EXPERIMENTAL WIRELESS STATIONS

PHILIP E. EDELMAN

1916 EDITION

EXPERIMENTAL WIRELESS STATIONS

THEIR THEORY, DESIGN, CONSTRUCTION AND OPERATION

INCLUDING WIRELESS TELEPHONY AND QUENCHED SPARK SYSTEMS.

A complete account of sharply tuned modern wireless installations for experimental purposes which comply with the new wireless law, with more than 80 illustrations.

By

PHILIP E. EDELMAN

Author, "Inventions and Patents," "Simple Experiments in Chemistry," "An Experimental Quenched Arc System," "How to Comply with the New Wireless Law," and many other articles in the technical press.

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*To the faculty of the West High School, Minneapolis,
and particularly to Mr. John H. Cook of the
Physics Department, as an appreciation
of the interest taken in the
Author.*

FOREWORD.

This book was written to fill a noticeable gap in the literature on the art of wireless telegraphy. As its name implies it is intended particularly for experimenters, that sane body of voluntary workers who take up the art as a hobby, study, or spare time vocation and who are generally misnamed, "amateurs." It is intended particularly as a guide to a rational worth while study of the art and only matter which directly contributes to the practical presentation of the art has been included.

One of the main objects of the book is to provide a standard design for so-called "Amateur stations," which will take the place of the many varieties of hit and miss apparatus constructed and purchased by experimenters.

This book is intended for experimenters who regard the art as more than a mere idle plaything, and it is hoped that it will serve as a stepping stone to a serious preparation for high positions in the practical field of the art. The earnest experimenter is separated from the wireless engineer and commercial wireless inventor by a very small space of time and application to study, while the position of an expert wireless operator is even easier to attain. Wireless today offers opportunities which are perhaps not exceeded by any other art or trade. The field is open and ready for serious workers, the work of absorbing interest, and the remuneration limited only by the capabilities and temperament of the individual and the circumstances concerned.

Inasmuch as both innocent and wilfull interference with other stations has to a large extent hindered experimenters as well as commercial operators, the design in this book is directed particularly to standard apparatus and stations of sane sharp tuned wave lengths which will not interfere with others. As far as the author is aware this is the first book to appear in which standard designs are given. On account of the new wireless law, experimenters are now forcefully restricted to this rational type of apparatus. In any case, serious workers will realize that it is only fair and even desirable. At the present stage of development, wireless experiments must be conducted on a strict basis of live and let live.

The matter in this book has been written with particular regard to clearness, simplicity, and direct usefullness. Makeshifts have been suggested in some cases and it is hoped that experimenters with limited means will welcome them. It is quite possible to have a wireless station at an outlay of less than one dollar. The approximate cost of the apparatus is given in some cases.

The author will be pleased to receive suggestions and corrections from his readers, but cannot promise or agree to give individual advice, further individual instructions, or answer other communications which require much time, since his time is all taken up with other activities.

In order to get directly to the pith of the subject little or no preparatory history and elementary matter has been given, as the readers are assumed to have some little knowledge of the fundamentals of electricity, magnetism, and mathematics. (This does not mean an extensive or complete knowledge.) The important principles upon which the wireless systems depend together with the working principles of the separate instruments have, however, been treated in some detail and in most cases "How it works and how to make it," have been combined. It is believed that several items are presented for the first time in this volume and the best modern practice has been presented, so that it comes within the limitations of the average experimenter.

The majority of the material given is the result of the author's own experiences together with the experiences of others, and it is believed that credit has been given for the important items or abridgements from other sources, which have been included. In many cases only the vital points for an instrument have been given, so that the individual can use his own ingenuity in working out the details. The reader is thus given an opportunity to be original without the usual waste of "cut and try." Every ambitious reader will very likely read from cover to cover, but the matter has been so arranged that each chapter is complete in itself. The advanced reader can turn to the particular subject in which he is interested without going through matter already familiar to him.

Although several manufacturers have offered cuts for this book, it has seemed best to give simple line drawings to illustrate constructional details rather than half tones which only show the general appearance of a particular type of instrument. Most of the drawings have been prepared specially for this book and the few taken from other sources have in most cases been credited.

In conclusion it may be remarked that no author is insensible to appreciation, and if you obtain more than the mere intrinsic worth from this book, the author will appreciate your courtesy in telling others so.

Philip E. Edelman.

Minneapolis, Minnesota,
October 15, 1912.

CHAPTER I.

NATURE AND THEORY OF WIRELESS TRANSMISSION OF INTELLIGENCE.

Before beginning the details of equipment, a brief outline of the essential theories which aid in understanding the art will be given. To begin with, it should be understood that many of the elementary theories have only been partially substantiated and that in any case they serve more for convenience than as scientific fact. It should

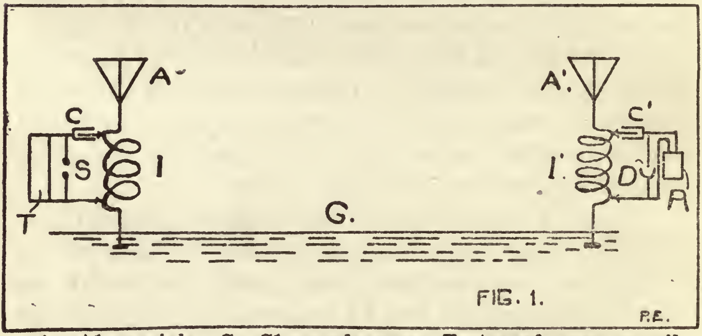

FIG. 1.

A. A1—aerials. C. C1—condensers. T—transformer or coil. D.—detector. I. I1—inductances. S—Spark gap.—G.—ground. R.—telephone receiver.

also be remembered, that while lines of force and similar terms are used as though the lines were visible and a matter of fact, they are merely imaginary and used for convenience.

In the practical wireless station with which we are concerned, electromagnetic waves are utilized to transmit intelligence in a telegraph code without the use of a conductor or wire between the transmitting and receiving stations. It has been found that these electromagnetic waves closely resemble light waves and for this reason some knowledge of the physics of light will be useful and an aid in the mastery of the wireless art.

In fig. 1 a simple diagram of the relations of the stations is shown. Briefly, electromagnetic waves are generated by means of a discharge through a suitable gap which sets up oscillations in a shunt circuit of capacity and inductance and these oscillations are in turn radiated from the aerial in wave trains representing the dots and dashes

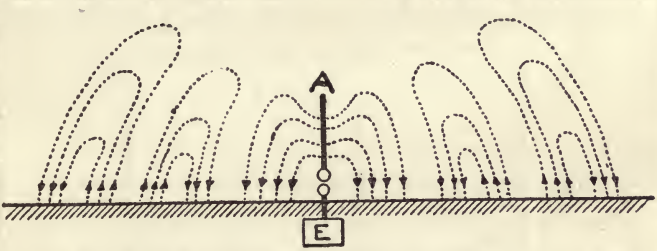

FIG. 1a. THEORY OF THE ACTION OF WIRELESS WAVES

of the code. By referring to the figure it will be observed that the sending and the receiving station are connected through the earth and that they have a second circuit through the space between their respective aerial capacities. It has not been established whether the ground acts as the return circuit or whether the space serves for this purpose, but experiments have shown that a considerable part of the efficiency of transmission is dependent on having good ground connections through soil, which is a comparatively good conductor. In fact, the variable conductivity over different portions of the earth materially affects the range and clearness of transmission, ranging from maximum over water, to a minimum over dry uneven expanses of land. The earth is an imperfect and variable conductor in itself and it is for this reason that transmission over different portions of the earth's surface varies considerably. It has not been established whether or not the curvature of the earth materially affects transmission, but it is not likely that it does. Good earth connections then, are essential to efficient wireless transmission.

A commonly accepted theory of the action of wireless waves is illustrated in fig. 1 a. The aerial (A) is represented by the upper part of a spark gap and the lower part terminates in a ground E. The aerial becomes

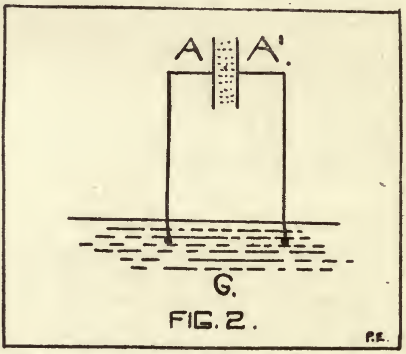

FIG. 2.

charged and sets up a field of force, the area of which depends on the intensity of the charge and other natural conditions. The lines of electrical strain are represented by the dotted lines and should be understood as of spherical form, although shown as in a plane on the paper. Now after the charge accumulates to a certain point, a spark passes between the gap electrodes, making the gap a temporary conductor. The aerial discharges at this point and as a result the strain in the electrostatic field is relieved. However, a new current is simultaneously produced which charges the aerial in substantially the opposite polarity to that of the first charge, and the process is repeated very rapidly a number of times. That is, the aerial is said to oscillate or vibrate. Now, each reversal of the polarity of the charge causes the direction of the strain to change so that the lines resulting from the first charge are displaced by lines running in the opposite direction, thus forming partial loops. These loops form a circular series of ripples or waves about the aerial and travel away from it at the rate of 300,000,000 meters per second (186,000 miles per second), or the speed of light. In the figure, the arrows represent the direction of the lines of strain and a little study of this imaginary diagram will aid in the understanding of wireless phenomena. It is understood, of course, that the gap is charged by a suitable condenser and source of power, which are not shown.

Two complete oscillations are represented by the loops of fig. 1a. and the aerial is ready for a third discharge.

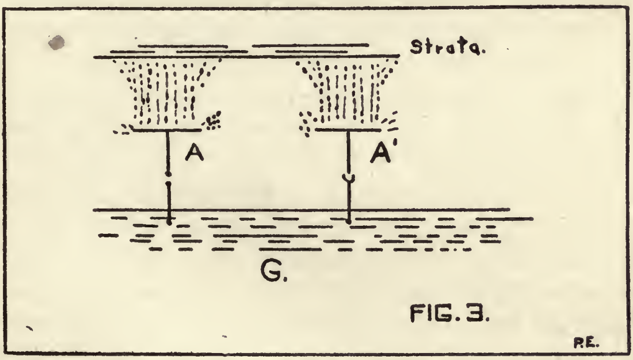

FIG. 3.

These oscillations really occur at an exceedingly rapid rate and has already been explained, the lines are only imagined to exist for the sake of tangible theoretical consideration.

The function of the aerial capacities of the stations will be best understood perhaps, when they are likened to a simple condenser. (See fig. 2.) If this theory is accepted, a wireless circuit is practically a closed circuit in which one branch takes the form of a condenser. However, since the distance between the two aerials concerned is generally many miles, it is not unlikely that the effect is similar to that indicated by fig. 3, since it has been established that the upper strata of the atmosphere and the surrounding space form practically a perfect conductor. At any rate, the distance to which transmission may be carried out is less with relatively low aerials than with high ones, the other conditions remaining the same, and for this reason the higher the aerial can be supported, the better. The item of cost is the practical limit, however, since after a moderate height is reached the expense increases in a proportion many times greater than the corresponding increase in height. In fact, the height of experimental aerials will naturally be limited for this reason and even in the few large commercial stations, the aerial supports form one of the largest items of expense.

Now the transmitted wave impulses do not travel only in the desired direction to the receiving station, but spread out in all directions with practically equal force. The direction of transmission can be regulated to some extent, however, by means of directive aerials which tend to make the range of transmission greater in one desired direction than in other directions. Wireless transmission is perhaps best understood by a comparison to the waves which result when a small stone is thrown into a smooth body of water. It is suggested that the reader try the experiment when the opportunity is presented, if he has not already done so. The stone thrown into the water corresponds to the wave generator at the transmitting station in wireless telegraphy, the water to the space or ether and the ripples to the electromagnetic waves. It should be observed that the ripples spread out continually in the form of a circle and that they gradually become feeble and feebler, until they are no longer visible. Wireless transmission presents a similar property and the electromagnetic waves become feebler so that the amplitude is approximately inversely proportional to the distance from the sending station.* Another factor which limits the transmitter's effective range is the item of absorbtion. Now, it has been found that the absorbtion varies in some cases with the wave length employed. In general, long wave lengths are subjected to *less absorption* than wave lengths which are relatively short. Inasmuch as the experimenter is expected to confine his experiments to the use of short wave lengths this is a matter of some importance. In transmission over water short wave lengths are nearly as good as the long ones, but over ordinary land, long wave lengths are a material advantage. However in the case of land transmission over dry soil, neither long nor short wave lengths appear to have an advantage. It is understood that short waves mean those having a wave length of 200 meters or less, while long waves refer to waves having from 1,200 to 4,000 or more meters for their wave length. Wave lengths between 300 and 600 meters are generally recognized as the most advantageous for ordinary purposes and since they are used for commercial purposes the experimenter is expected to use wave lengths which do not come within this range together with a safe margin, in order to avoid needless and useless confusion.

Other items which *affect* the *transmission* are *irregularities* in the composition of the earth such as mountains,

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* This is not a rigid rule or even exact.

minerals, etc., and daylight. It has been found that messages can be received over much greater distances at night than during the daytime. The difference is not marked or important over short distances and can be overcome to a considerable extent over long distances, by the use of long wave lengths. The reason why daylight affects the transmission is not really understood at the present time, although there are several theories. It is believed that the effect is due either to the ionization of the air or the upper strata or both, by the sun's light. When the theory that the aerial capacities of the stations form a condenser is used and it is remembered that the action of a condenser depends largely upon having a good dielectric material so that there will be little leakage, this theory seems plausible. Rain and damp weather have a similar effect on transmission because the dielectric is presumably rendered less conductive to the waves and more conductive to leakage.

Now since the waves tend to spread out in all directions, it will be evident that all the receiving stations within the range of a transmitting station will be capable of receiving the same message equally well, other conditions remaining the same. This lack of secrecy is a considerable detriment to the advance of the art and efforts are constantly being made to overcome this lack of direct communication in a desired straight line. Instruments and apparatus have been developed which make it possible to either receive or not receive a given message with a certain degree of precision and directive methods have been developed to a certain degree as has already been mentioned. Another serious drawback to the advancement of the art is the matter of interference. This is an item which directly concerns the experimenter and although several arrangements to overcome this objectionable feature have been developed, there is considerable room for improvements.

Interference can be understood by reference to the experiment of throwing the stone into the water. If two stones instead of one are thrown into the water, and if one is considerably larger than the other, it will be noticed that the ripples or waves from the larger stone tend to absorb and superpose those of the smaller stone. A similar drowning out occurs in wireless transmission, and when several stations are sending simultaneously it becomes practically impossible to select a desired message unless it is noticeably stronger than the remainder of the impulses. It frequently happens that six or more stations are sending simultaneously with approximately the same wave length and with strong apparatus, making it nearly impossible to receive an intelligible message from a single one of them. Further, when a long distance message is being received, and another station sending at approximately the same wave length and situated in the neighborhood of the receiving station starts in, the result is obvious. To be sure, apparatus has been developed which makes the selection of desired signals, to the exclusion of others, certain within limits, but such cases as the one mentioned can of course not be entirely avoided, with the best of the present apparatus. When the stations are all sending at wave lengths, which differs considerably from one another and are sharply tuned, the desired message can generally be received without much difficulty. However, if untuned or only loosely tuned signals are sent out from a moderately strong or neighboring station, it becomes practically impossible to tune them out because they are received by forced oscillations. It is like trying to hear a phonograph a block away when a band is playing within a few feet of your ears.

When *tuned* or sharply tuned *waves* are spoken of, it means waves such as are transmitted from tuned transmitting stations so that it is necessary to tune within a very few per cent in order to receive them. When *untuned* or forced oscillations are spoken of, it means waves which may be received without sharp tuning or signals which have several wave lengths without any definite characteristics. This is the sort which is so generally employed by beginners and even by commercial stations in some cases and can be received by all stations within range without any special effort. This property is certainly useful in case of emergencies at sea, but in ordinary transmission the stations with untuned wave transmission are like noxious weeds, and should be gotten rid of as soon as possible whenever they interfere with other stations. The matter of tuning will be more fully taken up, later.

The only other natural condition of importance which affects wireless transmission is the matter of atmospheric disturbances. Ordinary static disturbances resemble the disturbances caused by untuned waves and are practically impossible to entirely exclude, particularly when they are present in a large quantity. Certain localities have less trouble from static interferences than others, but there are only a few localities in which static does not cause more or less trouble. In cases of local electrical storms, transmission or reception becomes impracticable and even dangerous.

The sending and the receiving stations of a wireless system are similar and the same aerial capacity may be used for both sending and receiving. The receiving apparatus of an up-to-date wireless system generally includes a detector to detect or rectify the incoming oscillations, sensitive recorders, which generally take the form of telephone receivers, to receive the intelligence, and various inductive and capacity apparatus to tune the station to receive desired signals to the exclusion of undesired signals.

These points and the practical considerations which they involve will be discussed in detail in the following chapters.

The reader should always bear in mind that the radiant energy used for wireless work is as real as is the radiant energy of the sun. The length of the electric waves with which we are concerned can be controlled at will and while they may be made a fraction of an inch or several miles long by merely altering the oscillatory circuit as described in chapter four, practical work is at present carried out within 150 to 6,000 meters.

The matter in this chapter is only a mere outline of the many conditions involved in wireless transmission, and the reader is referred to works by Pierce, Fleming, Murray, and others, for further accounts of the history and theories of wireless transmission. The mathematical reader will find these volumes of particular interest.

CHAPTER II.

AERIALS.

The essential conditions for wireless transmission have been briefly outlined and we will now take up the matter of aerials. It will be remembered that short waves are more easily dissipated than long waves. This is particularly true during the summer months and when the transmitting station is in the vicinity of a large number of trees. Both the sunlight, and the foliage on the trees tend to absorb the shorter waves to a greater extent than the longer waves. Perhaps it is well to more fully define what is meant by wave length at this time.

