CRYSTAL RECEIVERS
AND
CIRCUITS

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BY

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PREFACE

It is one of the charms of the art of wireless that every aspect or branch of it possesses a fascination peculiar to itself, and that each constitutes an apparently endless field for experiment and research. Thus crystal receivers and their possibilities can be discussed irrespective of their rival, the valve. Conversely, when immersed in the subject of the valve, one is apt to relegate crystal receivers to the background of one's mind.

Another charm about wireless is that it is not a subject to be taken up and learned by heart—like Euclid, for instance. There is something mysterious about it—we do not even know that it is carried on by means of ether waves, for the ether is merely hypothetical. And notwithstanding all that has been definitely ascertained and laid down as fundamental, occasionally a fresh development lays some preconceived idea in the dust.

At the present time, it would perhaps be difficult to overrate the importance of crystal receivers in view of the fact that experiments carried out from powerful broadcasting stations, and with wave-lengths much greater than those hitherto employed, have already proved the possibility of crystal reception over greater distances than used to be thought possible. Again, Senator Marconi's experiments in 1924 with wave lengths of between 90 and 100 metres, resulting in wireless telephony between England and Australia, hold out the hope that before long crystal sets may have an effective range of hundreds of miles. Moreover, a crystal circuit is stated to have been evolved which provides amplification without the use of valves. And finally, apart from such developments, one may look forward to a system of relay stations which will bring every broadcasting station in the world within the reach of crystal receivers.

In the present volume will be found detailed descriptions of tuning inductances —variometers, basket and honeycomb coils —the coupling of aerial and receiver circuits, and the fundamental crystal circuits upon which all freak and " super " crystal circuits are based.

P. J. R.

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CRYSTAL RECEIVERS AND CIRCUITS

CHAPTER I

TUNING COILS

Before describing receiving circuits as a whole, it is desirable to discuss the principal tuning devices and their relative merits and defects, so as to pave the way to an understanding of their application to receivers, and the reasons for particular methods of tuning in individual cases.

Inductances may be primarily classed as fixed and variable. A fixed inductance is one which is not variable, and is employed in circuits where tuning is performed entirely by condensers.

In the case of a tapped inductance coil, the wire is tapped at every turn for so many turns, for fine adjustment, and then once every few turns for coarse adjustment. With an average outdoor aerial an inductance coil 10 centimetres diameter and 10 centimetres long, tapped at every turn for 10 turns and then once every tenth turn, would enable an aerial to be tuned to any wave-length between about 80 and 700 metres or a little more, according to the natural wave-length of the aerial itself.

Now it might be thought that we could go on increasing the number of turns in such a coil indefinitely, and thus increase the wave-length of an aerial to thousands of metres. And so we could, but in that case a tapped coil would be found inefficient for short wave-lengths and weak signals, for the following reason.

Suppose that a coil 10 centimetres in diameter and 20 centimetres long contains 200 turns of wire, giving a maximum wave-length of 1615 metres. The band of British broadcasting wave-lengths lies, for the most part, between 300 and 500 metres, so that if we desired to receive a wave-length of, say, 500 metres, we should adjust our tuning switches so as to include between 70 and 80 turns of the coil, thus cutting about 120 turns out of the circuit. This, however, is not the whole story. The unused portion of the coil, although not directly in the circuit, is joined on to it, and produces an effect known as dead-end loss.

Fig. 1 is a theoretical diagram of the simplest form of crystal circuit with an unduly long variable inductance and with the tuning switch set for a short wave-length, the "live" portion of the coil, B C, embraced in the circuit, being shown in thick line, and the unused or "dead" portion, C D, in thin line. (This difference in thickness of line has nothing to do with the thickness of wire, which is supposed to be the same throughout the coil.) Now although C D is cut out of the main circuit, it is affected by the live portion of the coil, B C, in several ways, of which it will suffice to name three.

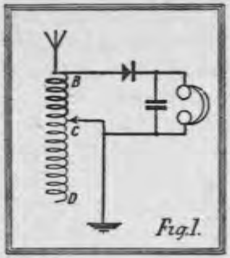


Fig. 1.

(1) The dead portion of the coil virtually constitutes an extension of the aerial, so that aerial currents will oscillate in it, although it is cut out of the receiver circuit.

(2) B C will tend to induce in C D an oscillating current which will react upon B C.

(3) Although B C and C D are joined, there will be a capacity effect between them.

Furthermore, the greater the number of tappings the worse the effect they produce.

It is obvious that the net result of these interfering factors will be to oppose a steady building up of the current oscillations, and thus to decrease the strength of the received signals. Clearly, then, the ideal method would be to have a set of fixed inductances, one for each wave-length it is desired to receive, which could be changed about according to requirements, for although this would not enable tuning to be dispensed with entirely, the range of the variable inductance could by such means be kept small, so as to eliminate dead-end losses as far as possible. This, in fact, is what is aimed at in the design of many receivers, but unfortunately it entails extra expense, unless the owner is prepared to wind his own coils.

Within certain limits, we may adopt this system of interchangeable inductance coils, and a comparatively small variable inductance, or a condenser, so as to reduce dead-end losses to a minimum, for fine tuning.

A set of ordinary cylindrical inductance coils being somewhat cumbersome to mount and to change at a moment's notice, a better and neater type may be employed, namely, either basket or honeycomb coils, which possess the advantages that a larger amount of inductance can be concentrated in a smaller space, and that they can be neatly mounted and quickly changed. Moreover, even in a fixed inductance coil of the cylindrical type, and apart from the question of dead-end losses, there is an appreciable amount of self-capacity, in series in the circuit. Capacity in series reduces wave-length, whereas the object of inductance is to increase wave-length; consequently to obtain the required wave-length we need a longer coil than would otherwise be necessary, in order to overcome the effect of its self-capacity. But the longer the coil the more wire it contains, and the greater the resistance interposed—which is just what we want to avoid, for resistance not only reduces efficiency: it flattens tuning. Although self-capacity cannot be entirely eliminated, it can be considerably reduced, and that is another advantage of basket and honeycomb coils: they are wound in such a manner that their self-capacity is reduced to a minimum. If we examine one of these coils it will be observed that they are wound so that, instead of the turns all being parallel, they cross each other. Such coils (of most makes) are mounted with a spigot and socket in the bottom of the mounting, which fit a corresponding socket and spigot in a fixed base on the receiver panel, the terminals

Fig. 2.

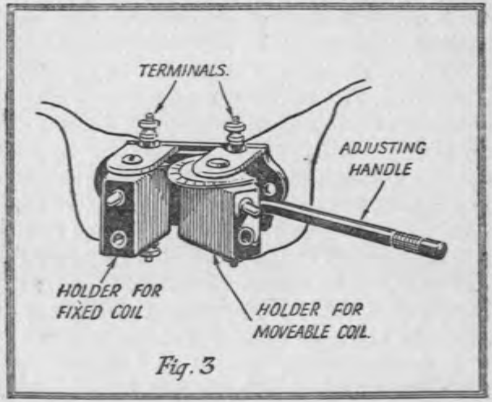


Fig. 3

in the base being wired up in the circuit. They are readily withdrawn and substituted by others (Figs. 2 and 3).

A complete set of such coils will thus enable a big range of wave-lengths to be efficiently covered, by plugging in a coil most nearly corresponding to the wave-length required; whilst tuning, as already mentioned, may be effected either by a variable condenser or by a small variable inductance.

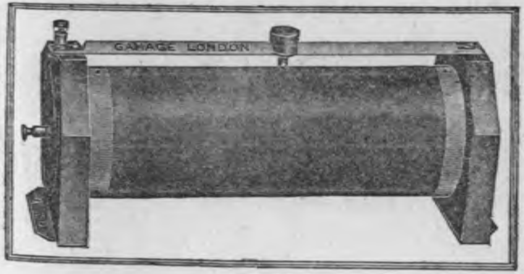


Fig. 4.

Tables I, 2 and 3 and Charts I and 2 in the Appendix give the wave-lengths covered by a set of Igranic honeycomb coils.

In another type of inductance coil, tuning is effected by means of a sliding contact rubbing against an untapped coil (Fig. 4). Parallel with the coil is a metal bar on which the slider moves, the slider being provided with a spring so that it exerts a steady pressure against the coil. One end of the coil is connected to a terminal, and one end of the bar to another terminal, for coupling the coil in the circuit. Wherever the slider tip makes contact with the coil it virtually taps it, so that any portion of the coil can be included in the circuit.

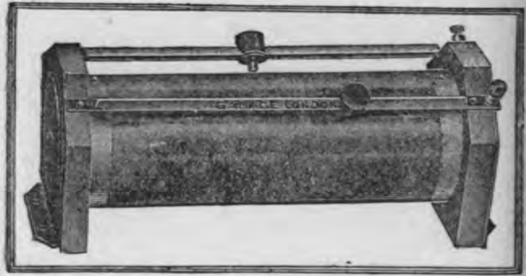


Fig. 5.

A two-slider tuner [Figs. 5, and 37 (on page 67)] enables a large amount of inductance to be employed in the receiver circuit, the advantage of which is as follows.

Every aerial circuit possesses a certain capacity, which means that less inductance is required to increase the wave-length than would otherwise be necessary. On the other hand, it is sometimes an advantage to

employ a comparatively large inductance in the receiver circuit, owing to the fact that the greater the inductance the greater is the electrical pressure across it due to high-frequency currents, and therefore the greater

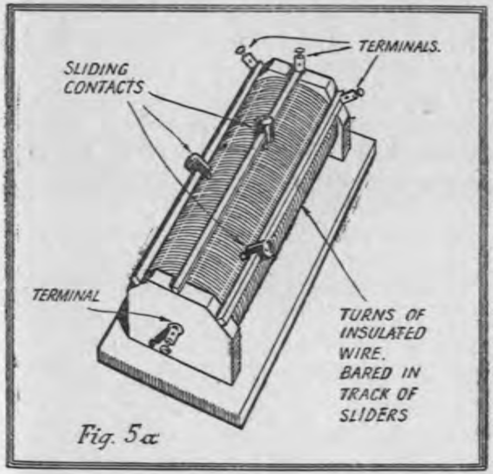


Fig. 5a

the electrical energy for overcoming the resistance of the crystal.

Three-slider tuners are also made [Figs. 5a, and 38 (on page 71)] which enable the amount of inductance common to the aerial and receiver circuits to be varied. When the number of turns common to both circuits are many, a comparatively large amount of current passes through the receiver circuit, but tuning is not so fine as when fewer turns are common to both and less current passes into the receiver circuit at each swing of the high-frequency oscillating current in the aerial.

Although, theoretically, tuning inductances with sliders are quite good, in practice they are apt to give trouble unless they are extremely well made. The wire is liable to become loose, or after constant use may wear and give rise to short circuits.

