the frequency of the alternator. This, for reasons seen later, is called the " audio " or " wave train " or " spark frequency ". The frequency of the oscillations of each individual train is called the " radio frequency " and is entirely independent of the frequency of succession of the sparks or wave trains, as it is determined by the constants (inductance and capacitance) of the antenna circuit. The value of the radio frequency can therefore be regulated by inserting capacitance or inductance in the antenna circuit. Thus placing an inductance coil in series with the aerial will increase the wave length (decrease the frequency), while a condenser inserted in series with the aerial decreases the wave length (increases the frequency). The frequency of the alternator in practice is of the order of 500 to 1,200 cycles per second.

Instead of using an alternator and transformer, an induction coil may be used. This supplies a high pulsating voltage at its secondary terminals instead of a high alternating voltage. The operation is the same in principle, the advantage being that such a set is readily portable, and easily set up. However, the wave trains may occur at slightly irregular intervals as the armature does not vibrate regularly as a rule.

The presence of a spark gap in the oscillatory circuit has the disadvantage of introducing quite a high resistance, so that the oscillations are rapidly damped out, and the interval

of time between two wave trains, although of the order of 1/1,000 second, is very much longer than the duration of the various wave trains. The result is that such sets are of low power and small range, as a great part of the energy of the oscillations, instead of being radiated into space, is wasted away as heat in the antenna circuit. Also, due to the rather

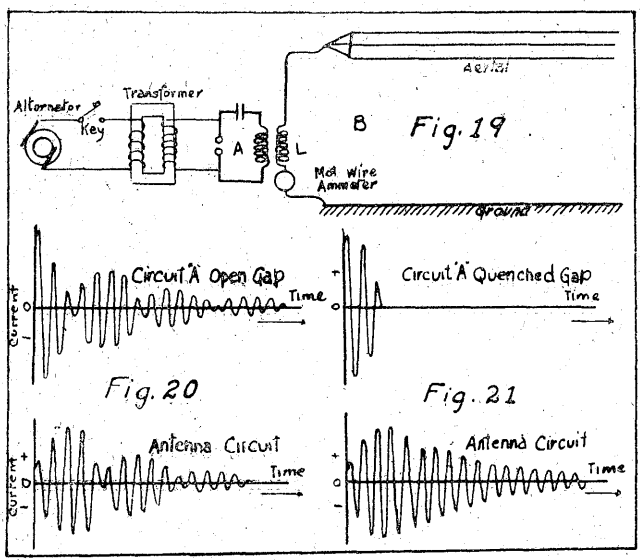


FIG. 19-21.

high decrement, tuning of the receiving set cannot be made very sharp. For long range sets, this method is then replaced by the indirect excitation method of transmission.

Indirect Excitation Transmission.

By this method, oscillations are started in an oscillatory circuit A, Fig. 19, exactly as with the direct excitation method, only this is a so-called closed oscillatory circuit; that is, both

the condenser and the inductance coil are of small physical dimensions.

Coupled to this circuit is the antenna circuit, comprising the large aerial-ground condenser and inductance through which the coupling to circuit A is made. Oscillations are set up in circuit A, as described above, each train of oscillations being rapidly damped out. Through the transformer action of the two inductance coils, these oscillations induce similar oscillations in the antenna circuit. When the oscillations in circuit A have been completely damped out, the antenna circuit, containing no high resistance such as the spark gap, will continue to oscillate for some time, so that for the same power input a greater amount of power will be radiated by using this method of exciting the antenna. For the proper operation of such a set it is of course necessary that the antenna circuit be tuned to the period of the closed oscillator circuit A. This is generally done as follows: Circuit A is first given the desired natural period by properly setting its variable condenser and variable inductance. The key is then closed and the antenna circuit adjusted by changing its constants until it is in resonance with circuit A. This condition is indicated by the maximum reading of the hot-wire ammeter inserted in the antenna for this purpose.

As in the previous case, many different arrangements of the circuits are possible. Instead of the alternator and transformer, use may be made of an induction coil. In some sets, the coupling of the closed oscillating circuit A to the antenna is made by means of one coil only, Fig. 22. This is called " conductive coupling ". The inductance of circuit A is then that part of the coil comprised between the points *a* and *b*, the portion of the coil included in the antenna circuit being that between *m* and *n*. It will be noticed that this arrangement of one or two inductance coils for effecting the transfer of energy from one circuit to another is, in principle, the same as an ordinary transformer, the only difference being the absence of an iron core. From this similarity, the arrangement has derived the name, " oscillation transformer ".

Some auxiliary phenomena take place when indirect excitation is used for setting up oscillations in the antenna. When a train of oscillations is started in a closed oscillatory circuit by the breaking down of the gap, the oscillations quickly damp out, mainly due to energy losses (resistance, gap, etc.) in the circuit itself. However, when such a circuit is coupled to some other oscillating circuit, such as in the case of Fig. 19, the closed oscillator, in addition to wasting away its energy in the usual internal losses, gives up at every cycle a part of it to the other oscillating circuit. So that its damping will be much greater. When the oscillations in the first circuit have died out, the second circuit has then stored a large part of the energy, and high frequency oscillations take place in that circuit. These react on the closed circuit and induce in it an emf. which causes the oscillations to start anew, due to the fact that the conducting gases in the gap were not given time after transfer of energy from the local to the radiating circuit to de-ionize or escape, and open the circuit. The second oscillating circuit thus gives back energy to the first, until it has returned all of it, at which time the first circuit is again in full oscillation. The phenomena then repeat in the same sequence. The result is a series of " beats " in each circuit, as represented in Fig. 20. The practical result is that the antenna circuit, instead of oscillating freely and radiating all its energy into space, feeds back and wastes some of it in the local oscillating circuit A.

To avoid this waste and secure the maximum radiation, it has been found necessary to prevent the transfer of energy back to the closed oscillating circuit, and a number of methods have been devised, all based on the same principle. The general principle consists of making the spark gap non-conducting after the circuit A has given up all of its energy; that is, after the oscillations taking place in it have been once damped out. If this is done, circuit A is open and an emf. induced back into that circuit by the antenna circuit will be unable to produce any current in it. Excitation by

this method is called " impact excitation ". This gives conditions shown in Fig. 21, from which it will be seen that after all the energy has been transferred from A to B, it is all spent in circuit B in free oscillations of low damping.

One method of making circuit A non-conducting consists in blowing out the spark in the gap by means of a violent stream of air produced by a blower of some sort. Such an

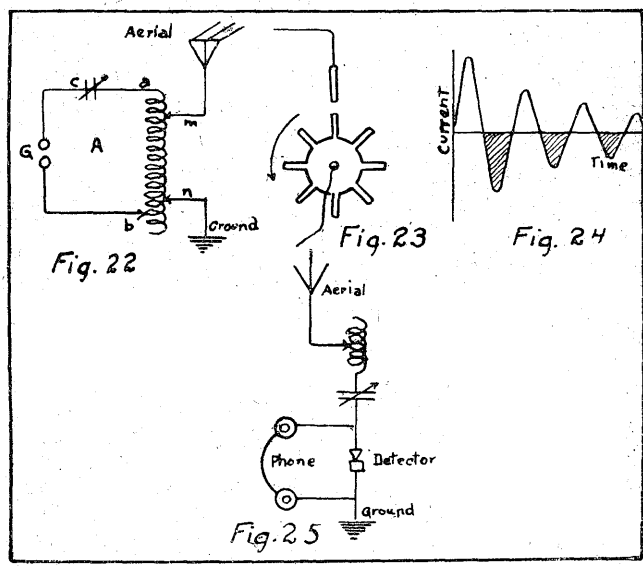


FIG. 22-25.

arrangement is called an air blast spark gap. Another method is the use of the " quenched gap, " in which the spark occurs in an air tight space between cooled electrodes made of metals such as zinc, aluminum or silver, all of which tend to prevent the spark from maintaining itself after the first energy transfer. A third method, used on a number of airplane transmitters, is the " rotary spark gap, " in which one of the electrodes of the gap is a stationary

metal post, at a small distance from wich is rotated a toothed metal disk forming the other electrode, Fig. 23. The disk is rotated at high velocity and a spark takes place every time one of the teeth of the disk passes in front of the stationary electrode. Each spark is extinguished very rapidly on account of the increased length of gap as the tooth turns away from the stationary electrode. There are two kinds of rotary gaps, called the " synchronous " and the " non-synchronous " gap. In the former, the disk is driven at such a speed, and has such a number of teeth, that there will be one spark for every cycle of the alternator. In the latter, the disk is driven at a different speed so that there will be more than one spark per cycle, or else one spark in every few cycles. The adjustment of such gaps is somewhat delicate and is not taken up here. While quenched gaps are of use in indirectly excited sets, they should be avoided in directly excited sets, as in this case the oscillations take place only in the antenna circuit and hence want to be prolonged as much as possible.

Principles of Reception.

In the previous paragraphs, a study has been made of the production in an antenna, of high frequency damped oscillations. These oscillations, it was pointed out, produce reversals of the electric field throughout space, and if the antenna is of suitable shape, of greater strength in certain directions than in others. Thus a damped oscillation in the antenna will produce a train of electric waves travelling from the source outward. When such a train of wave sweeps over any conductor, it will induce in this conductor an alternating emf. of proportional amplitude and of the same frequency as the oscillations of the train. If a circuit containing inductance and capacitance is acted upon by the oscillations, the alternating current set up in it will be a maximum when the natural freqnency of the circuit is equal to the frequency of the oscillations, or in other words, when the

circuit is tuned to the waves received, which means resonant with the transmitting circuit. A radio receiving set then comprises a circuit containing adjustable inductance and capacitance, so that it may be tuned to any frequency within certain limits. As it is of advantage that the receiving set intercept as much as possible of the energy of the incoming waves, it is made to cover as large an area as possible. This is accomplished by giving large physical dimensions to either the inductance coil or the condenser, in other words, by using an antenna. In such a circuit, for each wave train passing over the antenna there will be induced a train of high frequency oscillations. In order to perceive these oscillations, it is necessary to insert in the circuit some sensitive device which will respond to the extremely small currents induced in the antenna. The telephone receiver forms a very convenient device for this purpose because of its great sensitiveness and ruggedness. Reception of radio telegrams is thus almost universally done by sound.

As the frequency of the oscillations is far beyond the vibration frequency of the telephone receiver diaphragm, no sound would be produced by the latter under the influence of the alternating current induced in the receiving antenna. It is therefore necessary to rectify this current by means of a special device called a " detector ". This will conduct electric current fairly well in one direction, but practically not at all in the other. If such a detector is then connected in series with the telephone receivers, a wave train passing over the antenna will induce an alternating current in the circuit, but all the half cycles in one direction will be cut off by the detector, so that instead of a damped alternating current passing through the telephone, a series of unidirectional half-cycle impulses will flow, Fig. 24. As these impulses occur in such rapid succession that the receiver diaphragm will not respond to them their effect is added, giving one deflection of the diaphragm for each train of waves. When the train of oscillations is damped off, the telephone diaphragm falls back in place until the next wave train arrives at

the receiving station. If these trains arrive at a rate (for best results) of 500 to 1,200 per second, the successive vibrations of the telephone diaphragm will produce a sound in the operator's ear which will be of a very pure and steady note if the trains arrive regularly. which means that the spark of the transmitting set is occuring at very regular intervals, as determined by the vibrations of the induction coil vibrator.

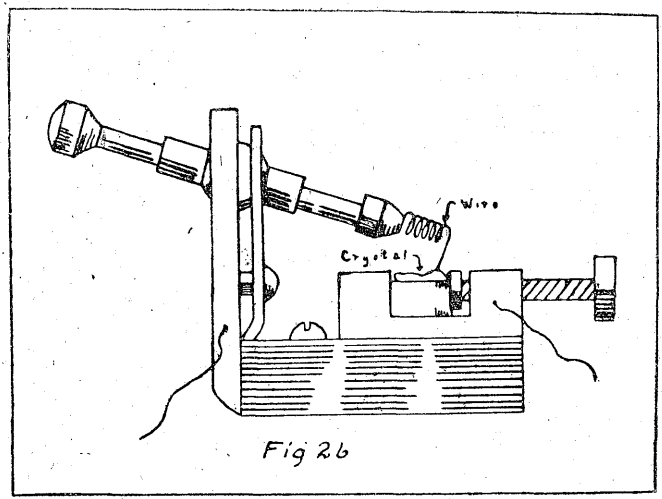
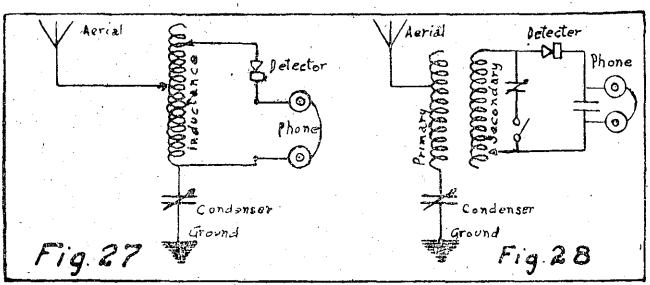


FIG. 26.

or by the alternating current frequency of the alternator. This wave train frequency is therefore called " audio frequency ", as was already pointed out, since it is of a frequency to which the telephone receiver and the ear will respond. The limits of audible frequencies are about 20,000 and 16 cycles per second.

There is quite a large variety of detectors. One used very widely on account of its simplicity is the crystal detector, a sketch of which is given in Fig. 26. It consists of a crystal of galena (lead sulphite) or iron pyrite (iron sulphite) held in

a special support. A fine metal wire is then maintained in position so that its point will rest with a light pressure against a spot of the crystal's surface. Certain points of the crystal surface give better results than others and almost completely stop the current flow in one direction. Such a spot is found by touching the wire point at various points of the surface, until the sound in the telephone receiver is great enough to be readily heard. This adjustment does not have to be repeated often if not disturbed by mechanical vibration. The selection of a good detecting spot on the



Damped Wave Receiving Circuits. FIG. 27-Inductively and Conductively Coupled. FIG. 28-Inductively Coupled.

crystal may be made by exciting the set by means of a small testing buzzer provided for the purpose.

From the previous paragraphs, it may be seen that a receiving set may be constructed by connecting an aerial to ground through an adjustable inductance and condenser, and a telephone receiver shunted by a crystal detector, fig. 25. The set is tuned by adjusting the inductance and the condenser until maximum response is obtained in the telephone. The high frequency alternating current induced in the antenna will then flow through the receiver in one direction (one half cycle), and through the detector in the other. Such a set, although very simple, has the disadvantage that the detector introduces a high resistance in the antenna, which prevents the latter from oscillating at maximum amplitude.

A better arrangement is therefore obtained by coupling the telephone and detector circuit to that of the antenna. This coupling may be inductive or capacitive. In case of the former, one of two coils may be used, just as in the case of sending sets. Such sets are shown in fig. 28. With circuits of this kind, the antenna circuit oscillates freely under the influence of the incoming waves, and induces the high frequency currents in the telephone circuit.

Tuning.

The waves emitted by transmitting stations are propagated in all directions, so that a receiving station may hear not only the signals of a particular station, but also those of all sets working within a good distance of it. It is evident that the reading of telegraphic signals would be absolutely impossible if it were not possible to weaken or eliminate all of the disturbing signals and on the other hand amplify the ones desired. If the disturbing signals are of wave lengths differing from that of the signal to be received, this selection of signals can be made by proper tuning of the receiving set.

When the resonance is very sharp, the receiving station may be sharply tuned. Reception by coupled circuits is almost always employed on account of the good tuning it affords, due to the possibility of double tuning both the antenna and the local oscillating circuits.

Coupling.

To maintain good tuning, it is necessary to avoid too close coupling, that is to say, to avoid bringing the two coupling coils too near together since in that case, the mutual reaction between the antenna and the oscillating circuits distorts the waves and decreases the sharpness of the tuning.

Care must be taken in the use of radio apparatus, not to put any metallic mass in the vicinity of the coils as this would be the seat of induced currents, the production of

which would take energy from the oscillating circuit and damp the oscillations.

Sources of trouble.

It has just been seen that tuning allows the elimination or the weakening of the effect of transmitted waves different in length from the ones to be received. For waves of nearly the same length, this elimination of interference will only be possible when the tuning is very sharp. This depends not alone on the receiving station. If the waves received have high damping, each incoming wave train is made up of only a few oscillations, and does not act very long on the receiving antenna. Sharp tuning requires the rhythmic repetition of the effects of a large number of successive oscillations. Oscillations of the lowest damping should therefore be used when sharp tuning at the receiving station is desired.

If two oscillations have the same or very nearly the same wave length, tuning cannot separate them, but receiving of either is nevertheless possible if the two sending stations have clearly defined tones. This depends on the difference in spark frequency (audio frequency) of the two transmitting sets, the higher this frequency, the higher the pitch of the note heard at the receiving station.

Other causes of serious trouble are electrical atmospheric disturbances, aurora borealis, the passage of electrified clouds, hail storms and drops of electrified rain. The atmospheric electrical discharges produce oscillating currents in the antenna, and the telephone receives them giving a series of mixed sounds. These noises are generally a series of impulses of low tone with the result that the high pitched musical signals are the least disturbed by atmospheric interference. This is often very troublesome in long distance receiving from powerful stations which work with long wave lengths. Although less intense on small field antenne, the atmospheric disturbances sometimes cause serious trouble in reading signals.

Influence of Ground Contour.

On a great plain, the waves are propagated normally in all directions from an antenna. In hilly regions, on the contrary, steep slopes form screens and deflect the waves. Near the foot of a steep hill, there is a region of shadow which is not reached by the waves coming from the opposite side. The waves reflected from the two slopes of a narrow valley, follow the valley. As it is necessary to avoid placing the receiving antenna in a region of shadow, an exposed position is sometimes preferable.

Telegraph lines and metallic conductors used in the construction of houses absorb the waves and their proximity is usually detrimental. In forests, an antenna receives and transmits badly because the sap of the trees conducts electricity and may be the seat of induced currents. When an antenna must be hidden in a wood it should be placed as close as practical to the edge from which the waves are coming, or in the middle of a glade. If possible, it is advantageous to install it above the trees. Interference with the waves by trees and houses is greater, the shorter the waves.

It is also necessary to choose a position for the ground connection where the ground is damp and conducting. An antenna in a position not entirely exposed may be good for transmitting and receiving waves in one direction, but not for another.

CHAPTER III.

UNDAMPED WAVE RADIO TELEGRAPHY.

The fact that the efficiency of the transmitting sets is greater, and that the tuning of the receiving sets is sharper for the waves having the smallest damping, gives rise to the desirability of using waves that are not damped at all. This means that an alternating current of constant amplitude and of radio frequency must be generated in the transmitting antenna. The use of alternators for this purpose presents very considerable difficulties, and is absolutely impracticable for portable sets such as are needed for military purposes. However, a new method of generation of undamped wave oscillations has come in for a very extensive application, consisting in the use of the three electrode vacuum tube.

Vacuum Tubes in Radio Communication.

Upon gaining a general idea of the newer apparatus used in the transmission and reception of communications by radio, one soon becomes impressed with the importance of the vacuum tube, as it occurs in nearly all of the principal types of modern radio apparatus. The same tubes may be used to transmit, to receive, to detect, to amplify, to modulate and to serve other important functions necessary to radio communication as it is now known. Their practical application to these numerous uses is an accomplishment of the last few years and the possibilities for further application are by no means exhausted. In fact, the whole field of radio work has been greatly influenced by the development of vacuum tubes, and by virtue of this it is now possible to effect radio communication through greater range with lower power and with greater selectivity than was formerly possible. Also, the tube has enabled the construction of appa-

ratus for these uses, which is readily portable—a most important feature in connection with military communication systems.