Now the *electromagnetic* waves which are generated and radiated at the sending station are similar to light waves in that they have the same velocity (186,000 miles per second) in air of the same temperature and pressure, have the physical properties of reflection, refraction and polarization, but are *different* in that light waves have a relatively short wave length while the electrical oscillations have a relatively long wave length. It may be explained also, that the length of a wave means the distance between like points on any two consecutive waves. It will be remembered and noted that the transmitter of a wireless station sends out a series of waves at a very rapid rate, so that by the time one has left the aerial and another leaves, the first will have traveled a distance roughly equal to the wave length. Since these wave impulses occur at a very rapid rate (high frequency), a single transmitted dot may be made up of several wave impulses.

The aerial capacity or antenna consists of metallic conductors insulated from foreign objects and elevated in the air. It is generally made up of a number of similar wires, and its purpose is to radiate electromagnetic waves when used as the aerial for a transmitter, and to receive or regenerate intercepted waves when used with receiving apparatus. The aerial itself may take a number of shapes and since each has individual characteristics, different effects are obtainable from different combinations of conductors. In the early stages of the art solid metal or wire network aerials were adopted and the experimenters used chicken netting, bronze screen and similar materials for aerials, but it was soon found that uniform conductors separated by a uniform distance were better suited for this purpose.

Now the dimensions of the aerial is one of the main factors which determine the efficiency of the wireless station and also limit the efficient wave length of the transmitted impulses. In accordance with good practice and in order to keep within the regulations embodied in pending wireless legislation,* the experimenter is expected and will very likely be required to limit his experiments to wave lengths which are not over two hundred meters long, or else to use wave lengths of a very long length, (2,000 meters or more). Now although low wave lengths are more readily absorbed and dissipated they are also more suited to low power apparatus than the long wave lengths. However, if the reader proposes to use power in excess of one K. W., it will be advisable to use the long waves for the experiments in order to obtain a desired degree of efficiency.*

When the experiments are to be carried out in the vicinity of considerable foliage it will be advisable perhaps, to use the long wave length, but in all ordinary conditions and particularly in cities having numbers of other stations, the *short wave length only* should be used. It should be remembered that the aerial itself is only one of the factors which determine the transmitted wave length and that the experimenter has a variable range of wave lengths at his service by employing tuning helixes, oscillation transformers, or if very high wave lengths are desired he may use a loading coil.

The first item to consider is the exact location for the *aerial support,* or the support and the height for the same. As has already been pointed out, the higher the aerial is placed above the surface of the earth, the better. When only occasional experiments are to be conducted, a tandem of kites, preferably box kites, will serve very well. The unsteady height resulting from the rising and falling motion is, however, not suited to delicate tuning, since the capacity of the aerial is thereby altered. There is no limit to the ingenuity which may be called to act in the selection of inexpensive aerial supports. A simple insulated wire dropped from the roof or an upper story of an apartment house, flat, water tower, or similar structure to a position some distance below (30 to 130 feet), will serve as a fair aerial. Insulated telephone cables may be impressed into service for receiving purposes alone. Two grounds may be used in place of an aerial, if no supports are available. Thus the water pipes may be used as an

* See Chapter 19. The law referred to has been enacted.

aerial while the gas pipes, or a cistern is used as the ground. Or the steel frame or tin roof of a building may be used for an aerial while another part of another building is used for a ground. Even leader pipes and gutters have been impressed into service in certain cases. Common wire netting suspended from trees or telephone poles may be utilized. It is always desirable to *insulate* even makeshift aerials and when two grounds are used, one should be connected through a condenser to the instruments. The author has even made use of a small aerial suspended in an attic, a brass bed in an upper story of a residence; and for very short distances such common things as dishpans, bed springs, and what not! may be utilized if nothing else is obtainable. During some experiments in Tripoli, Mr. Marconi is reported to have laid both the aerial and a similar set of conductors to act as a ground directly on the sand, parallel to the direction in which the signals were to be sent. It is said that no aerial supports were necessary because the sand was perfectly dry and resembled glass in its conducting properties. These items are merely suggested as suitable makeshifts in case other and more business like arrangements are not practicable and good results may be obtained with them by exercising reasonable skill.

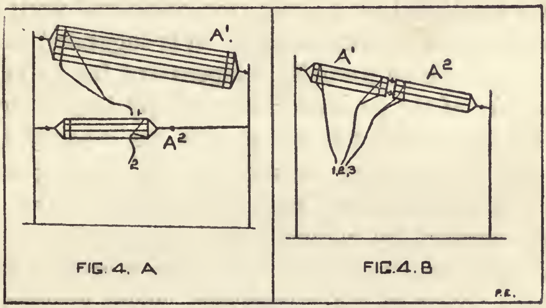
The supports should take the form of natural supports whenever possible as this will save considerable expense. Thus short extensions to trees, houses and building tops, and similar structures make excellent supports. Permission may often be obtained from the local telephone or light companies to place extensions on one or more of their poles so that they will not interfere with the regular service and some companies will even give aid if properly approached. The author has utilized such poles for his experiments for a good many years.

The erection of large poles from the ground up is a difficult task and one which had best be referred to the company which sells the pole or else to experienced erectors.

Good straight grained 2x2 stock is suitable for small poles up to 40 feet, and the size mentioned is preferably arranged into two or three lengths. Perhaps the best support for experimental stations, when natural supports are not available, is iron pipe. This form of support may also be used in addition to natural supports such as housetops, etc. The height of the aerial should always be sufficient to clear objects between stations if possible. For experimental purposes a height of about 50 feet is a good average, though a higher one is preferable when possible.

After the height has been determined, the other dimension to be considered is the spread of the aerial. In many cases a low height can be compensated by a corresponding increase in the aerial spread. However, since an increase in the horizontal spread of an aerial also increases the minimum wave length of the transmitted impulses, this dimension must be limited so that the minimum wave length will be about 150 meters if the wave length is to be limited to *200 meters* or less, the difference being left to the adjustment of the transmitting inductance. When possible it is a good plan to have a *duplex aerial,* which is nothing more or less than two separate aerials, one for receiving and sending in short wave lengths, and the other for receiving in the commercial wave lengths, but not for sending. While this means two separate aerials and should be regarded as such, much ingenuity may be used in utilizing the same supports for the two aerials. Thus one may be supported some distance below the other, and similar arrangements may be carried out in a variety of ways. The main objection to a duplex aerial is that part of the transmitted energy is absorbed by the idle aerial. (See fig. 4.) This can be overcome to an extent by placing the two aerials at right angles to each other.

The large receiving aerial of a duplex system may have a length of from 100 to 1,000 feet depending on the individual conditions,—about 400 feet being a good length. The length means the *effective length* including the several parts. For the vertical, horizontal, or dipped



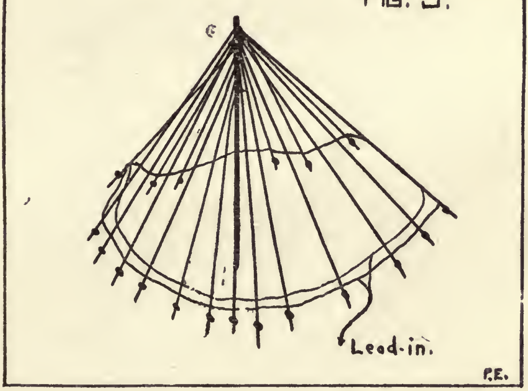
A.—A1—receiving aerial. 1-2 leads. A2—sending aerial. B—A1—A2—divided aerial. 1-2-3 leads. Transmitting—short circuit 2-3 and use—or leave 2-3 open and use either 1 or 2. Receiving—use 1—with 2-3 closed, other variations also.

aerial (straightaway) the length of one of the wires is the effective length. (See the figures.) The effective length of the T aerial is the length of the vertical part plus one-half of the horizontal portion, while that of the reversed L aerial is the length of the horizontal part plus the length of the vertical portion. In a loop aerial the length is the sum of the lengths of the sides of the reversed U loop. With the ordinary umbrella aerial, the length is roughly equal to the length of one of the uniform aerial conductors, as is also the case in a directive aerial having several independent and uniform conductors. In order to keep within the limits of the standard short wave length, an effective length of 120 or 125 feet should not be exceeded.* The transmitting aerial should, therefore, be made so that the effective length is within this limit. It is understood that the length of the lead-in is included in the effective length. The effective length is really the distance from the transmitting instruments to the aerial proper, plus the effective length of the aerial itself. In case a long ground lead is necessary to secure a ground to the instruments, its length must also be added to the effective length. In the latter case, the aerial itself must obviously be still further limited. It is suggested that the short length can be partially compensated for by making the *capacity* of the aerial correspondingly *larger,* but this must not be carried too far so that the capacity is too large for the charging capacity of the sending instruments. It is understood that the capacity of the aerial can be increased by adding more wires to it. A large electrostatic capacity in the aerial means greater energy and more power in the transmitted waves provided the transmitting instruments are able to charge it with a sufficient potential. The wires should always be arranged symmetrically and evenly spaced in order to decrease the effect of mutual induction between the adjacent wires as much as possible. An increase in the conductors of the aerial does not increase the capacity to a corresponding extent on account of this mutual induction. The distance between the respective conductors of an ordinary aerial should not be less than .02 of their common length. Thus in an aerial 100 feet long, the wires should be spaced at least 2 feet apart, or even more if possible. In addition

* This means that the length of the aerial proper should not exceed 75 feet, in order to allow for lead-ins.

to increasing the capacity of the aerial, an increase in the number of conductors *decreases* the resistance. A minimum of three wires and a maximum of 8 or 10 is the range of the number of conductors suitable for the average experimental station and it is not desirable to exceed these limits. Some results may of course be had with even a single conductor, but for efficiency a plurality of conductors is desirable.

FIG. 5.



The number of conductors used affects the *transmission* more than the reception of signals. It is desirable to use two conductors placed 6 feet apart instead of four wires only nine or twelve inches apart and the same rule may be applied for other dimensions, since much of the effect of the extra wires is lost by reason of their close proximity. When only two wires are used, they should of course have a correspondingly increased capacity. In any case, the size of the aerial conductors should not exceed No. 8, since larger sizes are wasteful and of prohibitive weight. No. 12 is a convenient size for experimental aerials. The constructional details will be more fully taken up a little later.

For short wave lengths, the author considers that the *umbrella* aerial or perhaps a modified umbrella will prove the most satisfactory because of the large capacity which is possible in a small space. Suitable forms for this type

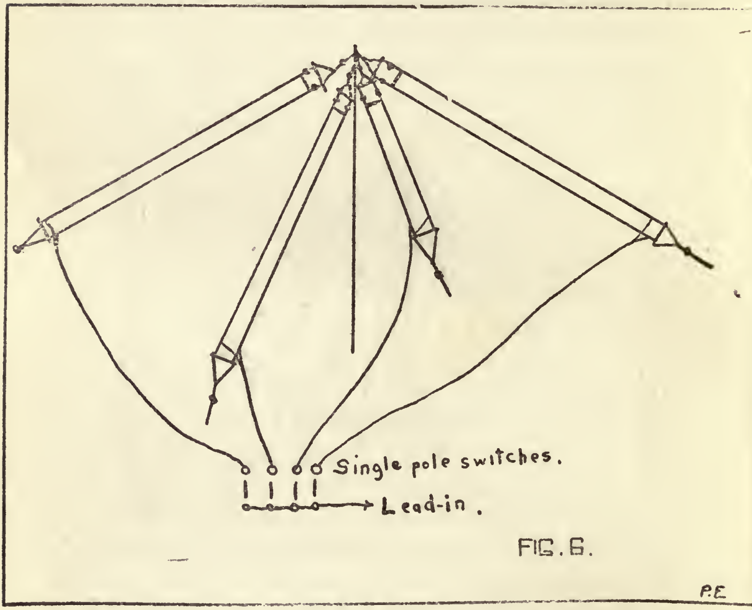


FIG. 6.

of aerial are indicated in fig. 5. This aerial is called the umbrella presumably by reason of its resemblance to the ribs of the umbrella. This arrangement may easily be converted into a *directive* aerial as shown in fig. 6, in which form it will doubtless be the most useful to experimenters. The several conductors are preferably insulated from each other in this case, though they may be connected together at the top or pole end. Each wire is separately connected to a single pole switch, preferably of the common porcelain base type. With this arrangement, one or more wires may be used independently from the remainder, or all may be used if considerable capacity for transmitting purposes is desired. This form of aerial is well adapted to experimental purposes and has the additional advantage of being mechanically strong and requir-

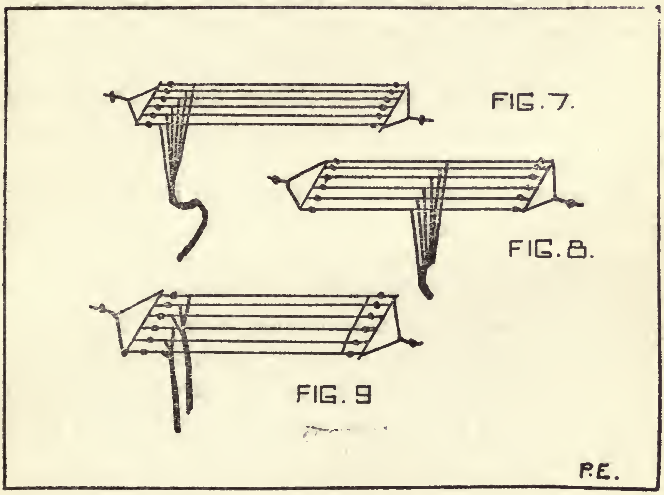


FIG. 7.

FIG. 8.

FIG. 9

ing only a single pole support. This type of aerial is particularly suited to house tops, the roofs of buildings, and similar places.

In congested places where the available space for the aerial is limited, as on ships, various types of horizontal or flat top aerials are used. Experimenters will find these types well adapted to their purposes. These aerials are also known by names which correspond to their respective shapes. The *reversed L* type is shown in fig. 7, and is highly directive by reason of its shape. The maximum radiation is in a direction opposite to that in which its free end points and it also receives signals at the best from the same general direction. The leads are taken off from one end of the aerial, and if the two ends are of uneven length, the lead should be taken off from the lower end. In the latter case, the aerial is called an inclined aerial. When the leads are taken off in the form of a *T* as in fig. 8, signals are sent and received the best in the plane of the aerial, but the directive effect is considerably less than with the L type. Instead of taking the leads off at right angles it is often necessary or convenient to take them at an angle to form an oblique lead. The several wires are preferably connected together at one end, although this is not essential.

By taking a double lead as illustrated in fig. 9, either as a T or L type, a *looped aerial* is formed. This inverted U type is adapted to close tuning and eliminates humming caused by neighboring telephone and power lines. These types may of course be considerably varied, but a simple form is desirable in order to secure close, sharp tuning.

Having gained some idea of the several types and general features of aerials, some of the constructional details will now be considered.

INSULATORS.

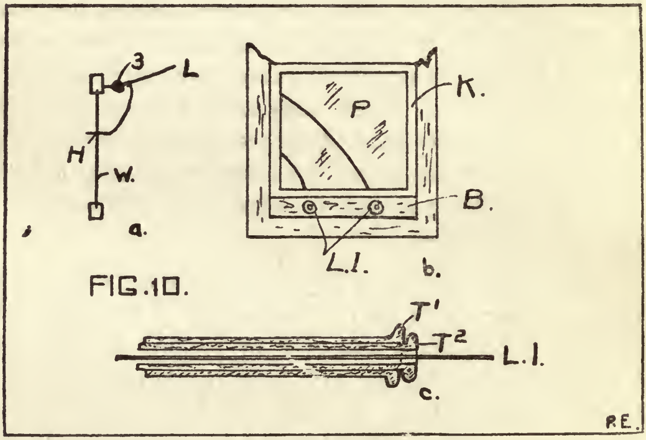
It is important that the aerial be suspended so that it is thoroughly insulated. The insulation should be effective during all kinds of weather and faulty insulation should be avoided with considerable care if an efficient station is desired.

Hard rubber, fibre, and unglazed porcelain are not very desirable as aerial insulators. A material known by the trade name of Electrose is made into a number of suitable forms. This type of insulator is also mechanically strong, since metal rings are molded directly into the insulating material. Corrugations are provided to increase the distance over which a surface charge must pass and also serve to prevent the formation of a conducting film.

Aerials for transmitting purposes are necessarily better insulated than those used for receiving purposes only, but in any case the aerial conductors should not touch foreign or partially conductive materials. Common two wire glazed porcelain cleats make convenient insulators for small stations. These may be had for a few cents a piece. The holes are 1½ inches apart, so that a single cleat is sufficient insulation for a receiving aerial and also for a transmitting station in which only 100 watts or a one inch coil is used.

When more power or larger coils are to be used, several of these cleats may be arranged in tandem. The cleats may be joined, and used by passing wire through the two holes so that the wire to be insulated is separated by the insulator from the wire attached to the support. There are various other forms of porcelain and glass insulators which may be had at supply houses and since they are all used in much the same manner, no further comment seems necessary. Strain insulators are useful in breaking up the guy wires used in supporting the poles, so that the transmitted waves are not unduly absorbed. This form of insulator is also useful for the main aerial supports. The leads or lead-in wires should be insulated with the same care as the aerial itself. The supports which hold the leads should have insulations of the same general nature as that provided for the aerial.

A problem is sometimes presented when it comes to bringing the wires into the building. A good way is to bore holes for the wires, in a glass window. Heavy porcelain tubes placed in holes in the woodwork are also suitable for small stations. A fairly good lead-in insulator can be made by using a nest of tubes, one over the other, starting with a half inch in outside diameter and ending in the largest convenient outside diameter. A



a.—W.—window. H.—hole in glass. 3—insulator to take up strain. L—Lead-in. b.—P—windowpane. K—slide casing. B board with insulators, window casing rests on B. c.—T1. T2—Porcelain tubes.

number of special insulators may be had at supply houses. See fig. 10 for several details of construction for the lead-ins. The wires should be anchored by an insulator just before entering the building in order to take up the strain.