CHAPTER II

VARIOMETERS, VARIO-COUPLERS, LOOSE-COUPLING, ETC.

A VARIOMETER is another form of variable inductance, but in order to understand how it functions a little preliminary explanation is necessary.

If two inductance coils, A and B, each of, say, 100 microhenries, be placed in series in a circuit, as in Fig. 6, the inductance of the circuit will be increased to 200 microhenries. If, however, B is made movable and is placed as shown in Fig. 7, the two induc-

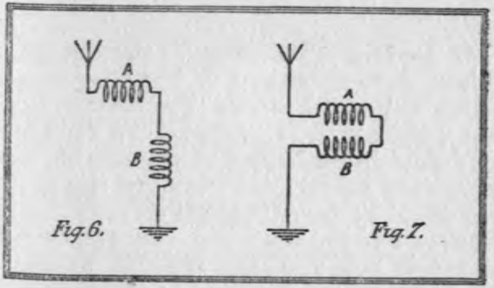


Fig. 6.

Fig. 7.

tances will react upon each other and the total inductance will be either more or less than 200 according to which way they are wound. Thus, if they are wound so that the magnetic lines of force produced by the current in A are in the same direction as those produced by the current in B, the total inductance will be more than 200. But if we move B round in the opposite direction so that B's lines of force are opposed to those of A, the two sets of lines of force will tend to neutralize each other, and the inductance will be greatly reduced. This increase and reduction will vary according to the proportion of the two coils.

In practice (Fig. 8) A is wound on a former, B being wound on a smaller former which is pivoted inside the former of A (see Figs. 6 and 7). Connections are made by means of terminals and contacts, so that both coils are in series and yet the inner coil can be rotated through any angle relatively to the outer coil. On the outside of former A is a pair of terminals to which the aerial and earth wires are attached, and also the wires of the receiver circuit. Tuning is then effected by varying the mutual inductance of the two coils. Fig. 8a (see special photograph at end of book) shows a new type of "Igranic" variometer, of which the coils are not wound on formers. The coils are shown outside the containing tube.

A vario-coupler (Fig. 9) is a sort of combination of a variometer and an ordinary tapped tuning inductance. The outer coil may be tapped for rough aerial tuning, and fine tuning may be effected by a variable condenser. The inner coil, appertaining to the receiver circuit, is connected to a third coil which in turn is tapped (Fig. 10),

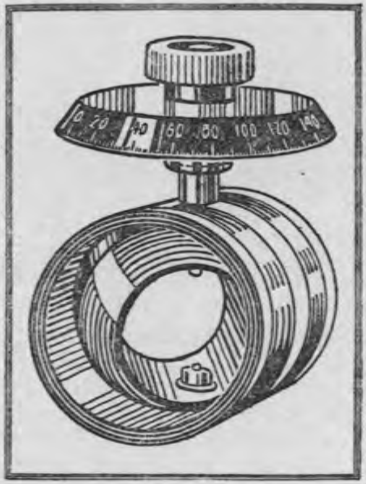


Fig. 8.

fine tuning again being obtained in the receiver circuit by a variable condenser. Fair selectivity can be obtained with such an arrangement of vario-coupler as that indicated in Fig. 10, but it is naturally more expensive and a little more troublesome to manipulate than a simple variometer, although the principle of coupling is the same in both cases.

In the case of variometers, as already explained, the wire of the two coils is connected, either in series or parallel, but there is another form of coupling, known as loose-coupling, in which the aerial circuit and receiver circuit are quite separate: that is to say, that there is no wire connection whatever between them. Each circuit is provided either with a tuning inductance, or with a fixed inductance and a variable condenser, the two inductance coils being so located, relatively to each other, that the oscillations in the aerial coil induce corresponding oscillations in the coil of the receiver circuit. It should perhaps be explained here that an aerial circuit is known as an "open" circuit, and a receiver circuit as a "closed" circuit.

When cylindrical coils are employed, the aerial inductance is wound on a former, and the closed circuit coil on a smaller former so that it can be slid inside the other, but so

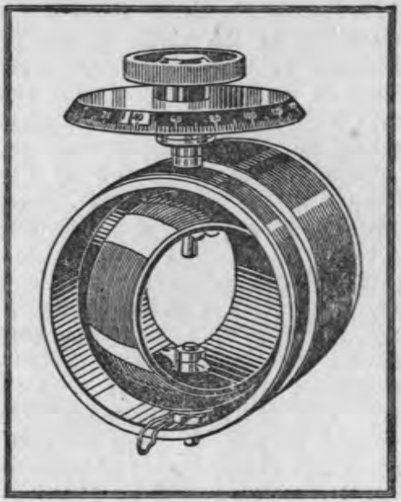


Fig. 9.

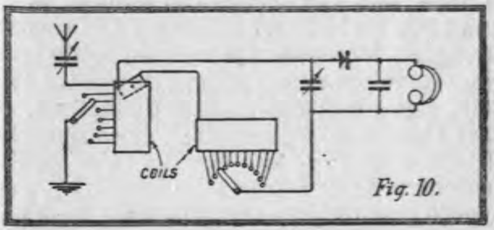


Fig. 10.

that they do not come into contact. If the coils are tuned, the leads from the inner coil are taken to the inside of the former and brought to one end, where they are connected to a set of studs in the receiver circuit. The leads from the outer coil are taken to the opposite end of the outer former, and connected to another set of studs in the aerial circuit. Each set of studs is provided with a switch arm for tuning.

Fig. 11 is an illustration of such a loose-coupler, Fig. 12 a diagram showing the tappings, and Fig. 13 a theoretical diagram of the aerial and closed circuits. From these illustrations it is clear that with loose-couplers there are two distinct circuits to tune instead of one, it being necessary to proportion the inductance and capacity of the closed circuit as well as those of the aerial circuit. If this were not done, the frequency of the closed circuit would not be in tune with the oscillations induced in it, and there could be no building up of current strength. Moreover, the induced oscillations react upon the aerial circuit through the two coils, and affect the original oscillations, so that there is a compromise. Consequently, if both circuits be not tuned to the correct frequency, there will be poor selectivity, and signals may even be unintelligible: care has

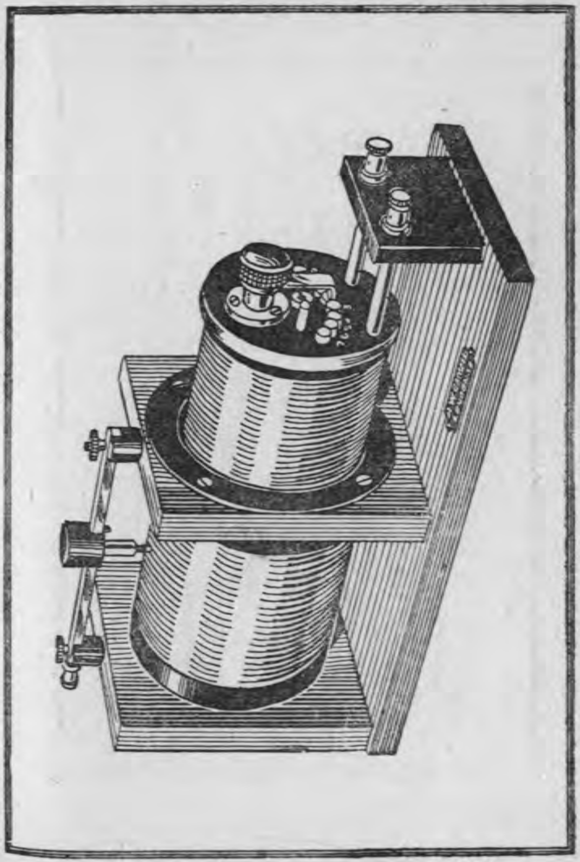


Fig. 11.

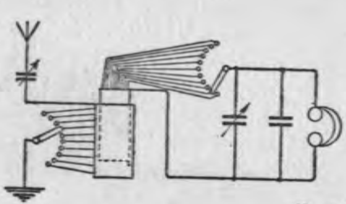


Fig. 12.

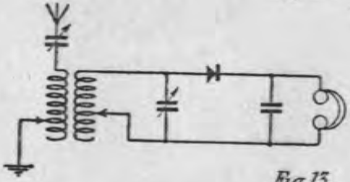


Fig. 13.

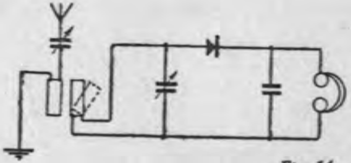


Fig. 14.

therefore to be exercised in proportioning the two coils.

The outer coil is fixed on the receiver panel and the inner coil is made to slide within it, so as to vary the degree of coupling —in other words, to vary the amount of induction.

An alternative arrangement consists of employing inductances of a fixed value, and tuning both circuits entirely by means of condensers. In such cases it is usual to employ a pair of basket or honeycomb coils, mounted face to face, one of the coils being hinged so that it may be moved in relation to the other, thus varying the degree of coupling (Fig. 14).

A transformer (Fig. 15) consists of two coils of wire, each in a different circuit, so placed relatively to each other that an alternating or an oscillating current in one will induce an alternating current in the other. This may be effected by placing one cylindrical coil within another, or end to end; or by placing two basket or two honeycomb coils face to face.

If the secondary coil (i.e. the coil in which it is desired to induce a current) be wound with a greater number of turns of wire than the primary, the induced current will be of higher voltage than the current in the primary, and the transformer is then known as a step-up transformer. If the secondary coil contain fewer turns than the primary, the induced current will be of lower voltage, and the device is known as a step-down transformer.

Fig. 15.

Again, a transformer may be of the air-core or the iron-core type: for low- or audio-frequency current an iron-core transformer (Figs. 16 and 17) is more efficient, but for high- or radio-frequency current it would be useless because, owing to the greater strength

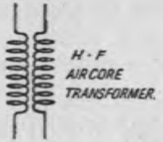


Fig. 16.

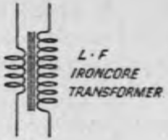


Fig. 17.

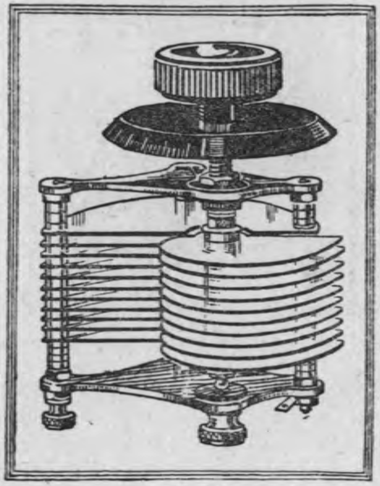


Fig. 18.

of the magnetic flux due to the iron core, a choking effect is produced, preventing the passage to and fro of the exceedingly rapid alternations of the current.