How these tubes work and how they can be made to serve such a multiplicity of purpose, are the questions which most naturally arise in the mind of every student. Answer to these two questions involves much highly theoretical discussion and more than one way of explaining the action in some instances. The following paragraphs, however, are intended to give an explanation general enough to be easily understood, while avoiding dual explanations of any particular action.

Electron Flow in Vacuum Tubes.

The electron flow in a vacuum tube will first be studied in a bulb containing two metal electrodes; one, a filament which may be heated by a local battery A, and the other, a flat piece of metal, called the plate, Fig. 29. If a battery B is connected across the tube with its negative pole to the filament and its positive pole to the plate, no current will be indicated on the ammeter I inserted in the circuit. However, if a current is passed through the filament by means of a battery A, bringing the filament to a red heat, a current of a few millamperes will be shown by the ammeter to flow in the circuit BFPIB. Thus, the heating of the filament causes a current to flow across the open space of the bulb. This may be accounted for as follows.

The explanation of phenomena observed in a great number of experiments has led to the assumption that there exists extremely small non-material particles having a definite negative charge of electricity. These particles are called electrons. They move in great numbers between the atoms of any metal. At ordinary room temperatures, they do not escape out of the metal, in most cases, but when the metal is heated, the material atoms vibrate about their mean position of equilibrium with a speed and amplitude which

increases with the temperature. The electrons, which follow the atoms in this thermal agitation, likewise acquire increasing speed as the temperature of the metal is raised. When it becomes red hot, the speed of the electrons is so high that they leave the metal, This phenomenon is illustrated by the experiment described above, wherein the filament was made red hot and an electrostatic force was present, due to the

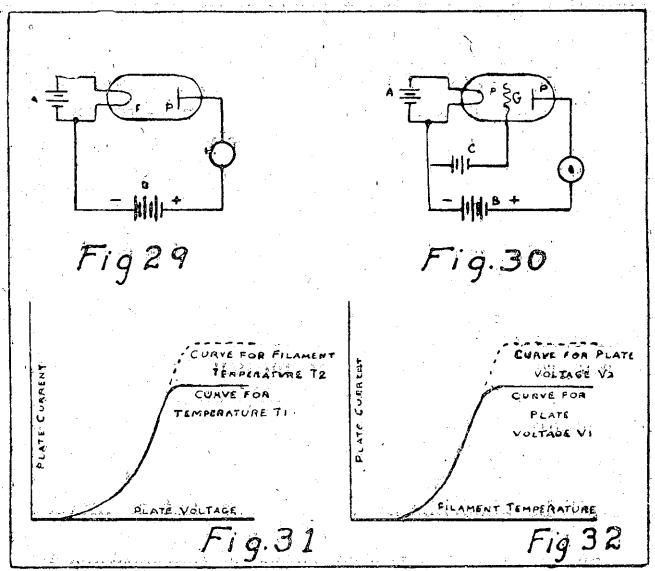


FIG. 29, 30 and 31-Two-Electrode Vacuum Tube and Characteristic Curves
FIG. 32-Three-Electrode Vacuum Tube.

connection of the B battery in the plate circuit, which tended to move the negative electrons from the filament to the plate by repulsion from the filament and attraction by the plate. Under these conditions, the electrons travel from the filament to the plate at a speed which may attain tens of thousands of miles per second, and transport negative charges across the space in the bulb from filament to plate. The passage

of electrons, each carrying its charge of electricity from filament to plate, constitutes a flow of electricity which is an electric current. It should be noted that the electron flow is from the negative filament to the positive plate, while the electric current flow is just the opposite from the positive plate to the negative filament. This is not difficult to explain, as the direction of flow of the electric current from positive to negative poles is a mere assumption which was made before the discovery of the electron flow, and could just as well have been assumed to be in the opposite direction.

If the polarity of the B battery, Fig. 29, is reversed, no electric current will flow through the ammeter, as the plate will be negative and will repel the negatively charged electrons and thus prevent any flow of electricity across the tube.

Operation of Two-Electrode Tubes under Various Conditions.

The two electrode vacuum tube is very frequently called a valve. For a given filament temperature, T_1, a definite number of electrons is emitted per unit of time. The number of electrons per second which will travel across the tube and reach the plate is the measure of the current in the plate circuit, and it varies within limits approximately as the square of the voltage across the space between plate and filament. As this voltage is increased, a certain value will be reached at which all electrons emitted by the filament will be absorbed by the plate, so that no increase of current will take place for higher values ot the plate voltage. This is shown in Fig. 30, curve for temperature T_1. In order to increase the plate current, it is then necessary to raise the filament temperature to some higher value, T_2, when the current curve will rise to a new value before bending over to the horizontal position.

Now, if the plate voltage is kept at a constant value, V_1, and the filament temperature raised by increasing the current from the battery A, the number of electrons emitted by the filament will vary approximately as the square of the filament temperature figured above the red heat tempera-

ture (1600° absolute for tungsten filament) until a point is reached where the electrostatic field, due to the negative charge of the electrons in motion in the tube, will exactly counteract that due to the positive charge of the plate. This condition is called the « space charge effect ». Any further increase of filament temperature would then tend to increase the number of electrons in the tube, and therefore the space charge. The latter then outweighing the charge of the plate, would repel some of the electrons back into the filament. A state of equilibrium is thus reached whereby the current remains constant independently of further increase of filament temperature, and the current curve will bend over and remain at a constant value of plate current, Fig. 31. If there is no potential difference between the filament and the plate, the space charge effect will prevent the flow of electrons to the plate.



FIG. 33.—French Audion Bulb.

To increase the current, it is then necessary to increase the plate voltage to some higher value, V_2. The upper limit to this voltage increase is that which prevails when a blue glow is observed around the plate. On old and defective tubes, this blue glow may appear at normal operating voltages, and then it is an indication of poor vacuum. It causes a hissing noise in the telephones and prevents good operation of the tubes.

The Three-Electrode Vacuum Tube.

The three-electrode tube, or audion bulb as it is also known, see Fig. 33, is a highly evacuated bulb containing a filament and a plate like the two-electrode tube already described, but in addition having a grid or wire screen support midway between the plate and the filament. The filament is made of some material, usually tungsten, or platinum coated with oxide, which when heated liberates a quantity

of electrons from its surface. The plate electrode is placed near to and usually encloses the filament.

It may take various forms, such as two flat plates, a cylinder, a cone, etc. The grid is made up of a network of metal wires, sealed into the tube and supported in such a manner as to be interposed between the filament and the plate so that any passage of electrons or current between these electrodes must pass through the grid.

If the plate is made positive with respect to the heated filament, a flow of electrons will take place from the filament to the plate, as explained in connection with the two-electrode tube. In their flow, the electrons must pass through the wire mesh of the grid, which can be made to have a controlling influence on the electrostatic field in the tube. Thus the rate of flow of electrons from filament to plate may be regulated by changing the potential of the grid with respect to the filament. If the grid is given a potential slightly negative to the filament, which may be done by a battery C, Fig. 32, it will repel some of the electrons emitted from the filament, but many of them, due to their high velocity, will pass through the mesh of the grid and reach the plate. Now, as the potential of the grid is made more negative, Fig. 34, the plate current will gradually decrease until the negative grid potential will be great enough to prevent all electrons from leaving the filament, thus stopping the plate current flow entirely. This is due to the action of the field created by the grid which has neutralized that created by the plate.

If the grid is made positive instead of negative, more electrons will be attracted toward the plate than would pass without the influence of the grid potential, and the plate current will be increased until saturation of the tube occurs. This saturation may be explained as follows: As the grid is made more and more positive, the plate current increases at a greater rate than the grid voltage, Fig. 34, so that a grid potential will be reached at which the space charge due to the negative electrons passing across the tube

will exactly counteract the influence of the positive grid potential. When this condition prevails, the maximum plate current is obtained. Further increase of grid potential tends to increase the plate current and therefore the space charge, but the latter, increasing at a greater rate, overbalances the influence of the grid and the plate current thus remains practically constant up to a certain grid voltage, beyond which the plate current slowly decreases. The limitation of plate current is due not only to the space charge effect, but also to the absorption of electrons by the grid in increasing numbers as its positive potential is increased. This absorption gives rise to a current flow in the circuit FGCF, called the grid current.

From the last two paragraphs it can be seen that if the grid is made alternately positive and negative, the plate current will be accordingly increased and decreased about its normal value in the absence of the grid. By means of a small dry battery it is possible to fix the mean potential of the grid at any point on the characteristic curve. The value of this mean potential (which is the grid potential existing when no oscillations are taking place) determines the operation of the tube as a rectifier or as an amplifier. The variations of grid potential modify the plate current, and the tube thus acts as a relay controlled by the very small variations of grid potential.

The electrostatic capacity of the grid being very small, the variations of its charge involve correspondingly small amounts of energy. It is therefore very sensitive, and having no inertia, it is able to follow the extremely rapid oscillations encountered in radio telegraphy-oscillations of frequency far beyond the range of mechanical or more common electrical devices.

Detector Action of Vacuum Tubes.

A simple connection of the three-electrode tube as detector is shown in Fig. 35. When a train of damped oscillations strikes the antenna, it produces an alternating voltage

in the antenna circuit as represented in Fig. 36-A. This voltage induces a similar voltage in the secondary coil, ab, of the receiving tranformer connected in the grid circuit, which is superimposed on the normal grid potential given

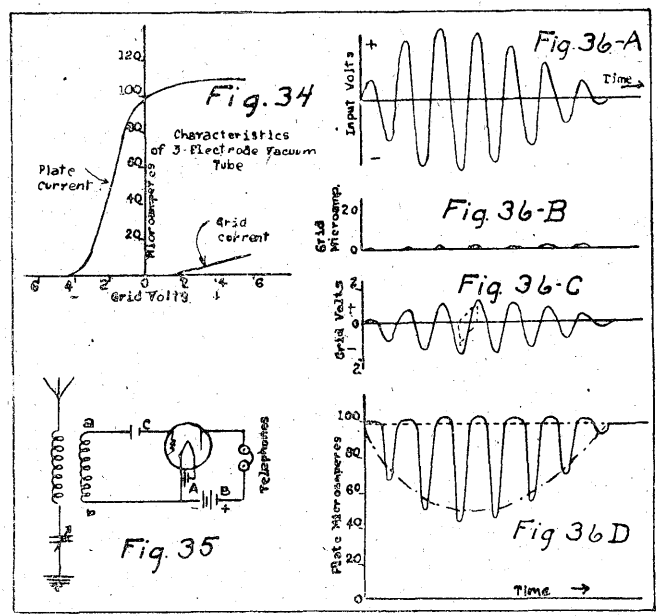


FIG. 34-Characteristics of Three-Electrode Vacuum Tube. FIG. 35-Three-Electrode Tube Used as Detector. FIG. 36-Analysis of Detector Action; (A) Input Voltage Due to Incoming Waves; (B) Resulting Grid Current; (C) Grid Voltage Resultant of Induced and Counter EMF.; (D) Current in Plate and Telephone Circuit.

by the battery C. The component of the grid current due to the alternating voltage will flow only during the positive half cycle of the oscillation, as seen from the grid current characteristic curve, Fig. 34, and indicated in Fig. 36-B. This current flow from grid to filament has a tendency to equalize the potential difference between them, so that the

actual grid voltage, instead of following a symmetrical curve similar to the antenna voltage, will be asymmetrical, the amplitude of the negative half of the wave being greater than that of the positive half, Fig. 36-C, as no current is then flowing.

Referring to the grid current characteristic curve, Fig. 34, again, it will be seen that an asymmetrical change in plate current will result from this asymmetrical change in grid potential, Fig. 36-D.

When flowing through the telephone receivers, this plate current will be smoothed out by the inductance of the telephone into a single unidirectional impulse; and such an impulse being produced for every wave train, a sound will be produced in the telephones at a frequency corresponding to that of the frequency of the trains. The operation of the tube as a detector will be best when the normal grid potential is near the upper bend of the characteristic curve, and will gradually become less effective as this potential is brought nearer to the lower bend, until a point is reached when rectification does not occur and where the asymmetrical variations of grid voltage produce symmetrical variations of plate current, Fig. 37. This particular part of the curve is used for amplification, as will be explained in a later paragraph. Beyond this point of no detector action, however, the rectifying properties of the tube reappear, so that it may be used as a fair detector on the lower bend of the characteristic curve (1).

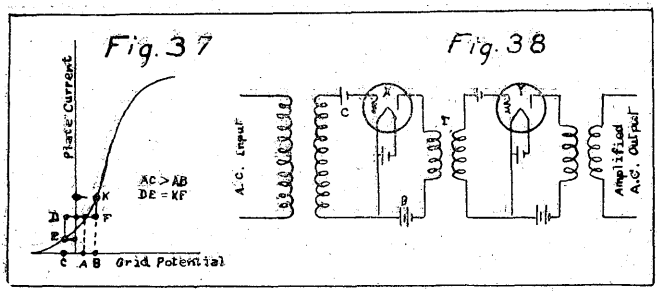
Grid Condenser Connection for Detector Action. — If the C battery, Fig. 35, is replaced by a small condenser (0005 mfd.), the detector action of the tube is different from that described above. During a period of no oscillations, the plate current assumes a certain value determined by the B battery and the filament temperature. If now an oscillation strikes the antenna, the grid will be made alternately positive and

(1) The curves of Fig. 36-B, 36-C and 36-D should lag about 180° behind the voltage curve of Fig. 36-A. This has not been shown because of its tendency to confuse.

negative. When it is positive, it attracts electrons, and being insulated from the filament, it retains these electrons and acquires a negative charge which lowers the plate current. The negative charge of the grid is then caused to leak off either through the condenser dielectric or through a high resistance shunting the condenser, so that by the time the next train of waves arrives, the grid is again at its normal potential.

Amplifier Action of Vacuum Tubes.

The energy of a signal wave at the receiving station is very often so extremely weak that it is necessary or advantageous to amplify the signals to make them more easily read. In radio telephony, this amplification has a special



Three-Electrode Vacuum Tube Used as Amplifier. FIG. 37-Point on Characteristic Curve Giving Symmetrical Amplification. FIG. 38-Connection for Cascade Amplification.

importance. The problem consists in producing changes in the telephone receiver current which are exactly proportional to the amplitude of the incoming waves, and without distortion. As outlined in the explanation of the detector action of the tube, a symmetrical oscillation in the primary (input) circuit induces an asymmetrical oscillation in the secondary or grid circuit, the voltage amplitude being less for the positive half cycle than for the negative. A point

may be found on the characteristic curve of the tube, Fig. 37, where the asymmetrical variation of grid potential produces symmetrical variation of plate current, so that the variations of the plate current will reproduce exactly those in the antenna without distortion. Furthermore, the very slight energy of the wave acting on the grid, produces very large variations of plate current because of the relay action of the tube, and this explains the amplification of the antenna oscillations.

To separate the amplified alternating current from the steady direct current in the plate circuit, the pulsating plate current is passed through a transformer, Fig. 38, which delivers the amplified alternating current at its secondary terminals. A second tube may be used to further amplify this wave if necessary, as tube Y, Fig. 38. When this is done, the process is called cascade amplification.

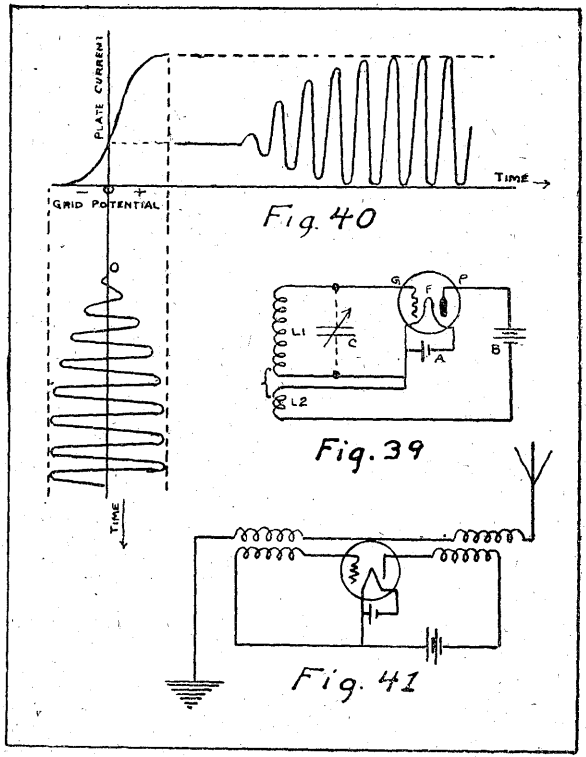
Oscillator Action of Vacuum Tubes. — Undamped Wave Transmission.

As the vacuum tube can be used as an energy amplifier, it can be made to generate and sustain oscillations by feeding back upon the grid circuit the energy amplified in the plate circuit. This can be done by electromagnetically or electrostatically (or both) coupling the grid circuit to the plate circuit. Such an arrangement is shown in Fig. 39, where the grid circuit GL_1FG is coupled electromagnetically to the plate circuit PL_2FP by means of the inductances L_1 and L_2.

If now a small change is produced in the potential of the grid, a change in plate current involving a greater amount of energy will result. This plate current, flowing through L_2 will in turn induce an emf. in L_1 of greater magnitude than the original potential change in the grid circuit. This produces a new change in the potential of the grid so that oscillations continue to increase in this manner until the amplitude of the plate current reaches the bends of the characteristic curve of the tube. At this point the oscillations

will have reached their final constant amplitude. Fig. 40 is a graphical representation of this phenomenon.

To produce oscillations, it is of course necessary that the values of inductance and capacitance, and the coupling, be



Vacuum Tube Used as Oscillation Generator. FIG. 39-Connection for Undamped Oscillation Generation. FIG. 40-Analysis of Generator Action. FIG. 41-Example ot an Undamped Wave Transmitting Set.

chosen of such values that the emf. induced in the grid circuit will be in phase with the alternating component of the plate current. To generate oscillations of any given

frequency, it is simply necessary to tune the oscillatory circuit by means of the condenser *c*, for instance. The circuit L_1C will then oscillate at its natural frequency, and these oscillations will be sustained by the plate current. The oscillator can then be coupled to an antenna and made to induce undamped oscillations in it which will be radiated into space. Such a circuit is shown in Fig. 41, but there are any number of connections which will enable the use of the three electrode tube as an oscillation generator. To use such a set as a radio transmitting set, it is simply necessary to insert a sending key at some point of the circuit. Then whenever the key is depressed, the antenna will radiate undamped waves.

Reception of Undamped Waves.

The reception of such signals is different from that of damped wave signals. The principle of damped wave reception is that every wave train, after being rectified, deflects the diaphragm of the telephone receiver, which then between two wave trains, springs back in place.

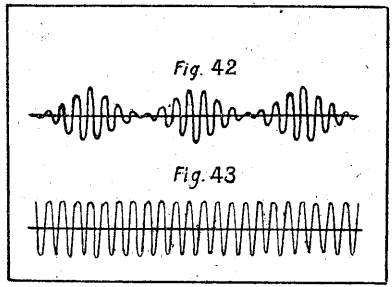


FIG. 42-43.

The succession of wave trains then sets the diaphragm into vibration at the spark frequency of the transmitting set.

In undamped wave telegraphy, the oscillations are not divided into wave trains: they are emitted without interruption, and with a constant amplitude, Fig. 42. Hence, the telephone diaphragm is deflected at the beginning of the signal, and so remains until the end of the signal, for the succession of the individual waves is so rapid that the diaphragm will not respond to the corresponding high rate of

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vibration. There is consequently no audible vibrations of the diaphragm. However, audible vibrations in the receiver may be obtained by several different methods.