The general manner of suspending an aerial is illustrated in fig. 11. The spreaders can be of wood or bamboo. Curtain poles are suitable for this purpose. Twisted wires, screw eyes, mast withes and similar hardware or improvised hardware are useful in fastening the insulators and supports.

ASSEMBLING.—CONDUCTORS.

In assembling the aerial conductors and the spreaders, it is advisable to arrange everything on the ground first. The wires may be of copper, tinned copper, aluminum, or phosphor bronze. Iron wire is not recommended, al-

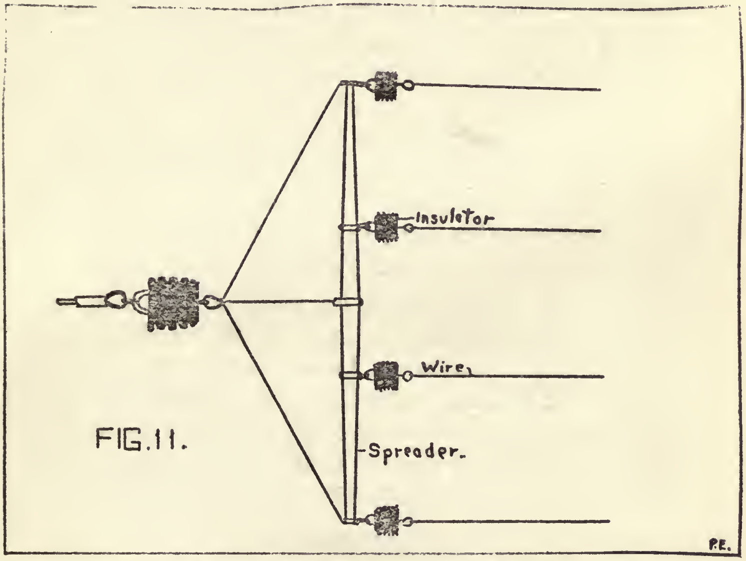


FIG. 11.

though it may be used. The phosphor bronze is the most desirable because it is strong, springy, and may be had in a standard strand of seven No. 22 B&S conductors. It is generally sold by the foot. Stranded conductors have a slight advantage over solid conductors.

Although copper has less than one-half the tensile strength of phosphor bronze, it is very easily obtained and quite suited to aerials. It has a good conductivity, is pliable, can be easily soldered, and may be had in strands if desired. Ordinary No. 12 telephone copper wire is suitable for experimental aerials. The wire used should never exceed No. 16 or its equivalent in fineness or No. 8 in coarseness.

Aluminum is not so good a conductor nor is it as strong as copper wire, but it is pliable and very cheap when compared foot by foot. The main difficulties with aluminum aerials are that the wires are easily broken by twisting and that a non-conductive coating soon forms which practically insulates the joints unless they have been well soldered.

In using aluminum wires, kinks, bends, and excessive strains should be avoided. This also applies to other wires. Aluminum is difficult to solder but special solders are obtainable which make the operation reasonably sure provided the joint is well cleaned to begin with. All joints in the aerial should be soldered and it is also advisable to tape them with a good quality of electrician's tape and rubber solution. Loose contacts in an aerial cut down the efficiency materially and also make the aerial weak mechanically. The high frequency currents must have as *clear* and as good a *conducting* path as possible if the waves are to be radiated without considerable loss.

JOINTS.

Fig. 12 shows a fairly good way to make a joint without solder. The wires should be *cleaned* and the *joint* made tight, after which, wrap several layers of tinfoil about the joint and tape well.* When the aerial is constructed with every concern for efficiency, the wires will

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* These points have appeared in several magazines and are in general use.

be thoroughly insulated even at the points where they make contact with the metal connections of insulators. This may be done by tape, and the chief object is to prevent thermo-electric and galvanic action between the dissimilar metals. Fig. 13 illustrates a suitable joint for lead wires which prevents the wire from breaking by the swaying motion given it by the wind. When electrician's tape and liquid insulation are used, a very good water and

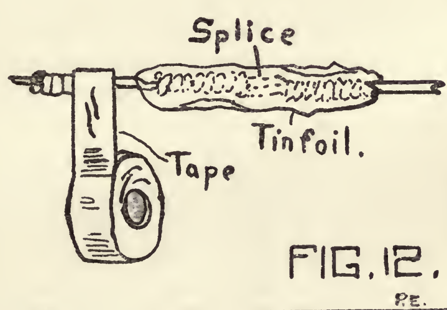


FIG. 12.

rust tight joint is insured. The wire conductors should be kept *free* from nicks, kinks, and sharp bends, since they are easily parted at such points.

WIRES.—SIZE.

Large spans require *larger sizes* of wires than short spans, since they are subject to greater strains. Numbers 8 to 10 are suitable for spans in excess of 200 feet, while numbers 11 to 15 are suitable for the shorter spans. In planning the conductors larger sizes should be used when aluminum wire is used than for copper, larger for copper than for phosphor bronze, and larger sizes should also be used according to the increase in the span.

AERIAL SUPPORTS.

It is always advisable to support the aerial by means of pulleys and ropes, so that it may be lowered for repairs when necessary. Good galvanized pulleys may be had at a low price at hardware and supply houses and ropes and flexible wires may also be had at these places. Flexible wire is preferable to rope, since the latter requires frequent renewals. The rope or wire should always be sufficient in size to take up all the strains as well

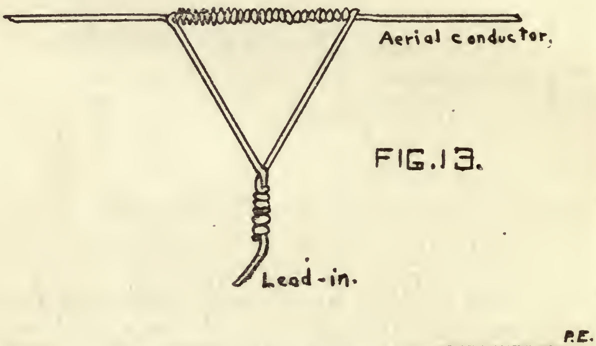


FIG. 13.

as a large overload. The working strain of manila rope may be found by dividing the square of the circumference in inches by 8 for the strain in tons. Thus, to find the size of rope required, estimate the weight, allowing for excess strains, and multiply the resulting weight in tons by 8. Extract the square root to get the circumference in inches. The safe strain for wire rope is found by multiplying the square of the circumference in inches by .3 for *iron* and .8 for *steel* wire. For small aerials a good grade of clothes line or clothes wire is suitable.

LEAD-IN WIRES.

The lead-in wires should have a capacity equal to the capacity of the aerial. Thus, if the aerial is composed of six number 12 wires, the lead-ins should have a capacity equal to that of six No. 12 wires, and this is preferably obtained by twisting six No. 12 wires together. When the lead-ins have a smaller capacity than the aerial itself, they offer impedence to the high frequency oscillations and the radiation is accordingly reduced. The *lead-ins* should always be as *short* and *direct* as possible and should be connected to the lower end of the aerial. When long variously twisted lead-ins are used, sharp tuning is practically impossible. The lead-in wires are essentially *not intended* to radiate the energy but to conduct it up to the aerial, from which point it is most efficiently radiated. When this is not possible, the aerial itself should be extended directly to the vicinity of the transmitting instruments. The lead-in wires should have nearly a straightaway course, i. e. without angles, bends, joints, or the like. If the term may be used,—high frequency currents abhor all joints, kinks, bends, and other defects in the conductor.

POLES.

While a number of suitable aerial supports have already been suggested, a few notes on poles may be well taken. Many experimenters will find bamboo an excellent material for short poles as well as for aerial spreaders. Portable poles may be made from this material. Jointed wooden poles are not desirable for poles exceeding 40 feet in length, a wooden truss work being more suitable for larger poles. Experimenters have made poles from 100 to 150 ft. high on the truss plan without great difficulties. In this form of construction, the pole is built up in the form of a long, narrow pyramid with a

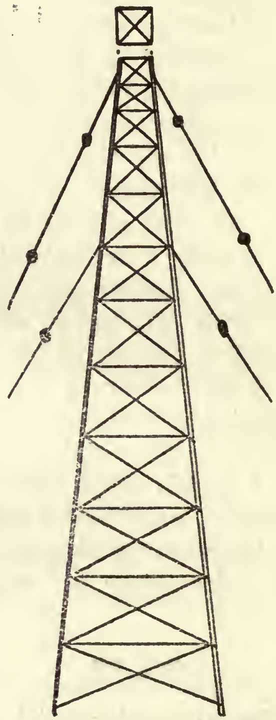


FIG. 14

base so that the builders can construct it piece by piece. (See fig. 14.)

Iron pipe makes a good material for aerial poles. The pipe can be had at any plumbers' or hardware supply house in nearly every locality. The stock should be what is known as "heavy." The pole may be made in sections, the lower section being the largest and the upper section the smallest of the progression. The sections are joined by reducing couplings, and the dealer should be consulted for suitable sizes and dimensions. It will be convenient to have the dealer cut and thread and fit the pipe unless the reader has experience and tools for this purpose. The pole and the joints should be covered with a water proof paint, such as a solution of asphalt. A hole to support a pulley should be drilled near the top, through which the rope to support the aerial is passed. It is desirable to insulate the pole at its base when such procedure is possible. Sockets for this purpose may be made from insulating material or purchased from supply houses.

The dimensions for a 40 foot iron pipe pole follow.

Sections—three.

1st. 15 foot length of 2 inch pipe.

2nd. 15 foot length of 1¼ inch pipe.

3rd. 10 foot length of ¾ inch pipe.

Reducers of malleable iron.

1st, between sections 1 and 2—2 by 1¼ inch reducer.

2nd, between sections 2 and 3—1¼ by ¾ inch reducer.

A top ornament or closure may also be provided.

Guy wires,—four wires at approximately a 30 degree angle from the top portion of each section. Size of wires, —No. 12 or 14 galvanized iron. The second and third sets are preferably broken by means of insulators.

GUY WIRES.

The experimenter should take considerable care to make his aerial strong so that it will not need repairs after every little wind blow. The iron pole will not support itself without the aid of the guy wires. In the case of an umbrella aerial the conductors take the place of the top set of guy wires. Small aerials are easily erected and the guy wires may be tightened by hand. Turnbuckles should be provided for larger poles, however, in order to take up the slack. The insulators in the guy wires should be placed every ten or fifteen feet and may be of the type already described. Strain insulators are preferable for this purpose, however.

While the matter of aerials has now been considered in some detail, the minor details are left to the individual resources of the reader, since the conditions vary widely in each case. The matter in this and other parts of the book is intended largely as suggestive rather than dictative, and various details may be modified, provided that the essential principles and dimensions are not violated. It is suggested that the umbrella, variable directive aerial, T aerial, and directive aerial will be most suited in the order mentioned, and that the duplex idea should be adopted if it is desirable to receive from the commercial stations without interfering with them.

CHAPTER III.

GROUNDS AND LIGHTNING PROTECTION.

Equally or more important than a good aerial is the item of a good ground. The quality of the ground connection materially affects the efficiency of a station and its operating range. Variations in the ground connection may cause a difference of failure or success. A good ground connection, then, is essential to an efficient wireless station. The various means for obtaining grounds may be itemized and considered as follows:

GROUNDS IN WATER.

This form consists of a mass of metal suspended in the ocean, a lake, a river, a well, or a cistern and forms a good connection. In fact, the grounding of ship stations through the hull affords a connection almost as good as metal. When connection is made to a pump or cistern pipe, the iron should be thoroughly cleaned and the conductor soldered to it.

IMBEDDED GROUNDS.

A good connection can generally be had by burying a large surface of sheet copper or zinc in damp earth, at least 12 feet below the surface and preferably more. A ground conductor should be *soldered* to the sheets which should be well connected to each other. The sheets may be in the form of old copper boilers which may be had from the scrap heap, and it is desirable to have a total surface equal to a single flat sheet, 10 feet x 10 feet. It is good practice to imbed the sheets in between layers of coke in order to insure a uniformly good contact during the different times of the year.

IMBEDDED GROUNDS. SPECIAL FORMS.

There are several ready made grounds to be had in the market, but since these are rarely intended for other than use for telephone lines and for lightning grounds, several of them connected together must be used for an effective wireless ground. They consist essentially of sheet copper formed so as to present a large surface to the ground and in some forms, a coke filling is used. *Chemical grounds* consist of the ordinary imbedded ground with layers of coke and calcium chloride, or calcium chloride alone around the metal. The calcium chloride is very cheap and insures a state of moisture about the plates at all times. About 50 pounds of coke and 25 pounds of calcium chloride will suffice in conjunction with 100 square feet of imbedded sheet metal to form a very good ground.

CONNECTION TO GAS AND WATER PIPES.

In the cities, the gas and the water supply pipes are commonly used, preferably the latter. Special ground clamps may be had from supply houses for a very small sum which are adapted for making good connection with the pipes. When the pipes are used for a ground it is advisable to short circuit the meter by means of a heavy piece of wire. The wire from the instruments to the ground should be run as *straight* and direct as possible and all joints should be *soldered*. When several pipes, as water, drain, and gas, are in close proximity to each other, it is advisable to connect all of them.

For small stations and also as a separate lightning ground, an iron pipe or several iron pipes two or three inches in diameter and ten feet long may be buried into the ground just outside of the building in a convenient position. The lower end is preferably pointed by hammering the pipes into a V shape. (A blacksmith can do this for you.) The ground wire should be thoroughly soldered with care to this pipe and the joint covered with pitch or asphaltum. If possible this ground should be *located* over a drain pipe or otherwise provided with a supply of water.

INDIRECT GROUNDS.

There are two general types of indirect grounds and neither is as desirable as a good direct ground. In one form, a second aerial is constructed and suspended in a position close to but insulated from the ground. It thus forms a capacity or condenser with the ground. This type is adapted to close tuning and is convenient when a direct ground is impracticable for one reason or another, but is considerably less efficient. The other form of indirect ground is similar, except that a large meshwork of bare wires or a netting is spread over the surface in the immediate vicinity of the station without insulation, so that it makes both direct and indirect contact with the earth. A very large area must be covered before this method is efficient, but it is sometimes used for portable outfits, in which case the network is spread out in grass or a similar moist surface in preference to other places. For experimental receiving purposes a fair ground may be had by driving a spike into a tree and making contact therewith. The steel frame of buildings may be used as a ground if nothing better is obtainable. In any case the ground wire should be run direct from the instruments and as short as is possible.

THE GROUND WIRE.

It is not necessary to insulate the ground wire, although it is advisable to do so. When it is over 20 feet in length it should be well insulated to prevent loss from induced currents. The use of a ground wire no less than No. 4, B. & S. in diameter is advised and even larger sizes are desirable. Of course smaller sizes will serve to a sufficient extent for experimental purposes, but the larger size means a better direct ground. Grounding *should not* be done by connecting to gas or electric fixtures, since these are often insulated from the ground and in any case afford poor connections.

PROTECTION FROM LIGHTNING.

Wireless aerials do not attract lightning, as the term is generally understood, but they do accumulate undesirable static charges during the stormy part of the year. When well grounded OUTSIDE of the building, the aerial forms an EFFICIENT LIGHTNING ROD and actually protects the station and surrounding buildings. These facts have been ascertained by the author by numerous experiments and although the author's station has been struck several times, no damage has ever resulted. Experiments were carried out with a condenser and gap in the aerial during the electrical storms and large charges were accumulated and experimented with at such times. Inasmuch as the experiment is attended with some danger, its repetition is not recommended. In the experiences of others with which the author is acquainted, several cases have presented warnings. In one case, the operator had his ears pierced while receiving (or trying to), from which it may be inferred that it is NOT ADVISABLE to operate during severe local storms. In another case, the operator had his aerial, which was a high one, well grounded and no harm resulted to it or the immediate neighborhood, while a grocery a block away was completely demolished. It is always desirable to ground your

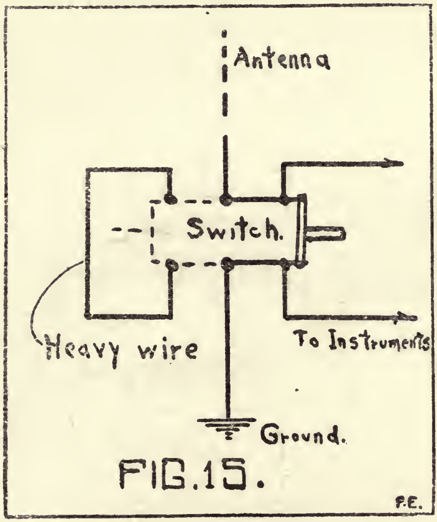
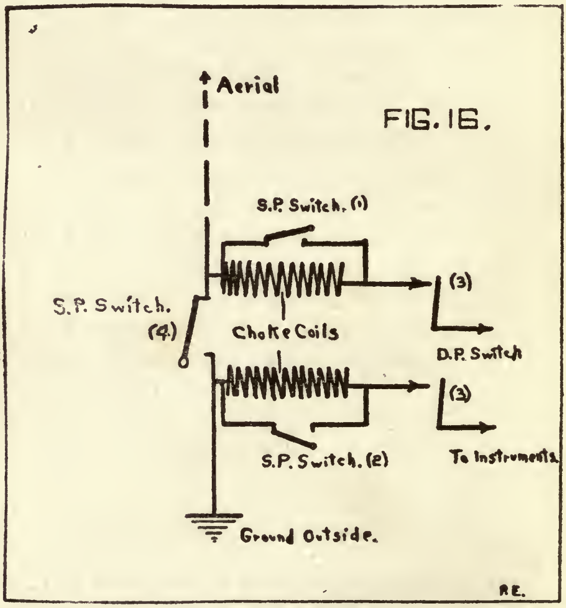


FIG.15.

aerial during storms and at all times when it is not in use. This is conveniently accomplished by means of a double throw switch on the *outside* of the building so that the aerial is grounded to an outside ground when not in use. The ground connection should be No. 4 B. & S. wire or even larger and very direct. (See fig. 15.) The switch should have a carrying capacity of 25 or 30 amperes. Fifty or 100 ampere switches are the standard size.