Tuning by means of an ordinary variable condenser (Fig. 18) is effected by turning a knob with the finger and thumb, thus causing one set of plates to overlap the other set more or less according to the amount of capacity required; but when greater refinement of tuning is desired, a vernier condenser (Fig. 19) is necessary. The vernier adjustment may form part of the main condenser, and consist of an additional movable plate which is moved by a separate knob quite independently of the other plates; or it may be a separate condenser in itself, in which case it may take one of a variety of forms: for instance, two semi-cylindrical plates, or a flat, movable plate as already described (Fig. 20).

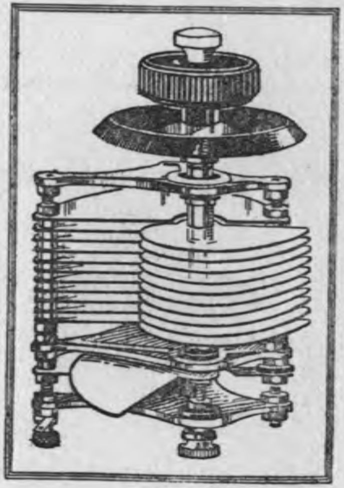
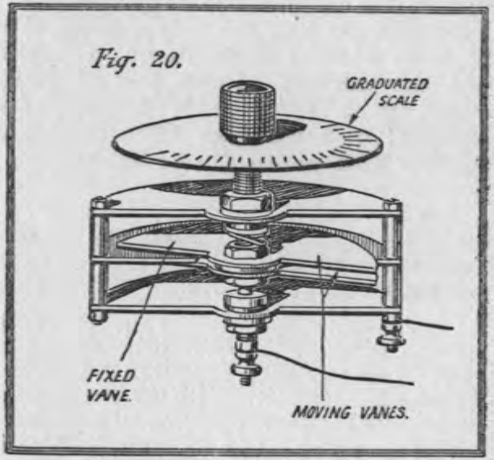


Fig. 19.

Fig. 20.



The following description will make the use of the vernier adjustment clear.

In an ordinary variable condenser there is a capacity effect between each pair of overlapping plates, so that, however little the knob is moved, *all* the plates of one set are caused to move relatively to those of the other set. But supposing that, having adjusted the condenser to as great a nicety as possible, we turn the vernier knob, then the same amount of movement will only vary the capacity of *one* pair of plates instead of a considerable number, and consequently much finer adjustment and therefore finer tuning can be effected.

CHAPTER III

TUNING BUZZERS. INSULATION. TERMINALS

WITH crystal receivers, difficulty is sometimes experienced, when tuning in, owing to the crystal not functioning properly. For instance, suppose that we are about to use a new receiver, or one that has been out of use for a time: if a sensitive spot on the crystal has not been found, it means searching for one whilst endeavouring to tune in. With some highly sensitive crystals this difficulty may not arise, but in other cases it may result in missing part of a broadcast programme.

In order to ensure that the crystal is functioning, before attempting to tune in, we may employ what is known as a tuning buzzer (which can be purchased for a couple of shillings). This is a device (Fig. 21) which operates on the same principle as an electric bell, except that the gong and striker are omitted. The buzzer terminals are wired up to one or two dry cells, the current from which passes through two small coils of wire in the buzzer. These coils are wound upon iron cores which are magnetized by the current in the coils. With the first rush of current from the battery, the iron cores are magnetized, and attract a small iron bar on a spring, the movement of this bar breaking the circuit and stopping the current. The iron cores then become demagnetized and allow the bar and spring to fly back and again close the circuit. The operation is repeated so that make and break is effected many times a second, giving rise to a shrill buzzing sound. The oscillations of current, due to the spark at the contacts, are productive of short trains of feeble electro-magnetic waves, the frequency of the wave trains corresponding to the sounds emitted by the buzzer. These electro-magnetic waves set up in the receiving circuit oscillating currents which are rectified by the crystal, so that the buzz may be heard in the telephone. If then, before the commencement of broadcasting, the crystal be adjusted so that the buzz heard in the telephones is at its loudest, we shall know that the crystal is functioning properly, and no unnecessary time will be lost in tuning in. After such adjustment, care should be taken not to shake the receiver and upset the crystal contact. When using the buzzer it is a good plan to connect one of the terminals to the earth lead of the receiver, or to attach a few feet of insulated wire to one of the terminals and lay it across the back of a chair. The buzzer should not be too near the telephone, otherwise it may be difficult to distinguish the buzz heard in the telephone from that of the buzzer direct.

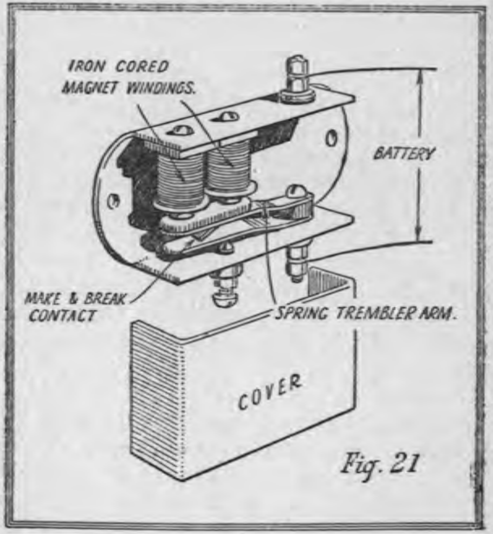


Fig. 21

Although it is not proposed, in the present volume, to describe the actual construction of inductance coils, a few words on the insulation of the wire employed may not be amiss. As already explained, every coil possesses more or less self-capacity, and such self-capacity will be least when the wire is bare. Bare wire, however, would have to be wound with a clear space between adjacent turns, so that in no case would they touch each other—an operation difficult of accomplishment. Some sort of insulation is therefore usually employed.

Now every kind of insulating material has a dielectric capacity, with the consequence that insulation increases the self-capacity of the coil. Some materials do so more than others, and it is therefore usual to select an insulating substance with as low a degree of dielectric capacity as possible. In many cases enamelled wire is employed; this, however, in unskilled hands is apt to get scratched or to have the enamel chipped off: if this happens, and adjacent turns come into contact, the coil will not function properly. For the amateur, cotton-covered wire is perhaps the most suitable, but it is necessary to render the cotton covering damp-proof: this may be done by immersing the coil in a bath of paraffin wax or shellac varnish, and then allowing it to drain and dry, care being taken not to collect more wax or varnish than is necessary to impregnate the cotton, otherwise the dielectric capacity will be unduly increased, and the coil may be spoilt.

It must be remembered that the cotton covering is entirely for the purpose of preventing the bare wire of adjacent turns coming into contact, and that the bath of wax is not intended to increase the insulation, but merely to render the cotton covering damp-proof, so as to prevent short-circuits.

The selection of terminals depends upon the method of finishing off the ends of the wires. A few different types are illustrated in Fig. 22. Type A is suitable for taking the end of a single thick wire (B) or a spigot (C) to which the end of a flexible wire has been bound and soldered. In the case of a single wire it is better to flatten the end slightly. The top screw is then screwed firmly on to the wire or spigot. In another type (D), instead of a screw, a small knob on the terminal is pressed down, forcing a plunger against a spring in the body of the terminal and bringing a hole in the plunger opposite the hole in the side of the terminal. The wire is inserted, and when the knob is released the plunger rises and grips the end of the wire.

Type E is suitable for taking a loop-ended wire. When " flex " is thus twisted into a loop, the insulation should be removed for an inch or two, care being taken not to break any of the wires. The ends of the strands should then be twisted tightly,

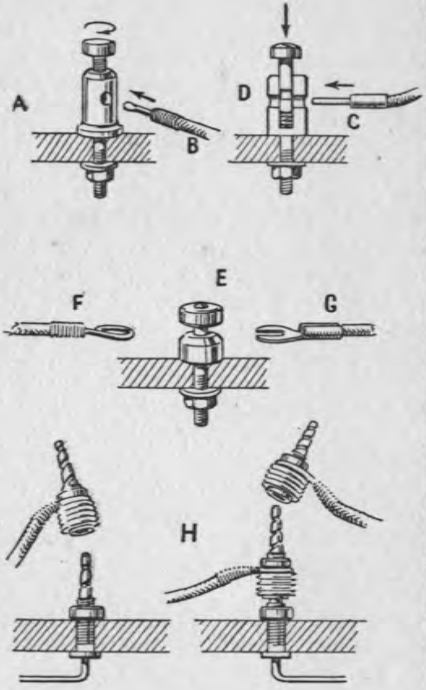


Fig. 22.

bent round to form a circle and twisted round the wire (F), and it is then best to apply a little solder to prevent the loop from coming undone. With this arrangement the top screw of the terminal has to be removed before the loop can be attached; and if the joint has to be made and unmade frequently, the strands may wear and break.

A better and more permanent method is a metal clip (G). The ends of the flex should be twisted as before, the ends of the strands bent back on themselves, and laid in the clip, which is then closed tightly round the wire, a drop of solder being an additional safeguard. With this arrangement it is only necessary to loosen the top screw of the terminal, push the clip beneath it, and tighten the screw.

An excellent form of plug terminal is shown in Fig. 22 (H). This is especially useful for coupling devices—two or more headphones, for instance—in parallel. Any plug will fit into any other plug, each having a separate wire attached to it.

CHAPTER IV

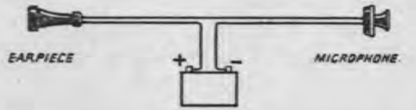
THE TELEPHONE

WONDERFUL as the wireless transmission of speech and music unquestionably is, it is important to bear in mind that it is only a particular stage of transmission and reception, and that, for the rest, we are dependent upon ordinary telephony for the commencement and conclusion of the series of operations involved. It therefore behoves us to devote some attention to the general principles of ordinary telephony, in order to comprehend the procedure as a whole.

Fig. 23 illustrates, diagrammatically, the lay-out of the simplest form of telephone installation, the transmitter and receiver being shown in detail in the enlarged sections. The transmitter comprises a small case containing a quantity of loose carbon granules in contact with an extremely thin metal plate termed the diaphragm. Without going into technical details or the question of relays, it will suffice to say that the diaphragm is wired up in the circuit, as also is a contact at the other end of the box of carbon granules. In the same circuit is a

battery, and when the circuit is closed a current flows from the battery through the carbon granules. If, whilst the current is flowing, a person speaks into the transmitter, the sound waves of his voice will impinge on the diaphragm, causing it to move backwards and forwards according to the strength and frequency of the vibrations of his voice. This movement of the diaphragm causes it to press with a varying force and speed against the carbon granules.