One method consists in utilizing a mechanical interrupter called a " tikker " which is connected in the circuit at the receiving station, in such a way that it periodically interrupts the current through the telephone receivers—the current induced by the incoming radio waves — and thus breaks it up into current-off-and-on periods of a low frequency to which the diaphragm will respond. This method has the disadvantage that all the energy received by the antenna during the current—off periods is lost.

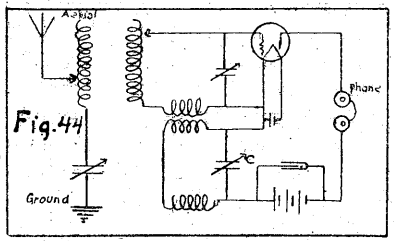


FIG. 44.—Schematic Circuit of an Autodyne Receiving Set.

A more recent and better method consists of a scheme for transforming at the receiving station, the continuous waves of constant amplitude into waves the amplitude of which varies periodically, Fig. 43. This end is attained by the application of the phenomenon, familiar in the study of sound wave propagation, called "beats". This is called the " heterodyne " method of reception.

The receiving set is tuned to the frequency of the incoming waves by means of its adjustable inductance coils and condensers. Then, undamped waves of slightly different frequency are generated locally at the receiving station and superimposed upon the oscillations in the detector circuit due to the incoming waves. The result is that the two rectified alternating currents add together algebraically to produce beats in the amplitude of the current through the telephones, of a frequency equal to the difference between the frequencies of the two currents.

Such a set may be constructed by modifying the receiver circuit shown in Fig. 35. It is simply necessary to couple the plate circuit of the detector tube to the grid circuit. The tube then acts simultaneously as a detector for the incoming waves and as a generator for the local undamped oscillations, Fig. 44. Such an arrangement of circuits is called an "autodyne" receiving set. The frequency of the local oscillations, may be changed by adjusting the setting of the condenser C for instance, and this will change the beat frequency and therefore the pitch of the sound in the telephone. A very pure note of any pitch may thus be obtained at the will of the receiving operator. The use of such sets allows exceedingly sharp tuning and practically eliminates all interference from other sending stations.

CHAPTER IV.

RADIO TELEPHONY.

The vacuum tube or audion bulb may be used for radio telephonic communication within limited ranges. The principles involved are the same as for undamped telegraphic transmission with sustained waves by means of the tube or audion, except that the sending key is replaced by a device for varying the intensity of the energy radiated, thus producing sounds at the receiving station corresponding to the inflections and modulations of the voice.

Several simple schemes have been evolved for producing these variations, the features of each being arranged in accordance with the conditions under which it is to be used. In all of them, however, the microphone by its variations of resistance under the influence of the voice acts upon the amplitude of the continuous sustained waves set up in the antenna by the vacuum tube and coil arrangement used in undamped telegraphy.

At the receiver, after detection, without the use of the heterodyne, the mean current in the telephones follows the variations of intensity of the waves received and reproduces the words spoken into the microphone at the transmitting station.

Microphone in low frequency circuit.

A simple means of causing the microphone to act upon the amplitude of waves emitted by an antenna consists in causing the variations of resistance in the microphone to modify the grid potential of the transmitting bulb. A battery P, a microphone, and the primary of a transformer are placed in series, and the secondary of the transformer is inserted in series with the grid so that the emf. of this secondary acts on the grid, see Fig. 45. When one talks into the

microphone the point of operation of the tube is thus shifted along its characteristic curve and a modification of the amplitude of the plate current and hence of the radiated wave results. The secondary of the transformer is shunted by a small condenser c which allows the high frequency currents to pass without traversing the secondary.

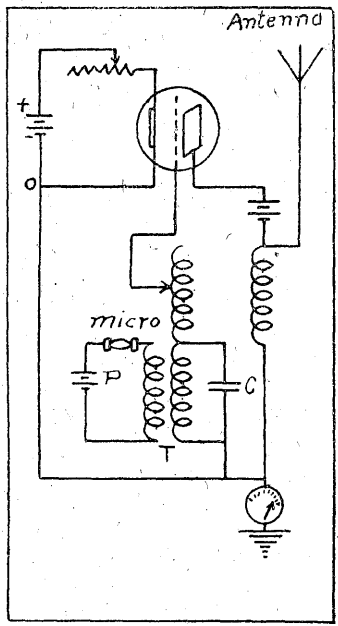


FIG. 45. — Microphone in low frequency circuit.

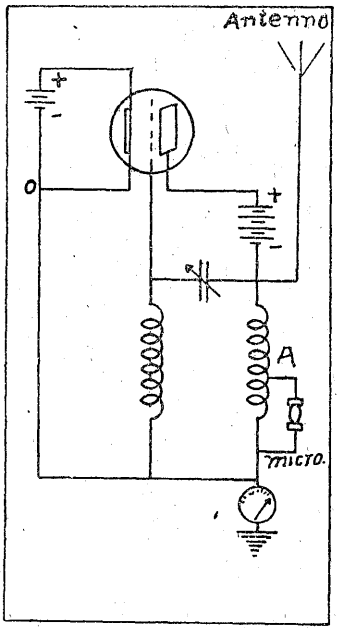


FIG. 46. — Microphone in high frequency circuit.

If the grid variations resulting from this arrangement are too feeble, a valve amplifier may be used to amplify the variations of current in the microphone and the amplified variations are then impressed on the grid resulting in a correspondingly greater variation in the radiated wave amplitude.

Microphone in high frequency circuit.

Another quite simple arrangement consists in shunting the microphone directly across several turns of the inductance or plate coil in the transmitter as in Fig. 46.

When the heating current is turned on, the transmitter sends out continuous sustained oscillations. When the microphone is used in speaking the variation of resistance therein furnishes a shunt of varying resistance across the several turns of the plate coil. This produces a greater or less resistance in the filament-plate circuit as well as in the open oscillating circuit composed of the antenna, inductance coil A, and ground, in accordance with the modulation of the voice. The effect of an increase in the plate circuit resistance is to decrease the amplitude of the current flowing from the battery to energize the antenna, and the amplitude of the oscillation is also directly decreased since there is a slight increase of resistance in the open oscillating circuit itself. The combined effect then is a considerable reduction in the amplitude of the transmitted wave. The effect of a decrease in resistance in the microphone and hence in the plate and oscillating circuits is the reverse and evidently results in an increase

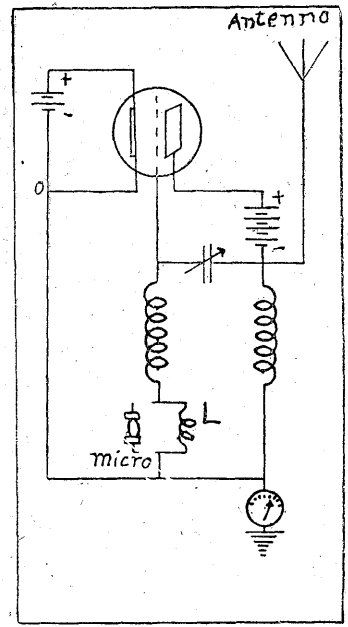


FIG. 47. — Microphone in series in grid cicruit.

in amplitude of the transmitted wave. This scheme is used in several of the French field sets designed primarily for sustained wave telegraphy, and gives excellent results within limited ranges. The E 10 and E 3 series are examples of this type. When the sets are of higher power, and the current intensity becomes greater than that allowed in the ordinary microphone it is necessary to use a special design of microphone. However, the common telephone transmitter gives good results with the sets above mentioned.

For more powerful sets a different arrangement makes it possible to obtain great variations of amplitude in the antenna while admitting only small high frequency currents into the microphone. A transmitter of the audion type is used, and the grid is given a sufficiently high self-inductance so that the adjustment which corresponds to the wave to be emitted necessitates only an extremely small capacity of the condenser. The microphone is placed in series in the grid circuit, being then traversed by a very small current. It has, however, a very noticeable action on the antenna current. The circuit consisting of the grid inductance and the coupling condenser, has a free period of oscillation less than that of the antenna. The variations of resistance in the microphone act upon the phase difference betwen the current in its oscillations and the difference of potential between its extremities, thus producing changes in the grid potential.

These changes in grid potential produce corresponding changes in the amplitude of the antenna oscillations with the effect already described. Ordinarily an inductance L is placed in parallel with the microphone so as to avoid the disturbance of tuning which might result from a complete cutting of the grid circuit by the microphone. See Fig. 47.

Microphone in an independent circuit which absorbs energy.

Still another method of producing the fluctuations in radiated amplitude is found in the arrangement shown in

Fig. 48. A high frequency alternator is connected directly into the antenna, and sets up oscillations of constant amplitude therein. Inductively coupled to the antenna is the plate circuit of a three-electrode vacuum tube, or audion, the grid of which is maintained at a considerable negative potential with respect to the filament by means of a battery C.

The current passing through the antenna coil A, induces an emf. in the plate coil B coupled to it and therefore a potential difference between the filament and the plate of the tube or audion, but on account of the strongly negative potential of the grid, this emf. produces a very small current in the plate circuit, i. e. the energy transferred from the antenna circuit to the plate circuit is very small. If the grid is made less negative, the same induced emf. in the plate circuit will produce a larger current, so there will be a larger transfer of energy from the antenna circuit to the tube. The tube will have absorbed power so to speak from the antenna circuit. The result of this absorption is that the normal output of the generator is divided between the two circuits in proportion to their impedances so that part only of the energy normally radiated without the reaction of the plate will now be radiated. The more positive the grid of the tube, more freely will current flow in the plate circuit, and the greater will be the power absorbed by the tube and therefore the less the amount of energy radiated. This variation of grid potential

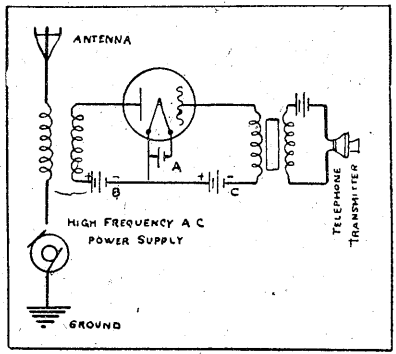


FIG. 48.
Microphone in independent circuit.

is brought about, as in the first method described above, through the use of a telephone transmitter coupled to the grid filament circuit through a transformer, as shown. The voice inflections and modulations result in varying potential impressed on the grid, and proportional variations in the energy radiated are produced, as described. The high frequency alternator may be an audion bulb or vacuum tube.

The vacuum tube, or audion may be used not only to modulate the a. c. power output of the high frequency alternator, as described, but to modulate the d. c. supply to that generator, thus accomplishing in another way the same final result,—the modulation of the antenna output. If the a. c. generator is an audion bulb, the modulator tube may be connected in parallel with the transmitting bulbs across the direct current supply, or plate battery, and the microphone or telephone transmitter is connected to the primary of a small transformer, the secondary of which is placed in the grid circuit of the modulator tube. As the resistance of the modulator tube is changed by the variation of grid potential due to the action of the voice on the telephone transmitter the amount of power to be transformed into oscillations by the oscillator tube will be correspondingly modulated.

Reception.

At the receiving station in radio telephony, the mean current variation due to the increase and decrease of amplitude of the intercepted wave brought about as above described, affects the telephone receiver after detection, and the disc vibrates exactly in accord with the inflections and modulations of the speaker's voice as in wire telephony. As stated, no heterodyne is used.

Since the oscillations set up in the receiving antenna are undamped, their syntony is good and it is possible to receive with a very loose coupling between primary and secondary.

The range is much less than that of the same set used for radio telegraphy, because the benefit of the heterodyne amplification is lost and also because the telegraphic key interrupts the wave entirely, while a telephonic transmitter only varies its amplitude.

Certain vowels, such as "a" or "o" produce large variations of the microphone resistance, while the vowel "i" produces smaller ones. If the action of the microphone has been so adjusted as to attain the maximum variation of amplitude for the vowels "a" and "o", the vowel "i" is less effective. As in order to understand spoken words it is necessary to detect all the syllables, the range is limited by the variations of amplitude (relatively small) of the less effective syllables. It is necessary to avoid too close a coupling for the microphone, for each strong syllable would reduce the intensity to zero in the antenna and would be badly reproduced.

This is also the reason why it is necessary to avoid loud tones in radio telephony, as in the ordinary telephone. When the transmitter is in an airplane the noise of the engine tends to make one speak too loudly. It is necessary to avoid yielding to this tendency.

CHAPTER V.

DESCRIPTION AND USE OF RADIO EQUIPMENT.

Transmitting set, Portable type N° 3 (French) — (Trench Set). General characteristics.

These portable sets, (see figure 49), are intended for use as near the front as possible, and in the immediate vicinity of the firing line, in order to allow liaison (transmission only) with a point situated behind the lines where a receiving set similar to the receiving set, Artillery Type A-I, is erected.

The equipment and design of these sets are such that they are very portable and rapidly and easily erected, relatively not very visible, and easily operated under all circumstances. Consequently, the sets are not very powerful and, on account of the limited capacity of the accumulators, cannot work for a very long period. They should be used only for very short messages.

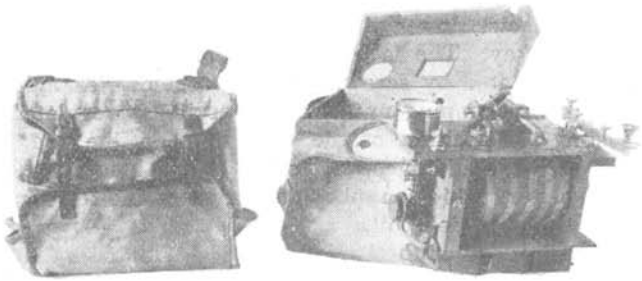


FIG. 49. — Transmitting Set, Portable Type-French.

The set, Type No. 3 belongs to the direct excitation of 30 watts nominal power. An induction coil supplied by a 10 volt set of accumulators supplies power through the primary to the secondary, antenna, and earth.

The primary current is interrupted by a breaking device operated electromagnetically by the core of the induction coil.

The antenna is a low, directive antenna supported by special supports at a height of about one meter above the ground; its length may be 25, 30, or 35 meters according to the wave length desired.

The frequency of the note emitted is about 100 vibrations per second.

The transmission limit of this set, with a receiving set similar to that used by the artillery, is, in certain regions, about 2 ½ miles. It may be considerably increased, if the antenna be placed higher.

Each set is packed, so as to be easily portable, in five separate parts, which include the transmitting box, accessories, antenna material and two storage batteries.

Description of the equipment.

The transmitting box (see figure 50) consists of an induction coil with a mechanical break in the primary. A condenser shunted across the break prevents sparking at the break contacts. In series with the primary coil is an ammeter and a key. The latter is of the plunger type, and its play is regulated by screwing the contact carrier tight by means of a clamping nut; the key spring is regulated by adjusting the position of the stop ring on the rod. By means of two binding posts, connection is made with the 10 volt battery which supplies power, when the key is pressed, to the induction coil.

The secondary of the induction coil is shunted by means of an unsymmetrical, adjustable spark gap, the electrodes of which are connected with two binding posts, respectively for ground and antenna connection.

All of the different parts are accessible. The main panel, on which the apparatus is mounted, may be removed by taking out the screws which hold it to the sides of the box

The method of adjustment is explained below. The adjustment of the breaking device is shown inside the cover of the box.

A canvas carrying case is provided for easy transportation.

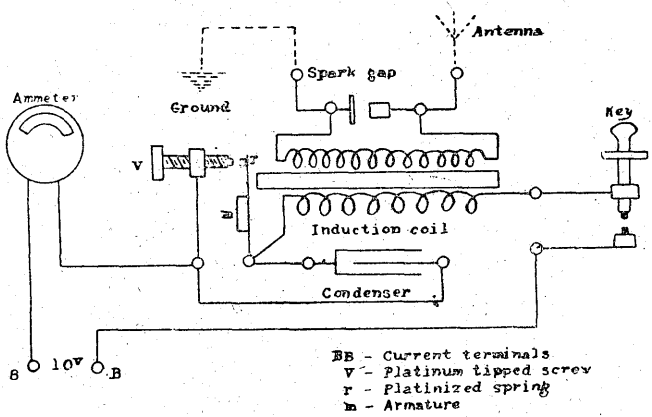


FIG. 50. — Transmitting Set, Portable Type No 3.

Equipment for ground connection and antenna.—The antenna equipment is composed of two hinged wooden supports with accessories for mounting, and the necessary antenna wire. Both arms of the supports are constructed so that they may be folded up for transportation : the upper section is provided with an insulator to which the antenna is fixed by means of a snap-hook. Each support is provided with guy rope and iron peg. The pull of the wire is balanced by the guy rope attached to the peg driven into the ground. The wooden supports are given suitable inclination, and the antenna may be lowered by relaxing tension on one of the guy ropes during intervals between transmission.

The connection between the antenna and the lead-in wire is obtained by twisting both wires together, or by means of a plug and socket.

The ground connection consists of a strip of wire mesh, or ground mat, soft enough to make good contact with the ground: it is provided with two terminals for connecting to the wire coming from the station. A ground stake permits improvement of the ground connection.

Each set is provided with two sets of antenna and ground connection material. (One as spare).

Accumulators. (*Storage batteries*).—Each set is provided with two 10-volt, 16 ampere hour batteries, provided with a shoulder strap for carrying purposes. Care must be taken that they are not upset when placed on the ground. In place of these batteries, two storage batteries of 10 volts, 20 ampere hours were formerly supplied and in some cases may still be sent out.

Accessories and spare parts.—Each set is provided with accessories contained in a canvas case, which may be attached to the belt. According as may be ordered in the field, these accessories may be taken to the first line, with the station, or left behind with the second set of antenna material and the second battery.

Adjustment of the equipment.

The adjustment of the equipment (except that of the spark gap) must be made in advance. This adjustment is very stable and is not easily changed but would be very difficult to make under fire of the enemy.

The adjustments necessary are the following:

Adjustment of the breaking device.

Adjustment of the antenna.

Adjustment of the spark gap.

Adjustment of the breaking device.—The only part of the breaking device which it is necessary to adjust is the platinum tipped screw. This is operated by a large milled red fibre knob and a lock nut fitted with a milled ebonite head. This allows the platinum tipped screw to be properly adjusted (it must be turned from right to left until it touches the head of the screw).

The platinum tipped screw must be adjusted so that when the coil is connected to a 10 volt battery, the ammeter will indicate about three amperes.

The breaking device must be forcibly set into motion instantly the coil is connected, care being taken that the distance between the core and the blade is not more than one or two millimeters. The screw which secures the core is placed on the left flange of the coil and must be tight.

Adjustment of the antenna.—The length of the antenna wire must be adjusted to one of three lengths — 25, 30 or 35 meters corresponding to the approximate wave-lengths desired, 100-120-150 meters.

Adjustment of the spark gap.—The longest spark-length of which the coil is capable should be found. This test must be made with the average antenna after it has been unwound and insulated from the ground. Under these conditions the spark is not very regular. Reduce the sparking distance in order to obtain a regular fat spark. The sparking distance will then be about two-thirds of the maximum sparking distance.

Operation of the set.

Transportation of the set.—The minimum personnel required to transport the set is three men.

The first one, who is in charge of the party, carries the transmitting box on his back and sometimes the accessory bag on his belt. The second carries the battery by means of a shoulder strap. The third one carries, over his shoulder, the bag containing the different parts of the antenna. Other men will carry, if necessary, the spare parts (battery and antenna). No special precaution is necessary while transporting the different parts of the set, except for the battery which must not be upset.

When the set is to be used for some time in a quiet area it should be installed in a shelter. During an attack the station is roughly set up, the connection between antenna

and transmitting box should be very short. The ground mat may simply be laid on the ground.