AN EFFICIENT LIGHTNING PROTECTION.

This arrangement takes advantage of the fact that the high frequency surges abhor impedence from a choke coil. The choke coils are in fact more advantageous than insulators would be. See fig. 16 for the connections. The



When using instruments open (4), close (1), (2) and (3). When not using instruments open (3), (1), and (2). Close (4).

main switch should be able to carry 30 amperes and when the station is in use the choke coils are short circuited by the auxiliary switches so that they will not impede the transmitted impulses. This arrangement prevents the charge from damaging the instruments or the building. The choke coils are made by winding 30 turns of No. 4 B. & S. wire on a large porcelain tube, two or three inches in diameter.

Lightning grounds should always be carried out to the outside of the building or station and if the regular ground does not meet this requirement, a separate ground must be used. Ordinary short gap lightning arresters are useless in wireless stations, because the transmitted impulses jump the short gap the same as lightning does.

The lightning protection for a station does not cost a great deal and is well worth while. It is one of the first items which should receive attention, particularly in mountainous regions.

When the station is not to be used for a long time, as during a vacation trip, it is desirable to lower the aerial conductors so that the liability to become blown down by winds or be struck by lightning is entirely removed.

It is not necessary to take the aerial down during stormy weather, however, or even desirable, provided that it is well grounded.

CHAPTER IV.

GENERAL FEATURES OF THE TRANSMITTER. RESONANCE.

In arranging the material for this book, the author spent considerable time in selecting a logical order for the several items and it is suggested that the most benefit will result from a consideration of the matter in the order given. It is certainly possible and perhaps even desirable to start in with any one chapter and to find the desired matter without reading through matter of indirect interest. In the present chapter the general features of the transmitter together with a consideration of resonance is to be considered, and it is suggested that this matter be understood before referring to the chapters on the several details.

To begin with, we are only to consider tuned transmitters, i. e. those which are coupled to the antenna circuit. There are two general types of coupled transmitters, the direct coupled and the indirect or inductively coupled. Each has certain characteristics which will be considered more fully. The exact circuits employed are of course somewhat varied, but since the general features are the same the circuit shown in fig. 17 may be regarded as typical of the direct coupled type, while that shown in fig. 18 may be regarded as typical for the inductively coupled type. For the present the circuits will be regarded as excited only by means of ordinary spark gaps. Other means for excitation which are within the limits of the average experimenter, will be considered in detail, later.

The first point to be thoroughly understood is that the transmitting circuits are *oscillatory* in nature and that the transmitted impulses are radiated as waves having characteristic properties. In wireless transmitters, the essential characteristics of the circuits are that they may be caused to vibrate at a very high rate. The phenomena is very much like other vibrations. For instance, in sound, if a bell is struck a sharp blow, it vibrates and the vibra-

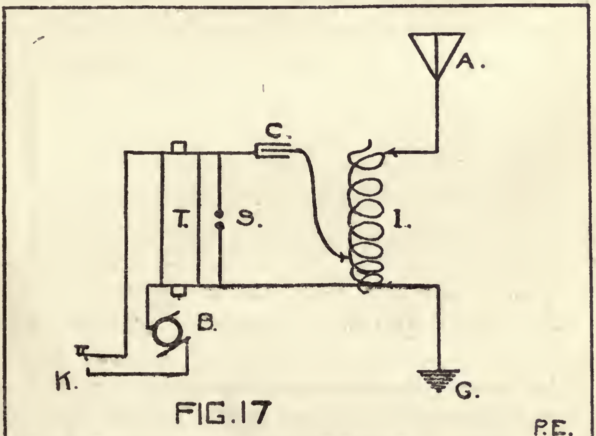


FIG. 17

tions in turn cause sound waves to be radiated from the surface of the bell. The loudness of the sound will vary according to the dimensions of the bell and the force with which it is struck. The tone of the resulting sound will also vary according to the dimensions of the bell itself, i. e. its characteristic dimensions and vibratory period.

In a wireless transmitter, we have the same features. The current which causes a high potential to charge a condenser, corresponds to the force which strikes a bell.

The condenser in turn sets up vibrations in the circuits so that waves are radiated from the antenna, in much the same manner as the vibrations of the bell cause sound waves to be radiated. In fact the difference in the waves radiated by the bell and a wireless transmitter lies in the characteristic properties (wave length, frequency, persistency, etc.) and in the medium through which the respective radiations are carried. (Air for sound and ether (space) for wireless waves.)

Now then, the circuits of the transmitter can be vibrated the same as a bell is vibrated and the character

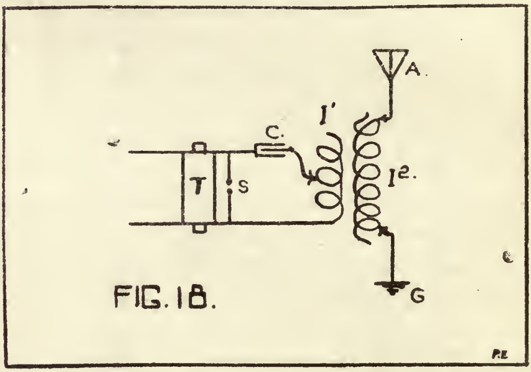


FIG. 18.

of the radiations will vary according to the electrical dimensions of the circuits and the force with which they are set into vibration. This is the ***keynote*** to an understanding of the why of wireless transmission. We can vary the characteristics of the transmitted radiations by changing the electrical dimensions or vibratory period of the transmitting circuits. This is accomplished by adding or subtracting capacity or inductance or both, in much the same manner as a violinist varies the effective length of a given string to produce different tones. It is understood that even the *slightest* change in the capacity or inductance of a circuit changes its *electrical dimensions* and also changes the period or rate of vibration. The actual vibration in the circuits is caused by the surgings of the discharge from the condenser, or as it is more often termed, the oscillatory discharge of the condenser.

By the referring to fig. 17, in which A represents the aerial, G, the ground, I, the inductance which may be varied and which also couples the condenser and the antenna circuits, C, the condenser, S, the spark gap, T, a transformer or spark coil, B, a source of current and K, a circuit closing key, it will be obvious that when the key K is closed the transformer or coil T, which is wound to produce a high potential at the secondary terminals, will cause a spark at the gap S. In practice the gap and the condenser are adjusted so that the condenser is first charged and then discharged through the gap S. Now it has been definitely proven that although the coil T only produces a secondary current at its terminals with a frequency of say 120 cycles per second, this same current when used to charge the condenser C and subsequently discharged through the gap S, causes an oscillatory current to discharge in the gap S which may have a frequency enormously greater than the original frequency of 120 cycles per second. This high vibration may in fact be as much as 250,000 per second or even more. It is this high rate of *oscillation* in the condenser circuit which causes radiations to be sent out, as has already been explained. The condenser circuit through the gap S, and the inductance I, (the oscillations do not pass through the secondary of T on account of the high resistance offered), is the actual part of the wireless transmitter which corresponds to the hammer of a bell. It differs from a simple comparison, however. It is found that the exact nature of the resulting vibrations depends on the dimensions of the several parts, S, C, and I. It will be obvious that the condenser in discharging through the circuit I, S, C, at a very high rate causes the turns of I through which it passes to vibrate at a corresponding rate. The oscillations are thus made useful for transmission purposes by forcing them to pass through a part of the inductance I. Now it is further found, that if the dimensions of circuit C, I, S, are changed, as by adding or subtracting capacity or inductance, that the characteristic properties of the resulting oscillations are varied, in much the same manner as the tone from a bell is varied if a lead weight is attached to its edge, or a violin string, if its effective dimensions are varied by the fingers of the violinist.

In further considering the circuit C, I, S, it should be understood that for the maximum effect, the several parts C, I, S, must be adjusted or varied so that they mutually contribute to produce the maximum effect. It is obvious that if there is too much capacity, the circuit will be unbalanced and consequently the coil T will not be able to fully charge it. Or if the gap S is too long the condenser will not discharge through it, while if too short, the condenser will not be fully charged before it discharges. Or further, if the number of turns of I in the circuit is too many or too little, the circuit will also be unbalanced. In any case or combinations of any single cases, the result will be similar to that when an excessive weight is attached to the rim of a bell, that is, the circuit through C, I, and S, cannot vibrate properly. If the difference between the adjustment and the ideal adjustment is not great, the oscillatory effect will not be stopped, but the properties of the oscillations will be correspondingly varied. In practice it is generally found that there is a certain adjustment for the circuit which produces a maximum result. It is of course understood that any change in the dimensions of the parts of the circuits causes a change in the *natural wave length* of the circuit and the resulting oscillations, the same as changing the diameter of a bell produces a different tone. Changing either the inductance or capacity in even small amounts causes a noticeable change in the wave length and intensity of the resulting oscillations. The parts of the circuit have been arranged in definite mathematical formulas so that the proper dimension for the several parts to produce a given result with a given station can be worked out by a simple mathematical operation. This feature will be considered a little later.

Now then, by referring to this same figure (17), it will be obvious that when an oscillatory current passes through some of the turns of I, that oscillations will also be set up in the antenna circuit A, I, G, by mutual induction between the portions of the turns of I included respectively in the antenna and in the condenser circuit. The ratio and relation of the respective turns included in the antenna and the condenser circuits determine the degree of coupling between the two circuits. The oscillations in the inductance I are of very high frequency, as has already been explained, and the two portions of the inductance act as a transformer. The inductance I forms in fact an auto transformer (step up). Now then, the voltage as well as the frequency through the part of I included in the condenser circuit is very high so that the frequency through the antenna circuit is of substantially the same frequency but a much higher potential, on account of the ratio between the turns included in the two respective circuits. The antenna circuit is thus supplied with a very high potential high oscillatory charge, corresponding to the oscillatory discharge of the condenser C. The antenna circuit is consequently very powerfully vibrated and as a result radiations are transmitted from this circuit in much the same manner as sound waves are transmitted from the surface of a bell, except the sound waves are transmitted through air, while electromagnetic waves are transmitted through the ether and are caused by the intimate relation of the vibrating antenna circuit with the ether, which presumably disturbs the ether at a corresponding rate. It is understood that the term *"ether"* is the name for an all prevailing material which is imagined and assumed to exist and to carry this electrically generated vibratory motion in the same general way in which the air carries the sound waves.

Now the exact nature of the radiations is determined by the dimensions of the antenna and condenser circuits, while their power is determined by the primary generating source as well.

RESONANCE.

Resonance in the transmitter means the method or art of producing resonant, attuned, or syntonic relations in and between the condenser and antenna circuits and is also further carried out between the condenser and the transformer or coil T, when maximum results are desired. In fig. 17, the condenser C, and transformer T are in resonance when the capacity of C is adjusted so that it is just enough and not too much to efficiently and economically receive a charge and discharge the same. This relation can be determined by a simple mathematical operation from a formula, which will be fully presented, later. Now, then, with the condenser determined, its *capacity* must necessarily remain the same for a given coil T, so that if the circuit through C, I, and S, is to be brought into resonance, the respective parts must be *suited* to the given capacity. The gap, S, is of itself a minor item, the essential features being an ability to handle the full discharge currents without undue heating and to be of the proper length so that the condenser is properly charged and discharged. The main tuning, then, must be done by increasing or decreasing the *number* of turns of the inductance I, through which the condenser circuit must discharge. Now a wire or ribbon conductor, such as is used for constructing the inductance I, has both capacity and inductance, though the latter is in great excess so that the capacity is nearly negligible. In a like manner, the condenser of itself consists essentially of capacity. Even the connecting wires between the condenser and the inductance have *capacity* and *inductance*, also *resistance,* so that in order not to materially effect the resulting oscillations they must be made very short and of large capacity so as not to impede the high frequency oscillations.

Every conductor has a definite period of vibration for electromagnetic waves, just as every wire in a piano has a definite vibratory period. Now the separate periods can be combined or superposed when a number of conductors or circuits are coupled or connected in much the same manner that two or more notes from a piano can be caused to produce a pleasing or displeasing tone. The condenser circuit, then, is made up of several parts which must have very little resistance and practically no *stray* inductance or capacity. Now, increasing the number of turns through which the condenser circuit passes also increases the time of the vibrations, causing a corresponding increase in the wave length. The wave length of the oscillations in the condenser can thus be *varied* by adding or subtracting the desired amount of inductance through which they pass, and the less the number of turns of inductance included in the circuit, the less will be the wave length.

Now then, consider the *resonant relations* in the *antenna* circuit. It is understood that the antenna itself, being made up of a plurality of spaced wires, consists essentially of capacity and also quite a little inductance. The antenna forms the capacity of the circuit in conjunction with the ground. The inductance of the circuit, then, will be the *variable factor* since the antenna is generally

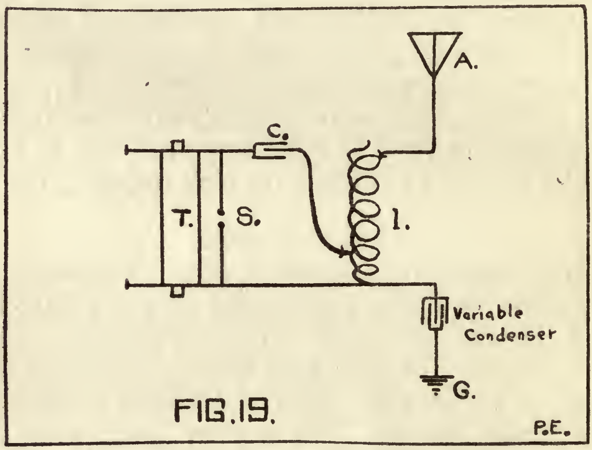


FIG. 19.

a fixed item. The wave length of the circuit A, I, and G, then will be varied according to the variations in the amount of inductance or turns of I, included in the circuit, in the same manner as has already been explained for the condenser circuit.

That is, when the number of turns of I, through which the antenna circuit is included, is increased, the *wave length* of the circuit will be *increased*. It will be obvious that since A is a fixed quantity the natural wave length of the antenna circuit cannot be less than that of A and

G without inductance,* in the circuit shown in fig. 17, and that the variations must then be limited to increase the wave length of the antenna system. As in the case of the condenser C, when the maximum results are desired, the capacity of the antenna A must be made the proper amount to begin with. This can be accomplished by using the length and number of wires which will produce a capacity and inductance within the limits of the minimum wave length desired. It is possible to lower the wave length by means of circuit like that of fig. 19, in which a condenser is connected in series with the ground circuit, but this method is not very desirable. In view of the limited wave lengths, to which experimenters are morally and legally assigned, this method can be utilized in cases in which aerials already in use slightly exceed the maximum wave length. The disadvantage of this arrangement is that the transmission is less efficient.

But to return to fig. 17: In order that the antenna and condenser circuits should be in resonance with each other, it is necessary that the adjustments of the inductance I, be made so that the wave length of the condenser circuit is the same as the wave length of the antenna circuit. The circuits will then be in a position to produce a maximum radiation. This condition is, however, difficult to obtain exactly and is further complicated by the phenomena of *beats,* that is, the oscillations in the two circuits superpose and interfere with each other so that two wave lengths are produced instead of one. This feature will be presently more fully discussed. Now if the circuits have been brought into resonance so that they are both attuned to, say, 300 meters wave length, and if it is desired to increase the transmitting wave length, both cir-

* See fig. 19 for exception.

cuits must be increased accordingly. The wave length of the condenser circuit is increased by adding more turns of inductance and the maximum wave length for the condenser circuit will be reached when this circuit includes all of the inductance. Since the *wave length* depends on the product of the inductance and capacity of a circuit, the maximum wave length of the antenna circuit will generally be reached before the maximum wave length of the condenser circuit is reached, so that after all of the turns of the inductance of the coil, I, have been included in the *antenna* circuit, the wave length cannot be further increased. Increasing the inductance of the condenser cir-

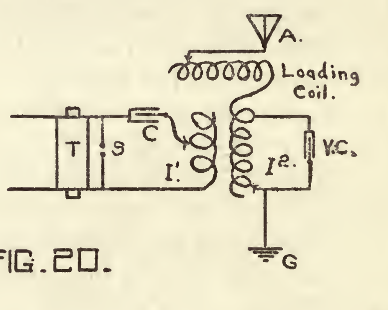


FIG. 20.

cuit in this case will throw the circuit out of resonance. The wave length is thus *limited* by the dimensions of the antenna A and the inductance I. Since it is impractical to have the inductance I too large and since the antenna A is in practice a fixed quantity, the arrangement of fig. 20 must be used if extra long wave lengths are desired. This method acts to increase the natural wave length of the antenna circuit. The shunt antenna condenser may be omitted if desired. The extra inductance is known as a loading coil and extremely long wave lengths may be obtained in this manner. As in the case of fig. 19, however, the efficiency of transmission is considerably lowered, since there is generally a limited range of wave lengths at which a given station can economically operate. However, for experimental purposes, this arrangement can be used to attain very long wave lengths (those exceeding 1,500 or 2,000 meters in length), a field as yet open to the experimenter and not morally restricted or forbidden to him.*

There is one other case of resonance with which the experimenter is concerned. When spark coils or adjustable types of transformers are used in connection with adjustable condensers in the condenser circuit, there may be more than one adjustment of the condenser, C, which will produce a maximum resonance effect with the inductance of both the antenna and the condenser circuit in a fixed ratio. This is a peculiar *harmonic effect* and it is remarkable that a maximum effect can be had with two different adjustments of the capacity through essentially the same circuit. Now when the power used in the coil or transformer T is decreased, (as when transmitting over a very short distance), the condenser C, and the other *adjustments* should also be *changed* if the maximum effect is to be carried out. To sum up;—

The resonance relations and wave length of a transmitter depend on the relations of the circuits and the adjustments of the several parts. Since some of these parts are of fixed dimensions, the others must be adjusted to correspond with them and co-operate to produce resonant circuits. The order of tuning is practically,—

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* See chapter 19 for effect of the new law.