Fig. 23.



Now the conductivity of the granules varies according to how tightly they are packed: consequently, as the pressure of the diaphragm varies, so the strength of the current which passes varies. At the receiving end, the current passes through fine coils of wire in the earpiece, these coils being wound upon iron cores. So long as a steady current flows, the iron cores are magnetized to a definite extent, and attract a piece of iron attached to a diaphragm in the earpiece, with a uniform strength. But when somebody speaks into the transmitter, causing fluctuations in the current, these fluctuations vary the degree of magnetization of the iron cores in the receiver, with the result that the diaphragm in the earpiece moves to and fro, in sympathy with the diaphragm in the transmitter, such movements setting up air waves which, impinging on the ear drum, produce the sensation of sounds corresponding exactly to those imparted by the speaker to the transmitter.

In wireless telephony, the beginning and end of the process is the same in principle, although the technical details vary greatly: for instance, a broadcasting transmitter is a much more delicate device than an ordinary telephone transmitter, whilst the earphones of wireless receivers are far more sensitive than those of ordinary telephones.

Fig. 24 illustrates, diagrammatically, the lay-out in the case of wireless telephony. At the transmitting end, electric current of considerable power is caused to oscillate in an aerial, thereby setting up electro-magnetic waves which, expanding in all directions, strike every receiving aerial in the world with a strength which varies according to distance and other considerations. The

alternating current set up by the waves in any receiving aerial is impressed with every variation in the current in the transmitting aerial caused by sound waves, and when these low-frequency variations have been sifted out by rectification of the current, they cause the diaphragm of the telephone receiver to vibrate with varying force and speed exactly as in the case of ordinary telephony.

After being repeatedly warned against introducing any unnecessary resistance into his receiving apparatus, the beginner is somewhat puzzled at being informed that high-resistance telephones of several thousand ohms are far more sensitive and therefore more suitable for wireless reception than ordinary 'phones of about 120 ohms resistance. Without involving ourselves in mathematical formulæ, the reason for this may be explained as follows.

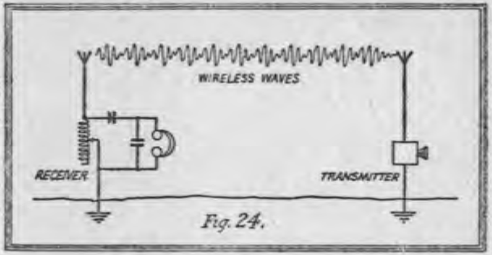


Fig. 24.

In crystal receivers, the crystal itself opposes a very high resistance to the passage of an electric current—it may be of the order of 10,000 ohms. This is an unfortunate fact which has to be faced. When a telephone is placed in series with a crystal, the resistance of the telephone may, without serious effect, be almost as great as that of the crystal itself.

If the telephone coils be wound with only a few turns of thick wire, the ampèrage of the rectified current from the crystal will not be reduced appreciably, and the iron cores will be magnetized by it to a certain extent. In practice, however, it is found that by using much finer wire, and winding the coil with many more turns, the same strength of current will produce a more powerful magnetizing effect, despite the fact that the greater the length of wire in the coil and the thinner the wire, the greater is its resistance. Thus, although the resistance causes a decrease in the ampères of current flowing, by virtue of the greater number of turns of wire, the magnetizing effect is increased, resulting in a more powerful pull on the diaphragm in the earpiece with every fluctuation when signals are passing, and therefore in louder sounds in the telephone.

Thus, although it appears paradoxical, generally speaking, the weaker the signal currents, the more advantageous it is to employ high-resistance telephone receivers.

It is possible to dispense with the telephone condenser, C, but such a condenser is an improvement, and a simple analogy will enable its object to be more readily understood.

Suppose that an air compressor is delivering compressed air through a pipe to a pneumatic machine, and that the pneumatic machine uses up the compressed air about as fast as it is delivered. The machine can be operated under such conditions, but there will be a certain amount of unsteadiness in running. But if a reservoir of suitable size be connected to the pipe between the compressor and the pneumatic machine, the reservoir will be charged with compressed air, the store of air thus formed will maintain a uniform pressure, and the machine will run more smoothly.

Similarly, if the rectified spurts of current from a crystal detector be allowed to flow through the telephone windings, without employing a condenser, the windings will smooth out the rapid jerks of current into a uniform stream, and fairly satisfactory results may be obtained, but they will not be so good as they would if the current impulses could be rendered more nearly continuous first. By coupling a condenser across the telephone, the current impulses from the crystal detector charge up one plate of the condenser, which induces an opposite charge on the other plate connected to the other side of the telephone. Thus a steady pressure of current is maintained through the telephone windings, the strength only varying when low-frequency fluctuations due to incoming signals occur.

It is important to note that, although the telephone condenser functions like a spring (as in the case of all condensers), it only serves as a reservoir for direct current, and has no influence upon wave-length, as tuning condensers have.

CHAPTER V

HOW TO CALCULATE INDUCTANCE AND WAVE-LENGTH

THOSE who have read the companion volume of this series, entitled "Receiving Devices: How They Function," will understand that there is a definite relation between inductance and capacity which determines frequency and therefore wave-length when tuning a receiver. Table No. 4 in the Appendix, covering the band of British Broadcasting wave-lengths, shows this relationship quite clearly. In the third column, L stands for inductance in microhenries, and C for capacity in microfarads, the figures in this column being the product of L and C corresponding to various wave-lengths.

By way of example, take first the case of a receiver (Fig. 26) comprising a fixed condenser, C, of ·001 microfarads, tuned entirely by a variable inductance, and suppose that we desire to tune in to a wave-length of 1600 metres. Referring to column 3 of the table, we find that for this wave-length the product of inductance and capacity should be ·72. Let x = the inductance: then

$\cdot 001 \times x = \cdot 72$, and $x = \cdot 72 \div \cdot 001 = 720$ microhenries. Fig. 25 shows a fixed condenser, C, which functions in conjunction with the telephones, and does not constitute a tuning device, as do condensers, marked C, illustrated in Figs. 26 and 27.

Again, suppose there is a fixed inductance of 500 microhenries (Fig. 27), and that we want to ascertain the range of capacity of a variable condenser, C, in parallel, for covering wave-lengths between 300 and 500 metres. For 300 metres the required capacity is $\cdot 02533 \div 500 = \cdot 0000506$; and for 500 metres, $\cdot 0704 \div 500 = \cdot 000141$.

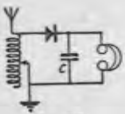


Fig. 25.

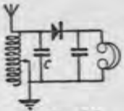


Fig. 26.

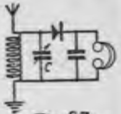


Fig. 27.

The reader should work out a number of examples so as to familiarize himself with this important part of the subject. Incidentally it may be mentioned that an aerial in itself possesses a certain amount of inductance and capacity which are uniformly distributed throughout its length. We shall refer to this again later.

Variable condensers being difficult to make, and fixed condensers being cheap to buy, comparatively few amateurs attempt to construct them, and it would therefore not serve much useful purpose to give the formulæ for working out condenser capacities. It is a different matter, however, in the case of inductance coils, which are quite easy to construct: there are many who take a delight in making their own coils, whether of the cylindrical, basket or honeycomb type. Table No. 5 in the Appendix, giving the inductance in microhenries of cylindrical coils of various sizes, should therefore prove useful. (Tables Nos. 1, 2 and 3 give the inductance values and wave-lengths of basket and honeycomb coils.)

Having found from Table No. 4 the L C values corresponding to a certain range of wave-lengths, and having fixed upon the capacity of the condenser employed, the inductance required is found as already described. Supposing that it is intended to construct or purchase a coil of the cylindrical type, it is first necessary to ascertain what length and diameter will give the required inductance. This may be seen at a glance by referring to Table No. 5, but to those who care to work out examples for themselves the following formula will prove of interest. For the benefit of those who do not know how to find the square root of a number, examples of how to do this are given in the Appendix.

Inductance in microhenries

$$= \frac{\pi^2 \times D^2 \times n^2 \times l \times k}{1000}$$

where $\pi = 3{\cdot}1416$

D = diameter of coil in centimetres.

n = the number of turns per centimetre.

l = the total length of coil in centimetres.

k = Nagaoka's factor, which varies according to the proportion of diameter and length of coil. (Table 6 in the Appendix gives the various values of this factor).

Thus in the case of a coil 10 centimetres in diameter and 8 centimetres long, with 10 turns per centimetre, substituting figures for letters the formula would become

$$\frac{3{\cdot}1416^2 \times 10^2 \times 10^2 \times 8 \times {\cdot}638}{1000} = 504 \text{ microhenries.}$$

There is still, however, another consideration. As already mentioned, an aerial in itself possesses inductance and capacity, which has to be taken into account, in conjunction with the inductance of a coil and/or the capacity of a condenser. The aerial inductance may be found by the use of a spark coil and wave-meter. The capacity can also be worked out, but the process is one that concerns the more advanced student rather than the beginner. The aerial capacity and inductance varies according to the length of the aerial and the number and size of wires comprised in it, but for the purpose of illustration we may assume a capacity of about ·0003 microfarads, and an inductance of 50 microhenries.

The formula for calculating wave-length due to inductance and capacity is :

Wave-length in metres

$$= 1884 \sqrt{\text{Inductance} \times \text{Capacity}}$$

In the case of an aerial with an inductance coil of 500 microhenries but with no condenser, and substituting figures, the formula becomes :

Wave-length in metres

$$= 1884 \sqrt{500 \times {\cdot}0003} = 730 \text{ metres.}$$

This, however, takes no account of the aerial inductance, one-third of which should be added, making the formula :

Wave-length

$$= 1884\sqrt{(500 + 17) \times \cdot 0003} = 740 \text{ metres.}$$

It is important to note that the above formula for ascertaining wave-length does not apply when there is no added inductance and capacity; i.e. in the case of an aerial in which L and C are uniformly distributed throughout its length. The formula for ascertaining the natural wave-length of an aerial, i.e. without added inductance and capacity, is:

$$\text{Wave-length} = \frac{1884 \times \sqrt{L \times C}}{1\cdot 57}$$

or substituting the values for an aerial given above:

Wave-length

$$= \frac{1884 \times \sqrt{50 \times \cdot 0003}}{1\cdot 57} = 147 \text{ metres,}$$

which is a little more than $4\frac{1}{2}$ times the length of a 100-foot aerial.

Suppose now that we want to add an inductance coil to enable us to tune up to a wave-length of 500 metres. The formula would become:

Wave-length

$$= 1884\sqrt{L \times C}$$

or substituting figures:

$$500 = 1884\sqrt{L \times \cdot 0003}$$

from which L equals 234.