Setting up the set.—On arrival at the appointed place, *the first radio operator* sets the transmitting box on the ground, opens it and takes out the connecting wires that are inside.

He connects the transmitting box to the battery which the second man has placed on the ground, taking care to make connections with proper polarity.

He makes the ground and antenna connections by means of the plugs and fastens the ground connection cable to the terminal of the strip of wire mesh.

As the antenna is to be stretched in the opposite direction to the antenna of the corresponding receiving station, radio operator No. 1 indicates the direction to his aids by using, if necessary, the compass placed in the case containing the accessories.

Radio Operator No. 2.—Places the battery near the transmitting box.

He helps operator No. 3 get a hammer and a support with its attached guy rope and peg out of the case. He then sets the peg by means of a hammer, at the place indicated by the man in charge, and then sets up the support.

He afterwards stretches the strip of ground mat in the direction of the antenna, burying it, if practicable, and connects the leading-in wire to the antenna, as near the insulator as possible; he lays the wire on the support.

Radio Operator No. 3.—Removes the antenna material from its case. He fastens the end of the antenna to the insulator of the support, which has been placed by radio operator No. 2 and takes the reel in his left hand; in his right hand he carries the second support and the hammer.

He walks in the direction indicated by the man in charge and unrolls the antenna wire; when he gets to the end, he sets the second support up after having fastened the antenna to it, sets the peg and stretches the antenna.

He then brings the hammer and reel back to the station.

Transmission.—Radio Operator No. 1 operates the set and

sends the telegrams. The operator must work slowly, working the key to its extreme positions through a distance of one millimeter.

While working, always look at the ammeter; it must always work properly; the operation of the spark gap may be seen through the glass cover.

The second radio operator, writes the messages in the sen-

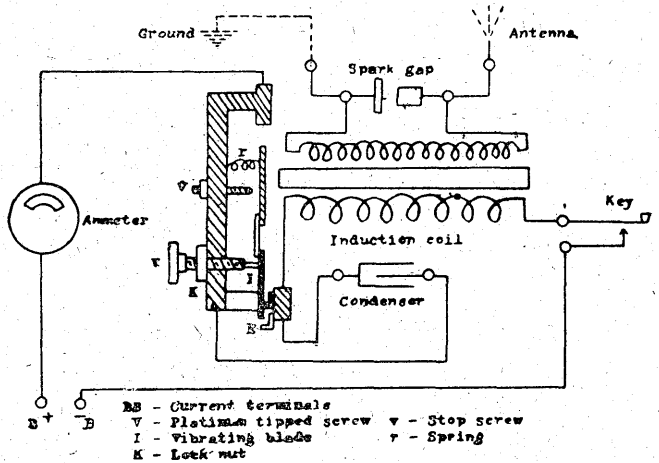


FIG. 51. — Transmitting Set, Portable Type No. 4.

ding book and takes the place of the first one, if necessary.

The third radio operator watches the antenna and repairs it if occasion requires.

Dismounting the set.—The three men reverse the order of the operations described above.

Transmitting Set. Portable Type No. 4 Model R. M. 1917.

Portable set No. 4 is a modification of set No. 3 and it differs from the latter only by a few alterations and improvements of the transmitting box, especially in regard to the make and break device and the key. See figure 51.

The make and break device of No. 4 set is of the vibrating type having its armature separated from the vibrating spring. It can be adjusted in three different ways :

1. Adjustment of the platinum screw V, (which is locked by turning the milled nut K).

2. Adjustment of the stop screw v (also locked by means of a nut).

3. Adjustment of the vibrating spring socket by means of a slide piece E.

Owing to the combination of the three adjustments described above, the make and break device may produce variable notes. Working on low pitch note is particularly satisfactory. The set is delivered adjusted for operating on low pitch notes and it is advisable to make all further adjustments only by means of the platinum screw. The key is an ordinary lever key which can be folded for transportation.

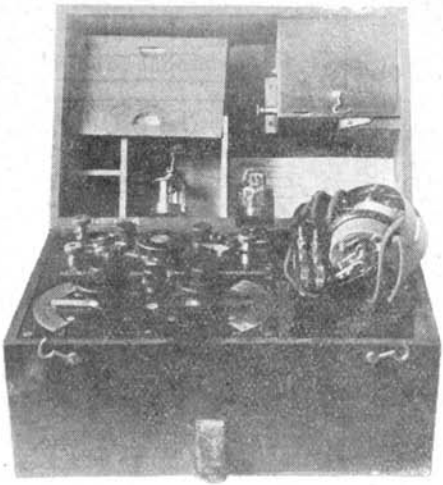


FIG. 52. — Receiver Type A-1.

The set operates on four amperes at 10 volts. The inductance coil (core, primary and secondary windings), is identical with that of set No. 3, the spark gap is also the same, except that it can be adjusted so as to give longer sparks (this being necessitated by the lower frequency of the spark).

The general arrangement of the transmitting box is similar to that of No. 3 set, the outside dimensions being, however,

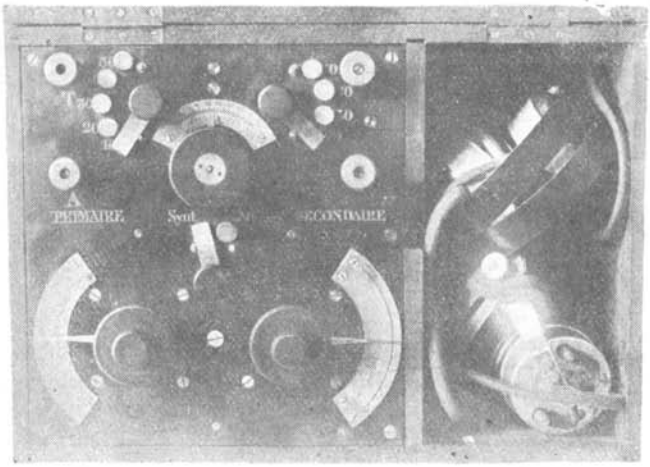


FIG. 53. — Receiver Type A-I. Face View.

slightly greater. The side handles are replaced by a leather strap.

The transmitting box is also transported in a leather bag. Accessories, storage batteries, antenna and ground material are the same as those delivered with set No. 3.

Receving Set. Type A-1.

The type A radio receiver, model Telegraphie Militaire 1915, Fig. 52 used for receiving damped wave signals of wave

lengths between 100 and 600 meters sent by aeroplanes, is made up as follows :

The primary circuit is composed of a 50 turn coil with take-offs every 10 turns (switch P) (Fig. 54) in series with a

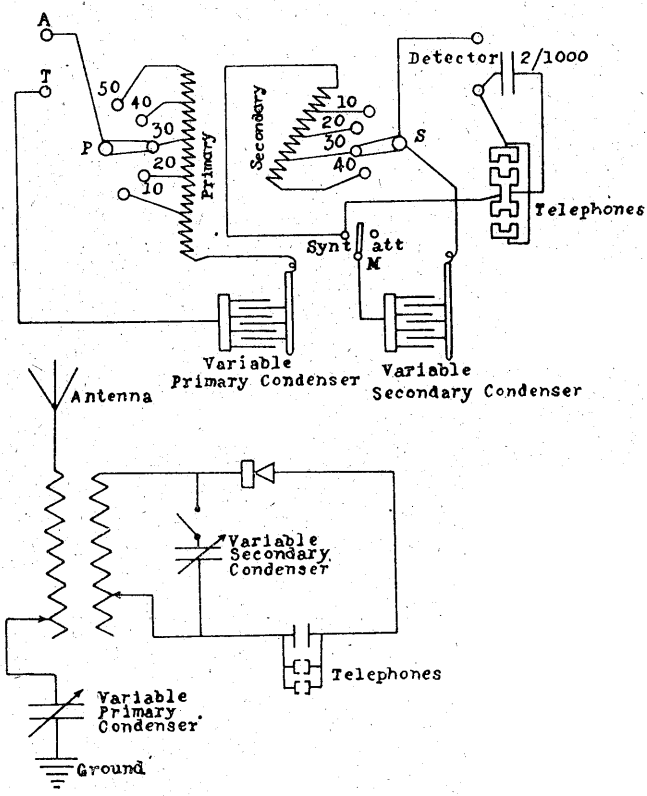


FIG. 54. — Circuits of Receiver Type A-1.

0.0005 microfarad variable air condenser. The minimum capacity is obtained when the index is on 0 of the scale, the maximum capacity when the index is on 90.

The secondary circuit is composed of a coil with 4 take-offs (switch S), and a variable air condenser, similar to that of the primary circuit. The coupling between the primary and secondary may be varied by turning the secondary coil on an axis perpendicular to that of the primary coil. The position of this secondary coil is shown by the index moving on a dial marked « Max-Couplage-Min » and scaled from 0 to 90. When the index is on Max and 90, both coils are parallel, i e., the coupling is a maximum; when on Min and 0, both coils are perpendicular, i. e., the coupling is a minimum. The first of these positions should be used when listening in for signals; the second position should be approached as closely as possible for tuning, as will be further explained.

The detector circuit is connected with the terminals of the secondary coil; it is composed of a crystal detector and telephone receivers. In parallel with the receivers is a small fixed stopping condenser with 2/1000 microfarad capacity. The secondary circuit may be, at will, aperiodic or tuned to the wave length being received. In the first case, the small switch M should be placed on the point « Att » and in the second case on the point « Synt ». This last position places the variable condenser in parallel with the secondary coil, while the first position leaves the condenser out of circuit.

Directions for use.

1st. Connect the antenna to the terminal marked A and the ground to the terminal marked T and find a sensitive point on the detector crystal. A small high frequency buzzer placed in the top of the Type A receiver is used for this purpose. This test buzzer has one exterior binding post which should be connected to the ground terminal. When the push button switch is closed the buzzer emits damped waves by which the detector point may be adjusted.

2nd. To tune the primary, place the small switch on the point marked « Att », the switch of the secondary coil S on

the point 40 and the adjustable coupling index on the point marked « Max ». Then place the switch of the primary coil, P, on the points marked 10-20-30-40-50 successively. With each position of the switch turn the primary condenser from one side of the scale to the other. Stop the switch condenser on the positions that give the best reception. Better results are obtained when the coupling is loose, so that the next step is to decrease the coupling by moving the index to the right, stopping it at the nearest position to « Min » which gives clear signals. This usually necessitates a slight readjustment of the primary coil and condenser.

3rd. To tune the secondary, place the small switch on the point marked « Synt » leaving the coupling at the position obtained in tuning the primary, usually between 10 and 20. Then place the switch S of the secondary coil successively on the points 10-20-30 and 40, and with it in position, turn the secondary condenser from one side of its scale to the other. Stop the switch and condenser index on the positions that give the best results. Again decrease the coupling moving the index as near « Min » as possible. As in the case of adjustment of the primary circuit, this will usually necessitate slight readjustment of the coil and condenser. The secondary tuning being obtained, increase the sound, if necessary, by slightly turning the coupling index towards the higher divisions. To avoid a close coupling, which will not prevent interference from foreign sendings, the index must not be turned too much.

Calibration of the secondary.

If the wave length of the sending station is known, the tuning of the secondary is made easier by using the calibration table given here and usually placed in the cover of the box, which shows, for each take-off of the secondary coil, both limits of the wave lengths obtained by varying the condenser from minimum to maximum. The values are approximate and vary a little with each instrument.

CALIBRATION TABLE
(For Standard Antenna).

SECONDARY COIL No. of turns	SECONDARY CONDENSER (Wave length limits when varied from 0° to 90°)	
	0°	90°
10	100	210
20	130	360
30	160	470
40	200	595

Amplifier Type 3-ter.

Description. The type 3-ter amplifier (see Fig. 55), is contained in a convenient carrying case, so arranged that it may be used, in the field without removal from the case.

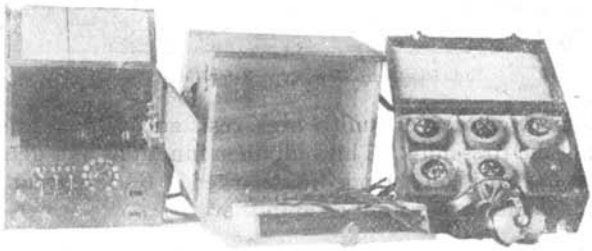


FIG. 55.—Amplifier, Type 3-*ter*.

The apparatus itself has a small wood housing about 27 cm wide by 26 ½ cm deep by 11 cm thick. On the front is an ebonite panel on which are mounted the control devices. In the lower left corner are three terminals marked L_1, L_2 and L_3.

Terminals L_1 and L_2 are used, (see Fig. 56), for radio telegraphy (T. S. F.), and if used with the type A receiver, should be connected to a plug inserted in the headset plug socket of the type A: or to the terminals of the type A

detector support according to whether it is desired to use the apparatus as an amplifier only, or as a detector and amplifier. Terminals L_2 and L_3 are used for ground telegraphy (T. P. S.).

The three blade double-throw switch S when placed on the position marked H. F. (high frequency) connects a small

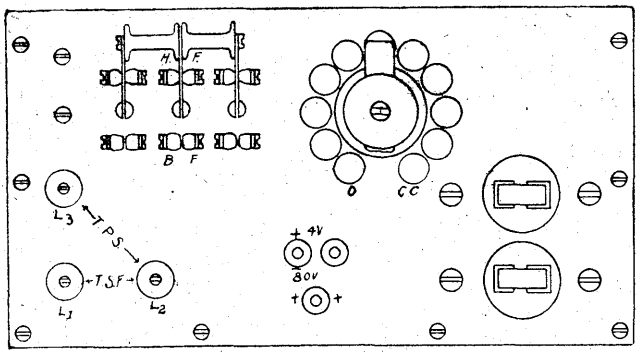


FIG. 56.—Amplifier Type 3-*ter*-Face View.

0003 m. f. condenser and a high resistance to the grid circuit of the first bulb. This bulb then functions as a detector. If the switch is on the position marked B. F. (low frequency) all three lamps are used as amplifiers.

Turning the eleven point rheostat R clockwise increases the current used to heat the filament in the bulbs. The extreme left and point, marked 0, is a dead contact, which allows the battery circuits to be broken.

Battery connections are made by means of four flexible conductors provided with the amplifier. These conductors are connected to a three pole hard rubber contact socket, the negative pole of the 80 or 40 volt battery and the positive pole of the 4 volt battery being connected to the same receptacle. This socket fits onto the three pins at the bottom of the panel marked with voltage and polarity signs. The pins are spaced so that only one position of the socket is

possible, and this is indicated by two arrows on its top edge. However, great care must be exercised in connecting the other ends of the flexible conductors to the battery terminals. Both voltage and polarity are clearly indicated for each conductor, and they should be carefully noted. Never connect the *4-volt flexible conductor terminals to the terminals of the 80 volt battery, and see that the minus* (—) *terminals of the conductors are connected to the negative poles of the batteries and the plus* (—) *terminals of the conductors are connected to the positive poles of the batteries.*

The bulbs used in the 3—ter amplifier are inserted in receptacles placed on a panel of ebonite which is suspended on two heavy rubber elastics to protect the bulbs from excessive shock.

The spacing between the pins of the bulbs is arranged so that it is impossible to make wrong connections. The letter G, indicating the grid pin, should be toward the front, thus giving an indication of the proper connection. The pins should be completely inserted, and good contact assured. If a pin fails to make good contact, the defect may be remedied by inserting a knife blade in the split and spreading it slightly.

Use of the amplifier.

When it is desired to use the apparatus as an amplifier only, the three pole switch, S, in figs 57 and 58 is placed on the position marked B. F. When the switch is placed thus, the low frequency current from the galena crystal, or other similar rectifier, is carried through the primary of a small transformer T_1, the secondary of which is in the filament-grid circuit of the first bulb. The filament-plate circuit of the first bulb contains the primary of a second transformer T_2, and the secondary of T_2 is in the filament-grid circuit of the second bulb. The connections of the third transformer T_3 and the bulb are the same as for T_2, and the second bulb, except that the plate-filament circuit of the last bulb contains the telephone headset sockets. It is seen, then,

that the rectified current received by the amplifier is successively amplified by the three bulbs, being finally passed through the headsets to operate the receivers. Each bulb amplifies about five times giving together with the effect of the transformers in all about 1.000 fold amplification.

In this first case the amplifier terminals L_1 and L_2 should

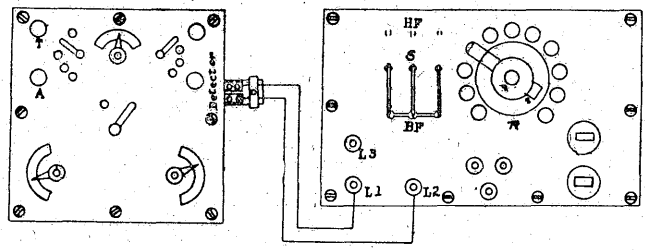


FIG. 57.—Amplifier used with Receiver Type A for Amplification solely.

be connected as stated, to a plug inserted in the headset plug socket of the type A receiver, if the amplifier is used with a type A. (See fig. 57.)

When it is desired to use the amplifier as a detector as well as an amplifier, the switch S is placed on the position

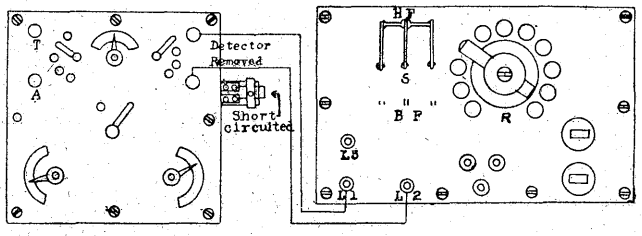


FIG. 58.—Amplifier Used with Receiver Type A for Detection and Amplification.

marked H. F., and the terminals L_1 and L_2 connected to the large binding posts on which the detector crystal is mounted, if used with the type A. The headset plug socket is then short circuited by means of a plug with wire con-

necting the two binding screws. (See fig. 58.) With this disposition the secondary circuit of the type A is connected on one side to the positive pole of the filament of the first bulb, and on the other side with the grid through an intermediate condenser C with imperfect insulation resistance, or shunted by a higher resistance of 1 to 5 meg. ohms. The

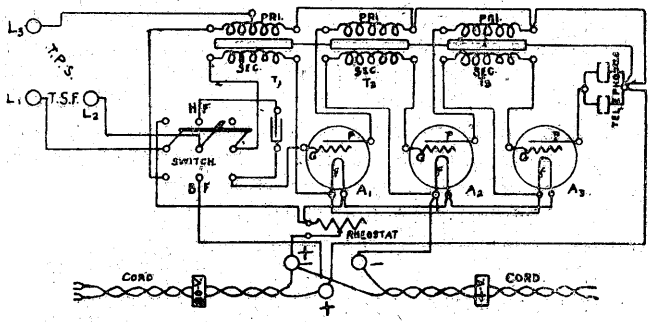


FIG. 59.—Circuits, Amplifier, Type 3 *ter*.

first bulb acts as a detector in the manner described above in the description of the audion as a detector and the second and third bulbs amplify the current in the plate-filament circuit of the first bulb.

Precautions to be observed with the 3-ter amplifier.

The apparatus must be carefully protected from mechanical vibration, though this feature is provided against in the later model 3-ter by means of the elastic band support for the ebonite bulb-base.

The instrument should be kept dry and free from dust at all times and for this reason should be kept in the carrying case provided.