1. The transformer or coil being fixed, the condenser must be varied to resonate with it. If the power is changed, a corresponding change must be made in the condenser if the maximum effect is to be preserved.

2. With the condenser a fixed quantity, to produce a given wave length in the condenser circuit, the inductance must be varied to co-operate with the capacity, and although the wave length may be greatly increased, the addition of excessive inductance cuts down the transmitting efficiency.

3. The aerial being a fixed quantity, the antenna circuit can be adjusted for a desired wave length by the addition of inductance, but if too much inductance is used, with or without a shunt capacity, the efficiency of transmission is reduced. A series capacity may be used to diminish the natural wave length.

4. The wave length of the two circuits should be very nearly the same, and if one is changed, the other must also be changed. In short, the several circuits and parts must be maintained in a nice balance in order to obtain the maximum results and resonance and this balance must be maintained within the limits of the power employed in order to maintain the efficiency of transmission. This means that the small stations are naturally limited to small wave lengths, while large stations may be operated at longer wave lengths without appreciable loss, and often with gain.

The relations in the circuit of fig. 18 are very similar to those of fig. 17, and the adjustments are carried out in the same manner. In fact the chief difference in the two circuits is in the matter of the coupling, and the effect is essentially the same in other respects.

In this arrangement the antenna and condenser circuits include the primary and secondary of a mutually inductive system which is not directly connected. The relative distances between the two coils is also made adjustable in practice, so that the *coefficient* of coupling can be varied. The chief advantage of this arrangement is that it permits of sharper tuning, but it has a disadvantage in that this is accomplished at the expense of the intensity of the resulting radiations.

RESISTANCE.

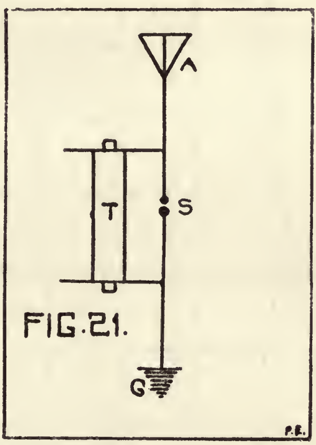
Resistance is an important item in a wireless system. The high frequency oscillations travel over the surface of a conductor only and do not penetrate into the body of the conductor, as in the case of low frequency currents. Plenty of conducting surface must therefor be provided in both the condenser and the inductance coil as well as in all connecting wires or ribbons. Otherwise, a large amount of power is wasted in heat. Resistance also aids in preventing sharp tuning, so that there is an added reason for making all the parts of the transmitter of large and generous dimensions. A further desideratum is that all of the circuits as well as the several parts, including the antenna itself, should be as *uniform* as possible. That is the several conductors should be as direct and uniform as possible, all joints electrically strong, the aerial well insulated, the ground good, the spark gap well cooled, and the several contacts always well made. Observance of these items together with reasonable skill in attuning the several circuits is sure to produce very satisfactory results.

SHARP TUNING—BEATS.

Reference has already been made to the phenomena of beats in a wireless transmitter. Now it has been established, that when the condenser and antenna circuits are coupled by either the direct or inductive method, that the primary or condenser circuit has two periods of oscillation instead of one, and that the secondary or antenna circuit has the same two periods of oscillation. This holds true with perhaps a few exceptions, in every case, including the ideal coupling of the two circuits adjusted to the same wave length. As a result, the transmitter emits two distinct waves instead of one, thereby complicating the difficulty of selective receiving from a field of stations, still further. This is undoubtedly due to the fact that the primary and secondary circuits are alternately charged and discharged. The primary circuit starts out at a maximum, the secondary gradually building up while the primary decreases until the operation comes around to the beginning of the cycle, and is again repeated. The phenomena of beats is caused in much the same manner as in sound waves and the reader is referred to an elementary text on Physics for a further understanding of the term. The analogy is complete, when the electromagnetic waves are regarded as having similar properties to those of sound waves.

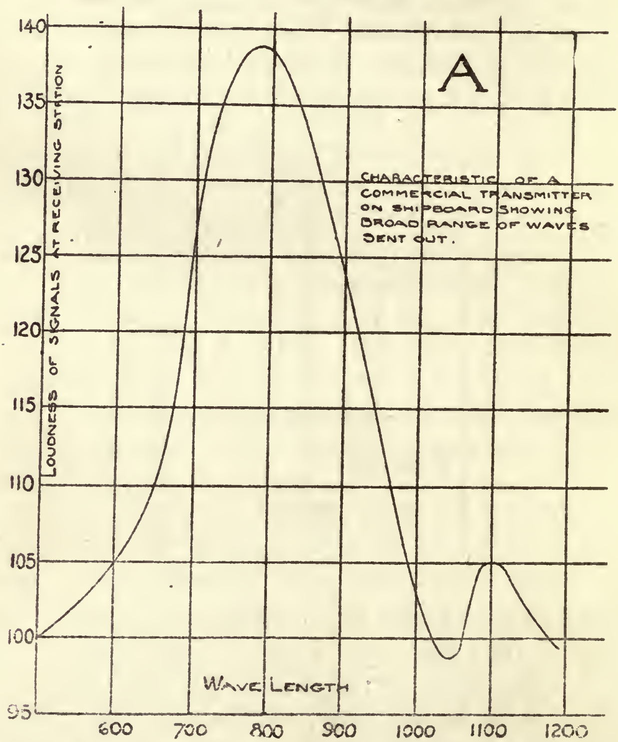
The experimenter is directly concerned with this phenomena, in that it materially concerns the matter of sharp tuning. Now when the transmitter is in resonance, the station is said to be tuned and if the resonance is very good, it is said to be *sharply tuned.* This is the desideratum of real scientific wireless work. On the other hand when the circuits are not in resonance, the station is said to be untuned.

In this condition the station is only a very little better than a direct untuned station (see fig. 21), and when in this condition a wide band of wave lengths are sent out which are difficult to tune out. Since this is the kind of waves which have been largely employed by amateurs, it has brought forth considerable criticism. Even commercial operators have willfully or innocently used untuned waves or at least poorly tuned waves in the past. On account of the large number of stations in operation at the present time, this form of *"pick me up wave"* is in disrepute because it causes unwarranted interference. At any rate it is not scientific or business like and is soon to be stopped, let us hope. In fact, it is equally or more important to have a sharply tuned station than to have one

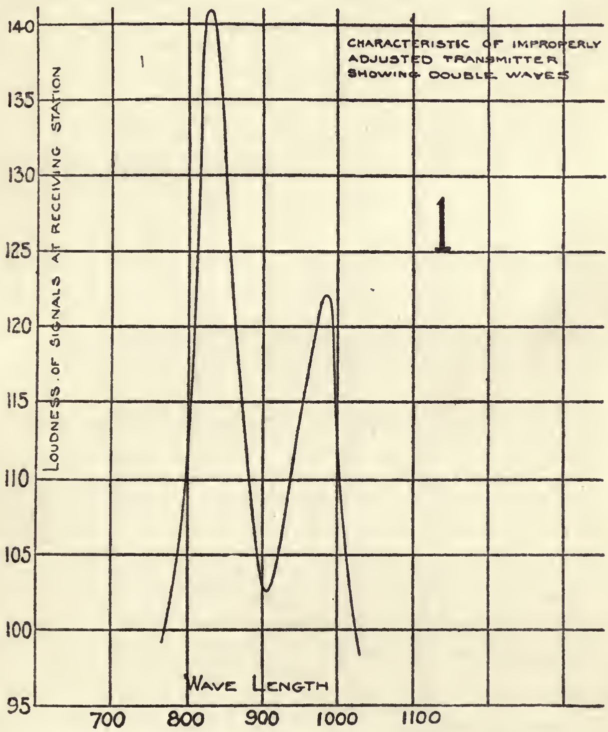


of limited wave length alone without sharp tuning. By reason of the limited wave length, tuning among experimenters themselves will become all the more difficult on account of the limited range, and the sooner all amateurs install and operate sharply tuned instruments, the better it will be for all concerned. To make this clear, some curves submitted to the radio communication committee of the House of Representatives by Mr. Kolster of the Bureau of Standards are reproduced here.

These curves are plats to show the amount of energy received under different conditions. By referring to chart A the figures, 600, 700, 800, etc., at the bottom indicate wave length in meters. The numbers at the side of the sheet (95 to 140) represent the strength of the signal received at the receiving station. Thus at 600 meters, the

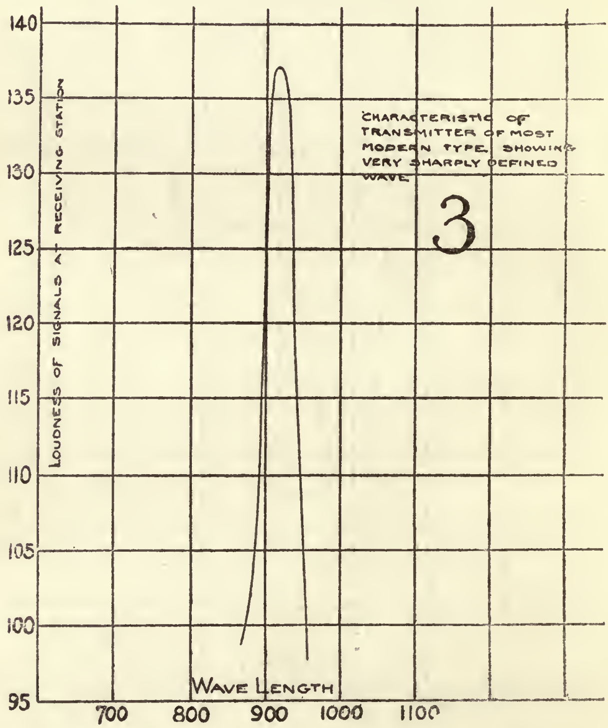


strength of the received signal is 105. At 700, it is stronger, approximately 127, and so on. The curve thus indicates the wave length and its corresponding loudness of the signal. The signals are the loudest between the wide range of 700 and 900 meters, and were taken from a ship station. The station is sending out a wide band of wave lengths (750-950 meters), so that it is sure to interfere with other stations. At a short distance, within, 1,100 meters the current makes another rise. That is, the particular station under consideration sends out a sec-



ond wave length defined at 1,100 meters as well as the broad band of 700-950 meters. This station is not sending out any definite wave length, so that it interferes with all other stations within a considerable range. Amateurs in the past have for the most part sent out wave bands of similar dimensions so that the meager efforts of commercial operators to tune out interference with crude apparatus have been of little avail.

The chart 1 shows the double wave length from an ordinary spark excited commercial station, one wave being



approximately 830 meters and the other 980 meters. The chart indicates that the station concerned was very badly tuned. As a contrast to this chart, the curve of chart 3 may be noted. This was made from a well tuned modern wireless set and the signals are sharply defined within a range of 75 meters.* This means that a difference of 75 meters would entirely cut out this station under good conditions.

While details of tuning will be again discussed, it is thought that every reader must realize the importance of sharp tuning, resonance, and definite wave lengths.

DAMPING.

The damping of electromagnetic waves may be compared to sound waves as in the case of the other properties. That is, damped electromagnetic waves correspond to the sound which is emitted from a bell when a soft object such as the finger touches it, so that the vibrations are limited or damped. This is a common experiment and when a similar property is understood for electromagnetic waves, the term should not be difficult to understand.

Undamped waves, then, are those which are free to vibrate without impedance while damped waves are those which are more or less hampered.** Now, absolutely undamped waves are practically impossible, but the nearer the transmitted waves approach this point, the more efficient will be the transmission, just as the sound from a bell is greater and lasts longer if the bell is free to vibrate without impedance. When the transmitted waves meet considerable impedance, they are said to be damped or strongly damped and in this condition are not very

* Refers to a Quenched Spark Set.

** Perfectly undamped waves are not obtainable in practice but can be approximated by using arc systems. See Chapter 12.

efficient for wireless transmission. The damping is caused largely by the resistance which the circuits offer to the oscillations and generally speaking, the conditions for undamped waves require a minimum resistance.

The ordinary spark system with a close coupled circuit similar to that of fig. 17, emits waves which are more or less damped, depending upon the adjustment, while the arrangement of fig. 18, emits waves which are less damped, the other conditions being practically the same. In the arrangement of fig. 18, the coupling is free, so to speak, so that the vibration of the antenna circuit is not greatly impeded, while in the arrangement of fig. 17, the antenna circuit has a close coupling with the condenser circuit so that its vibrations are hampered and limited to a considerable extent. Undamped waves or continuous waves are a desideratum in efficient long distance transmission, and it is for this reason that the untuned and even the close coupled circuits are gradually being superseded by the inductively coupled circuits and also by high spark rates instead of the ordinary spark rates resulting from ordinary spark gaps. This matter will be more fully discussed later on. In order to keep the damping to the smallest possible point, it is necessary to keep the resistance of the circuits down to a minimum, and when it is remembered that the resistance of a conductor to high frequencies is greater than to currents of low frequencies, the need for large direct conductors should be all the more apparent.

CHAPTER V.

PLANNING THE TRANSMITTER.—CALCULATION OF WAVE LENGTH, CAPACITY, AND CIRCUITS.

In planning the transmitter, the main conditions which govern the design are the distance over which the transmission is desired, the number of stations and their location, to which it is desired to communicate, the local and intervening conditions, such as the condition of the soil, atmosphere, and other natural conditions, and the item of expense.

Perhaps the matter of expense is the main item and it is always desirable to keep within defined limits. The matter of expense does not follow directly according to the transmission distance and will in fact vary considerably according to the conditions in each case. The actual amount depends on the price paid for raw materials, labor, transportation, and since all of these items are variable, the exact amount must be figured for each case. Thus, if the raw materials may be obtained so that no transportation charges have to be paid, or if the apparatus can be had second hand, or if the labor is negligible, and so on, the cost will be materially reduced. Ordinary experimental stations do not entail a great deal of expense, however. While everything should be made as workmanlike and businesslike as possible, extraordinary finishes and polishes are not essential to success.

RANGE OF TRANSMISSION.

While this cannot be accurately determined to begin with, it may be approximated to a sufficient extent. The experimenter generally has a few definite stations with which direct communication is desired and in all cases which permit the use of a *directive* aerial, this type should be adopted for the purpose specified. When communication is desired in all directions, the *umbrella* or *T type* aerial will be the best to adopt. The distance to which a given station can send is governed largely by *natural* conditions, such as character of the soil, foliage, mountains, minerals, height of aerial, and other similar items, as well as the per cent of efficiency which the apparatus is capable of, by itself. The variables are so great that while transmission has been carried out over a distance of 90 miles or more by the use of a one inch spark coil at an expenditure of perhaps 100—200 watts, there are other extreme cases in which a 1 K. W. set has only been able to send a few miles. Again, the same set will be able to send to different distances under different conditions and at different times. Thus, the transmission in winter is generally better than during the summer, the transmission at night is generally nearly twice as good as during the day time, the transmission during favorable atmospheric conditions is from two to ten times greater than when carried out under unfavorable atmospheric conditions, and so on. In order to obtain working data, the working distance under practical conditions and with efficient well adjusted sets is taken as a standard, and, of course, under favorable conditions, this limit is often greatly exceeded.

This *standard transmission* calls for a range of one mile for every ten watts of energy which is used at the transmitting station. Thus, a ½ K. W. (500 watts) set is expected to cover 50 miles, a ¼ K. W. 25 miles, a 1 K. W. 100 miles, and so on. The range for spark coils will be similar and should be reckoned on the watts used instead of the spark length alone.

If the set is operated under very favorable conditions this limit will generally be exceeded, but of course, if the adjustment or the instruments, or the natural conditions are poor, it is not likely that this limit can be attained. With this basis and the desired range known, the power required can be easily found.

This done, the question is limited to the immediate selection of the type and size of transformer or spark coil to be used. Since a transformer requires a source of alternating current such as a lighting circuit and since this method is simpler and more satisfactory for experimental purposes, it should be adopted whenever possible. Transformers may be had in the market at a figure which can scarcely be duplicated by the experimenter, even if his own time is not considered, and the same may be said of spark coils. The construction of such apparatus of course, affords considerable education and satisfaction, but on account of the expense, little or no gain may be expected. Very often, good second hand coils and transformers may be had for little or nothing. Discarded automobile spark coils are easily obtained at garages for a mere song and are satisfactory for short distances.

There are two general *types* of *transformers,* the open and closed core types. The former, while less efficient from the electrical standpoint is more efficient for wireless purposes than the ordinary closed core transformer. The latter type, to be of the greatest use for wireless purposes must be specially designed. In wireless transmission the secondary of the transformer is largely on open circuit and the conditions are different than the ordinary transformer loads. For the maximum results, it is necessary to *apportion* the primary and secondary inductance and the mutual inductance properly, just as it is necessary to bring the condenser and antenna circuits into resonance. Almost any high tension transformer or spark coil will do, of course, but special designs are necessary when efficiency is desired. In the ordinary transformer, the load on the secondary increases in practically a direct ratio with the current input, while in a wireless station the load is essentially a condenser. This condenser reaches a maximum charge only when the constants of the transformer bear a resonant relation to the capacity of the condenser. When the resulting discharge causes a spark, the secondary of the transformer becomes practically short circuited so that the ordinary transformer would draw a greatly increased amount of power and an arc would be formed in the spark gap. Now this arc is very undesirable since the condenser cannot be properly charged while it lasts and as a result an ordinary transformer cannot produce good oscillations.

The wireless transformer, then, must be designed to draw a comparatively small amount of power when the condenser discharges and short-circuits the secondary winding, so that the spark will extinguish just as soon as the condenser has been discharged.