Deducting one-third of the aerial inductance: $234 - 17 = 217$ microhenries, which is the inductance of the coil required.

Let us now consider the effect on wave-length of introducing a condenser of, say, ·0002 microfarads in parallel.

Then wave-length

$$= 1884\sqrt{(217 + 17) \times (\cdot 0002 + \cdot 0003)}$$

= 644 metres as against 500 metres without the condenser in parallel. A condenser of ·0005 microfarads' capacity in parallel would give a wave-length of about 815 metres.

There is one more case to consider, namely, the introduction of a condenser in series. In this case, the total capacity is not that of the aerial and condenser, but has a value obtained by the formula:

$$\frac{\text{Condenser capacity} \times \text{aerial capacity}}{\text{Condenser capacity} + \text{aerial capacity}}$$

Let us take the case of a variable condenser and a range of from ·0002 to ·0005.

Then the minimum wave-length

$$= 1884\sqrt{234 \times \frac{\cdot 0002 \times \cdot 0003}{\cdot 0002 + \cdot 0003}}$$

$$= 316 \text{ metres,}$$

and the maximum wave-length

$$= 1884\sqrt{234 \times \frac{\cdot 0005 \times \cdot 0003}{\cdot 0005 + \cdot 0003}}$$

$$= \text{about } 400 \text{ metres.}$$

From the foregoing examples it is clear that a condenser in parallel increases wave-length, but that in series it decreases wave-length. If, for instance, a switch were provided, so that the condenser (Fig. 27) could be placed either in series or in parallel with the fixed inductance of 234 micro-henries, the range of capacity between ·0002 and ·0005 would enable the wave-length to be varied from 316 to 815 metres.

CHAPTER VI

THE FLOW OF ELECTRONS IN A SIMPLE CRYSTAL RECEIVER

FIG. 28 is a theoretical diagram of a simple crystal set, in which A is the aerial, E the earth, L the tuning inductance, S and S_1 the switch arms for coarse and fine adjustment, D the crystal detector, T the telephone,

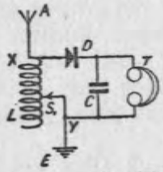


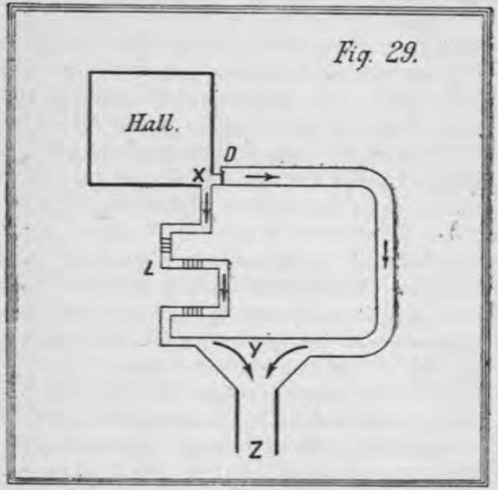
Fig. 28.

and C the telephone condenser. Let us suppose that tuning to a wave-length of 300 metres has been effected, and that a stream of carrier waves is sweeping across the aerial in which the current oscillations have been "built up" into a steady surging up and down, but that no signals are passing; and let us consider what takes place, starting with an upward rush of current. The stream of electrons passes through the coil, L, into the aerial. Within one two-millionth part of a second they reverse in direction and begin to return to earth. What exactly happens then would involve a good deal of technical explanation, but it is near enough for our purpose to say that the returning stream find themselves in the position of having to overcome and push back electrons which were following them, and having also to overcome the effect of inductance, which tends to impede the sudden return flow.

The result is that, upon encountering the coil, the electrons become more or less choked in their effort to get through it: in a sense this effect may be compared with that when there is a panic following an alarm of fire.

Think of a hall (Fig. 29) full of people, with two exits side by side; suppose that one exit, X, is open, and leads to a long passage with many corners and staircases, and that the other exit, D, has a door which is kept closed by a spring, attached to it on the outside, the spring being so strong that several persons pushing against it could not open the door. Now consider what would happen upon an alarm of fire.

There would be a rush of people for the open exit, and some of those who were not in front would vainly endeavour to push open the door against the spring. Everybody would make for the exits, those behind



pushing those in front until the pressure became so great as to overcome the strength of the spring so that the door would open sufficiently to permit some of the crowd to pass through. As the pressure further increased, the door would be forced open wider and wider until a considerable number of persons could pass through it. Consider the state of affairs at this point.

The persons leading the processions would, if they travelled at the same speed as those immediately behind them, be practically free from pressure. Farther back there would be a mass of tightly packed people in the passages, handicapped, in the one case, by turnings and staircases, struggling forward. But the worst pressure of all would be in the hall, close to the exits where the frenzied people are making desperate efforts to force those in front of them forward.

The downward rush of current from aerial to earth produces an analogous state of affairs. The inductance coil retards the flow of electrons (much as the turnings and staircases and the limited size of the passage from X would retard the rush of people) until at the points X and D (Fig. 28) the electrons behind exert a sufficient pressure to overcome the resistance of the crystal (which corresponds to the door with the spring), which then allows many of them to pass through it. Those electrons that get through constitute a little spurt of electric current.

Suppose that at a certain distance from the exits (Fig. 29) the two passages join, forming another passage of ample size.

Such a junction would correspond to the point Y (Fig. 28) where the electrons passing through L join forces with those passing through D and T, and the passage would correspond to the wire YE, along which all the electrons travel to earth. Remember that (in the case of the 300-metre wavelength under consideration) the electrons have only one two-millionth part of a second to complete their journey.

A little thought will enable the reader to apply a somewhat similar analogy to the return journey of the electrons, by imagining the panic-stricken audience finding themselves suddenly face to face with flames at Z (Fig. 29). Word would be passed from mouth to mouth, and the crowd would begin to surge back towards the hall, those nearer to Z having first to overcome the pressure of those nearer the hall. The door, D, would close and prevent the trapped people in that passage from returning into the hall, and the only available passage would be L.

Similarly, during the next two-millionth part of a second, the charge returns into the aerial, but this time none of the electrons can return through the crystal, because the crystal only permits them to pass through it in one direction. Thus the process continues so long as the carrier waves are passing, the telephone condenser serving to accumulate electrons and thus maintain a steady pressure of current passing through the 'phones, which current merely deflects the diaphragm in the telephone headpiece and retains it in one position.

Now let us suppose that signals are being transmitted. As explained in previous chapters, these signals cause corresponding fluctuations in the carrier waves and in the aerial current, and therefore in the rectified current passing through the 'phones. Such fluctuations, corresponding in the matter of frequency to the original sound waves, cause deflections of the telephone receiver diaphragm from the position to which it is deflected by the current due to the carrier waves, and in turn the diaphragm, hitting the air, produces air waves of the same low-frequency as those of the original sound waves.

A little reflection will make it clear that, the higher the frequency of the aerial current the greater the pressure of electrons on the coil: also that the greater the inductance of the coil the greater the pressure will be, and that the greater the pressure the greater the number of electrons or amount of current which will force its way through the crystal and the telephone receiver windings. (It is usual to denote such pressure as the e.m.f. produced across the coil by h.f. currents.)

Conversely, it is easy to suppose that, if we eliminate inductance, there will be so little pressure that no current will be able to force its way through the crystal to the telephone. It would correspond to substituting for L (Fig. 29) a straight passage wide enough to enable all the people to escape from the hall without undue crowding at the exit, so that there would be insufficient pressure to force open the door of the other exit.

It should be explained that the foregoing analogy is a very homely one, and as a matter of fact incomplete. It will serve, however, to convey an idea of how a potential difference due to h.f. currents is set up across an inductance coil.

Let us now assign definite values to the devices indicated diagrammatically in Fig. 28. The detector may consist of a piece of hertzite, galena, or any other suitable kind of crystal. The telephones should be of not less than 2000—preferably 4000—ohms resistance, and the telephone condenser may be of the fixed type, of ·001 microfarads capacity. Suppose that we only want to use the receiver for the reception of waves of from 300 to 500 metres, with a loading coil (i.e. an additional coil of a fixed inductance value) to increase to 1600 metres: it is necessary first to find the value of the variable inductance coil, which we will assume is of the cylindrical, tapped type. (In order to be on the safe side it will be best for the tuner to cover a range up to 600 metres.) From Table 4 in the Appendix we find that for this wave-length the product of inductance and capacity should equal ·1014.

Let us assume the aerial inductance to be 50 microhenries and the aerial capacity ·0003 microfarads; the required inductance, L, may be found as described in Chapter V.

From Table 5 it will be seen that we have a choice of different sizes of coil, those of smaller diameter being longer for a given inductance than those of larger diameter.

For instance, a coil 8 centimetres diameter and 12 centimetres long has an inductance of 586 microhenries, whilst a coil 10 centimetres diameter and 8 centimetres long has an inductance of 504.

In the case of a coil 10 centimetres diameter we find from Table 5 that 3 centimetres of the coil have an inductance of 120 microhenries. This means that, if we do not desire to tune in to less than a 300-metre wave-length, we could include about 30 turns of the coil permanently in the circuit. To allow a margin, however, it will be better

to include only 20 or 25 turns permanently in series.

It should be understood that the figures in the above examples are only approximate, because, as already mentioned, the capacities of aerials vary considerably, according to their length and the number of wires composing them.

Having fixed upon the size of tuning inductance coil to cover a wave-length range of from 300 to 500 metres, we may provide a separate plug-in coil of a fixed inductance value, which can be inserted in series; the inductance of which will then be added to that of the tuning coil, so that we can tune in to a wave-length of, say, 1600 metres or more. This plug-in coil would, of course, be removed when using the receiver on 300 to 500 metre wave-lengths.

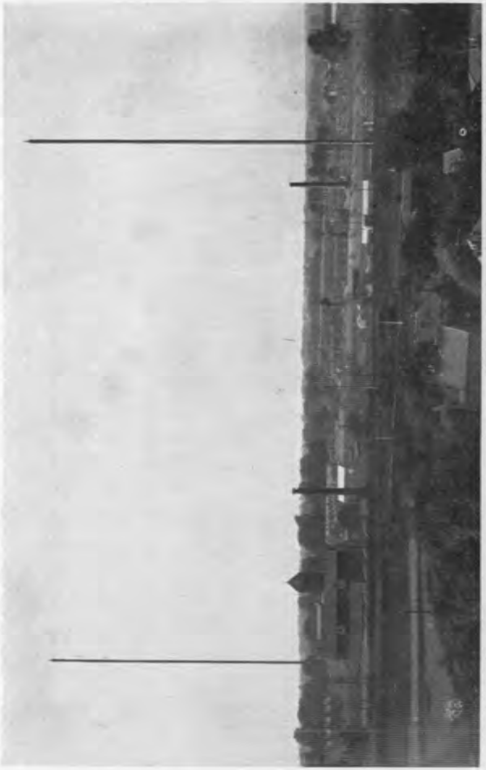
CHAPTER VII

DIAGRAMS AND EXPLANATIONS OF FUNDAMENTAL CRYSTAL CIRCUITS

In the circuit diagrams in this and succeeding chapters, where the tuning of inductance coils is indicated by a single arrow, this does not imply a single-slider tuning inductance, but is intended to cover both fine and coarse adjustment of whatever type of tuning coil is employed, except where otherwise stated.

