Experimental Wireless Telegraphy and Telephony—III*

Simple Receiving Apparatus and Elementary Circuits for the Beginner in the Art

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PERHAPS it would be more logical to start with a description of transmitters and their operation, rather than the receiving end. Obviously, wireless waves start at the transmitter, and there is little use speaking about the receiving set until one knows how to generate and propagate the waves. Theoretically, that is true; but in practice there are many amateurs and experimenters who never go beyond the mere reception of radio messages and time signals, hence it is well to deal first with the side of the subject which interests everyone, namely, receiving. It is well to mention here that any radio receiving set which receives wireless telegraph signals is ready to receive wireless telephone signals; in other words there is no difference between wireless telegraph and wireless telephone waves so far as their reception is concerned.

GENERAL PRINCIPLES OF WIRELESS RECEPTION.

Receiving sets are divided into two general classes, those for damped or non-persistent waves, and those for undamped or persistent waves. Sets for damped waves in practice involve the simpler connections and form a good starting point for the discussion, although it will be shown later in introducing undamped wave sets, that a very slight modification of the damped wave apparatus will give one method of receiving undamped waves. Damped waves are commonly received by a crystal detector or a vacuum tube detector, which will be described later on, and a telephone receiver, in conjunction with suitable tuning devices. The tone heard in the telephone is that of the groups

waves, then these waves, though extremely feeble, will, after a few impulses, build up comparatively big oscillations in the circuit. Electromagnetic waves have the power of exciting oscillations or inducing a certain amount of energy in any conductor on which they happen to impinge. This high frequency oscillating energy is usually too small to make its presence known, were it not for the aid of a suitable detector.

Fig. 4 Fig. 5
Two arrangements for coupled sets

In reality, then, for the reception of signals all that is needed is an antenna circuit tuned to the same wave-length as that of the transmitting station, and an instrument capable of evidencing the current which flows in the antenna connecting wire. The first sketch in the accompanying group of receiving arrangements represents the simplest possible type of receiver, and will operate on either damped or undamped waves. A current-indicating instrument is shown at A. In practice the current is too feeble for any hot-wire or thermo ammeter. An ammeter is more suitable for quantitative measurements than for receiving telegraphic signals, since the dots and dashes are not readily distinguished unless made so slowly as to be impracticable for transmitting purposes.

A more sensitive receiving device is a telephone receiver having a large number of turns of wire compactly wound. The current is made known by vibrations of the diaphragm at audible frequency, but the frequency of a radio current is so high that the diaphragm cannot possibly follow it. The effect is as if the diaphragm tried to go both ways at once, with the result that no observable motion takes place. To remove this difficulty a crystal rectifier is put into the circuit, which permits current to flow in one direction, but not in the other; or more exactly, the current in the reverse direction is negligibly small compared with the current in the principal direction. This action was described in the first part of this series.

It is found that the cumulative effect of one group of train waves, for instance that due to one condenser discharge at the transmitter, pulls the telephone diaphragm away from its neutral position. The number of such pulls per second is equal to the number of wave trains per second. With a 300-meter wave having 1,000 wave trains per second the radio frequency is 1,000,000 and the audio frequency is 1,000 or one is a thousand times as high as the other. The upper limit of audio frequency for the human ear is 16,000 to 20,000 sound waves per second, so that even if the telephone diaphragm could, with a rectifier, follow the radio frequency, the ear would not hear the signals. In telegraphic signalling, either a dot or a dash lasts long enough to contain many wave groups, and in the telephone, where the pitch corresponds to the spark frequency, a tone is heard during the length of the dot or dash.

SIMPLE RECEIVING SETS.

The second sketch of the group shows the simplest connection for receiving signals with a telephone receiver. It is suitable only for damped waves. At D is shown the rectifier, commonly called a detector, although it detects nothing; it simply alters the waves so that the telephone can detect them. The apparatus as shown receives best from a transmitter of the same, or nearly the same, wave-length. It is true that the presence of the detector and telephone introduces high resistance in the antenna circuit and thus renders it not very selective, so that it will respond to a wide range of wave-lengths. Tuning to resonance is made

Fig. 1 Fig. 2 Fig. 3
Simplest forms of wireless receiving sets

of damped waves or the spark frequency or wave trains, already described in this series.