In connecting the terminals L_1 and L_2 to the receiving circuit, be careful not to twist the wires or allow them to come in contact or even close proximity with each other, and they should not be allowed to touch the apparatus except

at the terminals. When the current is on and the bulbs are illuminated, none of the metal parts of the circuit should be touched. These precautions are necessary to prevent the howling of the amplifier. Often a howling noise can be heard even when these precautions are observed, and when this is the case, it may be stopped sometimes by reversing the plug in the Type A headset socket, thus reversing the connections to L_1 and L_2. This howling is due to reactance of the various circuits on one another, and often the capacity of the operator's body, if he touches any part of the circuit, is sufficient to set it up. For these reasons, as far as practicable, all the metallic parts exposed near the circuit, such as the case of the headset receivers, and the transformer cores are connected to the negative pole of the heating battery, which has the potential common to all circuits.

Bulbs may be tested by the use of a millammeter in the circuit of the 80 (or 40) volt battery. The current from filament to plate is shown by lighting each bulb in succession. Each should show not less than 2 milliamperes for 80 volts supplied. Should a bulb give no reading with a properly charged battery it may be due to the fact (1) that it is not completely pushed home; (2) that the connections between the pins and base are poor; (3) that it is burnt out; (4) that one of the connections inside the amplifier is broken. A current of over 10 milliamperes indicates a short circuit. Before deciding that the apparatus is out of order, at least two sets of bulbs should be tried.

E-10 Radio Sets.

The series of E-10 Sets used by the French, namely, the E-10, E-10bis, E-10 ter, and E-10 Artillery types, are all very similar in construction with slight modifications to adapt them to the needs of the particular conditions under which they are used. The most important of these to Heavy Artillery units is the Artillery type, which is constructed with a view to receiving the more or less feeble waves emitted by airplane sets.

E-10 Radio Set Artillery Type. — Description.

The French E-10 Artillery type radio set, (see fig. 60), was designed for use with undamped waves in transmitting, and for receiving either damped or undamped waves. Its wave length limits are approximately 550 and 750 meters. It is also possible to use it for radio telephony within limited ranges. The set is contained in a convenient field case, the dimensions of which are 57.5 centimeters wide, by 45 centi-

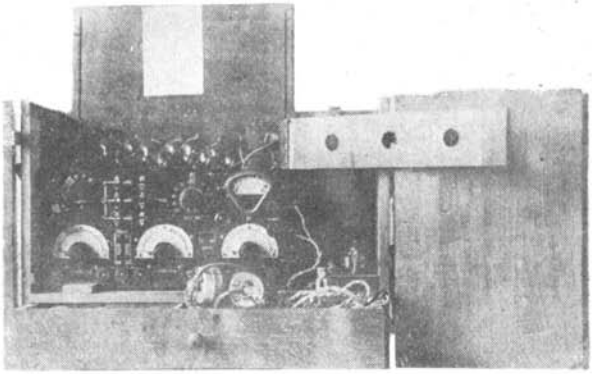


FIG. 60.—E-10 Set Artillery Type (French).

meters high by 33 centimeters deep, and the weight of which is 34 kilograms, (75 pounds). Inside the case is mounted the sending key: and an eight day clock, a stationery drawer and compartment for extra bulbs, headsets, battery leads, fuses, etc., are compactly arranged. Hinged doors on the front permit the use of the set in the field without removal from the case. It may, however, be removed when necessary by taking out the two wood blocks and sliding it forward.

The set itself is made up in a small cabinet 28.5 centimeters in height by 24 centimeters deep and 40.5 centimeters wide. The top and the upper section of the front are hinged,

giving easy access to the audion bulbs; and the front section has three holes through which it may be easily ascertained whether or not the bulbs are lighted. The lower part of the front is an ebonite panel on which are mounted the control devices. On the right or transmitting side are (see fig. 61).

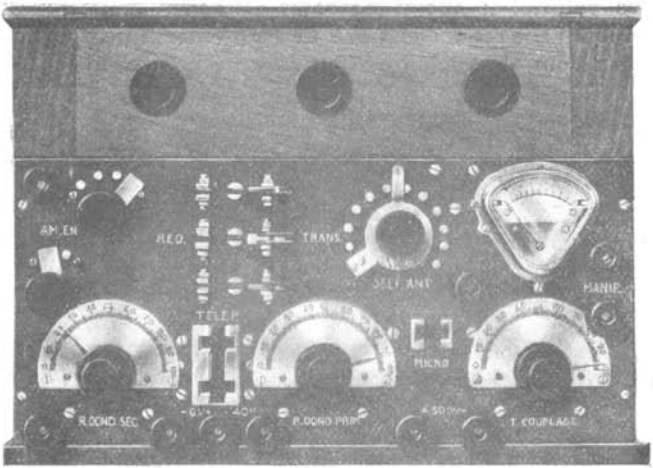


FIG. 61.—E-10 Set Artillery Type-Face View.

1. The antenna inductance switch; marked Self.-Ant; 2. Ammeter; 3. Small light which may be substituted for the ammeter, after adjustment, to indicate radiation; 4. The coupling condenser marked T. Couplage; 5. The telephone transmitter socket marked Micro; 6. The two binding posts for the key marked Manip; and 7. The binding posts for the 300 volt battery leads. On the left, or receiving side, are: 1′. The three blade double throw switch to shift from transmitting to receiving; 2′. The headset plug sockets marked Telep; 3′. The rheostat for the heating current marked Lampes; 4′. A small switch marked Am and En which permits shift from damped (AM) to undamped (EN) waves;

5′. The primary receiving condenser marked R. Cond. Prim; 6′. The secondary receiving condenser marked R. Cond. Sec; 7′. The antenna binding post A; 8′. The ground binding post T; and 9′. The 6 and 40 volt battery binding posts. The polarity of each is indicated and the positive (+) of the 6 volt battery and the negative (—) of the 40 volt battery are common. A description of the interior circuits is found later on page 84, it being thought advisable to show the principles of operation with simple diagrams first.

Antenna and ground.

The artillery set is designed to operate on the same wavelengths when connected to either of the following antenna systems. One type consists of two 60 meter lengths of antenna wire forming a V, the angle between them being 60 degrees. This antenna is supported 7, or preferably 12 meters above the ground upon coupled bamboo poles or upon steel masts. A more efficient antenna consists of two strands of antenna wire, each 80 meters in length, and supported 2 meters apart and 12 meters above the ground at the end farthest from the apparatus, and 7 or 12 meters above the ground at the other end. A wire 15 to 20 meters long leads from the point of the V or from the end of the antenna to the apparatus.

The ground should consist of four copper nets buried at least 45 centimeters, such as are supplied with the type A receiving sets, and the ground lead should be as short as possible.

Batteries.

The filament current of the transmitting and receiving bulbs is furnished by a 6 volt storage battery; the plate potential of the receiving bulbs by a 40 volt battery and the plate potential of the transmitting bulbs by a battery of from 300 to 320 volts. It is not possible to use one of the 40 volt transmitting batteries to supply the plate potential

of the receiving bulbs. The batteries are connected to binding posts on the front panel, as indicated on the posts, by the flexible leads which are supplied, and *care must be used to preserve* the polarity according to the signs on the binding posts. It is a good plan to insert a switch outside the set in the 300-V circuit; a fuse is already provided within the set.

Principles of operation.

The principles of the audion bulb and heterodyne are made use of for both sending and receiving, there being transmitting bulbs and three receiving bulbs mounted on an ebonite panel supported on thick rubber elastic to avoid excessive shock.

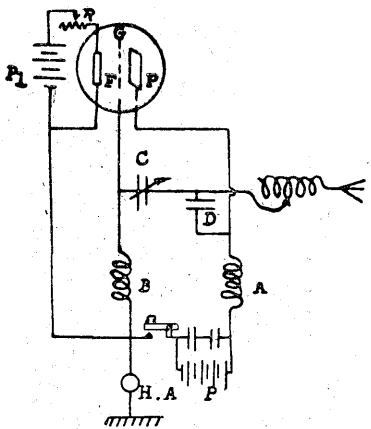


FIG. 62.—Schematic Transmitting Circuit E-10 Artillery Type.

Transmission.

A coil A (fig. 62) is placed in the plate circuit of the three transmitting bulbs connected in parallel, represented here by one bulb for simplicity. A battery P of 300 volts is connected so that the plate is positively charged through coil A. Coil B is placed in the grid circuit and these two coils are statically coupled by means of a variable condenser C. The filament circuit, the current for which is supplied by a 6 volt battery P_1 through a rheostat R, is also connected to the ground through a hotwire ammeter H. A. A key is inserted between the filament and plate circuits at M. The antenna is connected to the coil A through a fixed condenser D and also the coil B through the variable condenser C. The pur-

pose of the condenser D is to prevent condenser C and the antenna from being charged to the potential of the 300 volt battery P, thus avoiding possible rouble from a short circuit in C, or by means of a faulty or destroyed antenna.

Briefly the operation of the transmitter supplied by this arrangement of coils and audion bulbs is as follows. The plates being positively charged, when the key M is closed, negative electrons from the filament are attracted through the grid to the plate and a current flows in the plate-filament circuit. This current energizes the coils A and B and since both A and B are connected to the antenna on one side and to the ground on the other, oscillations are set up in the

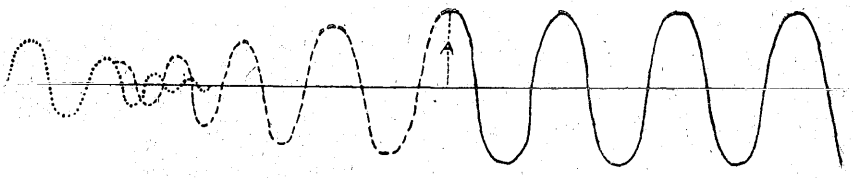


FIG. 63.

antenna. These oscillations would of course be damped except for the effect of the electro-magnetic coupling and the electrostatic coupling C between the coils A and B in the plate and grid circuits. In fig. 63 the wave represented by the dotted line may be considered as the resulting wave if there were no coupling between the grid and plate circuits. However, with the coupling present, from the first oscillation the grid receives a positive charge by electro-magnetic induction between A and B, and also electrostatically through the condenser C, the amount of which may be varied since C is a variable condenser. The potential of the grid being positive, an increased number of negative electrons is attracted from the filament and consequently an increased current flows in the plate-filament circuit. Therefore the amplitude of the second oscillation instead of being less than that of the first, is greater, and since a

greater amount of current flows in the plate-filament circuit each time, each successive oscillation will have a greater amplitude than the preceding one, as indicated by the broken lines in fig. 63. However a point is soon reached when the decrease in amplitude due to antenna losses which also increase in proportion to the increase of energizing current, equals the increase in amplitude supplied by the grid action, and then the sustained wave of constant amplitude, A, results. In any case a limit to the amplitude of the radiated wave is found in the maximum amplitude of the plate-filament current, where a further increase in grid potential no longer increases the plate current.

Receiving.

The receiving side of E-10 Artillery Type contains a fixed primary coil I (fig. 64), and a variable condenser C_1 in the antenna circuit, this being the same coil used as a variable inductance for transmission but so connected that it is not variable when used in the receiving circuit. The secondary receiving circuit is made up of two coils N and N_1, only N_1 being inductively coupled to the primary, and a variable condenser C_2. One side of the secondary circuit is connected to the grid of the first bulb L through a condenser C_3 of very small capacity across which is shunted a high resistance, R_3. On the other side it is connected to the positive end of the bulb filaments. The plate circuit of the first bulb contains a battery P_2 and the primary of a low frequency transformer. When oscillations are induced in the secondary circuit from the antenna, or primary circuit, this first bulb acts as a detector in the manner previously described in the explanation of the vacuum tube or Audion. Briefly, the plate-filament current is caused to pulsate by the variation of the grid potential and the resultant fluctuation of the plate potential is amplified through transformers and the two amplifying bulbs L_1 and L_2; and then affects the receivers, giving a signal. The frequency of the vibrations pro-

ducing this signal is determined by the frequency of the *wave train* emitted by the sending station.

By shifting the two point switch marked AM (damped) and EN (undamped) a small coil H is connected in or shunted out of the plate-filament circuit of the first bulb L, at

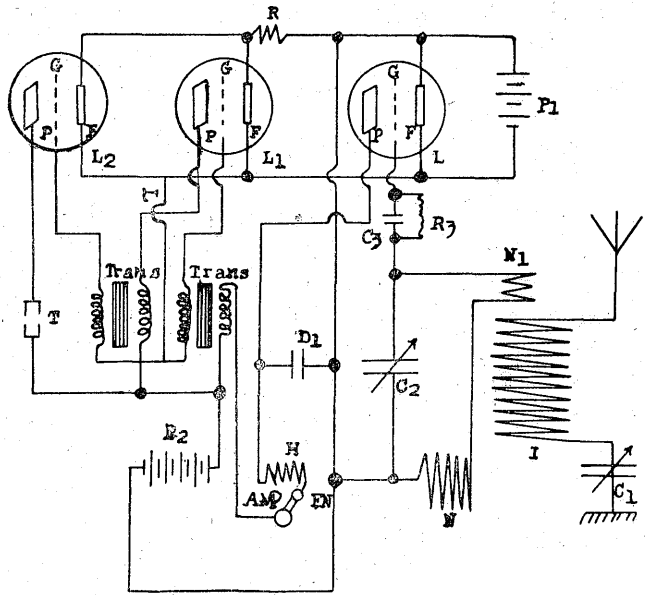


FIG. 64.—Receiving Circuits E-10 Set Artillery Type.

will. This coil is magnetically coupled to coil N of the secondary receiving circuit and when receiving undamped waves it is placed in the circuit by putting the small switch on the point marked EN (undamped). With this arrangement oscillations are set up in the plate-filament circuit which are superimposed on those received from the antenna in the same manner as with an independent heterodyne. The resultant wave varies the grid potential of L

through the condenser C_3 and resistance R_3. This causes the plate-filament current to pulsate as with damped waves; and the pulsation after having been amplified affects the receiver diaphragms in the same manner as in damped reception.

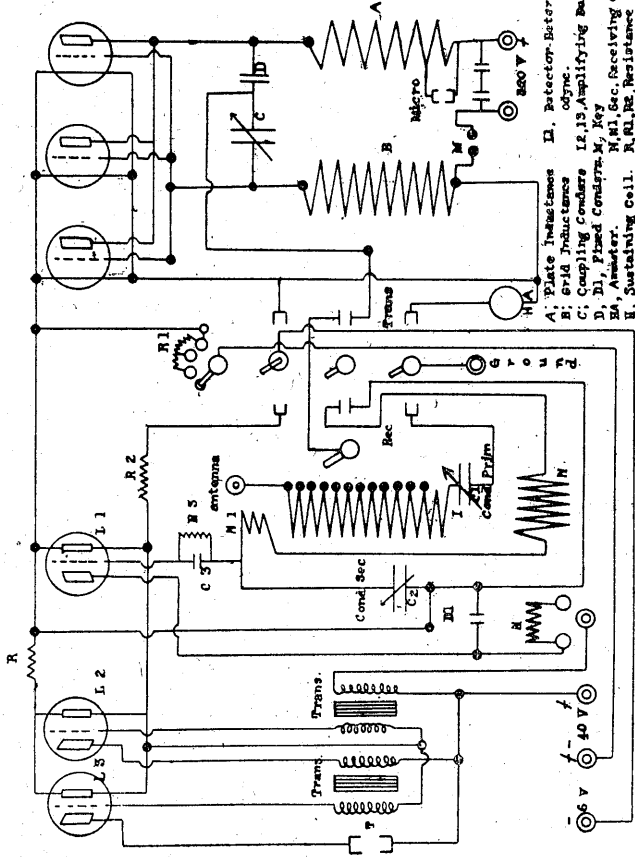


FIG. 65.—Circuits E-10 Set Artillery Type.

Mounting.

The parts composing the transmitting and receiving circuits are suitably mounted in a single box, as described. The connections are shown in fig. 65. The resistance shown at R_1 is controlled by the switch on the panel and constitutes the heating rheostat. The resistance shown at R_2 is provided to reduce the heating of the receiving bulbs as it need not be so great as that of the sending bulbs. A resistance R is also provided to reduce the heating of the amplifier bulbs still more.

The three blade double throw switch shown in fig. 65 changes from transmission to receiving and vice versa, *no further adjustment* being necessary. The upper blade shifts the heating current from the transmitting to the receiving bulbs and connects the resistance R_2 into the circuit.

When on the transmitting side, the second blade connects the antenna into the transmitting circuit, and when on the receiving side, it closes the secondary oscillating circuit, left open when transmitting so that it will not absorb any energy should it be in resonance with the wave length sent out. The bottom blade shifts the ground from the transmitting to the receiving side and vice versa.

The transmitting key is connected to the two binding posts on the right side of the ebonite panel, shown in fig. 65, marked M. When the telephone is used these binding posts are short circuited by screwing down the transmitting key, and the transmitter plug is inserted in the socket marked Micro.

The small pilot light on the front ebonite panel should be substituted for the ammeter HA, by means of a shifting contact inside the ebonite panel behind the ammeter. The glow of the light gives a satisfactory indication of resonance and its use saves the delicate wire in the ammeter.

A small condenser D_1 between the plate and filament circuits of the first bulb eliminates « howling » and aids reception.

Adjustment and operation of the set.

Having connected the 300 volt, the 6 volt and the 40 volt batteries to their proper binding posts, and having fastened the ground and aerial leads to T and A respectively the method of tuning is as follows :

1. Transmission. Throw the three blade double throw switch to the right on the point marked Trans. Switch the heating current on and commence working the key. Then modify the capacity of the coupling condenser C to set up oscillations in the antenna circuit. Measure the emitted wave length with the small wave meter provided, by placing the latter on top or near the set and, having switched on the small wave meter light, turning the dial until the increased brilliancy of the glow indicates resonance with the transmitted wave, the length of which is then indicated by the graduation opposite the pointer on the left of the face of the meter. (For a description of the T_1 wave meter see page 88 of this pamphlet.) If a greater wave length is desired increase the antenna inductance by turning the inductance switch clockwise. If a smaller wave length is desired lessen the amount of antenna inductance by turning the switch counter-clockwise ; the wave meter being used to determine the wave length resulting from the change. Having obtained the approximate wave length desired, more exact and finer adjustment may be made by means of the condenser C. The small wave meter battery should be switched off when not actually in use.

It is essential to have the radiated oscillations sufficiently stable, and to see by means of the ammeter, the small light, or the wave meter, that they are set up each time the key is closed. If they are not stable enough for reception the coupling should be made tighter. Decrease the antenna inductance by one point, and this will necessitate an increase in capacity of the condenser C i. e., a tighter coupling.

While working the key in transmission it is necessary to watch the small pilot light to see that oscillations are set up continuously.

2. Receiving. Throw the switch on the left side marked REC. If the wave length of the sending station is known the wave meter may be used to tune the receiving circuits to that wave length. Set up oscillations by turning the small switch on the front of the wave meter on point marked V first having set the indicator at the graduation corresponding to the desired wave length. Using successive positions of the primary condenser vary the secondary condenser until the point which gives loudest reception from the wave meter, in the headsets, is found. The two circuits will then be in resonance and adjusted to the wave length emitted by the wave meter and hence the sending station. If the wave length of the sending station is not known, it is quite simple to tune it in, by placing the primary condenser in successive positions and varying the capacity of the secondary condenser. It should be remembered that the primary inductance is not variable when on the receiving side so that varying the antenna-inductance switch is without effect on the wave length. Having found the sending station a slight readjustment of the primary condenser will ordinarily better the reception. The adjustment is the same whether damped or undamped waves are received.

When tuning for undamped waves a noise, or click, is often heard just at the moment when the varying of the primary condenser creates resonance between the primary and secondary circuits. The noise is due to a sudden decrease in the amplitude of the oscillations owing to the fact that the antenna at that moment is in exact resonance with and takes part in the oscillation, thus absorbing some of the energy of the secondary. This indication of resonance between the two circuits simplifies tuning by enabling them to be kept nearly in resonance throughout the process. Better results are obtained if, after tuning, a slight decrease in the heating of the bulbs is made by means of the heating rheostat.