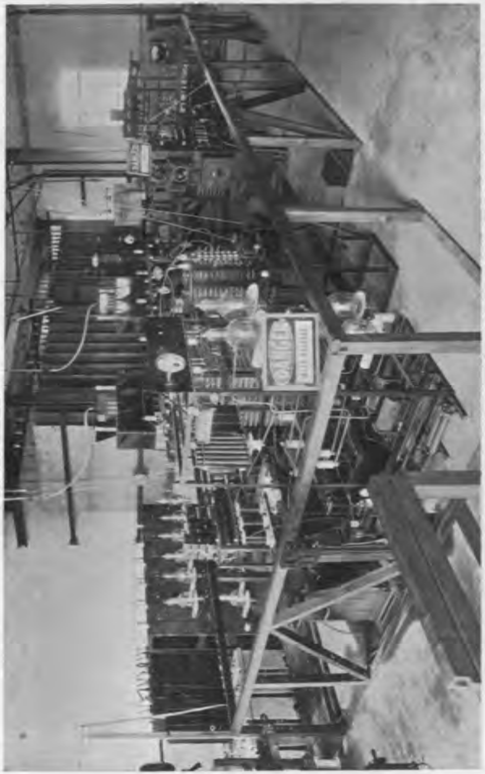
Fig. 30 illustrates a circuit with a fixed inductance and a variable condenser in parallel. In this case the inductance coil and condenser should be proportioned so that with the condenser set at its maximum capacity the maximum wave-length required may be obtained, and with the condenser set at its minimum capacity the minimum wave-length required is covered for. The coil may be of the untapped cylindrical, or of the honeycomb type. A vernier condenser should be employed if possible.

The Chart No. 1 and Table No. 1 in Appendix afford a ready means of rapidly deciding upon the most suitable honeycomb



[*By permission of Marconi's Wireless Telegraph Co., Ltd.*

The High Power Broadcasting Station at Chelmsford (5xx), showing the Aerial and 450 feet high masts. The broadcasting transmitter is housed in the building with a white roof and door in the left centre of picture.



[By permission of Marconi's Wireless Telegraph Co., Ltd.*

THE CHELMSFORD (5XX) STATION BROADCASTING TRANSMITTER.

The valve panel in the left background is the rectifier panel; that in the centre is the independent drive panel. The modulating panel and main oscillator panel are in the centre in front of main condenser, the plates of which can be seen suspended in the background.

inductance coils to employ for different wave-lengths, in conjunction with condensers of different capacities. (It should be explained that the number of each coil denotes the number of turns of wire comprised in it.) As an example of how to use this chart, suppose that we have a variable condenser of a maximum capacity of ·001 microfarads, and that we want a coil to cover a wave-length of 500 metres. We should take half the maximum capacity (= ·0005 microfarads), and find the corresponding figure on the base-line of the chart. The vertical line from the ·0005 point will be found to cut a horizontal line drawn from a point marked 500 metres on the left-hand side of the chart. Now follow the curved line, nearest to the intersection point, to the extreme right, and it will come opposite the number of the coil required, which in this case is 50.

Let us now suppose that the receiver is fitted up with this coil, and that the full capacity (·001 microfarads) of the condenser is brought into play. Following the vertical line from the point marked ·001 on the base-line, to where it cuts the number 50 curve, and then following the nearest horizontal line to the left, we find that the maximum wave-length obtainable is approximately 700 metres. (The table gives 693 metres.) With the condenser out of action, we should follow the extreme left-hand vertical line upwards to where it cuts the 50 curve, and this intersection point will mark the minimum wave-length, namely, 150 metres. For intermediate capacities of the condenser the corresponding wave-lengths may be obtained.

Conversely, suppose that we have a coil of, say, 60 turns, and want to know the capacity of a condenser which will cover a wave-length range up to 500 metres: we should follow the curved line from the point 60 on right-hand side of diagram to where it cuts the horizontal line drawn from the point 500. Reading downwards we find that the maximum condenser capacity would be a little more than ·0003 microfarads.

The chart and table take no account of aerial capacity and inductance. Either these may be added, and the result worked out as already explained in Chapter V, or an approximate result may be obtained by deducting the natural wave-length from the maximum wave-length required before selecting the coil or condenser, allowing a fair margin.

In the circuit in Fig. 31 tuning is effected by a condenser in series with the aerial circuit. In this case the fixed inductance should be proportioned for the longest

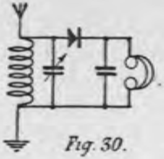


Fig. 30.

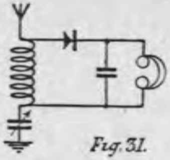


Fig. 31.

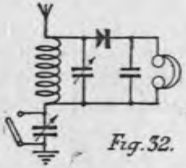


Fig. 32.

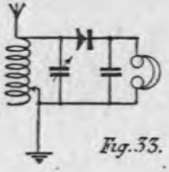


Fig. 33.

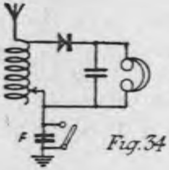


Fig. 34

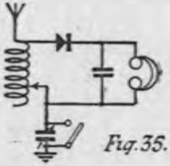


Fig. 35.

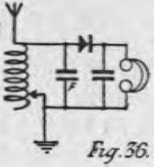


Fig. 36.

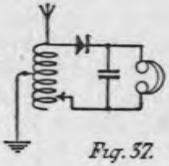


Fig. 37.

wave-length it is desired to receive when the condenser is set at its maximum capacity, reduction in wave-length being effected by reducing the condenser capacity. Values for the inductance and capacity may be assigned by employing the formulæ already given, and this applies to the various circuits still to be described. In this case, again, a vernier condenser is desirable for fine tuning.

In Fig. 32 we have a fixed inductance with one variable condenser in series and another variable condenser in parallel, both preferably of the vernier type. In this case the inductance may be proportioned to the average wave-length it is desired to receive. The wave-length may then be shortened by reducing the capacity of the series condenser, or lengthened by increasing the capacity of the parallel condenser. A switch may be provided for short-circuiting the series condenser.

An alternative arrangement consists of providing only one variable condenser and a double-throw switch so that the condenser may be switched either into series or into parallel with the coil.

In the circuit in Fig. 33 tuning is effected by both a tuning inductance and a variable condenser in parallel. A coil tapped for coarse adjustment only may be employed, with a vernier condenser for fine tuning. Alternatively, the coil may be tapped for both coarse and fine tuning, if the purpose of the condenser is chiefly to increase the wave-length.

Fig. 34 illustrates a circuit with a fixed condenser in series, with a switch for short-circuiting; tuning being effected entirely by a variable inductance. Short-circuiting the condenser increases the wave-length.

The circuit in Fig. 35 is similar to the last, except that the series condenser is of the variable type.

Fig. 36 illustrates a circuit in which there is a fixed condenser across the tuning inductance. The condenser, with the full coil in circuit, determines the maximum wave-length, which is reduced by reducing the number of turns of the tuning inductance in the circuit.

In Fig. 37 the circuit is tuned by a two-slider inductance.

Fig. 38. In this case tuning is effected by a three-slider tuning inductance.

Fig. 39 illustrates the application of a potentiometer to a circuit employing a tuning inductance and a carborundum crystal.

Fig. 40 is a theoretical diagram of a variometer-tuned circuit, explained in Chapter II.

In Fig. 41 there are two distinct circuits with no physical connection between them. First, there is the aerial circuit, tuned by a variable inductance (or it may be by other means), and secondly, the receiver circuit. The receiver circuit is energized by induction from the aerial circuit through the aerial inductance and the inductance coil in the receiver circuit, tuning of the receiver circuit being effected by a variable condenser. Alternatively the aerial may comprise a fixed inductance and variable condenser, or the receiver circuit may be tuned by a variable inductance. In either case the two inductances constitute the primary and secondary coils of a high-frequency transformer.

Fig. 42 is a similar circuit, but in this case honeycomb coils are employed to serve the double purpose of inductances and transformer coils. By hinging or pivoting one of the coils the degree of coupling can be varied.

In still another circuit two honeycomb coils of suitable inductance values may be wired in series in the aerial circuit and hinged so as to constitute a variometer, thus enabling a tuning condenser to be dispensed with, within a certain range of wave-lengths. A third honeycomb coil in the receiver circuit may then be hinged, and loosely coupled to the fixed coil of such a variometer,

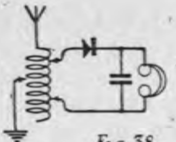


Fig. 38.

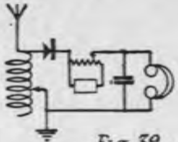


Fig. 39.

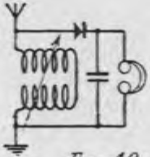


Fig. 40.

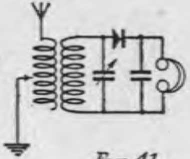


Fig. 41.

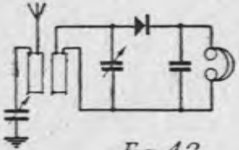


Fig. 42.

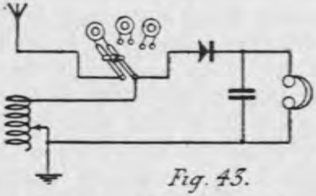


Fig. 43.

tuning of the receiver circuit being effected by a variable condenser.

In Fig. 43 the circuit is primarily tuned by a tapped inductance coil, a set of honeycomb coils of varying inductance being so arranged that any may be switched into the circuit without dismounting any of them.

The reader who aspires to design his own receiver, and to conduct experiments, would do well to familiarize himself with the charts and formulæ that have already been explained; to substitute different values for inductance and capacity in the various circuits illustrated, for various ranges of wave-lengths; in fact, to "ring the changes" with inductance, capacity and wave-lengths; for the circuits illustrated in this chapter constitute between them the basis for a large variety of crystal circuits. By so doing he will render himself independent of detailed instructions as to the design of receivers, or alternatively will find it comparatively easy, when examining theoretical circuits in wireless journals, to judge of their merits and demerits, and for what ranges of wave-lengths they are suitable.