If a spark coil is used at the transmitting end and use is made of a slow magnetic interrupter, of the type used early in the radio art, the note received at the receiving end will be low and unpleasant to the human ear. If the interrupter is adjusted so as to give a greater number of magnetic breaks per second, the note at the receiving end increases in pitch to a corresponding degree. The low harsh notes, besides being very unpleasant to the ear of the receiving operator, are undesirable because of the similarity which they bear to static disturbances. Indeed, when using low pitched signals the operator at the receiving end is often apt to confound static for signals. Modern damped wave transmitters, however, employ a high spark frequency of approximately 500 cycles, which, besides being pleasant to the ear of the receiving operator, is readily read through atmospherics or static disturbances.

Undamped waves are ordinarily received by a vacuum tube method which produces local current more or less out of phase with the incoming signals, this difference resulting in a current which sets up audible tones known as "beats" in the telephone receiver. There are other methods of receiving undamped waves which will be described later.

The fundamental principle of reception of signals is that of resonance, or what we have already referred to as tuning. If the receiving circuits are tuned to oscillate at the same natural frequency as the incoming

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Most important symbols used in representing instruments and arrangements of wireless circuits

Fig. 6 Fig. 7
Inductively coupled receivers

possible if a tuning coil is introduced such as L in the third sketch, to vary the inductance of the circuit and hence the wave-length. Thus it becomes possible to receive signals of any wave-length, by merely varying the number of turns of wire introduced in the antenna circuit by the tuning coil.

It is well to notice how simple is the apparatus actually needed for reception, contrary to what the uninitiated person supposes. Three pieces of apparatus—telephone receiver, rectifier or detector, and tuning coil—will receive effectively from damped wave stations. The main disadvantage of such a simple set, however, is in not being able to tune out stations that one does not wish to hear. Also the amplitude of the oscillation is much diminished by the high resistance of the detector and telephone. The principal resistance is that of the detector.

The apparatus shown in the third sketch gives practically the same results if the telephone is in shunt with the detector, instead of in series with it. In this case the explanation of the action is as follows: Suppose that the current flows easily upward through the rectifier, but not downward. During a group of incoming waves, the antenna thus receives an accumulated positive charge, and during the intervals between wave groups it discharges downward through the telephone. It cannot send current downward through the telephone. The pulsations of current pass through the telephone with successive wave groups.

To avoid the difficulties attendant upon the presence of the detector in the antenna circuit, it is customary to place the detector in a separate circuit coupled to the antenna; or another viewpoint is that the detecting instruments are placed as a shunt to the tuning coil. For instance, the fourth sketch shows a decided im-

Fig. 8 Fig. 9
Simple connections for vacuum tube detectors

provement over the previous arrangement, and requires no more apparatus except that the tuning coil has two adjustable contacts or "sliders" instead of one. Oscillations now take place freely between the antenna and ground. Two telephone receivers are shown, connected in series, one for each ear.

A further improvement is shown in the fifth sketch, where a variable condenser has been added. This is called a direct coupled connection. Let L_1 be the inductance in the antenna circuit, C_1 the capacitance between the antenna and ground, L_2 and C_2 the corresponding constants in the closed circuit shown by heavy lines. The antenna circuit is called the primary, since the energy enters the set there. The circuit containing L_2 and C_2 is called the secondary and is the closed oscillating circuit. In the same manner in which the transmitting antenna circuit is a good radiator of power, so the receiving antenna circuit is a good absorber. It is tuned to resonance with the incoming waves by adjustment of L_1 . The power is given over magnetically to the secondary, which is tuned to resonance by adjustment L_2 and C_2 . Comparatively large oscillations result in the secondary, producing voltages across the condenser which are detected by the crystal and telephone, which are not in either oscillating circuit. The oscillations are not damped thereby, and sharp tuning is obtained.

INDUCTIVELY COUPLED RECEIVING SETS.

In the sixth sketch is shown the inductively coupled set, which is in wide use today. This may be taken as the standard upon which all later changes are based. A fixed condenser of about 0.005 mfd. is shunted around the telephone and this increases the strength of the signals. Its action is explained as follows: Suppose the principal current flows downward through the detector and telephone. While this current flows, the fixed condenser is charged with top plate positive. When the reversal of the radio oscillation comes, the current through D and T ceases. Then the condenser discharges down through T and tends to maintain the current till the next oscillation downward through the instruments. In this way the gaps between the successive pulsations of rectified current are filled in, and the cumulative effect of a wave group is strengthened. In practice the telephone cord, containing as it does two conductors separated by dielectric, forms a condenser which in some cases is sufficient so that an added fixed condenser gives no improvement.