3. Receiving telephone communications. When receiving telephone communication the heterodyne coil H is

shunted out as when receiving damped waves, by placing the small switch on the position AM. The heterodyne is more sensitive and may be used to tune in the other station, and then switched out. It may be necessary to increase the secondary condenser a little after switching out the coil H, because the latter modifies the period of the secondary circuit.

The wave meter.

A simplified type of wave meter, usually model T_1, is issued with E-10 sets.

Description.

Wave meter model T_1, consists essentially of an oscillating circuit made up of a variometer Sv and a fixed condenser C (fig. 66.) A small incandescent lamp A with its metallic filament connected into the circuit serves as an indication of resonance. It is fed by a small dry battery P. An electro-magnet E operates an armature in such a way as to set up damped oscillations in the coil Sv. A switch M allows the battery P to be connected to the lamp A, or to the vibrator V, according to whether it is desired to measure oscillations in a sending set or to set up damped oscillations for adjusting a receiving set.

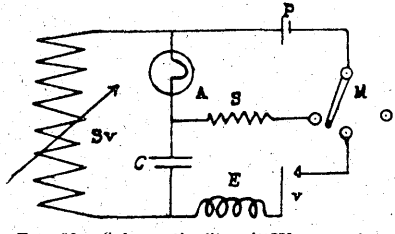


FIG. 66.—Schematic Circuit Wave meter Model T_1.

The wave meter is mounted in a wood box 135 m/m high by 125 m/m wide and 115 m/m deep, (fig. 67); the control devices are mounted on the front of an ebonite panel. The switch M can be placed on three points. The lowest is a dead contact, on which the switch must always be placed when the

apparatus is not in use. The second point marked V, connects in the vibrator, and the third point L connects in the small lamp placed on the upper left corner of the wave meter. The movable coil of the variometer is fastened to the knob B and the dial Q. The dial turns in its seat flush with the face of the ebonite panel. A mark R indicates the division on the dial Q which corresponds to the position of the movable coil and the wave length emitted or corres-

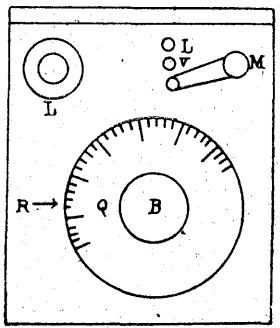


FIG. 67.—Wave meter Model T,.

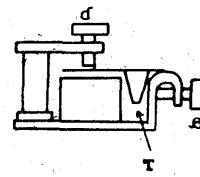


FIG. 68.—Vibrator Wave meter Model T,.

ponds to the position of the movable coil and the wave length emitted or received.

A small hinged shutter in the top of the box gives access to the battery and vibrator (fig. 68). The vibrator has two regulating screws a and b. The screw a controls the space between the armature and the magnet by means of a small v—shaped spring r. The normal space is a few tenths of a millimeter.

The contact point is of platinum or gold, and must touch the armature so that the vibrator starts when the switch M is placed on the point V.

The variometer Sv is made up of two parallel coils, the smaller turning inside the larger on an axis, in the plane of the turns. The two coils are in series and the total induc-

tion varies with their relative positions. The ratio between the maximum induction and the minimum induction obtainable by varying the position of the coils from parallel to perpendicular is approximately 3.5 to 1, and the wave length limits measurable with such an apparatus are in the ratio of 1.85 to 1 approximately. This type is graduated to read wave lengths from 550 to 1000 meters.

Method of use.

1. To measure wave lengths emitted from a local station: Place the meter near the transmitting set, and put the small switch M on the point marked L. The small lamp then glows, and when the wave meter circuit is in resonance with the radiated wave, the glow will brighten considerably. Resonance with the radiated wave length is obtained by regulating the variometer coils, i. e., by turning the knob B. When the lamp burns with maximum brilliancy resonance is indicated, and the wave length of the emitted wave may be read from the dial opposite the index R.

When used in the above manner the lamp acts as a thermal indicator. The battery circuit is through the lamp and the coil S, the resistance being so regulated that the lamp is only slightly reddened. When resonance is attained the oscillating current flows in this circuit with maximum intensity and not being able to cross the battery P, being stopped by coil S, the oscillations are added to the continuous current of the battery in such a way as to increase the brilliancy of the light.

It is necessary to adjust the coupling between the sending set and the wave meter, that is, the nearness of the latter to the sending set, in order to obtain precision. When they are too close together the exact point of resonance is not indicated. Also, if the transmitting set is powerful enough there is danger of burning out the lamp. When the wave meter is too far from the set, however, the lamp circuit will not be noticeably affected. With undamped sets the wave meter

should be a little removed, while with damped sets a closer position is necessary.

2. To measure received waves : The receiving set is first adjusted to resonance with the transmitted wave, the coupling which gives keenest reception being chosen. Keeping the headset on, the operator places the wave meter near the receiving set and starts the vibrator by placing the switch M on the point V. The wave meter oscillations are heard in the headset and by turning the knob B thus varying the relative position of the variometer coils, these oscillations may be brought in resonance with the circuits of the receiving set. Moving the wave meter up to or away from the set enables the sound to be regulated to a minimum volume and still be heard clearly and exact resonance is determined by further slight variation of the knob B. The wave length of the circuits of the receiving set and hence the received wave length is now read from the dial opposite the index R.

E—10, E—10 bis and E—10 ter Radio Sets.

These sets are all constructed on the same general plan and this plan is, as stated, practically that used in the E—10 Artillery type already discussed. There are a few points of difference, however, that should be noticed. The first of these is found in the arrangement of the transmitter, and though slightly different from the Artillery type the transmitter on all other E—10 sets is practically the same. A description of its arrangement follows.

Transmission.

In fig. 69 a coil AB is shown connected at one end to the plate of the transmitting bulbs, represented by one bulb, through the key M and a small condenser F. At the other end it is connected to the grid, and from an intermediate contact O to the filament. The antenna A and antenna inductance I are placed on the grid side, and the ground on

the plate side of this coil. A variable condenser C is placed across all except two turns of the coil and serves to vary the coupling between the grid and plate circuits. If P were connected directly to O, as in fig. 70, it is seen that a capacity between the battery P and the ground, or a defect in insulation causing a short circuit, would, due to the resistance of A, shunt out the coil and prevent oscillations in the antenna. To avoid this difficulty, the heating circuit from P is passed through a coil E wrapped around A and having the same number of turns and hence same resistance as A, shown in fig. 69 on the side of A for simplicity. This does not interfere with the high frequency oscillations in the antenna circuit. The small condenser F in the plate circuit allows high frequency oscillations to pass and does not shortcircuit the power terminals. The slight oscillations caused by the commutator action when a generator is used for the plate current are choked out and absorbed by the condensers at F_1 and the iron coils S_1 and S_2 (fig. 69).

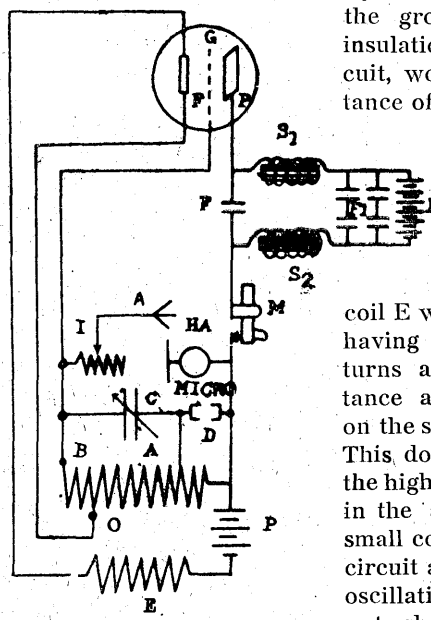


FIG. 69.—Schematic Circuits E—10 Set.

Adjustment.

The receiving circuits and the adjustment of both sending and receiving apparatus, are exactly the same as described for the Artillery type.

Special features.

E—10. The E—10 operates on waves from 550 to 750 meters in length, using a V—type antenna 30 meters in length, any other antenna of similar dimensions, or an airplane antenna.

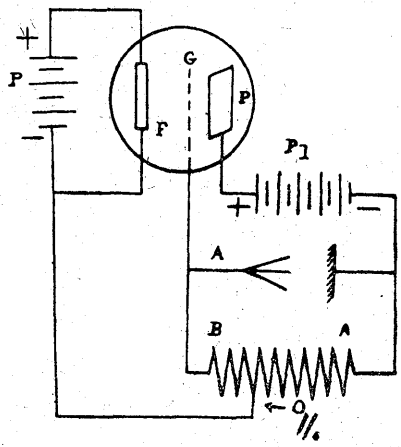


FIG. 70.

For transmitting waves from a ground station a 25 meter V—type antenna should be used.

E—10 bis. This set may be used with slightly longer wave lengths, its limits being 600 to 1000 meters approximately. For that purpose the receiving side has: (1) a switch with two points marked "petites ondes" and "grandes ondes" which allows the switching in of all or only a part of the antenna inductance I. (2) A second small switch marked "couplage" which allows the coupling of all or only a part of the secondary coil N_4 (fig. 65) to the primary. Different types of antennae used with this set give the following results:

1. Single wire antenna 45 meters long including 4 meter lead in. . . . . 600 to 1120 meters
2. Single wire antenna 40 meters long including 1 meter lead in: with buried ground nets. . . . . 600 to 1150 —
3. Single wire antenna 40 meters long including 1 meter lead-in: with one net laid out on top of the ground. . 590 to 1020 —.

4. Airplane antenna 80 to 100 meters long . . . . . 600 to 1000 meters
5. V—type antenna with 50 meter branches and 15 meter lead-in . . 900 to 1420 —

The secondary receiving circuit can, however, only be tuned in to receive wave lengths of 450 to 1150 meters.

E—10 ter. The dimensions of the transmitting coil are slightly longer in this set than in the E—10 bis, it being designed for use with a short antenna, usually about 14 meters long, and installed on tanks. Its wave length limits are 600 to 1000 meters.

E-3 Radio Set. — Description.

The French type E—3, E—3 bis and E—3 ter set can be used for any undamped wave communication of the wave range indicated.

Use.

All three sets transmit sustained wave signals, either telegraphic or telephonic, by means of oscillations set up by the standard French amplifier lamps of the transmitting box, with 320 volts on the plates and 6 volts on the filaments. Four lamps connected in parallel are used, putting 0.6 to 0.8 ampere into the antenna. The antenna used with the E-3 set is horizontal, V-shaped, 50 meters on each side, 60° angle, supported 7 meters above the ground on bamboo poles. A wire 15 meters long leads from the apparatus to the point of the V. Connected to this antenna the E-3 set transmits wave-lengths between 600 and 1050 meters, to a distance of about 60 miles for telegraphic and 10 miles for telephonic transmission. The E-3 bis set, connected to an antenna similar to that described above, with a supplementary antenna loading coil, transmits wave lengths between 1,000 and 1,400 meters and has the same range as the E-3 set. It may also be used with the antenna of the E-3 ter set,

which has 3 horizontal branches each 80 meters long, making angles of 40° with each other, and a lead wire to the point of the angle, 20 meters long, and is supported 7 meters above the ground on bamboo poles. Connected to this antenna without the supplementary antenna loading coil the E-3 bis set emits wave lengths between 1,000 and 1,500 meters. These sets receive both damped and sustained waves, of a range of wave-lengths somewhat greater than that for trans-

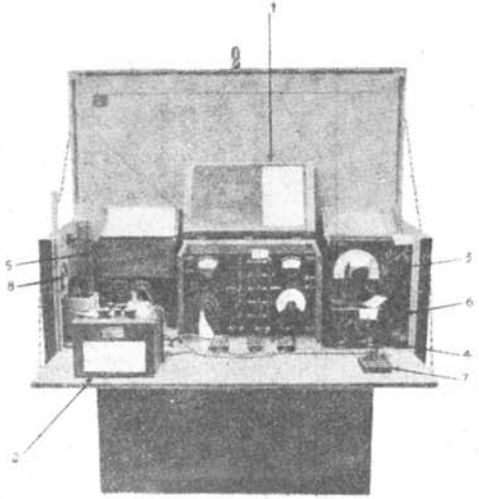


Fig. 71.—Set, Radio Type E—3 French.

mission. The transmitting box circuit with one amplifier lamp operating, is used as a heterodyne for receiving sustained waves and a Type 3-ter amplifier for detecting and amplifying the signals received, damped or sustained. The full set (see fig. 71) includes (1) an antenna inductance or loading coil of 130 turns; (2) A Type E-3 Sending apparatus and heterodyne; (3) An E-3 Receiving apparatus, similar to the Type A set; (4) A Type 3-ter Amplifier; (5) one 4 volt battery for the amplifier, one 6 volt battery for the hetero-

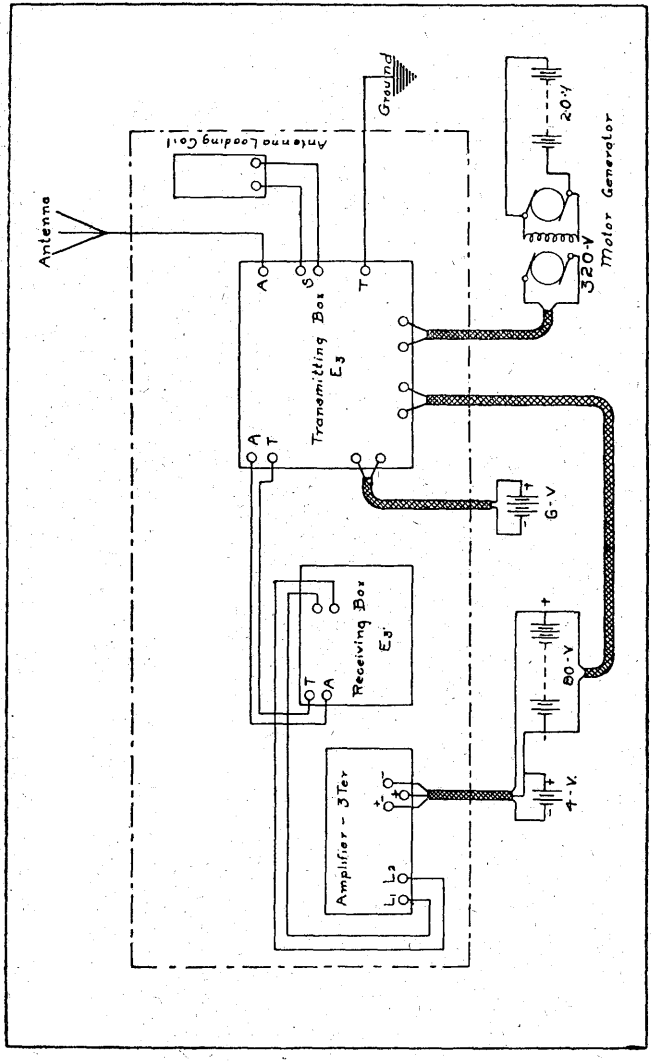


FIG. 72.—Exterior Connections Radio Set Type E—3.

dyne, one 40 volt battery for the amplifier and heterodyne, and eight 40 volt batteries (320 volts) for the transmitter. (A 320 volt direct current generator is sometimes used in the place of the eight 40 volt sending batteries); and (6) a wave meter. The exterior connections of these elements are shown in Fig. 72.

Loading coil.

The loading coil of 130 turns is controlled by 2 eleven point switches. One of these is adjustable turn by turn up

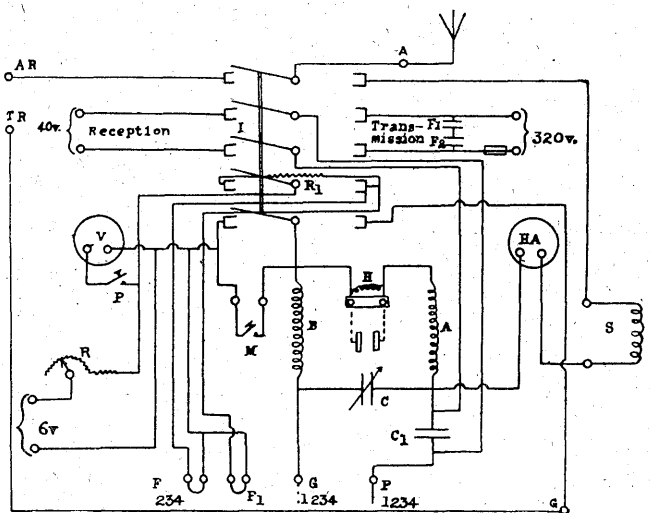


FIG. 73.—Transmitting Box and Heterodyne Set Radio Type E—3.

to ten turns, while the other adjusts by ten turns. With this coil in the antenna circuit, wave lengths from 600 to 1000 meters may be sent.

The E—3 sending apparatus and heterodyne.

Fig. 73 shows its interior circuits. A 6 volt battery connected at the terminals indicated in the figure is used to

heat the bulb filaments and the current is varied by the rheostat R. The 320 volt battery (or generator) is connected to the terminals as shown.

Receiving.

When using the E-3 to receive undamped waves, only one bulb of the apparatus remains in circuit, and it functions as a heterodyne. A simplified diagram of the set under these conditions is shown in figure 74. The connecting and disconnecting of the various circuits for transmitting and receiving is simplified by the use of a five pole double throw switch. For receiving, the switch shown in fig. 73 at I disconnects the 320 volt and connects the 40 volt batteries. It also cuts three bulbs out and puts a resistance R_1 in series with the bulb that is left in, and remains lighted. The sending key M is also short circuited, and the plate coil is disconnected from the ground, allowing the bulb and coils to operate as an independent heterodyne.

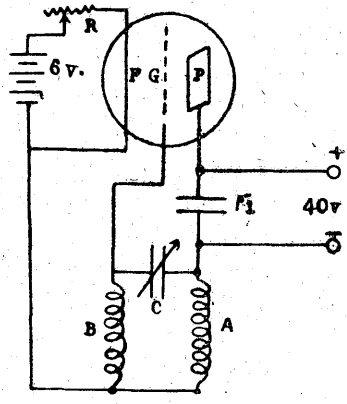


FIG. 74.—Schematic Receiving Circuits Set Radio Type E—3.

Transmission.

For transmitting, a special double commutator direct current dynamo is sometimes furnished with the E-3 and so there are two condensers F_1 and F_2 of 2 m. f. each in series across the power terminals, as shown in fig. 75, to prevent variation of the plate potential due to small fluctuating currents from the generator commutators. A fixed condenser

C_4 of .0005 m. f. capacity is placed in parallel with these two condensers and in the plate circuit. It allows current to flow from Coil A to plate P by reason of its small capacity, and together with Coil S and condensers F_1 and F_2 completely suppresses the slight commutator fluctuations. A fuse is usually placed in the positive side of the 320 volt circuit. A large variable condenser C furnishes a static coupling between the plate and grid coils. The key is inserted in the

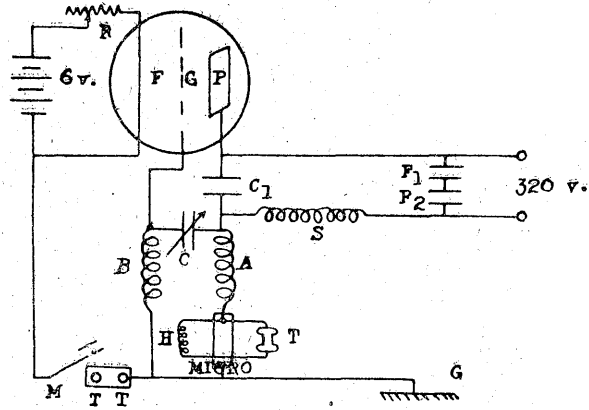


FIG. 75.—Schematic Transmitting Circuits Set Radio Type E—3.

plate circuit at M, and the microphone for telephonic transmission at T.