We may conclude this chapter with a few words of advice on the subject of mounting honeycomb coils. Whilst the plug-in type is quite satisfactory for an ordinary fixed inductance, for variometer coils and those used for loose-coupling, the type for use in gimbal holders (Fig. 44) is preferable. The reason is that, not only can the angular relation of the coils be varied, but the coil, being pivoted in the holder, can be rotated on its axis, thus enabling a greater refinement of coupling to be effected. "Igranic" coils especially designed for gimbal holders may be obtained, and Chart No. 2 and

Fig. 44.

Tables Nos. 2 and 3 in Appendix give the wave-lengths of such coils when shunted by variable condensers. The chart should be used in the same way as the chart relating to other "Igranic" honeycomb inductance coils.

On no account should coils be mounted so that they move in a vertical plane, because, when wear takes place, it is difficult to keep the movable coil in position for a certain setting. Coils should therefore be mounted so as to move in a horizontal plane, as shown by the right-hand diagram in Fig. 44a. The left-hand diagram shows how they should *not* be mounted.

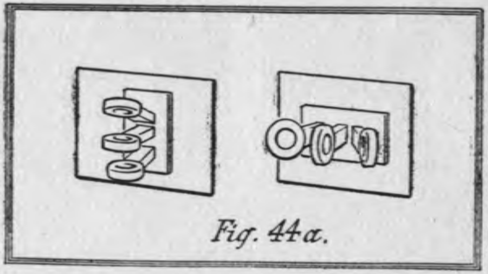


Fig. 44a.

From the foregoing it is evident that, with a variable condenser having a maximum capacity of ·001 microfarads and a vernier adjustment, a variable inductance, a set of honeycomb or basket coils, a pair of telephones, one or two crystal detectors, a fixed telephone condenser, an outdoor aerial, a few switches and a few yards of wire, many instructive and interesting experiments can be carried out by anybody within 10 or 15 miles of a broadcasting station.

CHAPTER VIII

THE MICROPHONE AMPLIFIER. A CRYSTAL CIRCUIT WHICH AMPLIFIES

It is a fortunate peculiarity of human nature that, although self almost invariably comes first, one soon tires of any particular form of pleasure from which others are debarred. Thus, in the case of wireless reception, although a person may install a receiving set primarily to gratify his own whim, in most cases he will not be satisfied unless and until others can join him in the pleasure of listening-in. Rivalry, again, prompts the owner to extend the use of his receiver for the benefit of others: no proud possessor of a receiving set likes to be reminded that only one person at a time can benefit by his apparatus, whilst friends and neighbours are able to dispense wireless delights to a number of persons at a time.

Apart from selfish considerations, the majority of owners take pleasure in allowing others to participate in the enjoyment of an entertainment which may cost less than a halfpenny for a whole evening. Anent this matter of cost, an amusing incident recently

occurred. A listener wrote to the British Broadcasting Company decrying a certain evening's programme, and received a reply to the effect that if he sent in a similar complaint regarding two more programmes the sum of one penny would be sent to him by the B.B.C.! It is to be hoped that the correspondent in question took this as a gentle hint that he was virtually "looking a gift horse in the mouth."

The amateur who is fortunate enough to possess a full P.O. aerial, and to reside within a few miles of a broadcasting station, may receive signals on his crystal receiver of sufficient strength to operate more than one pair of telephones, but it must be remembered that the aerial current is divided between them, so that, in cases where two pairs of telephones are used, the strength of the received signals in each would be only half that in one pair where only one pair is used.

In other cases, however, the signals received, whilst sufficient for one pair of telephones, are too weak to operate more than one. In such cases it is sometimes desired to increase or amplify the signals sufficiently to operate two or more pairs. To effect this desirable result, either of two courses is open. One is to provide a low-frequency valve amplifier, the other being to install what is known as a microphone amplifier. In so far as first cost is concerned, the valve amplifier is cheaper, but against this advantage we have to set the cost of current for operating the valve, and the cost of replacing the valve with new ones periodically. On the other hand, although the first cost of a good amplifier is high, once installed it is practically everlasting, and the consumption of current is so small as to be almost negligible.

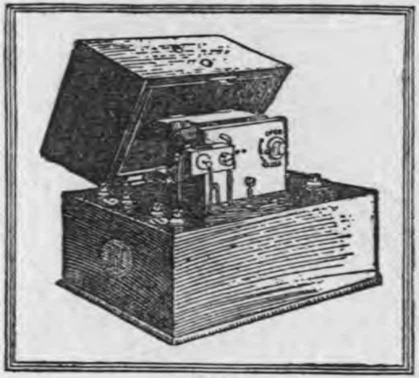


Fig. 45.

The Brown amplifier (Fig. 45) operates as a relay, and is brought into service as follows. The telephones are disconnected from the telephone terminals on the wireless receiver, and these terminals are wired up to corresponding terminals on the amplifier which is contained in a neat little wooden box. A 6-volt dry battery (which serves to operate the microphone for several months) is wired up to a second pair of terminals on the microphone, the telephones being then connected to a third pair of terminals. The rectified currents from the crystal (which would otherwise pass directly through the telephones) pass through the microphone, where they impress their variations on the current from the dry battery which, in turn, passes through the telephones, thus amplifying the signals and actuating the telephone diaphragm with correspondingly greater force, sufficient to operate several pairs of telephones, providing that the original signal currents from the aerial are of reasonable strength.

As mentioned in the Preface, a Russian inventor, M. Lossev, is said to have invented a crystal circuit which, with the aid of an 8-volt battery, effects amplification without the use of a valve. Not only so, but it is claimed that transmission can also be effected over short distances. If these claims prove to be well founded, we may expect sensational developments in the design of crystal sets.

APPENDIX

HOW TO WORK OUT SQUARE ROOTS

THE square of a number is denoted by an index number; thus, 12 squared is written $12^2 = 144$.

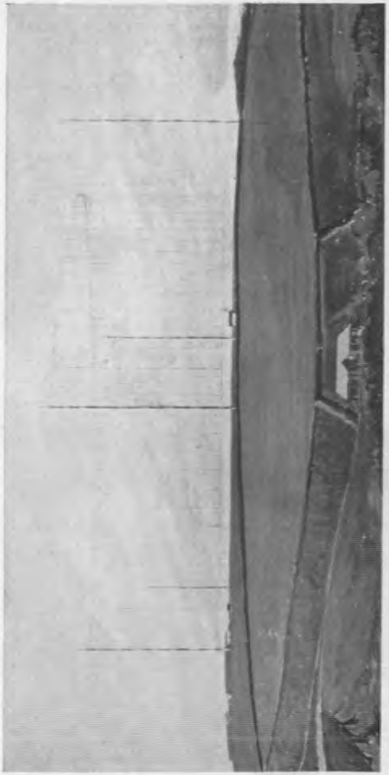
The square root of a number or quantity is that number which, multiplied by itself, results in the given number or quantity. The square root of a number or quantity is denoted thus: $\sqrt{18 \times 8} = \sqrt{144}$.

Suppose that it is required to find the square root of the whole number 20736.

From right to left, divide off the figures in pairs, thus: 2, 0 7, 3 6

Next find the number which, multiplied by itself, gives a result nearest to, but not exceeding, the end figure on the left, which is in this instance 1. (Should the number of figures be even, the square root of the first two figures must be taken instead of the square root of the first figure.)

```
        2, 0 7, 3 6 ( 1 4 4
        1
        -
  2 4 ) 1 0 7
          9 6
       -------
2 8 4 )  1 1 3 6
         1 1 3 6
         -------
         . . . .
```



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THE MARCONI EXPERIMENTAL BEAM TRANSMITTING STATION AT POLDHU, CORNWALL.

Movable Coil extracted from fixed Coil.

Complete Variometer enclosed in ebonite protecting tube.

Fig. 8a.—Air-Cored Variometer

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Place a 1 on the right hand of the quotient sign: multiply it by itself and subtract from 2. Now bring down the next pair of figures, 0 7, place the division sign on left, multiply the figure in the quotient by 2, and write the product as a divisor. Ignoring the right hand figure 7 for the moment, divide 10 by 2. Now although 2 will go into 10 five times, as will be seen, 5 is too much: we must therefore take 4, which is then written down in the quotient, and also on the right of the 2. Now multiply 24 by 4, subtract the answer from 107, and bring down the 3 6. Double the quotient 14 and use it as a fresh divisor. Ignoring the 6, 28 will go into 113 four times. Place a 4 next to the 8 and in the quotient. Multiply the divisor by 4 and subtract. The square root is 144.

Let us take an example of decimal numbers. It is required to find the square root of ·000144. Mark off the numbers in pairs to the right of the decimal point:

```
       ·0 0, 0 1, 4 4 ( ·0 1 2
        0 0
        ───
            0 1
              1
            ───
    2 2 ) . 4 4
            4 4
            ───
            . .
```

The first item in the quotient will be 0. Bring down 0 1, the square root of which is 1. Subtract it and proceed as before. The answer is ·012. To find the position of the decimal point in the answer, mark off from right to left as many figures in the quotient as there are pairs of figures in the given number.

Supposing there has been a remainder, a pair of 0's would have to be brought down as many times as required, until the quotient is near enough to the square root, which in many cases cannot be *exactly* obtained. These pairs of 0's must be allowed for in comparing the quotient with the given number for the purpose of finding the position of the decimal point in the quotient.

Where the given number consists of a whole number and decimals, the figures must be marked off in pairs from the decimal point to the left for the whole numbers, and to the right for the decimals, thus:

1, 6 5, 0 5 ·3 0, 7 0

TABLE No. 1

DATA OF "IGRANIC" PLUG TYPE HONEYCOMB DUOLATERAL INDUCTANCE COILS

Coil No.	Inductance micro-henries.	Sel Capacity micro-farads.	Natural Wave-length metres.	Wave-length in metres when shunted by			
				·0001 mfds.	·0003 mfds.	·0005 mfds.	·001 mfds.
25	31	25	53	117	190	243	336
30	46	32	72	147	233	294	411
35	62	37	90	174	272	344	477
40	95	32	104	216	335	424	590
50	130	38	133	252	395	498	693
60	179	39	157	298	464	585	814
75	217	38	170	326	511	644	895
100	576	24	220	504	815	1036	1445
150	1230	25	333	738	1190	1520	2110
200	2180	23	420	976	1580	2015	2820
250	3340	24	538	1215	1960	2490	3480
300	5080	20	608	1470	2400	3010	4280
400	11470	16	810	2175	3585	4580	6430
500	14500	18	956	2470	4050	5170	7240
600	20190	18	1140	2905	4770	6100	8800
750	31250	19	1450	3720	5950	7650	10640
1000	57800	18	1900	4920	8090	10320	14470
1250	94700	17	2380	6280	10320	13180	18500
1500	138700	21	3200	7720	12580	16000	22400

Note.—The above figures have been taken from coils mounted in "Igranic" Coil Holders of the Biplug or Triplug types, and may only be relied upon when "Igranic" Honeycomb Inductances are used with these Coil Holders. The use of other makes of Coil Holders will probably cause some discrepancies in the figures given, owing to differences in design.