The connections shown in this last sketch give an effect similar to the direct coupled arrangement. In either case, on account of the coupling between the primary and secondary coils, there are reactions of each coil upon the other, with consequent double oscillations when the coils are near together. Sharp tuning becomes impossible. It is found, however, that if the resistance of the circuits is low, extremely sharp tuning is obtained. The antenna is tuned to the incoming waves by changes of the inductance L_1 . Sometimes, if very sharp primary tuning is desired, a variable condenser is shunted around L_1 , and the fine adjustments are made therewith. The secondary is tuned to the primary, the operations of tuning being done alternately until the telephone gives the best response. In the secondary the coarser tuning is done by changes of the inductance L_2 , and the fine tuning with the variable condenser C_2 .

For receiving a longer wave in the primary circuit than is possible by using all of the inductance L_1 , a series inductance L_3 , called a loading coil, is added, as shown in the seventh sketch. Also a variable condenser may be added as per dotted lines, to increase the wave-length and afford fine tuning. The secondary may also be provided with an extra inductance in series with L_2 , if needed. For receiving short waves on a large antenna, series condenser C_4 is inserted in the ground wire. It is short circuited when not in use.

In the typical sets so far described a crystal rectifier is used as the detector. The principal disadvantage of this type of detector is that it cannot be depended upon to stay in adjustment. A good deal of time is required for the frequent readjustments. The eighth sketch shows exactly the same connection, but with the crystal detector replaced by a Fleming valve, V . This is a glass bulb containing two electrodes and having the air exhausted. One electrode in the vacuum is a lamp filament which is heated by current from a storage battery A . The other electrode is a metal plate. The heated filament gives off a stream of electrons toward the plate, as will be covered in detail in a subsequent section of this series. Current from incoming electric waves can pass through the vacuum in only one direction determined by the electrons, the current in the opposite direction being suppressed. In this way the tube acts as a rectifier. It is very stable and about as sensitive as a good crystal.

A still further improvement is shown in the ninth sketch, using a vacuum tube having three electrodes. It is seen here that the circuits joined to the filament and the nearer electrode are exactly the same as in the preceding arrangement. The telephone, however, is in a circuit with a battery B , and the signals received thereby are much louder than with the Fleming valve arrangement. For the theory of action of the three-electrode vacuum tube as a detector, it is best to wait until the entire subject of vacuum tubes is taken up and thoroughly discussed later on.

Suffice it to add here that because the vacuum tube detector is a voltage-operated device—in other words, the highest potential applied on the grid will give the maximum signal in the telephone receiver—it works best with minimum capacity and maximum inductance in a circuit.

CAPACITY COUPLED RECEIVING SET.

A method of coupling receiving apparatus to the antenna circuit which affords compactness is shown in

Fig. 10 Fig. 11
Wiring schemes for capacitive receivers

of the secondary circuit and thus throws the receiving set out of resonance with the incoming signals. Time is lost in again tuning in the station. Another disadvantage is that capacity coupling cannot be used successfully on short or amateur wave-lengths for two reasons: first, the coupling condenser must be very small and the movement of the operator's hand sets the receiving equipment out of resonance, so delicate is the electrical balance; secondly, it usually proves most unstable and cannot be depended upon; thirdly, it is less efficient when employing vacuum tubes as detectors.

When simplicity of tuning is the principal requirement, and it is desired to reduce the tuning operations to a minimum number, even at the expense of a certain amount of selectivity, the following methods are used:

In the eleventh sketch is shown a modification of the capacitive connection; in practice the change from

Fig. 12 Fig. 13 Fig. 14
Wiring schemes for receiving damped and undamped waves

the tenth sketch. By fixing the primary and secondary coils L_1 and L_2 permanently at right angles to each other, inductive coupling between the two is prevented. Instead, the coupling between the two circuits is effected through the condensers C_1 —although usually one condenser is used—which are referred to as "coupling condensers." Such an arrangement is called "electrostatic" or "capacitive" coupling. The condensers are arranged so that by turning one handle both are varied together. One of the condensers, C_1 , the one connected to earth, may be omitted, but better results are usually obtained with two. The advantages of capacitive coupling are as follows: (1) The coils are of compact form. They are wound as rings with rectangular or square winding section, thus giving large inductances in small space. This is a great saving of room compared with sets using variable inductive coupling where the coils must be so constructed that one of them can move with respect to the other, and where they are usually wound on long tubes in order to get suitable variation of coupling. (2) The coils are fixed. In the inductive type they must sometimes be separated by many inches for very loose coupling. (3) The coupling is quickly and easily changed.