In practice this may be attained by using an auxiliary adjustable resistance or *reactance* in the primary circuit of an ordinary transformer, or an adjustable inductance in series with the secondary of a closed core transformer, or else by combining this principle in the transformer itself. With the open core type of transformer, an adjustable *inductance* in the primary circuit becomes essential, and this method also allows of considerable flexibility in bringing the transformer into resonance with different capacities in the condenser circuit. Wireless transformers generally have several adjustments which allow the power input to be varied so that a corresponding change may be made in the condenser capacity without throwing the circuit out of resonance. In practice, it is common to rely upon the instinct of the operator to adjust the amount of capacity and power input to the right point as indicated by the appearance of the resulting spark discharge. The main point is that the spark in the gap should not form an arc. With spark coils this method must be largely used since an accurate calculation of the required capacity is difficult. Spark coils should only be used when alternating current is not available. Either batteries or a D. C. generator may be used to operate spark coils and while they may be operated on 110 volts A. C. in connection with an electrolytic interrupter, this method is not very desirable. Data for wireless transformers and spark coils will be found in Chapter 6. The auxiliary primary apparatus such as keys, kickback preventers, and other items will also be considered later since their design depends largely on the amount of power used.

After the power and source of power to be used have been decided upon, the proper amount of *capacity* to be used should receive attention next. This item depends on several quantities, which may be listed as—

1. The power supplied to the condenser. (Watts.)
2. The frequency, or number of sparks per second.
3. The secondary discharge voltage.

In the case of an alternating current transformer, the transformer supplies an amount of power to the condenser which may be represented by P kilowatts. If the condenser and spark gap are arranged so that the condenser charges to a sparking potential once each half-cycle, or the natural spark rate, (twice the natural frequency. Thus, 120 times per second if the primary frequency is 60 cycles),

$$P = \frac{nCV^2}{1,000} \text{ Kilowatts}$$

in which P represents the power, n the frequency (as 60 or 25 cycles), C the capacity of the condenser in farads, and V the potential in volts to which the condenser is charged at the time the spark begins.

This formula may be simplified to the following form:

$$C = \frac{1,000 \times \text{Power in K. W.}}{nV^2}$$

Now, when the power, the number of cycles, and the voltage to which the condenser is to be charged, are known, the required capacity can easily be calculated from this formula. It will be evident that the higher the frequency, the less will be the needed capacity, so that for the same output, a smaller capacity may be used for 60 cycles than for 25 cycles, and so on.

For example, suppose that the power source and power conform to the following data after the desired transmission range has been decided as approximately 25 miles.

Transformer, ¼ K. W., primary voltage 110, frequency 60 cycles, secondary voltage 20,000.* Substituting these values in the formula

* This example serves more for an illustration than as a typical case.

$$C = \frac{1{,}000 \times \frac{1}{4}}{60 \times 20{,}000 \times 20{,}000} = \frac{1{,}000 \times .25}{60 \times 400{,}000{,}000} = \frac{.25}{24{,}000{,}000} = .0000000105 \text{ approximately}$$

, that is .0000000105 of a Farad.

On account of the large unit represented by a farad, wireless capacities are invariably calculated and carried out in microfarads, a microfarad being 1,000,000th of a farad. To change this result to microfarads then, the answer is multiplied by 1,000,000, giving a result of .0105 microfarads.

This calculation is very simple and sufficiently accurate for all ordinary purposes. When the construction of condensers for transmitters is taken up, we shall see how the desired capacity can be worked out.

It will be obvious from the formula that when a low potential is used, the capacity must be relatively large, and that if a high potential is used, the capacity will be correspondingly small. In practice the transformer used generally has a potential of from 15,000 volts for ¼ and ½ K. W. to perhaps 30,000 or more for the larger sizes. However, there is no material gain in the amount of necessary dielectric material for a given amount of power, whether or not a high or low voltage is used since the small capacity for a high voltage is compensated by the corresponding increase in thickness which is necessary to withstand the increased voltage without breaking down. If the capacity is not properly designed, it is liable to break down, as well as act to cut down the transmitting efficiency considerably. An increase in the *frequency,* then, is the only factor which will materially decrease the actual bulk of the condenser. Generally speaking, a high voltage within limits is advantageous for transmitting purposes because of the resulting transmitting efficiency, but this item should always be kept within limits and particularly so, when small and only moderately insulated aerials and instruments are used.

In estimating the voltage to substitute in the formula, 15,000 volts to the centimeter of spark length is generally allowed, (1 inch being 2.54 centimeters), since this has been found the approximate value for a heated and ionized spark gap.

Table of capacities required for condenser circuit when Spark coils are used.

Length of spark in inches.	Capacity in microfarads
¼ inch	.001
½ inch	.002
1 inch	.004
2 inches	.008
3 inches	.012
4 inches	.016

These values are approximate, but will vary according to the particular coil used. Spark coils for wireless purposes should be rated in watts instead of spark lengths. Manufacturers, please note.

Now, with the condenser and transformer decided upon, the inductance for the primary or condenser circuit is the next item to work out. We have already seen how the wave length is varied by the amount of inductance and capacity in the circuit and since the capacity is preferably a fixed value, (wireless manufacturers making transformers generally supply a fixed condenser of the proper dimensions to begin with), the amount of inductance will decide the wave length in most cases. Indeed, when the condenser is properly calculated and constructed the author believes that this method is the preferred standard. Before proceeding further, the method of determining the wave length must be understood. This involves only simple mathematics and can be easily mastered by every reader, if it is not already familiar. A careful reading together with the working of a few problems is all that is necessary.

CALCULATION OF WAVE LENGTHS.

The wave length is expressed in the metric system as a certain number of meters long. Now, feet can easily be changed into meters (sometimes written "Metres") by dividing the number of feet by 3.281, (1 meter being 39.37 inches). If the time comes when a universal system of measurement is adopted, we will be saved this constant translation from one system to another.

The formula reads,

Wave length $(\pi) = v \times 2\pi\sqrt{LC}$,

(π) being a symbol for wave length, v the velocity of light in meters $= 3 \times 100{,}000{,}000$ in one second, L = the inductance in *henrys,* and C = the capacity in *farads.* $\pi = 3.1416$. (.000001 Farad = 1 microfarad. .000001 Henry = 1 microhenry).

This formula can then be simplified as follows:

Wave length $= 300{,}000{,}000 \times 2 \times 3.1416\sqrt{L.C.} =$ 1,884,960,000 times the square root of the product of L and C. or 1,884,960,000 times the square root of the product of L and C in microhenrys and microfarads respectively.

Now, for a given wave length, the product of L and C will be a *constant* quantity, so that if the capacity C is large, L will be small, or if the inductance L is large, C will be small. The quantity (LC) varies as the square of the wave length, so that if the wave length is to be doubled (LC) must be made four times as great, or if a given wave length is to be tripled, (LC) must be made nine times its original value.

Now, in the formula there are three items to be filled in by mathematical quantities. If any two are known, the value for the other one may be readily found. Thus, if a wave length of 200 meters is desired with the use of the .0105 microfarad condenser already calculated for the case taken as an illustration, the necessary inductance can be readily found. In order to still further simplify the formula so that it will not be necessary to extract the square root of (LC) it may be expressed,

$$\left(\frac{\text{Wave length}}{1{,}884{,}960{,}000}\right)^2 = \text{L x C, expressed in henrys and farads respectively.}$$

Using this formula, and expressing L and C in microhenrys and microfarads respectively,

$$\left(\frac{200}{1{,}884.960{,}000}\right)^2 = \text{L x .0105}$$

cancelling and dividing,

1,884.960,000) 200...1st

18.849,600$\not{0}\not{0}$) 2$\not{0}\not{0}$ ..2nd.

9.424,800) 1. (.1061, quotient....3rd

substituting this simplified value,

$(.1061)^2 = \text{L x C} = \text{L x .0105}$ for the example taken

that is,

$$\text{L} = \frac{.011257}{\text{C}} = \frac{.011257}{.0105} = 1.072 \text{ approximately}$$

that is, to obtain a wave length of 200 meters when the inductance is an unknown quantity and the capacity is .0105 microfarads, the formula gives 1.072 microhenrys as the proper amount of inductance.

Now, this calculation is very simple, and may be used to find any of the values, wave length, capacity, or inductance, provided the other two are known.

It might be well to memorize or jot down this formula in a convenient place, and if desired it may be remembered in the following form which applies to all cases which may arise.

$$\left(\frac{\text{Wave length}}{1{,}884.960{,}000}\right)^2 = \text{LxC} \qquad \begin{matrix}\text{Giving C in microfarads direct}\\ \text{Giving L in microhenrys direct}\end{matrix}$$

When the *wave length* is 200 this formula gives,

$L \; x \; C = .011257$, so that any inductance and capacity which will give a product of .011257 when expressed in microfarads and microhenrys respectively, will satisfy the equation and give a wave length of 200 meters. Now, since the condenser is worked out to correspond to the transformer used in each case, the required inductance can be found from the following for any case, the wave length remaining at 200 meters.

$$L = \frac{.011257}{C} \qquad \left(\begin{matrix}\text{Giving L in microhenrys.}\\ \text{C being in microfarads.}\end{matrix}\right)$$

The author has worked out these simplified values very carefully and they have all been checked and rechecked. It is believed that this set of formulas places the calculation of wave lengths within the reach of all the readers.

When the construction of inductance is taken up, the matter of calculating the inductance so that the helixes and transformers are of the required design, will be taken up.

The reader should have a pretty good idea of the relations of the circuits to each other by now, so that it will be evident that to use a high wave length of 1,500 meters, the inductance must be nearly 50 times as great as for a wave length of 200 meters with the same condenser, and aside from the item of decreased efficiency, the dimensions of the necessary inductance make it impracticable. Small experimental stations should, therefore, limit the wave length to the smaller value.

SPARK GAP.

Before considering the secondary or antenna circuit, a few notes on the general requirements of the spark gap will be given. The length of the spark gap is governed by the potential at the terminals, so that it must be *increased* as the potential at which the condenser is charged is increased, the other conditions being constant. The other dimension, or the size of the faces of the spark electrodes, must be sufficient to conduct the energy without undue heating. These are the essential features of a gap and the exact size and shape admits of numerous variations. Suitable constructions for various types of gaps will be taken up in detail later.

ANTENNA CIRCUIT.

The proper dimensions for the antenna circuit are obtained in much the same manner as for the condenser circuit, and both of the said circuits must be adjusted to very nearly the same wave length for the maximum result. There is some difficulty in calculating the capacity and inductance of an antenna with any degree of accuracy, since there are many elusive quantities which make up the total. When the primary or condenser circuit is accurately calculated and adjusted, the antenna or secondary circuit can probably be best adjusted to resonance with the primary circuit by means of a hot wire ammeter, wave meter, geissler tube, or miniature light bulb, and some of these methods will be taken up in detail later.

The capacity of the antenna wires increases with the height, but not directly. It is nevertheless desirable to have the aerial as high up as is possible. The capacity of stranded wire is only a very little greater than that of a solid conductor having the same outside circumference. The capacity of a number of wires in close proximity is considerably less than the sum of the individual capacities. Solid metallic structures in space have only a very little greater capacity than ordinary wires, and a few small wires uniformly spaced have practically as great a capacity as a solid sheet or tube occupying a similar space. The use of sheets, netting, tubing, and the like is therefore not economical or desirable. The approximate inductance and capacity of aerial wires can be worked out by a complicated process, but since even this method admits of considerable error, these formulas are omitted.

Perhaps the most simple and satisfactory method of apportioning the antenna conductors for a given set is as follows: Take three-fourths of the wave length in meters to find the wave length to be embodied in the antenna conductors. That is, make the natural wave length of the antenna approximately three-fourths of the total wave length. To do this, it is necessary to make the effective length of the aerial approximately .6 of, the total wave length in meters, in feet. This is calculated by a process which is simple and of no direct interest, and to illustrate,—

For a wave length of 200 meters, the effective length of the aerial should be .6 of 200 in feet, or 120 feet. (See Aerials.) This is only a rough approximation, however. For large wave lengths, this method is not recommended. When this method is used, a margin of approximately one-fourth of the total wave length is left to the adjustment of the secondary portion of the oscillation transformer. In constructing the aerial itself, it is well to allow one No. 12 conductor or its equivalent in the antenna for every 100 watts of energy to be used, and to provide a minimum of two conductors even if only 30 watts are to be used. Thus, a ½ K. W. set should have five antenna conductors at least, and so on. In fact the limit is soon reached so that it is impracticable to use more than three-fourths or one K. W. with a wave length of 200 meters or less. For one K. W. and larger sets, a high wave length should be planned for. This will mean a considerable increase in the total expense, as everything is best enlarged accordingly. (See Chapter 19 for legal requirements.) A ¼ or ½ K. W. outfit is ideal for experimental purposes.

We have now considered the main factors of the transmitting set and station, and the details are ready for attention. In choosing a site for a station, a quiet place is to be preferred and this matter is particularly true of the *operating* room. The latter should be provided with good ventilation, sound, tight walls, and should have a total floor space of about 125 square feet if possible, though less may be used. A corner of a workshop, laboratory, or similar ready made place is suitable.

Note: It should be remarked that the estimated range of one mile for every ten watts can not be expected over *long* distances with short aerials and wave lengths on account of the absorbtion of short waves.

CHAPTER VI.

TRANSFORMERS. SPARK COILS.

Transformers for wireless purposes are relatively inexpensive and quite efficient. They are rated according to the power, as ¼ K. W., ½ K. W. and so on. They can only be used when an alternating current supply is available. For experimental purposes a transformer giving a secondary potential of 15,000 or 20,000 volts and of ¼ or ½ K. W. is recommended, preferably the former. The reader is advised that it will probably cost as much to construct a suitable transformer as to buy it in the open market and that some skill is required in addition to the data here given if an efficient transformer is to be constructed.

In its simplest form, a transformer is nothing more than two independent coils of wire wound around a common iron core. An alternating current impressed upon one of the coils (the primary) causes a current to be generated in the other coil by mutual induction, although the two coils are insulated from each other and the core. The second coil is called the secondary and is generally wound for wireless purposes so that it has a large number of turns. The voltage of the primary and the voltage of the secondary have a ratio corresponding to the relative number of turns and a corresponding amperage. Thus, if the primary has 100 turns and is supplied with a voltage of 100 and current of 10 amperes, (1 K. W.), and the secondary has 50,000 turns of wire, the secondary voltage will be 50,000, but the amperage will only be onefiftieth of an ampere.* Now, there are many quantities to consider in designing a transformer, and a desired design can be nicely calculated. However, in order to cover the most ground in the least space, the matter in this chapter will be limited to the direct construction of designs which have already been worked out as suitable.

The core is generally arranged in the form of a rectangle and is made up of thin laminations of soft sheet iron, each lamination being coated on one side with varnish for insulation. This is to prevent eddy current loss and is essential. The arrangement of the coils admits of many variations, but for simplicity of construction it is preferable to place the primary winding on one leg of the core and the secondary on an opposite leg. The flux leakage is somewhat greater than when the primary and secondary are evenly divided on the two cores, but the construction and particularly the insulation is facilitated by this method. The foremost requirement of wireless transformers is good insulation, and this item should receive particular attention in the construction.

The following data will be found useful in constructing suitable transformers (closed core type), with outputs which compare favorably with the inputs. The construction must be carefully carried out or the dimensions and sizes will not hold good. This data is for transformers operating on 60 cycles at a voltage of 100 to 120, which is the current most in use. The cores are arranged in the form of a rectangle and the primary is placed on one leg, while the secondary is placed on the other. These legs are denoted by the letter B in the table. The letter

* This is taken without considering the core and copper losses. Good wireless transformers are about 90 per cent efficient.

TABLE OF TRANSFORMER DATA.*

Watts	100	250	500	750	1000	1500	2000
A	9	9½	9½	9½	11	12	11
B	6½	7	7	7½	10	10	15
C	1½	1¾	1¾	1¾	2	2½	2½
D	16	12	14	13	6	5	4
E	5	5½	5½	5½	6½	8¼	8½
F	3/16	¼	¼	¼	¼	¼	¼
G	Empire Cloth						
H	16 D.C.C.	16 D.C.C.	14 D.C.C.	14 D.C.C.	12 D.C.C.	10 D.C.C.	8 D.C.C.
J	3½	4	5½	6	7	10	14
K	8	9	9	10	18	22	23
L	34 Enamel				32 Enamel		30 En'l
M	2½	2½	2½	2¾	5	5	9
N	⅛	⅛	⅛	⅛	¼	¼	¼
O	¼	¼	¼	¼	¼	¼	¼
P	7	7	7	8	10	10	16
Q	¼	¼	¼	¼	¼	¼	¼
R	Empire Cloth.						

Key to Table.

A—Length of Core (outside measurement).
B—Width of Core (outside measurement).
C—Thickness of Core.
D—Number of primary layers.
E—Width of secondary sections (each side).
F—Thickness of insulation between core and primary.
G—Kind of insulation between core and primary.
H—Size (B and S) primary wire.
J—Weight of primary wire.
K—Approximate number of pounds secondary wire.
L—Size (B and S) secondary wire.
M—Length of windings.
N—Thickness of separators for secondary sections.
O—Thickness of sections in secondary.
P—Number of sections in secondary.
Q—Thickness of insulation between core and secondary.
R—Kind of insulation between core and secondary.

* Popular Electricity.

C denotes one side of the core. The core proper is square, so that when the thickness is given as 2 inches, it means that the core is 2x2 inches. The separators (N) are of the proper size when fibre is used.

CONSTRUCTIONAL DETAILS.