E—3 Receiving apparatus.

This apparatus is very similar to the Type A receiver previously described but will receive wave lengths from 500 to 1000 meters, and is especially designed to receive undamped waves. The primary coil has 79 turns tapped by a 5 point switch at the 30th, 38th, 47th, 61st, and 79th turns. A small fixed mica condenser and a variable air condenser are in parallel with each other, and in series with the primary coil. Minimum capacity is afforded with the variable condenser

index at 0, and maximum capacity with it at 90. The secondary coil has 108 turns tapped by a 4 point switch at the 33rd, 54th, 81st, and 108th turns. It revolves inside the primary, affording a variable coupling, a strong coupling being used to pick up stations, and a weaker coupling to cut out undesired stations. A variable air condenser is in parallel with the secondary coil. The detector, headset plug sockets and fixed stopping condenser are arranged as in the Type A set. Also the secondary variable condenser may be switched in or out by means of a small switch marked ATT, and SYNT., the former position leaving the secondary free to oscillate in any period; or the latter making it dependent upon the amount of capacity inserted with the variable condenser.

Calibration of receiver.

The following calibration table for primary and secondary holds for the prescribed V-type aerial with 50 meter branches, and with a 15 meter lead-in; and the prescribed ground composed of five nets buried in a V as near the set as possible, the fundamental wave length of this antenna being 325 meters and its capacity .0004 microfarad.

Primary coil	Condenser reading 0 to 90	Wave length
Step 1. 30 turns	0 to 90	450 to 570
— 2. 38 —	— — —	520 to 660
— 3. 47 —	— — —	590 to 740
— 4. 61 —	— — —	680 to 880
— 5. 79 —	— — —	820 to 1050
Secondary coil		**Wave length**
Step 1. 33 turns	0 to 90	190 to 530
— 2. 54 —	— — —	235 to 760
— 3. 81 —	— — —	240 to 1000
— 4. 108 —	— — —	230 to 1180

The amplifier.

A 3–ter amplifier is used and may be connected to serve as a detector and amplifier, in which case the first bulb

acts as a detector and the other two as amplifiers; or all three bulbs may be used as amplifiers. The connections are the same as when 3-ter is used with the Type A, which are shown in figures 58 and 57 of this pamphlet. One of the 40 volt batteries used in transmitting may also be used to furnish the plate potential, and a separate 4 volt battery is used for the filament current.

The wave meter.

Wave meter Type No. 1 range 100 to 1100 meters is supplied with the E-3 set; wave meter Type No. 5 range 500 to 2000 meters with the E-3 bis and E-3 ter sets. A description of these wave meters is given later.

Use of the set for transmission.

The five pole double throw switch on the E-3 Transmitter being on the transmitting position marked T, light the bulbs by turning the rheostat handle. Depress the key and vary the condenser until maximum reading on the ammeter is obtained. Then make a series of dots and dashes and see if the ammeter functions properly. The variations of the condenser should be very slight and, when adjusting, vary the heating of the filament, being careful not to burn the filament out. For wave lengths up to 800 meters the ammeter should not read more than .7 to .8 ampere; and .6 to .7 ampere for wave lengths up to 950 meters; and .5 ampere for 1,000 meters. The reason for a decrease in output of current for greater wave lengths is that the loading coil has an inductance much greater than the plain antenna. For larger wave lengths the small coil H, (Fig. 75) may be placed in circuit by removing the brass bar from the binding posts marked "Micro". Signals must be sent slowly, and be sure to notice the ammeter readings and see that it functions properly when each dot and dash is made.

Calibration of transmitted waves. — The wave meter is placed near the loading coil of the set to be tuned and its

vibrator set in motion. The variable condenser of the meter is set on the desired wave length on its scale. Then depress the key of the transmitter and note the sound in the wave meter telephones. If the set is not in resonance, vary the loading coil until the transmitter is in resonance with the calibrated circuit. When this is true the loudest sound will be heard in the telephones. With the adjustments of the instrument at this point of maximum sound the wave length of the transmitter may be read on the scale of the wave meter. The set should be so tuned that the least variation of the condenser will decrease the sound in the wave meter telephones.

Use of the set for reception.

Calibration of the heterodyne. It is best to have the heterodyne calibrated so that changes may be made readily from one wave length to another. To make this calibration, place the wave meter near the set containing the heterodyne. The 5 pole double throw switch of the set being on the receiving side, start the heterodyne. Adjust the wave meter to proper wave length; start its vibrator, then adjust the variable condenser of the set under test until the loudest sound is heard in the telephones of the wave meter. Then the corresponding wave length can be read from the scale on the wave meter.

Receiving transmitted signals.— The heterodyne having been calibrated it is set on the proper wave length, the primary of the receiver is then tuned; with the condenser switch of the secondary off, i. e., on ATT. The secondary switch should be on point 4, and the coupling as loose as possible. The primary switch is moved successively over points 1, 2, 3, 4 and 5. While it is on each point the condenser is moved slowly over its entire scale and back to the zero position. When the maximum sound is obtained during these operations the setting should be noted. Then the condenser switch must be placed on "Synt" and the secondary tuned in the same way as the primary, leaving

the coupling between primary and secondary as loose as possible in order to assist in weeding out interference from damped waves. The heterodyne will prevent interference from undamped signals. When tuning to obtain resonance with the transmitted wave it is necessary to vary the heterodyne condenser slightly to verify its setting. It is best to have the receiver calibrated so that ready changes may be properly made. As soon as a distant station is properly tuned on the receiving set its wave should be calibrated by measuring both the heterodyne and the receiving set.

Calibration.

As soon as a station is installed the following work should be attended to and properly recorded :

1. Calibrate the loading coil for various wave lengths.
2. Calibrate the receiver for various wave lengths.
3. Calibrate the heterodyne for various wave lengths.

Wireless telephony.

Connect the microphone by removing the brass short-circuiting bar from the posts marked " Micro " on the set ; short circuit the key. The apparatus is then adjusted for the proper wave lengths as in radio telegraphy. Speak loudly, distinctly and directly into the microphone at the same time having the mouth piece in a vertical plane. Wireless telephone signals are received just the same as damped telegraph signals, and therefore the heterodyne circuit must be broken by the rheostat used to furnish current to the filament of its bulbs.

Use of interrupter when transmitting.

For shorter ranges the E-3 set when equipped with the small direct current dynamo, may be used to send waves that can be received as ordinary damped waves. This is made possible by the use of an interrupter, placed in series with the key, that makes and breaks the sending circuit. Bin-

ding posts on the key (which are ordinarily short circuited) permit easy installation of the interrupter. The interrupter is a toothed disc mounted on the shaft of the dynamo. Every other sector of the disc is insulated, which causes the transmitter current to be broken, giving the effect of ordinary damped waves.

Wave Meters.

At the front great care must be taken to see that all radio sets are properly adjusted for wave lengths assigned to the station. This is due to the fact that so many sets operate in a small zone simultaneously. Without correct tuning, interference would cause confusion, and inefficient work would result. The necessary adjustment is accomplished by means of a wave meter. The importance of its use is greatly increased with the increased use of undamped waves, for the highly selective qualities of tuning possessed by sets using such waves enable many sets to be used simultaneously on waves differing only slightly in length, and wave meters must be used te accomplish this fine tuning.

Types T_1 and T_2.

The simplified Type T_1 wave meter issued with E-10 sets and its use in tuning these sets for sending and receiving have already been described. The Type T_2 is constructed and used in exactly the same manner as the T_1 the only difference being that it is calibrated to read wave lengths from 1000 to 1800 meters instead of 550 to 1000 meters.

Types no. 1 and no. 5.

These wave meters (see Fig. 76) are issued with the E-3 series of radio sets. They may be used in conjunction with any other radio sets of corresponding range of wave lengths. They are identical in size and external appearance differing only in the range of wave lengths for which they are

adapted. Wave Meter Type No. I (see Fig. 76). has a range from 100 to 1,100 meters; Type No. 5, a range from 500 to 2,000 meters.

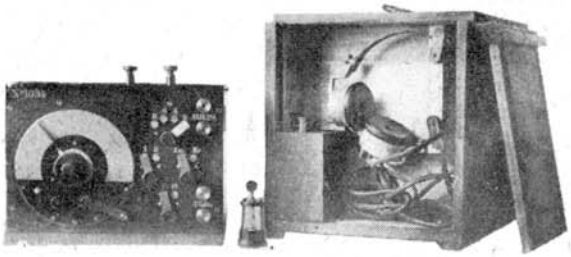


FIG. 76.—Wave Meter Type No. 1.

The wave meters may be used:

1. To measure the wave length emitted by a station.
2. To measure the wave length received by a station.
3. To adjust the station in advance for the reception of a given wave length.
4. To measure the natural wave length of an antenna.
5. To measure the capacity of a condenser.
6. To measure an inductance.
7. To measure the effective capacity and the inductance of an antenna.
8. To receive strong signals.

Description.

Fig. 77 shows the circuits of the small tyne wave meter.

A is the calibrated oscillating circuit.

B is an auxiliary coil.

C an impulse excitation circuit.

D a receiving circuit.

The oscillating circuit A consists of a variable condenser F and two coils R and M. The condenser has an inner and an outer scale. When the lever E is on point I, waves may

be measured from 100 to 350 meters, using the inner scale of condenser F. When lever E is on point 2, waves from 250

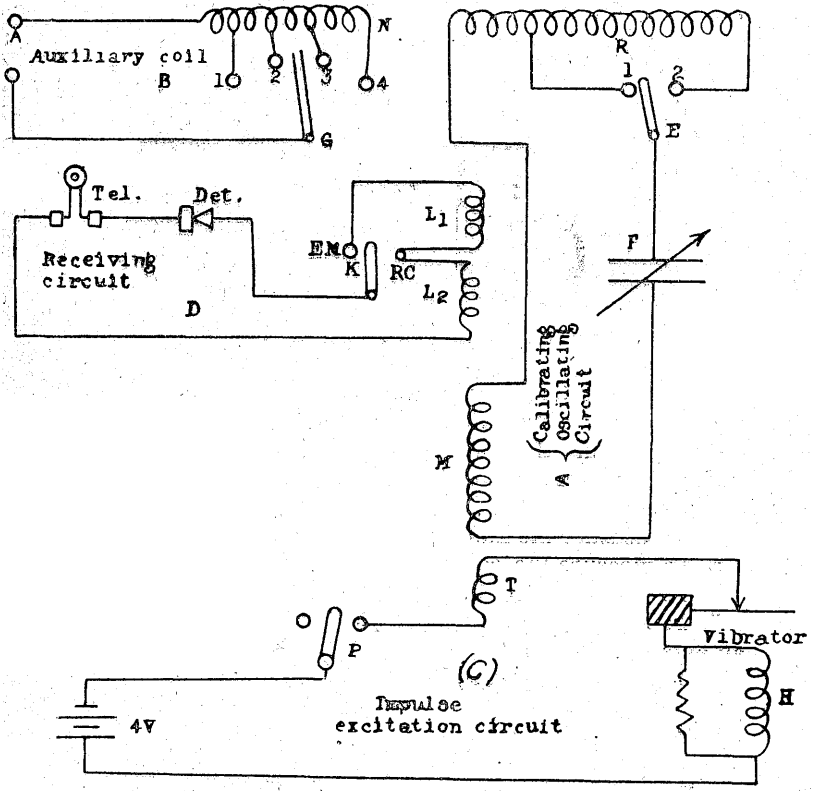


FIG. 77.—Circuits : Wave Meter Type No. 1 and Type No. 5.

to 1,000 meters may be measured, using outer scale of condenser F.

The Auxiliary Coil B is made up of 8 turns and by using the letter G it is adjustable by two turns on each contact point. The impulse excitation circuit C is made up of a coil

T and a vibrator H, the latter acting as a quenched spark gap. The variations of current set up by the vibrator H, acting through coil T will induce currents in circuit A through coil M. The coil M being in the circuit A, will set up oscillating currents with a wave length corresponding to the adjustments of the variable condenser F and the inductance controlled by switch E. The circuit D is the receiving circuit and is sensitive to any oscillation set up in the calibrated oscillating circuit A. Circuit D contains two coils L_1 and L_2. They are in series but are wound in opposite directions, each coil having the same number of turns. The circuit also contains a telephone receiver and detector.

Use of the meter to measure the wave length of a transmitting set.

Place the wave meter at a distance from the transmitter of which the wave length is to be measured, this distance varying with different powered sets. The stronger the emissions the further away the meter must be placed. Next put on the telephone head set and in the usual way adjust the detector. Place the lever K on the point marked EM. When on this position start the transmitter to be measured and press the key. The emisssions will only effect the receiver circuit D through the calibrated oscillating circuit, A. The reception of the emissions of the transmitter directly by circuit D is prevented because the coils L_1 and L_2 are made up of the same number of turns and wound in opposite directions. The coil M of circuit A is built closer to coil L_2 than to L_1 therefore oscillations in circuit A will effect coil L_2 more than coil L_1 : then this difference is readily heard in the telephones in the receiving circuit D. This being true we can adjust the calibrated circuit A until it is in resonance with the transmitter. This is done by listening in telephones of circuit D and adjusting condenser F and inductance E until the maximum sound is heard. Then by referring to the calibrated scale of the condenser we can read directly the wave length of the emissions from the transmitter under test.

Use of the meter to measure the wave length of signals received from a distant station.

The auxiliary coil B is inserted in series with the aerial and the receiving set of the local station. In coil N place adjusting lever G on contact I. This places two turns of coil N in series with the aerial. Next adjust the receiving set until you hear the maximum signals from the station to be measured, using as loose a coupling as possible. Next close switch P in circuit C which starts the vibrator H. Then T of this same circuit will induce a current in calibrated circuit A. Adjust condenser F and inductance coil, using lever E until the sound is heard plainly in the receiving set. Then the circuit A is in resonance with the signals that were sent from the station under measurement. If the circuit C fails to emit energy enough to let coil R induce into coil N audible signals, then the lever G must be placed on points 2, 3, or 4 of the coil N so as to insert more turns. The receiving set must be adjusted on the incoming signals when the lever G is moved before taking the reading of F. When these adjustments are made the scale on condenser F will give the wave length of the distant station. The measurements are more accurate when the least number of turns in coil N are used.

To calibrate a receiving set.

Place the wave meter in circuit as in measuring the wave length of signals received from a distant station. Then start the vibrator H by closing switch P. Adjust the circuit A for any desired wave length as shown by the scale on condenser A. Then adjust the receiving set under test until the maximum sound is heard using as loose a coupling as possible. Then receiver will be tuned to the wave length indicated by the scale on condenser F. Then by readjusting the circuit A and repeating the above process the receiving set may be calibrated for any desired wave lengths.

How to measure the wave length of an antenna.

Insert the auxiliary coil B in the antenna circuit of the receiving set. Then short circuit the condenser in the primary circuit of the receiving set and reduce the primary inductance to as small a value as possible. Then cut the condenser of the secondary out of circuit and reduce the secondary inductance until it shall be in resonance with that of the primary circuit. Then close switch P which starts the vibrator M. Adjust the circuit A until maximum sound is heard in the receiving set under test. Then the wave length of the aerial may be read from the scale on condenser F. This will not give the exact wave length of the aerial as allowance must be made for the small inductance that was left in the primary of the receiving set.

The wave meter as a heterodyne.

When the auxiliary coil B is inserted in the aerial circuit of a receiver the meter can be used as a heterodyne by starting the vibrator and adjusting the calibrated circuit to approximately the same wave length as the signals to be received. The wave meter circuits then set up waves of approximately the same length as the incoming signals but the period will vary from that of the signal so that one instant it adds to their amplitude and at the next instant it decreases it, producing audible signals in the telephones of the receiver.

Other uses.

In addition to the uses already explained the wave meter can, as stated, be used to make numerous other useful measurements :

1. Capacity of a condenser.
2. Self inductance in a coil.
3. Capacity and inductance in an aerial.

These measurements give only approximate values and

are of no practical use to radio at the front so their description is omitted here.

Owing to an error in standards all TM wave meters

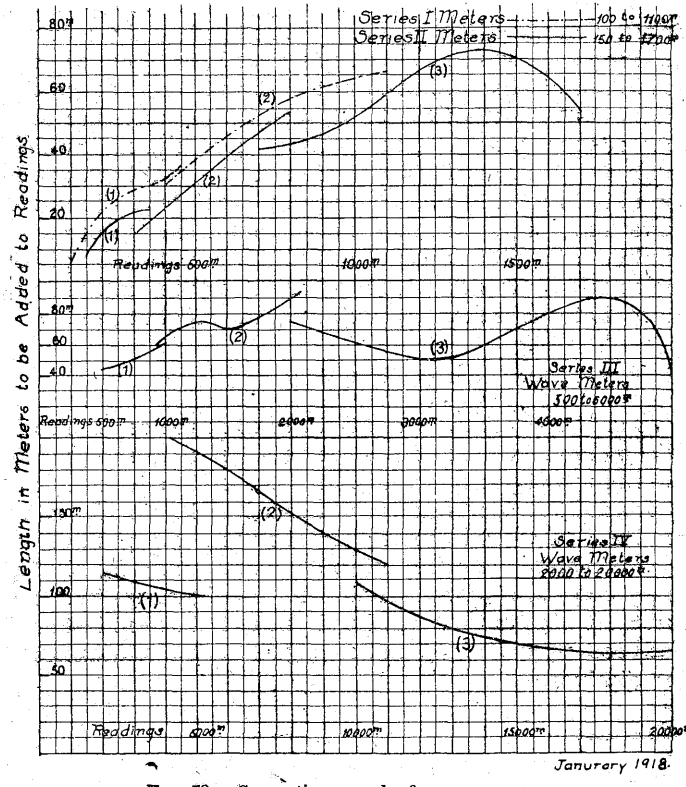


FIG. 78.—Correction graphs for wave meters.

issued previous to January 1, 1918 are incorrectly calibrated. Graphs giving the corrections to be applied to the readings made with these instruments Series I, II, III and IV are given in Fig. 78. It is necessary to add to the readings made from the scale, the length in meters indicated by the graph.

Example : The reading on scale 3 of a Series II wave meter is 1150 meters. The corresponding correction shown on the graph is 63 meters. The wave length corrected to accord with a 1918 scale, then, is :

$$1150 + 63 = 1213 \text{ meters.}$$

The number of the scale on the wave meter to which the curve applies is given in parenthesis near the curve. In the first set of curves the Series I wave meter corrections are indicated with a broken line thus : —.—.—.—. Series II wave meter corrections are indicated with an unbroken line thus : _____.

All French wave meters correctly calibrated are conspicuously marked " Longueurs d'ondes rectifiées 1918 " on the front panel.

Chapter VI.

RADIO IN THE FIELD.

Location of the Radio Receiving Station.

Several important points must be considered in determining upon the location of the Battalion Receiving Station for heavy artillery fire adjustment. Since it is necessary, or at least advantageous, that the Panel Station and the receiving station be close together in order to allow vocal communication between them, the selection of a location for the easy display of panels is an important feature. Positions on the reverse side of a gentle slope or in rear of a masking hedge or wood afford proper concealment from enemy aviators and do not give away the station location. This feature becomes of considerable importance when the large 9 × 9 meter panels are used as they are much more easily seen than the smaller 4 × 4 meter ones. In cases where it is found difficult to conceal the panels from the enemy as above, it is then necessary to separate the Panel Station and the Radio Receiving Station in order to protect the latter from bombardment attracted by the panels. Communication must then be maintained between the two by means of telephones.