A great disadvantage of the capacity coupled set, however, is that when receiving from long-distance modern sharply-tuned transmitting stations, the varying of the condenser coupling changes the wave-length

the previous connections to the simpler connections here shown are accomplished by one switch. The secondary is removed, and the telephone is put in shunt with the detector instead of with the fixed condenser FC . If a medium value of coupling is used it is not usually necessary to alter it, therefore the only tuning adjustment is that of the primary inductance.

Another device for quick-tuning is shown in the twelfth sketch. This employs an inductive coupling. The primary is tuned sharply to the incoming waves, while the secondary is untuned. With the connections as shown, the secondary will respond in practically the same manner to a wide range of wave-lengths, owing to the high resistance of the detector. The only adjustment the operator has to make is that of the primary inductance. Sometimes additional provision is made for adjustment of the coupling by separating the coils; this gives variation in the sharpness of tuning and in the signal strength.

All these methods of quick tuning are used when listening for possible calls from a number of stations, because it is convenient to have apparatus that will respond to a wide variety of wave-lengths. As soon as the desired station is heard, the operator can then switch over to the usual receiving arrangement which ensures the desired degree of selectivity.

(Continued on page 91)

field, that of the hardening of oils and fats by hydrogenation—a problem to which we have referred on previous occasions—the previous history of the catalyst plays an important, not yet understood part. The catalyst generally used for the purpose of making the oil combine with more hydrogen is metallic nickel, reduced from the oxide or the hydroxide, themselves obtained from various salts; the method of reduction is of great influence. In order to secure a very fine subdivision of the catalyst, nickel carbonyl, which decomposes at 200 deg. C., has been directly mixed with the oil. Still more efficient is the Lesing process which supplies the nickel carbonyl along with the current of hydrogen passing into the oil at 200 deg. C.; the nickel then acts as soon as liberated, and excellent results have been obtained with 0.1 per cent. of nickel, while of ordinary nickel catalysts 5 per cent. may be wanted. For these nickel catalysts carbon monoxide seems to be a “poison.”

Dr. Philip also dwelt on the oxidation of ammonia by air in the presence of bright platinum at dull red heat. The reaction is $4\text{NH}_3 + 5\text{O}_2 \rightarrow 4\text{NO} + 6\text{H}_2\text{O}$. We referred to this process recently in our issue of November 1 (page 498). As regards the mechanism of catalysis, it has been suggested, Dr. Philip stated, that the catalyst forms intermediate compounds, *e. g.*, with the oxygen which are decomposed again by the hydrogen. The chemical view, Dr. Philip pointed out, was only tenable if this rate of the formation and decomposition of the intermediate compound were greater than that of the uncatalysed reaction, and in many cases, for instance, with catalysis by glowing porcelain, such compounds seemed to be out of the question. Yet the physical condition of the surfaces might be altered by these intermediate reactions, and surface condensation and concentration were certainly to be reckoned with. No single theory would fit all cases of catalysis, however, and chemical and physical factors had to be taken into account.

In the domain of absorption phenomena we find again that the problems can be exactly formulated for gases and liquids, but become more complicated when solids are concerned. According to Henry's law the volume V of a gas taken up by unit volume of a liquid is proportional to the pressure P under which the absorption takes place. Thus for carbon dioxide and water, when P is expressed in centimeters of mercury and V in cubic centimeters at normal temperature and pressure, V/P has the fairly constant value 0.145. That holds also for the absorption of acetylene by acetone which takes up 250 volumes of acetylene; the acetone expands when absorbing the acetylene, and for this and other reasons the steel cylinders are partly charged with some porous absorbent, as we noted in our article, published early this year, on “Cylinders for Dissolved Acetylene.”

Since the absorption increases with pressure, and water absorbs at ordinary temperature nearly 50 times more carbon dioxide CO_2 than hydrogen, the bulk of CO_2 can be removed and separated from the hydrogen in water gas by exposing the gas to water under pressure. Water dissolves at 0 deg. C., 0.0489 volume of oxygen, 0.0239 of nitrogen, 0.0215 of hydrogen and 1.713 of carbon dioxides, and at 20 deg. C. 0.031, 0.0164, 0.0182, 0.0878 volumes. More oxygen is thus taken up from air than nitrogen, and more oxygen given up again subsequently on releasing the pressure. Now air contains 21 per cent. of oxygen; by one absorption this percentage is raised to 33, and by eight successive absorptions to 97; such processes for the commercial production of oxygen have been patented, but they are hardly commercial. The purification of the crude ammoniacal liquor from sulphuretted hydrogen H_2S and from CO_2 is, however, carried out on this principle by a process patented by Hills in 1868. The liquor is passed in a tower over a series of trays steam-heated from the bottom; the CO_2 and H_2S being less soluble in the liquor than the ammonia, small percentages of the former two gases can be reduced to about one-tenth of their values, 0.12 and 0.04 per cent. Dr. Philip also referred to the caisson-sickness, which is mainly due to the liberation of nitrogen from the blood on decompression; the oxygen remains bound in the blood, in labile fixation.