The core. Fig. 22 shows the arrangement of a square core and details. The strips are best cut out by means of square shears which may be found at any hardware

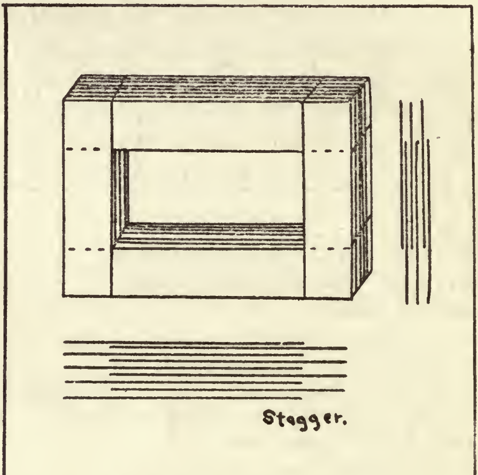


FIG. 22.

or tinshop. When this type of core is used, it will be necessary to use an auxiliary primary inductance or reactance coil in order to compensate for the capacity and maintain a high power factor. This type of transformer lacks sufficient inductance after the windings are in place, so the arrangement of fig. 23 should be adopted if possible.* This form of core gives rise to considerable magnetic leakage, causing an increase in the primary inductance, and makes the use of auxiliary inductance unnecessary. When the primary has *insufficient* inductance

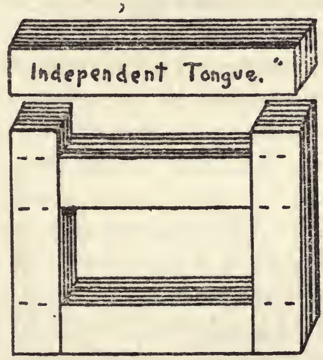


FIG. 23.

the spark forms an undesirable arc at the gap, so that this is an important item. In some types of wireless transformers, this extra portion or tongue is made so that the air gap is adjustable, giving a close control of the current. This extra portion does not materially alter the dimensions given in the table, but extra iron must be allowed and calculated if this arrangement is adopted. *Transformer iron* may be had from supply houses cut to size, or a good grade of stovepipe iron may be used.

* Extra iron must be allowed as the table is for plain cores.

The legs should be wound with a few layers of empire cloth. The core can be squared up by tapping it with a hammer or mallet. The secondary leg should be further *insulated* by additional turns of empire cloth, the number of which should be ample to take care of the estimated secondary voltage and a 50 per cent overload. No. 6 is a convenient size for the empire cloth and has an average puncture voltage of 7,800. A good way to find the desired number of turns is to use as many times the number of turns used for the primary leg as the number of secondary turns is times the number of primary turns, that is, the insulation is best proportioned according to the relative turns of the two windings.

The Primary. Wind the primary evenly on the primary leg, leaving some 6 or 10 inches at the ends of the wire for leads. Taps may be taken out towards the end, if different inputs are desired, in which case the number of primary turns should be slightly increased over the number given in the table. The winding is best done by hand on account of the heavy wire and should never approach too near to the part of the core which forms a joint, or beyond the empire cloth, it being understood that the latter is kept within the limits of the leg proper. The completed winding can be covered with a few turns of empire cloth or tape.

The Secondary. The sections are wound on a section former in a lathe or makeshift lathe. The arrangement of a section winder is shown in fig. 24, and should be made in proportion to the size of the coil to be wound. This former should be made from iron, steel, or brass and not of wood, and is preferably made by a machinist so that the plates are *true*. The saw cuts (slots) are to allow threads to be passed around the completed section before it is removed. This round form is more convenient than a square former, although the latter may be used. The resulting air space is no disadvantage since it acts as a cooling duct. The winding should be done slowly and evenly, avoiding kinks and breaks. A broken wire should be soldered.

With a little practice this winding will not be difficult, and can be rapidly carried out. The section should

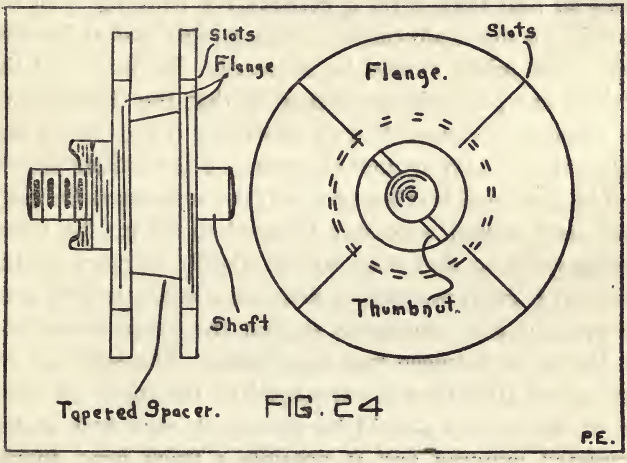


FIG. 24

be tightly wound and when completed, the threads should be passed around it and through the slots to keep it in shape. Leave several inches at the beginning and end of the winding for connections. After it is bound, the section should be removed with care and placed into a pot or pan containing melted paraffine or a mixture of paraffine and beeswax. The later should not be too hot since its insulating value is less if it is at too high a temperature. Let the section soak in the wax for some time until air bubbles cease to rise, then lift it out by means of a string or spoon. Place the section on a porcelain plate and squeeze the excess wax out by pressing on the section from the top with another cold porcelain plate.* The other sections can be wound while the first few are being insulated. to save time. These sections can be taped with a strip cut from empire cloth if desired. The fibre separators can also be soaked in the wax mixture.

Assembling. The sections should be connected in series so that they form a consecutive winding with the connections made alternately at the middle and at the outside. The joints should be soldered. Be sure that the sections are properly connected so that the direction of the winding is consecutive as otherwise one or more sections will buck up against the rest. The sections should then be arranged on the core with the separators between them, and melted wax may be used to fill up the intervening space so that they will be rigidly in place on the core. It is good practice to divide the insulation between the sections into two parts so that the inner connection can be placed between two separators. The sections are best joined after they are arranged on the core. A number of separators should be placed at each end of the completed winding and if possible a thick head should be provided as a flange for each end of the coil.

The primary and secondary legs are now joined by the core pieces and squared up. The tongue of the tongue type is left alone for the present. In the tongue type, the primary core is placed at the tongue end. This tongue should be nicely bound by itself. The core is then clamped together and nicely squared up by means of strap or angle iron and bolts.

The transformer can now be mounted in any suitable manner and the terminals brought out to suitable binding

* Glass may also be used.

posts. The tongue is left in an adjustable position close to the core but insulated therefrom, so that its relative distance can be adjusted according to the amount of condenser used across the secondary terminals. Tests should be made with a telephone receiver and battery for short circuits, for breaks and if any are found they must be located and repaired. It is well to cover the secondary with a number of layers of empire cloth. The other details are left to the reader.

REACTANCE COIL.

A suitable reactance coil for use with the transformer when a plain core type is employed, may be constructed by making a hollow coil of wire and sliding an iron core in or out of it according to the desired adjustment. The core should be of sheet iron and of dimensions corresponding to the size of the primary leg of the transformer core. That is, if the primary leg is 10 inches long, and 2x2 inches, the core for the reactance should be this same size or a little larger. Now make a wooden or fibre frame about one-eighth or three-sixteenths of an inch thick with inside dimensions so that the iron core can slide freely in and out of it, and wind about two or three layers of wire on it. The wire should be a few sizes larger than the primary wire, if possible. Thus, if the primary wire is No. 12, No. 10 is suitable for the reactance coil. This reactance is connected in series with the primary winding and the adjustment is made by putting more or less of the iron core inside of the winding.

It is believed that the foregoing will be sufficient working directions to enable the reader to construct efficient transformers and reactances, provided that the work is carefully carried out. Many minor details have been omitted, and unless the reader has some experience, he will very likely find several little points which must be independently solved. The main requisite is again stated to be, INSULATION.

Inasmuch as open core transformers are less efficient than closed core types and little if any easier or cheaper to construct, designs for this type are omitted.

SPARK COILS.

A spark coil is similar to a transformer except that it has an open core and operates by means of an interrupted current. These coils are preferably purchased, since they may be had almost as cheap as the materials for construction. However, for those who may wish to construct coils and who have some idea of the details, the following data for wireless coils is given. Wireless coils require a different design than ordinary spark coils. The sections may be wound as has already been described for transformer sections. The core in this kind of coil is made up of a bundle of straight soft iron wires, which may be had cut to size from supply houses. The other requirements, such as insulation, etc., are similar to those for transformers, and with the aid of the diagram of the relations of the circuits shown in fig. 25, it is not thought that there will be any difficulty in carrying out the construction. The vibrator is best purchased from a supply house, since it is as cheap or cheaper than making one. The construction of the condenser is similar to the construction used in receiving condensers, and the reader is referred to this heading for further instructions.

TABLE FOR WIRELESS SPARK COILS.

(Size.)	A.	B.	C.	D.	E.	F.	G.
¼ in.	5½	½	CT	1-16 in.	20	225	Em.
½ in.	5½	½	CT	1-16 in.	20	225	Em.
1 in.	5¾	½	Em	2	18	170	Em.
2 in.	7	⅝	Em	2	16	184	Em.
3 in.	8	¾	Em	2	16	208	Em.
4 in.	8¾	1	Em	3	16	232	Em.
5 in.	9½	1	Em	3	16	256	Em.
6 in.	10	1¼	Em	3	14	214	Mi.
8 in.	14	1½	Em	3	14	320	Mi.
10 in.	24	3	Em	4	12	400	Mi.

(Size.)	H.	I.	J.	K.	L.	M.	N.
¼ in.	4	38	3 oz.	1	1⅜	4¼	250
½ in.	4	38	4 oz.	1	1⅜	4¼	300
1 in.	6	38	¾ lb.	2	1¾	4½	800
2 in.	6	36*	1 lb.	2	2¼	5¾	1400
3 in.	8	36*	1½ lb.	2	3	6	2000
4 in.	8	36*	2 lb.	3	4	6	2500
5 in.	8	36*	3 lb.	3	4½	6	3800
6 in.	⅛ in.	36*	5 lb.	4	5	6½	6000
8 in.	⅛ in.	36*	8 lb.	8	8	7	8500
10 in.	⅛ in.	28*	12 lb.	16	11	12	10,500

IN THIS TABLE,—

A—Length of Core in inches.
B—Diameter of Core in inches.
C—Insulation on Core—(C. T.—Carboard tube, E. M.—Empire Cloth.)
D—Thickness of insulation on core.
(In layers, except ¼ inch and ½ inch sizes.)
E—Size (B&S) Primary Wire (D. C. C.)
F—Number Turns Primary Wire.
G—Kind of insulating tube.
(Em—Empire Cloth) (Mi—Micanite.)
H—Thickness Insulating Tube. (Layers for Em. and inches for Mi.)
I—Size (B&S) Secondary Wire. (* means Enameled.)
J—No. Pounds Secondary Wire.
K—No. Sections in Secondary.
L—Approximate Diameter, Secondary. (In inches.)
M—Distance between coil heads. (In inches.)
N—Total No. Sq. In. of Foil in Condenser.

Note: These coils use a medium speed vibrator. To use table, find length of spark wanted (Size) and read across, as ¼ inch—5½—½—C. T. etc., ¼ inch—4—38—3 oz. etc.—Adapted from Pop. Electricity.

A transformer is to be preferred and should be used whenever possible. The spark coil will operate satisfactorily on one or two six volt storage cells. A spark

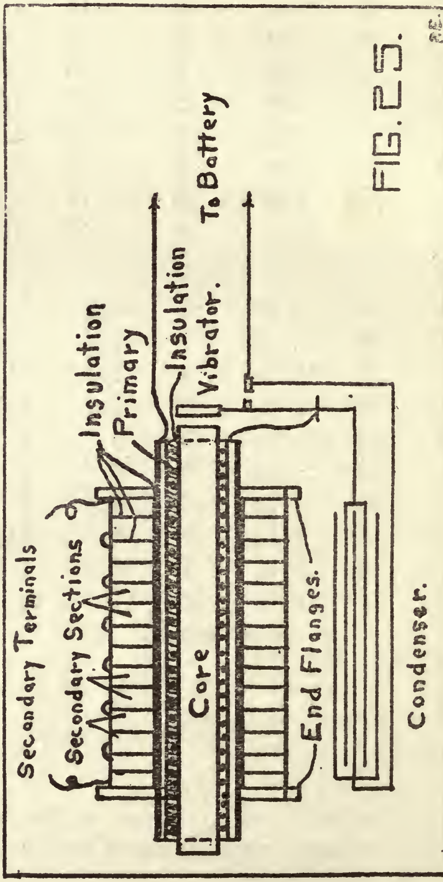


FIG. 25.

coil may also be used with an electrolytic interrupter on 110 volt A. C. or D. C. current. (See Chapter 7.)

CHAPTER VII.

AUXILIARY APPARATUS. KEYS, ELECTROLYTIC INTERRUPTER, KICKBACK PREVENTION, AERIAL SWITCHES.

ELECTROLYTIC INTERRUPTER.

By using an electrolytic interrupter, a spark coil can be operated on 110 V. A. C. or D. C. The author finds

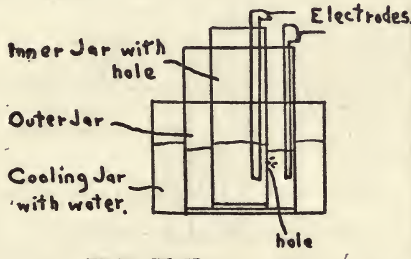


FIG. 26.

after numerous trials that the interrupter shown in fig. 26 is the most serviceable for experimental purposes. This interrupter is very inexpensive and such common things as mason or other jars may be utilized. The electrodes can be either brass or lead, preferably the latter. The electrolyte is made up by adding a little sulphuric acid to water, or else by adding some sal ammoniac to water. Other salts may also be used, but common table salt is not suitable. The proper amount is found by experiment. It is advisable to use the cooling jar as shown, as the interrupter heats rapidly when in use. The only difficulty in construction will probably be the hole in the glass or porcelain, or clay (glazed) jar. This may be readily bored with a new sharp twist drill, using turpentine as a lubricant. The glazed clay is the easiest to bore. The hole should not be too large, or too much current will pass. The following sizes for the holes are suitable.

1-32 inch for coils giving up to ½ inch spark.

1-16 inch for coils giving up to 2 inch sparks.

3-32 inch for coils giving up to 3 inch sparks.

1-8 inch, largest size advised. This size allows from 5 to 8 amperes to pass.

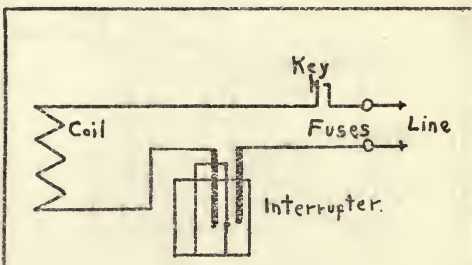


FIG. 27.

In using the interrupter, the vibrator contacts of the coil must be screwed down tight as the vibrator is not needed. The interrupter is connected in series with the coil. (See fig. 27.) The interruptions will be faster with the smaller size hole other conditions being the same, and they depend upon the fact that a gaseous insulating film is generated at the point of contact by the current which temporarily breaks the current. The interruptions or makes and breaks occur at a high rate of speed. The interruptions can be regulated to some extent by means of a variable inductance in series with it and the coil. This may be constructed like the reactance coil described in Chapter 6.

KICKBACK PREVENTION.

In using transformers or coils and interrupters connected to lighting circuits, the high tension currents often kick back into the line and cause considerable damage. The common effect of kickbacks are punctured meters, arcs in electric light fixtures, short circuits and blown

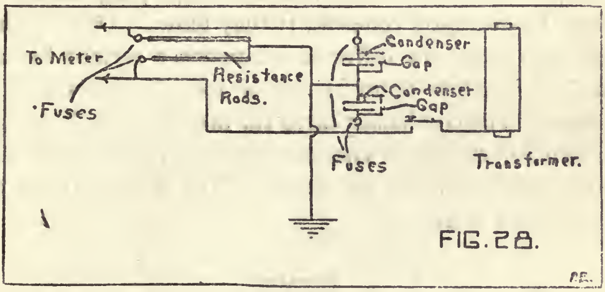


FIG. 28.

fuses. In fact, whenever more than 200 watts are drawn from the line to operate a coil or transformer, steps should be taken to prevent kickbacks. An efficient triple preventer is shown in fig. 28. The protection is threefold, ground dissipators being provided in the form of condensers, high resistances, and minute gaps. These are all connected across the terminals of the line supplying current to the primary of the coil or transformer. The gaps should be very carefully made so that they do not touch each other by a minute distance. The condenser should have a large capacity and may be of the following dimensions or their equivalent.

Each condenser has ten plates of 8x10 glass,* between which are sheets of tinfoil 6x8 inches alternately connected to form a capacity. This is constructed like any other condenser.

The high resistance is attained by using graphite rods, each having about 1,000 ohms resistance, and should be of large diameter to dissipate the heat which is accumulated after a time. These rods are also connected directly across the line. The ground may be the regular ground of the station or else the lighting ground may be conveniently used. This arrangement will take care of kick-backs and will save the remainder of the circuits from damage. The fuses shown are 6 amp. plug fuses, and should be promptly renewed if they blow. This arrangement may mean the difference between a serious fire and constant freedom from injury or trouble and should be adopted. The condenser cares for ordinary small charges, the gap for excessive charges, and the rods are an additional protection for the meter. The latter can be dispensed with if desired.

KEYS.

The key used for breaking the current into dots and dashes must handle considerable currents in most cases and ordinary telegraphy keys are only suited when a few watts are used, as with small spark coils. The reader can easily construct a heavy key along the lines of a telegraph key, using large pieces of zinc or two silver dimes for contacts. An attachment for an ordinary telegraph key which will handle large currents is shown in fig. 29. The regular contacts are not used with this ar-

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* Heavy paraffined paper can be used.

rangement. A similar arrangement can easily be constructed. The arrangement is so simple that further comment seems unnecessary. The contacts can be of zinc

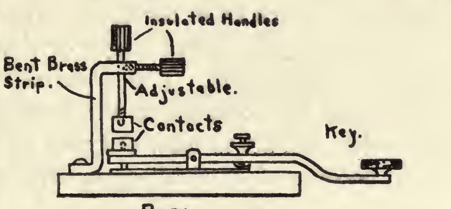


FIG. 29.

or silver and should be of large surface. The distance between the contacts can be adjusted as shown. The average telegraph key will have to be mounted on a separate base to use this arrangement. A similar set of contacts can be magnetically operated as shown in fig. 30, in which

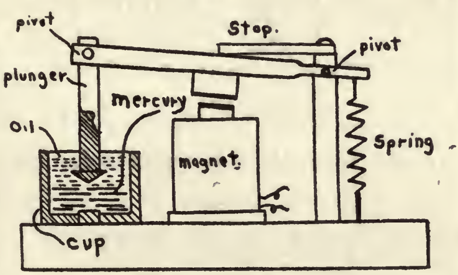


FIG. 30

case an ordinary telegraph or strap key can be used to close the circuit. This arrangement is advisable when currents in excess of 1·0 amperes must be handled. Springy metal can be substituted for the mercury.