The Receiving Station must also be placed so that the antenna wires will be free from danger of being grounded or knocked down by trees. Positions too close to active batteries or busy roads should be avoided, for the noise and vibration interferes with reception.

Dugout.

In places where it becomes necessary to locate the Radio Receiving Station in a dugout the dugout should be sufficiently large to accommodate the instruments and a table

large enough to insure their being well protected from the dampness of surrounding walls and affording sufficient writing space for two operators. Flooring should be provided to keep the operators' bodies insulated from the ground.

Care should be used to keep the antenna lead well insulated where entering the dugout; and to preserve as much air space between the antenna lead and walls ot the dugout as possible. A straight lead to the instruments is desirable. However, at the point of entrance to the dugout passage way, or through the insulator tube in the wall, a " drip loop " to prevent rain drops from coursing down the lead to the instruments should be provided. Sharp turns as well as unnecessary loops should be avoided. When it is necessary to go through wood or sand bags, tube insulators should be used.

Good results are usually obtained by burying the ground net, in the floor of the dugout, and placing the stakes in an out of the way location near the table, connecting the net and stakes to the instrument as described. Where the soil at the bottom of the dugout is of chalk or sand the ground net should be placed on the outside of the dugout in the surface soil which is a better conductor than the sand or chalk. The lead wire from the dugout to the ground net should be separated as far as possible from the antenna lead wire. If there are two doors to the dugout it is better to let the two leads come in different doors. If the ground net is not available, satisfactory results will be obtained by digging a narrow trench around the floor of the dugout next to the wall and burying eight or ten loops of bare copper wire, the ends of which are connected to the two stakes and the receiving set.

The Receiving Station should never be located near the telephone exchange or electric power lines; nor in dugouts or offices where other business is carried on. It is absolutely essential that nothing other than that connected with the radio station should occupy the radio dugout or quarters.

Erection of Antenna for Use with Type A Set.

The antenna most commonly used with the Type A radio set, previously described is a standard 50 meter V Type. It is composed of two 50 meter branches of special stranded tinned copper antenna wire, with a lead-in of 15 meters. usually mounted on double bamboo, or American lance poles spliced with iron coupling, so as to give a total height of 7 meters. The branches of the V should make an angle of approximately 30 with each other, and the V should be so placed that the bisector of this angle, if prolonged through the apex would pass approximately through the center of the target sector assigned to the battalion. This directional effect is important because it aids the strength of signals sent by an airplane operating in the direction of the target, thus permitting more selective tuning. With such an antenna the shortest wave length to be received with the Type A receiver is approximately 180 meters. If shorter wave lengths are desired the lengths of the two branches may be reduced to 35 meters.

The ground.

With the Type A sets a copper netting and two ground stakes are supplied for the establishing of a ground. Satisfactory results are obtained when this net is buried 10 or 15 inches and the two ground stakes placed at one end of the net, driven in the ground and connected to the binding posts on both sides of the net. The net should be buried as close to the receiving set as possible, in order to have a short ground lead. Directly under the antenna or in prolongation of it is the best position for the net.

Material.

To set up the above described antenna the following material is necessary :

100 meters stranded tinned copper antenna wire.
15 meters insulated wire for lead to set.
8 bamboo poles (2 extra).
1 shovel.
3 couplers, double; or 6 couplers, single.
3 guy ropes or wires, 18 meters long.
6 stakes for guys.
3 ebonite insulators for poles.
3 meters copper wire for ground connections.
1 copper net.
2 ground stakes.
2 hammers.

Duties prescribed for operators.

A systematic method of erecting the antenna is prescribed. In practice drills as well as in action, all electrical connections should be made mechanically secure as well as electrically secure. Care should be taken in fixing of guys, ropes, poles and other parts in the erection of the antenna to see that each part, and hence the whole, is well secured. For a personnel of 3 men the following routine is prescribed.

No. 1 selects two of the strongest bamboo or lance poles and couples them together with one double or two single iron couplings, on the spot where the apex of the V is to be placed and fixes one of the ebonite insulators to the top of the pole. He then splices the two antenna wires together and splices the lead-in to them. The antenna wires are then fastened to the insulator and the wire or rope guys fastened below the insulator. He then drives two stakes in the ground on a line perpendicular to the bisector of the V and 8 paces apart. His guys are then fastened to these stakes. He now indicates to Nos. 2 and 3 the direction they must go and unreel their branches of the antenna, allowing about 30° between the branches. Fig. 79.

No. 1 then erects the apex pole, allowing it to lean slightly against the strain of the guys in direction of the branches so that it will stand alone as shown in Fig. 80.

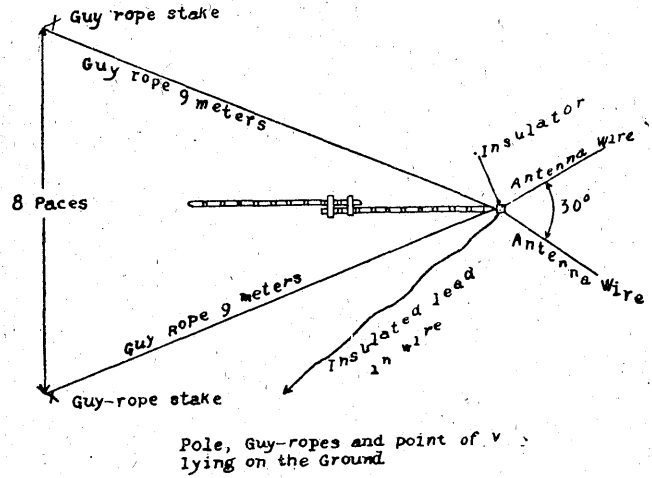


FIG. 79.— Erection of Antenna.

He then buries the ground net about 10 to 15 inches deep, connecting the ground lead to its binding posts. The two

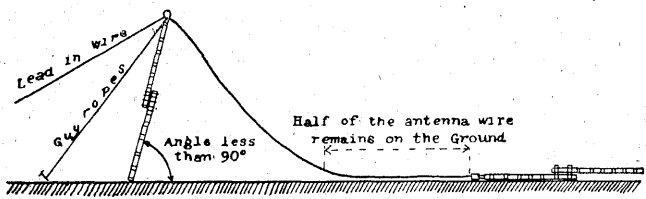


FIG. 80.—Erection of Antenna.

ground stakes are then driven in about half their length and connected with the net by means of the ground lead. No. 1

then connects the antenna and ground wires to the receiving set; and if the amplifier is to be used he also installs it.

No 2. also clamps two poles together, fixes an insulator to the top of the pole, fastens the guys below the insulator and having given the end of his branch of the antenna to No. 1, starts in the direction pointed out by No. 1, unreeling his branch of the antenna as he goes. He takes with him two coupling poles with the guys fastened on, two stakes, and a hammer. When he has unreeled the full length of his wire he fastens it to the insulator on top of the pole, lays the pole in prolongation of the wire so that half the length of his branch will remain off the ground, as shown by Fig. 80. His two 9 meter guys are then laid out on the ground at an angle of 60° to each other, and the guy stakes driven in at the end of the guys. The guys are then fastened to the stakes and the poles are lifted, carefully, against the strain of the guys. The guys should then be adjusted so that the antenna has a very slight sag, care being taken that the two branches are the same in this respect.

No. 3 erects the other branch of the antenna in exactly the same manner as No. 2.

The antenna branches should, of course, be measured to determine their proper length beforehand. This length should be, as stated, 50 meters for each branch. Small wood reels should be provided for reeling up the guys and antenna wires. Care should be taken, when ropes are used for guys, to prevent the shrinking and stretching of the ropes due to weather conditions from breaking antenna wires or lance poles.

Antenna for Receiving Press.

The large European stations used to send out otficial communiques and press messages operate on a wave length much higher than can be received with the Type A set used in Artillery fire control, the wave length limits of which are 180 to 550 meters approximately.

Eiffel tower may be received by means of a simple single wire antenna of a hundred or more meters in length and a crystal detector inserted in series with this antenna and a well established ground. Particular attention should be paid to the ground, a net buried ten or twelve inches and a stake at each corner all connected together will give satisfactory results. Buried shell cases have been used to replace the net satisfactorily. The telephone should be preferably the 2000 ohm type issued with Type A sets and the leads are attached to each side of the detector stand, thus simply shunting the detector with the telephones. Fig. 81.

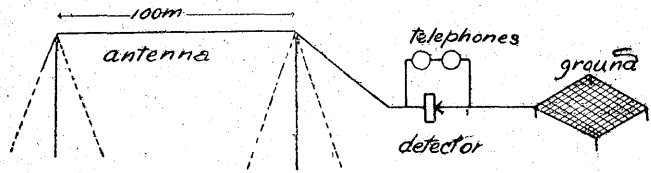


FIG. 81.—Simple Radio Receiver.

If a 3 ter amplifier is available the L_1 and L_2 terminals should be connected to each side of the detector and the head phones inserted in the amplifier in the regular manner. The signals will be greatly amplified then. Or, the amplifier may be used without a crystal detector using the first bulb as a detector, by inserting the L_1 and L_2 terminals in series with the ground, that is connecting L_1 to the antenna and L_2 to the ground (or vice versa) and placing the 3 pole double throw switch on H. F.

A simple constructed coil of the slide tuner Type may be made from material usually available in Heavy Artillery organizations. Its use in the antenna circuit above described or a similar antenna enables the tuning out of interferance and the receiving of stations of a greater wave length than can be received with the simple antenna circuit alone. Pyrene fire extinguisher tubes make excellent cores and a

sufficient number of turns of enamelled wire about No. 22 cover the full length of the tube give a wave length enabling the reception of most of the large European damped stations. Even the light field wire issued for telephone work may be used in constructing a coil of the type described. Such coils are known as " Auto transformers " or directly coupled receivers, for the same turns are used to form both primary and secondary circuit. The head phones and detectors issued with Type A sets are used in the secondary circuit. The connections used are shown in Fig. 82, P being the slide contact of the primary, S being the slide contact of the secondary and D and T being the detector and telephones.

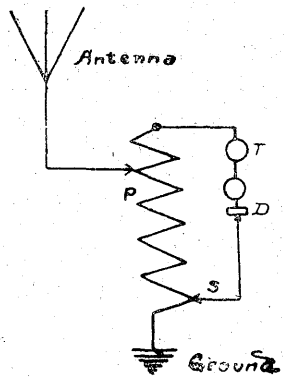


FIG. 8.
Circuit of simple slide Tuner.

Use of 3-ter amplifier as heterodyne.

For the reception of undamped or sustained waves, the inconvenience of not having an independent heterodyne may be overcome by a carefully executed change in wiring the first bulb of the 3-ter amplifier, by means of which the first bulb is made to oscillate as well as amplify, thus supplying the local sustained waves necessary for undamped wave reception. The change consists in simply inserting a variable capacity in parallel with the plate circuit of the first bulb, by means of a fine wire lead to the plate *pin* of the first bulb. The capacity may be supplied by two of the type A condensers connected in parallel or by the type wave meter condenser. This method of connecting a 3-ter amplifier gives excellent results, though great care must be used while making the connections not to interfere with the

circuits of the amplifier, or the type A. The receiving set used is connected to the amplifier in exactly the same manner as for damped reception,i.e. the telephone plug with two leads is inserted in the socket and the two leads connected to L_1 and L_2. The crystal detector is used, and its adjustment plays an important part in the success of the heterodyne.

Chapter VII.

MISCELLANEOUS.

Meteorological Data.

Meteorological information is supplied to artillery units from French Sounding Posts, sometimes by telephone but usually by means of Radio transmission. These sounding posts are of two kinds:

1. Army meteorological posts.
2. Army Corps sounding posts.

Army meteorological posts are distributed over the territory independent of the location of units. It is the information from these posts that is usually used by the heavy artillery. The data is transmitted by radio sets using damped waves of 500 meters, the messages of which can be received at 100 kilometers without amplification. It is sent out every four hours commencing at a specified initial hour. A table that is issued through G. H. Q., giving the list of Army meteorological posts with the initial hour of emission, should be obtained by the radio officers of all artillery units at the front.

Army corps sounding posts are established by army corps, the data therefrom being especially fit for light artillery. It is generally transmitted by telephone but in each army certain Army corps posts may let out their information by radio. The wave length used is variable and the hour of emission is regulated by Army headquarters.

The information is transmitted in a code of groups of 6 characters each.

1st Group: Consists of the index of the station transmitting in three letters sent twice.

2nd Group: Gives the character of the wind data sent; the altitude of the station; the temperature and pressure.

Following groups: Give the wind direction and velocity

at succeeding altitudes, at 0m, 200m, 500m, 1000m, 2000m, 3000 m, 4000m.

Second Group Code	1st Figure.	3 means sending ballistic wind.
	2nd —	Altitude in 100s of meters of meteorological post e. g.: 1 = 100 meters.
	3rd & 4th Figures.	Temperature in degrees (minus temperatures are indicated by adding 50 to their absolute value: 62 = 12° below zero).
	5th & 6th —	Pressure in millimeters at above altitude, cutting off the 7 e. g.: 56—Pressure at the Meteorological post altitude would be 756 millimeters.
Other Groups' Code	1st & 2nd Figures.	Altitude in 100 meters for which the ballistic wind is given: 05 means 500 meters.
	3rd & 4th —	Direction wind comes from at this altitude. A compass chart of 0 to 40 is used. 10 = East. 20 = South. 30 = West. 40 = North. 00 = Calm.
	5th & 6th —	Velocity of wind in meters per second with the addition of 50. Ex. 63 = 13 meters per second wind.

It is important that radio operators be able to receive and record meteorological data correctly. The meteorological stations always repeat the message and it should be record-

ed the second time by the operator, each figure being checked as it is put down. The following method of tabulation should be used:

Time 1.30 P. M.
21 October 1918.

MNSMNS	MNSMNS
311856	311856
023258	023258
053261	053261
103365	103365
203369	203369
303474	303474
403675	403675

Explanation of message:

MNS is the call letter of the Army Meteorological Post transmitting.

2nd group: 311856 indicates;

3—Ballistic wind;
1—100 meters Post altitude;
18—Temperature 18°;
56—Pressure at altitude of 100 meters (Post altitude) 756 millimeters.

3rd group: 023258 indicates;

02—Altitude 200 meters. (Above Post Altitude).
32—Wind direction at 200 meters high. (Above Post Altitude).
58—Velocity of wind 8 meters per second.

Transmission of Standard Time.

Every artillery unit equipped with radio should every day receive standard time from the Eiffel Tower. The tower

transmits standard time, on wave length of 2700 meters, damped, three times a day, i. e. at 10.00 A. M., 10.45 A. M. and 11.45 P. M. (Greenwich time, the time used by the Allied armies in France and by French railroads).

Commencing at 9.56 a. m. groups of three dashes are sent till 9.57, the end of the last dash indicating 9.57 exactly. Between 9.57 and 9.58 a series of dash, dot, dot, dash is sent and then three dashes, the end of the last one indicating 9.58 exactly, and so on until 10.00 a. m. The general scheme follows:

A. M.: 9.56 — — — — — — — — — — — — : 9.57 a. m.
: 9.57 — . . — — . . — — — — — — : 9.58 a. m.
: 9.58 — . — . — . — — — — : 9.59 a, m.
: 9.59 — — . — — . . — — — . — — — — : 10.00 a m.

Commencing at 10.44 a. m. a similar scheme is used, signals being given every two minutes with one dot being used to indicate exactly the odd minute:

A. M.: 10.44 — — — — — — — — — . : 10.45 a. m.
: 10.46 — . . — . . — . . . : 10.47 a. m.
: 10.48 — . . . . — . . . . — . . . . . : 10.49 a. m.

Time is transmitted at 11.45 P. M. in the same manner as at 10.45 A. M. Standard time should be received as follows:

While the Tower is sending preliminary signals, the radio operator on duty will adjust his receiving apparatus and carefully watch the motion of the split second hand of a stop watch.

Just as the Tower sends the signal indicating the precise time, he will carefully note down the time of the watch. By comparing the watch time with the transmitted time he will get the correction to be applied to the watch.

To avoid any mistake, do not attempt to time the reference watch itself.

The radio officer for infantry and artillery units, the local radio service for large unit staffs, are responsible for reception of standard time.

All advisable measures must be taken within the units to insure standard time transmission over the telephone to the most advanced units. The lists of units to receive daily time transmission should be posted in every telephone station.

For transmission of standard time over the telephone, the transmitting operator will call up the receiving station and announce:

"Am going to transmit standard time at (such) hours."

He then watches the split second hand of a stop watch, taking into account the required correction, warns his correspondent 10 or 15 seconds before the time announced by calling "Ready," and just as the split second passes on the required division he announces the time, calling, "Time." The receiving operator goes through the same performance as the radio operator when receiving from the Tower.

European stations.

The list on the next page gives the call letter, working time, wave length, and nature of message sent, of the more important European Stations.

Communiqués.

French official communiqués are sent out from Eiffel Tower, Paris, in French, at 3:00 p. m. and 11:50 p. m. and from Lyon, France in English at 12:00 noon. German official communiqués are sent out about 1:00 p. m. and 7:30 p. m. (time is variable) from Nauen, Germany.

NOTE. The schedules given above are based on standard European time, and consequently are subject to a one hour variation in accordance with the time plan of the French government adopted since the war. During the spring and summer all stations listed may be expected one hour later than the time given. For example, Eiffel Tower may be expected in the afternoon at 4:00 p. m.

DAMPED				
Time.	Call letters.	Name.	Work.	Wave length in meters.
3:50 a. m.	H B	Budapest, Austria.	Press	3500
9:56 a. m.	F L	Eiffel Tower, Paris, France.	Time	2700
10:44 a. m.	F L	Eiffel Tower, Paris, France.	Time	2700
11:00 a. m.	P O Z	Nauen, Germany.	Press	3900
12:00 Noon	T S R	Czarskoie Selo, Russia. .	Press	4500
12:30 p. m.	M P D	Pohldu, England.	Press	2800
1:00 p. m.	M C I	Carnavon, England. . . .	Press	11000
1:00 p. m.	P O Z	Nauen, Germany.	Press	3900
3:00 p. m.	F L	Eiffel Tower, Paris, France.	Press	2700
3:30 p. m.	I C I	Coltano, Italy.	Press	7000
5:30 p. m.	O S M	Constantinople, Turkey.	Press	2700
7:30 p. m.	P O Z	Nauen, Germany.	Official	3900
8:00 p. m.	V A	Mezieres, Austria.	Press	1500
8:00 p. m.	B U C	Roumanian Hdqrs	Press	3000
9:30 p. m.	E A C	Cadiz, Spain.	Press	2700
10:00 p. m.	P O Z	Nauen, Germany.	Press	3900
11:50 p. m.	F L	Eiffel Tower, Paris, France.	Press	2700
12:00 a. m.	M C I	Carnavon, England. . . .	Press	11000
3:00 a. m.	S D	Malta.	Press	2700
No fixed hour	L P	Leipzig, Germany. . . .	Press	4000
No fixed hour	E G C	Madrid, Spain.	Press	4000
No fixed hour	M P D	Pohldu, England.	Press	2800
UNDAMPED				
12:05 a. m.	B Y C	Naval Station, England. .	Press	10000
4:00 a. m.	Y N	Lyon, France.	Press	10000
4:00 p. m.	B Y C	Naval Station, England. .	Press	10000
8:10 p. m.	B Y C	Naval Station, England. .	Press	3500
No fixed hour	P O Z	Nauen, Germany.	Press	10000
No fixed hour	Y N	Lyon, France.	Press	10000

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