Since the concentration of a gas is proportional to its pressure, we may write Henry's law also $C_1/C_0 = K$, designating by the C the concentration in the liquid and the gaseous phase. When a solid is present, the amount of gas taken up by the solid C_s is also found to increase regularly, but at a slower rate than the pressure; the simple relation $C_s/C_0 = K$ does not hold, therefore, but in many cases the formula

$C_s/C_0 \frac{1}{n} = k$ is applicable, *e. g.*, for charcoal and

carbon dioxide where $n = 3$. It is believed that the gas absorbed by a solid is not uniformly distributed throughout the solid as it is in a liquid. There is a “dual” relation, in fact. There is first a very rapid adsorption of gas or liquid by the surface layer of the charcoal, followed by a much slower diffusion and penetration of the gas into the interior of the charcoal (absorption). The former surface effect is a question of seconds or minutes, the latter of hours and days. The regularity of the phenomena may therefore be obscured; but many experiments made at rising and falling pressures and temperatures have established the applicability of rules. The whole series of the phenomena of surface films of gases and occlusion of gases fall into this category. It is well known that charcoal becomes a very powerful absorbent for most gases at very low temperatures. It is not understood, however, why different kinds of charcoal from various woods, differently treated, differ so strongly as to absorptive power. The masks developed during the war for the absorption of poison gases contain charcoal. Treated successfully with “doses” of 6 liters of air charged with 1 per cent. of poison gas, Dr. Philip mentioned three charcoals, A, B, C retained successively: A, 78, 5, 0; B, 100, 20, 0; C, 100, 100, 97 per cent. of the gas; all the three charcoals were the same, but B had been heated four hours, and C six hours longer than A.

The dual character of the sorption by solids is also distinct in cases when charcoal and other absorbents are first charged with a substance (iodine, acetic acid) by being left in contact with a solution of the substance and then shaken or left in contact with a more diluted solution of the same substance. Silk, *e. g.*, takes up picric acid from solutions, and gives it up again when shaken with the solvent afterwards, the equilibrium being reversible. If the whole dyeing process relied on this sorption only, fast colors would be impossible, but chemical reactions and other factors come into play in dyeing. Vegetable and animal charcoals, Fuller's earth, clays, colloids, are largely utilized as absorbents. We do not know why certain modifications of their preparation, frequently merely shorter or longer heating, or the presence of ashes apparently, so strongly affect their efficiency, and we cannot help that the animal charcoal, which is to remove the coloring matter and other impurities from the sugar solution, also absorbs sugar. But part of this sugar can be recovered again by washing the charcoal with water, because the process is an equilibrium reaction. All these considerations are of signal importance also in soil problems. If the soil were not able to retain the salts used for fertilization, the rain would wash out the fertilizer. Colloidal gels in the soil seem, however, to be capable of absorbing the base (ammonia, *e. g.*), leaving the sulphuric acid to combine with the lime, somewhat as the fibre combines with the basic dye, and sewage farming is based on an adsorption of organic matter by the soil. But these problems are still obscure.

Experimental Wireless Telegraphy and Telephony (Continued from page 85)

SIMPLE RECEPTION OF UNDAMPED WAVES.