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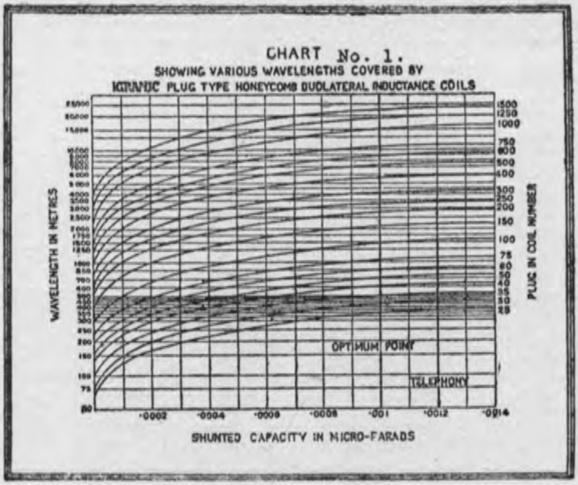

CHART No. 1.
SHOWING VARIOUS WAVELENGTHS COVERED BY
IGRANIC PLUG TYPE HONEYCOMB DUOLATERAL INDUCTANCE COILS

TABLE No. 2

DATA OF "IGRANIC" GIMBLE-MOUNTED HONEYCOMB DUOLATERAL INDUCTANCE COILS

Coil No.	Natural Wave-length in metres.	Wave-length in metres when shunted by mfds.			
		·0001	·0003	·0005	·001
15	49	116	188	240	335
25	97	178	277	348	483
30	128	224	344	432	596
35	159	267	405	503	697
40	206	318	466	578	791
50	249	392	580	720	987
60	310	480	705	877	1200
75	390	615	911	1130	1550
100	405	727	1120	1410	1950
150	541	1060	1665	2100	2930
200	661	1320	2090	2640	3680
250	783	1580	2510	3170	4420
300	935	1890	2990	3800	5290
400	1130	2350	3740	4740	6600
500	1290	2700	4300	5460	7610
600	1810	3840	5860	7430	10350
750	2140	4440	7090	8960	12500
1000	2580	5460	8730	11100	15400
1250	3530	7400	11800	13500	20800
1500	4930	8550	13100	16400	22600

Note.—The above figures are the result of readings taken from "Igranic" Gimbal-mounted Honeycomb Duolateral Inductance Coils mounted in the "Gimbolder" (Regd.) Coil Holder, and may be regarded as being accurate only under such conditions.

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TABLE No. 3

"IGRANIC" GIMBAL-MOUNTED HONEYCOMB DUOLATERAL INDUCTANCE COILS

Table showing wave-lengths obtainable by using Gimbal Type Coils as Variometers when mounted in the "Gimbolder" Coil Holder.

Coil Nos.	Natural Wave-lengths.		Coil Nos.	Natural Wave-lengths.	
	When Inductances are added.	When Inductances are in opposition.		When Inductances are added.	When Inductances are in opposition.
15 & 25	113	110	200 & 250	1040	955
25 & 30	154	145	250 & 300	1215	1105
30 & 35	204	193	300 & 400	1500	1290
35 & 40	252	240	400 & 500	1730	1490
40 & 50	302	292	500 & 600	2430	2130
50 & 60	368	350	600 & 750	2990	2650
60 & 75	510	476	750 & 1000	3510	3025
75 & 100	575	526	1000 & 1250	4640	4100
100 & 150	680	620	1250 & 1500	5650	4920
150 & 200	860	776			

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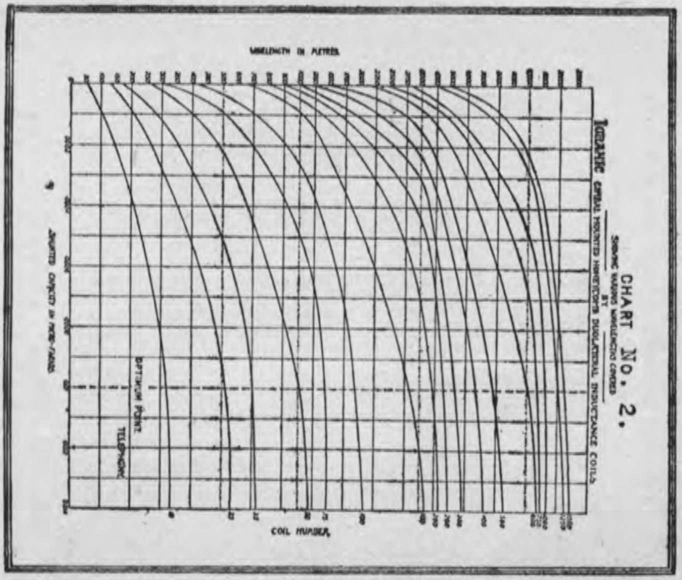

TABLE No. 4

OF WAVE-LENGTHS CORRESPONDING TO THE PRODUCT OF INDUCTANCE AND CAPACITY

Wave-length in metres =1884$\sqrt{L \times C}$.	Frequency.	L × C.
100	3,000,000	·002816
150	2,000,000	·00634
200	1,500,000	·01126
250	1,200,000	·0176
300	1,000,000	·02533
320	938,000	·02883
340	882,000	·03255
350	857,000	·03448
360	833,000	·03648
380	790,000	·0407
400	750,000	·045
410	732,000	·0473
420	714,000	·0497
430	698,000	·052
440	682,000	·0545
450	667,000	·057
460	652,000	·0596
480	625,000	·0648
500	600,000	·0704
600	500,000	·1014
1600	187,500	·72

Note.—The figures in column 3 are the product of inductance (L) in microhenries and capacity (C) in microfarads. For explanation of use of this table *vide* Chapter V.

TABLE No. 5

INDUCTANCE OF A COIL WOUND WITH 10 TURNS PER CENTIMETRE

Length in cms.	Diameter in Centimetres.					
	4	5	6	7	8	9
1	5·78	7·89	10·14	12·49	14·94	17·47
2	16·59	23·28	30·5	38·1	46·2	54·5
3	29·5	42·25	56·02	70·87	86·57	97·15
4	43·4	63·0	84·57	107·9	132·8	159·0
5	58·0	84·92	115·0	147·6	179·6	220·3
6	72·9	107·6	146·7	190·2	236·2	300·2
7	87·9	130·7	179·3	233·1	291·2	353·7
8	103·3	154·2	212·5	277·2	348·0	423·7
9	118·7	177·8	246·1	322·7	406·0	470·5
10	134·2	201·8	280·0	368·0	464·5	568·5
12	165·2	249·3	348·7	460·5	586·0	717·5
14	196·4	298·2	418·2	554·0	702·5	868·7
16	227·7	347·2	478·8	648·2	825·2	1023
18	259·0	395·7	557·8	743·0	950·0	1178
20	290·5	444·7	628·0	838·0	1074	1333
22	321·7	493·7	698·5	933·5	1205	1490
24	353·5	543·0	751·2	1038·7	1322	1647
26	384·0	591·7	889·2	1125	1447	1845
28	416·5	641·2	910·5	1221	1572	1961
30	448·0	690·2	980·5	1316	1697	2120
32	480·0	739·5	1052	1413	1822	2278
34	511·0	788·7	1122	1509	1948	2380

Note.—For explanation of the use of this table *vide* Chapter VI.

TABLE No. 5 (*continued*)

Length in cms.	Diameter in Centimetres.				
	10	12	14	16	18
1	20·06	—	—	—	—
2	63·1	81·12	99·7	119·5	139·7
3	120·0	155·8	196·0	233·0	273·7
4	186·3	243·5	305·2	369·5	436·0
5	259·2	342·2	430·7	502·3	620·5
6	337·5	448·2	567·5	698·7	823·7
7	420·2	560·7	711·7	873·2	1046
8	504·0	676·7	863·5	1062	1278
9	590·5	800·7	1020	1256	1512
10	679·5	920·2	1181	1464	1762
12	860·7	1175	1518	1886	2283
14	1046	1435	1862	2329	2822
16	1234	1701	2219	2785	3400
18	1424	1970	2577	3245	3962
20	1615	2241	2945	3715	4547
22	1807	2515	3312	4187	5140
24	2000	2790	3682	4667	5735
26	2194	3067	4057	5152	6342
28	2421	3347	4432	5637	6952
30	2582	3625	4807	6125	7565
32	2778	3905	5187	6615	8182
34	2982	4187	5565	7162	8800

Note,—For explanation of the use of this table *vide* Chapter VI.

TABLE No. 6

Table giving the values of K, for the ratio of length to diameter of a coil between 0·01 and 10, as calculated by Professor Nagaoka.

Diameter Length.	K.	Diameter Length.	K.
0·00	1·0000	0·70	0·7609
0·02	0·9916	0·72	0·7556
0·04	0·9832	0·74	0·7504
0·06	0·9750	0·76	0·7452
0·08	0·9668	0·78	0·7401
0·10	0·9588	0·80	0·7351
0·12	0·9509	0·82	0·7301
0·14	0·9430	0·84	0·7252
0·16	0·9353	0·86	0·7205
0·18	0·9276	0·88	0·7157
0·20	0·9201	0·90	0·7110
0·22	0·9126	0·92	0·7063
0·24	0·9053	0·94	0·7018
0·26	0·8980	0·96	0·6972
0·28	0·8909	0·98	0·6928
0·30	0·8838	1·00	0·6884
0·32	0·8767	1·20	0·6475
0·34	0·8699	1·40	0·6115
0·36	0·8632	1·60	0·5795
0·38	0·8565	1·80	0·5511
0·40	0·8499	2·00	0·5255
0·42	0·8433	2·2	0·5025
0·44	0·8369	2·4	0·4816
0·46	0·8306	2·6	0·4626
0·48	0·8243	2·8	0·4452
0·50	0·8181	3·0	0·4292
0·52	0·8120	3·5	0·3944
0·54	0·8060	4·0	0·3944
0·56	0·8001	4·5	0·3409
0·58	0·7943	5·0	0·3198
0·60	0·7885	6·0	0·2854
0·62	0·7828	7·0	0·2584
0·64	0·7772	8·0	0·2366
0·66	0·7717	9·0	0·2185
0·68	0·7663	10·0	0·2033

Note.—For explanation of how to use this table *vide* Chapter V.

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