While damped waves are transmitted as detached groups or trains, undamped waves are usually not separated into groups. Undamped waves, even if rectified, will not be detected in a telephone receiver unless the waves are broken up into groups in some way. This is because the telephone diaphragm and the ear cannot respond to so high a frequency as that of the radio oscillations. Hence it is necessary to interrupt the undamped wave dot or dash into many groups by rapid interruptions of the current. It is arranged in practice to have, for example, 1,000 interruptions a second, giving a 500-cycle note in the telephones; and as long as a signal continues a note of pitch 1,000 is heard. These interruptions may be made to take place either at the transmitting or the receiving station. A method for producing them at the transmitting station is to insert a rapidly operating circuit breaker called a “chopper” in the antenna wire; or if it is inconvenient to break the current, the chopper may be used to short circuit some of the turns of the antenna inductance coil to throw the circuits out of resonance periodically. This divides up the waves into groups to which the receiving telephone can respond. A rather more convenient method is to have the chopping done at the receiving station, for then the receiving operator can control the pitch of the received signals at will thereby listening to the note best adapted to his ear. There are at least five ways of modifying the waves at a receiving station to obtain an audible frequency: (1) a

chopper in series with the detector and telephone; (2) a variable condenser with rapidly rotating plates; (3) a “tikker” used instead of a detector; (4) a “heterodyne” in a separate circuit; (5) an “autodyne” or vacuum tube device arranged so that the detecting tube also produces the heterodyne action. The last method is explained in the section dealing with vacuum tubes, further on.

The chopper may be any device for rapidly making and breaking the current. It is inserted in the circuit of the detector and telephone as in the ordinary damped wave set. It consists of a rotating toothed wheel with stationary contact touching the successive teeth, or a break controlled by an electrically-operated tuning fork, or it is sometimes a light high speed vibrator similar to that of an electric bell.

If the movable plates of the tuning condenser in an inductively coupled set are rotated rapidly the apparatus will be in tune once for each revolution. Each of these revolutions will produce an impulse of the telephone diaphragm. The speed can be adjusted so that the impulse will cause sounds while waves are being received. In practice it is found best to keep part of the capacitance of the condenser constant, and vary only a part of it. If the main plates were rotated the apparatus would give sounds at only a small sector of each revolution, near the resonance adjustment. To accomplish a more prolonged train of impulses during one revolution the adjustment can be held near resonance for a longer proportion of the time if the rotating condenser is made very small, and is placed in parallel with the condenser. The large condenser does not then rotate except for ordinary hand tuning. The capacitance of the large condenser plus the maximum capacitance of the rotating condenser is adjusted to give resonance. The circuit is not far from this condition when the moving plates are farthest apart, so that the signals affect the receiver during a considerable portion of the revolution.

The tikker is usually a stationary fine wire of steel or gold with its end running in the groove of a smooth, rotating brass wheel. It is a slipping contact device. The wires do not remain in perfect contact with the wheel, but owing to the slight irregularities there are variations of contact, which in effect keep making and breaking the circuit. Referring to the thirteenth sketch, with the tikker contact open, suppose the secondary inductance and condenser C_2 to be tuned to resonance with the incoming waves. If now the tikker is closed when C_2 has any stated value of charge, some of the charge will be given to the condenser C and furthermore the radio oscillations cease because the addition of C throws the apparatus out of tune. When the tikker is opened the condenser C discharges through the telephone, and in the meantime the secondary oscillations build up again, ready to give a charge over to C when the contact is closed. In this manner the current impulses through the telephone are of the same frequency as the operation of the tikker, and this can be controlled by the speed of the wheel. The capacity of C should be about 1 mfd. No separate rectifier is needed. The tone obtained is not musical, since C_2 is charged to different potential differences at the different times when the tikker closes, and the action depends also upon a somewhat irregular contact.

In the heterodyne method an apparatus is arranged to produce undamped electric oscillations in the receiving circuit, of nearly the same frequency as that of the waves which are being received, and their combined action is made to affect the receiving telephone. Beats are produced having a frequency equal to the difference of the frequencies of the two waves. The connections are shown in the fourteenth sketch. Any source of undamped or slightly damped oscillations is connected at A. In the antenna circuit at B is a single turn or loop, coupled inductively to A. The antenna circuit thus gets the effect of the oscillations from A as well as from the incoming waves. Suppose those received have a frequency of 100,000, and the heterodyne A is adjusted to give a frequency of 99,000. As long as both act, the telephone will respond to a pitch of 1,000 vibrations per second, which is of course audible. When the incoming waves cease, the heterodyne continues to act along at 99,000, but this is inaudible. Therefore signals are heard only during the time when the incoming radio waves are received.

While a radio telephone transmitting apparatus operates on undamped waves it is not necessary, or indeed permissible, to use a chopper, tikker, or heterodyne at the receiving station. The transmitted waves are modified or varied in intensity by the spoken sounds and these sounds are reproduced in the telephone of the ordinary receiving set such as is used for damped waves.

(To be continued.)

¹See *Engineering*, February 8, 1918, page 155.

²See *Engineering*, 1918, page 562 and 583 ante.