Another arrangement for handling large currents is shown in fig. 31. Other arrangements for the same purpose are to connect a large condenser in shunt around the key contacts to absorb the spark, and to use oil about the contacts to prevent arcs from forming. The magnets shown in the figure may be either single or double pole and of any suitable dimensions. The essential feature is that the poles should be extended to the locality of the contacts, so that they can act to blow out arcs which form before the latter become of unwieldly proportions. Note

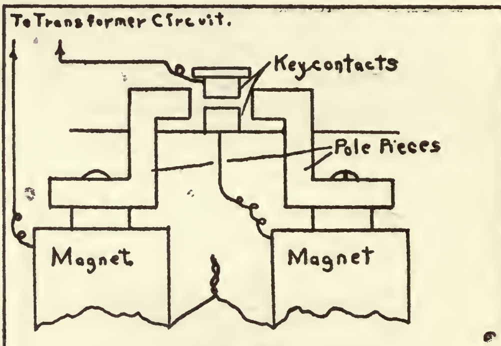


FIG. 31.

the connections. Strap iron is suitable for the pole extensions.

AERIAL SWITCHES.

There are many forms of aerial switches, the object of which is to change from the sending to the receiving instruments. For small stations, an ordinary double or triple pole double throw switch can be used and connected as shown in fig. 32. For large stations, either a very large double or triple pole double throw switch can be used. The aerial switch is conveniently located, preferably at the point where the aerial leads enter the operating room. A switch which allows of rapid change from sending to receiving instruments and vice versa is a desideratum, one type of such a key being shown in fig. 33. The details of construction are left to the reader, the essentials being that the contacts and switch pieces should be well insulated from each other, it being desirable to use hard rubber throughout. On account of the leverage it is only necessary to move the handle a short distance

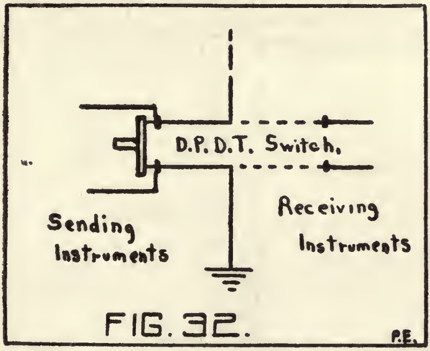


FIG. 32.

from the sending to the receiving position. The blades correspond to the radii of a circle in this type.

AUTOMATIC AERIAL SWITCH.

This form is very much desired and used by experimenters. It automatically disconnects the receiving set the instant that the key is used to send and as soon as the message is sent, the receiving set is again ready to receive. This particular embodiment is adapted to a closed circuit transmitter. The figure (34) is self explanatory, and the reader will have little difficulty in making and attaching this arrangement to an ordinary key. Credit for the design is due to Mr. G. S. Vernam.* German silver or

* C. W. Bul.

brass may be used for the springs and platinum is desir-

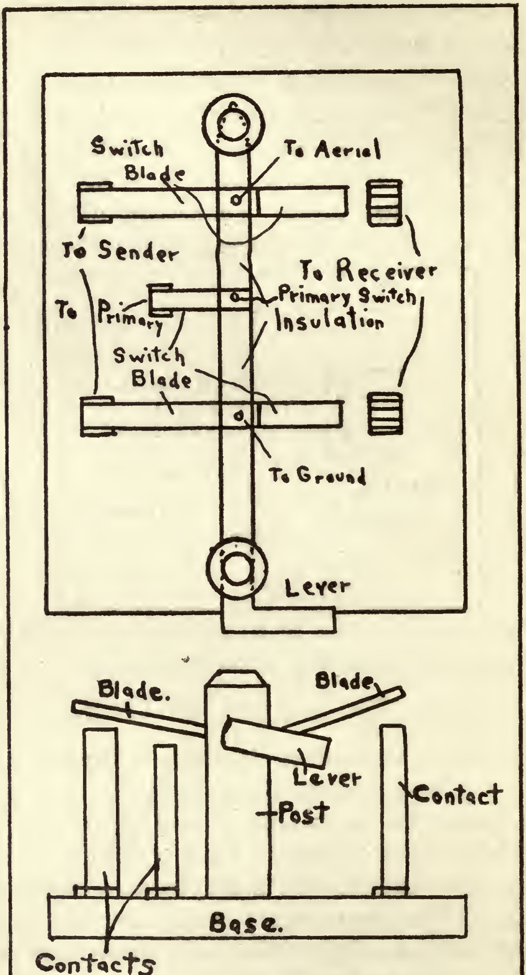
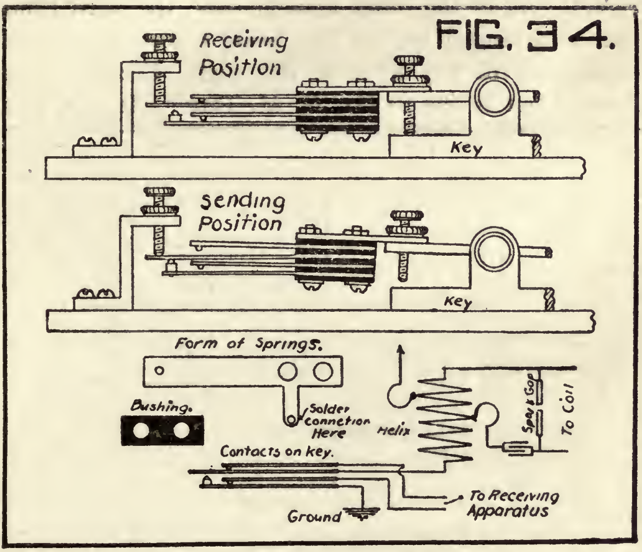


FIG. 33.

able for the contacts. The spring strips are insulated by hard rubber or fibre bushings and rubber tubing, the whole being clamped together by two brass machine screws. A short brass strip is used to attach the device firmly to the back end of the key lever. The springs must be adjusted so that the first two and the second two make contact

FIG. 34.



when the key is up, and the second makes contact with the fourth when the key is down. This will be clear by referring to the diagram. Connections may be soldered to the lugs on the springs.

AUTOMATIC SWITCH FOR HEAVY CURRENTS.

The foregoing switch is only suited to small stations. The one shown in fig. 35 is adapted for heavy currents and is also suitable for an inductively coupled transmitter. The key is not materially different from the foregoing and can be readily understood and constructed from the diagram. The object of these keys is to protect the receiving detector from injury while sending and they operate through the sending inductance. This increases the wave length of the aerial for receiving to some extent, but is not harmful. This particular form is suited for both close and inductively coupled transmitters or receivers. As in the other arrangement, the hard rubber sheet is arranged on the key, being placed between the button and the key lever in this case. Credit for this arrangement is due to Mr. N. M. Tate.* It is also sat-

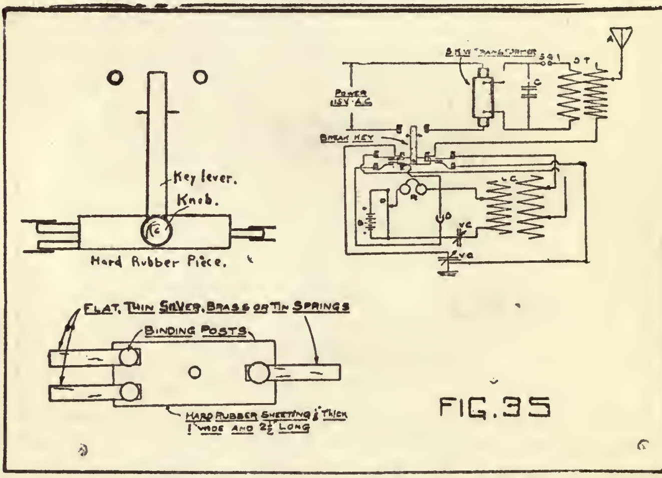


FIG. 35

isfactory to mount the contacts on the back of the key on the adjustment screw.

IN GENERAL.

The wiring in a wireless station should be carried out in accordance with the code requirements. A copy of the requirements may be had gratis by addressing the National Board of Fire Underwriters at either New York, Chicago or Boston.

* Mod. Electrics.

CHAPTER VIII.

TRANSMITTING CONDENSERS.

A *condenser* is a device which stores energy and in its simplest form it consists of two coatings of tin foil separated by an insulating substance, such as air, paper, glass, or oil, which is called a dielectric. The two coatings are insulated from each other as far as metallic connections are concerned and if they are charged by means of an induction coil or transformer they will discharge with a brilliant crackling spark when connected through a suitable gap. Now this discharge occurs so rapidly that it appears to be a single discharge, but it is in fact made up of a number of rapidly oscillating discharges, first in one direction and then in another. During this process the polarity of the charge on the two coatings is rapidly reversed so that a given coating is first charged in one polarity and then in another at a high rate. The vibrations from the discharge are called oscillations and gradually die out with more or less rapidity according to the degree of damping. The reason why a spark gap causes damping will be discussed when the matter of spark gaps is taken up. The time taken by an ordinary discharge is generally a small part of a second, but during this small space of time there may be as many as 100,000 to 1,000,000 oscillations.

Now the nature and amount of this charge depends on the dielectric rather than the coatings employed. It has been definitely established that the charge of a condenser resides on the respective surfaces of the dielectric and not on the coatings or tin foil. When a condenser is charged and the coatings removed, tests will show that they are not electrified to any appreciable extent, but if they are returned to position to form a complete condenser with the same dielectric, they will form a highly charged condenser again. The dielectric of a condenser actually undergoes a strain and as in the case of mechanical strains, this results in heat after a time.

The two coatings of a condenser are always charged oppositely, that is when one coat is charged positively, the other is charged negatively. These charges in oscillating back and forth travel at a speed of 300,000,000 meters per second or the speed of light. When a condenser is charged by a transformer, there are four stages as follows:

1. First quarter cycle, condenser coatings are charged to the potential of the impressed E. M. F.

2. E. M. F. decrease during the second quarter cycle so the charges on the coatings rush back to the transformer. (A discharge occurs in the spark gap at this point, resulting in oscillations as has just been described.)

3. Third quarter cycle. Same as the first quarter cycle except that the direction and polarity of the charge is reversed.

4. Fourth quarter cycle; same as second quarter. A second discharge occurs in the gap.

There are two discharges at the least for each cycle, or if the frequency of the transformer is 60 cycles there will be at least 120 discharges per second.* The higher

* A large number of discharges is obtained by interrupting the natural discharges with a rotary gap. See Chapter 10.

the frequency of the impressed E. M. F. is, the higher will be the value of the circuit including the capacity, because of the increased rate of change of flux. An increase of the capacity within limits also aids in increasing the current. In wireless work, a capacity or condenser behaves in the following definite manner:

1. The apparent *conductivity* is directly proportional to the capacity and the frequency of the E. M. F.

2. The apparent *resistance* or capacity reactance is inversely proportional to the capacity and the frequency of the E. M. F.

We have already seen how the capacity required for a given transformer may be found. All that remains then is to find the dimensions for a condenser which will give the required capacity.

CALCULATION OF CAPACITY.

Now, in order to standardize experimental apparatus, the author considers that the *parallel plate* type of condenser is the best to adopt because its capacity or a desired capacity can be readily calculated. The formula is,

$$C = \frac{kA}{4\pi d} \quad \text{c. g. s. electrostatic units.}$$

in which, C represents the capacity, k, the dielectric constant, air or other gas at atmospheric pressure being practically 1. Other values of k for different dielectrics will be found in the Table of Dielectrics. A represents the area of one of the plates overlapped by the other plate, and d is the distance apart of the plates in centimeters. This formula is accurate only when the distance between the two plates is relatively small in comparison with the length and breadth of the plates.

This may be expressed.

$$C = \frac{KA}{4\pi Dx9x10^5} \quad \text{or } C4\pi D \times 9 \times 10^5 = KA$$

to express the capacity in microfarads.

To find the desired area, this may be arranged,

$$A = \frac{36.\pi DC \times 10^5}{K}$$

DIELECTRIC TABLE.

(K) Constants for,

Air, empty space, or gases at atmospheric pressure	1.
Glass	6. to 10
Light flint glass	6.5
Dense flint glass	6.5 to 10
Hard crown glass	7.
Mica	6.6 to 7.5
Hard rubber	2.7
Kerosene oil	2.
Castor oil	4.78
Shellac	2.7 to 3.5
Ebonite	2.5 to 3.
Manilla paper	1.5
Paraffin	1.75 to 2.3
Resin	1.77 to 2.5
Porcelain	4.38
Water	80.

Note, an average result is best to use in the formula. Glass should be taken as 7½ or 8 when ordinary glass or old photographic plates are to be used. The emulsion should be cleaned off before using the latter.

Now the quantity 36 pi x 100,000 is the same in every case, so the formula may be simplified to

$$A = \frac{DC \times 11309760}{K}$$

and when glass is used for the dielectric, which has a constant of 8; this may be further simplified to

$$A = DC \times 1413720 \quad \text{because} \quad \frac{11309760}{8} = 1413720.$$

So the calculation of the capacity and area for a given or desired condenser is really not difficult. The figures are in the metric system and to change to inches after the area has been found in centimeters change in the following ratio:

1 inch = 2.54 centimeters. 1 centimeter = .3937 in.
1 square inch = 6.45 sq. cm. 1 sq. cm. = .1550 sq. in.

In order to illustrate the use of this formula,—suppose it is desired to find the necessary area for the tinfoil to make up a condenser of .002 microfarad, using glass .1 centimeter thick. Ordinary glass plates are .05 inch thick or approximately .125 centimeter thick. Using the simplified formula, we get

$$A = .1 \times .002 \times 1413720 = 282.74 \text{ sq. cm.}$$

Now this surface can be apportioned in almost any desired manner. For instance, three plates of glass of this size 12 by 14 centimeters and covered with tin foil on each side, 9 by 10½ centimeters would be approximately right.

To take another example,—desired capacity .02 microfarad, using manilla paper .02 cm. thick,—what area of foil for A is required.

Use the simplified general formula,

$$A = \frac{DC \times 11309760}{K}, \text{ substituting}$$

$$A = \frac{.02 \times .02 \times 11309760}{1.5} = \frac{4523.9}{1.5} = 3015.9 \text{ sq. cm.}$$

This can also be proportioned as desired, about 30 sheets of the dielectric being used.

Almost any desired capacity can be worked out to a close degree of accuracy in this manner. These quantities have been carefully worked out. It will be noted from the formula that there are several factors which determine the capacity of a condenser, A, D, and K, so that if two are known, the third may be found.

Now in designing a condenser for transmission purposes, the thickness of the dielectric must be sufficient to withstand the impressed voltage and an overload without puncturing. For this reason one centimeter to every 40,000 volts should be allowed. Thus if the voltage is 10,000 the dielectric should be made .25 centimeters thick and so on. However, if glass can not be had in this size or a large enough size, two or more capacities of the same dimensions can be connected together, in series. This method makes the use of ordinary thickness of glass possible with high voltages, but since the capacity is thereby cut down, in approximately the same ratio, the capacity for each unit must be correspondingly larger. Thus if a single unit is used which has a capacity of .2 microfarad, and if two condensers must be used in series to secure this same capacity without breaking down under the impressed voltage, each must have a capacity of .4 microfarad. So that to *increase* the voltage which a condenser made up of a given size of plates may stand, by connecting units in series, to *twice* the voltage which a single unit can stand, each *unit* must have *twice* the capacity of a single unit if two are connected in series to give the *capacity* of the single unit. While we are on this subject, it is well to note that when condenser units are connected in parallel, the total capacity is the sum of the capacities of the condenser units, but the puncturing voltage which the parallel set can stand is limited to that of its weakest unit. For this reason the units used should be of identical dimensions whenever possible.

STRUCTURAL CONSIDERATIONS.

The condenser is a very important part of the wireless station and unless properly constructed, the transmission efficiency will be materially affected. The main requirements are,

1. The foil used should be a *good conductor* and of sufficient size to carry the charges without undue heating. Copper is preferably used and may be had in thin sheets for this purpose. Tin foil should be heavy if used at all. The kind used by florists is generally suitable. The high frequency currents require a large surface and if this is not provided, the conductor is likely to burn up.

2. *Radiation* surface is necessary to dissipate the heat which is generated in the dielectric. When used in air, the condenser plates are generally spaced a short distance apart for this purpose, and when immersed in oil, the liquid acts as a cooling agent.

3. Contacts should be *soldered* to the tin or copper sheets forming the coatings to make the best contact possible. The resistance of poor joints to high frequency currents is much greater than to low frequency currents. Stranded conductors make good leads to condensers. A

common method of construction is to clamp projecting portions of the coatings tightly together to form a single conductor at the terminals.

4. Brush discharges, surface leakage, and other losses should be minimized. This is accomplished by using a good grade of *dielectric,* allowing a safe margin around the coatings, making the coatings *uniform* and even, making the coatings fit the dielectric tightly, and placing the complete condenser in an insulator such as boiled linseed oil.

(5) Contacts should be as *large* as possible, to avoid undue resistance.

The items under (4) are perhaps the most important and require careful attention in designing and constructing a condenser. Plate condensers offer the most satisfactory solution to the several problems and in addition have the advantage already mentioned of being *readily calculated* for a given purpose. Plate condensers separated in air are not as desirable as those imbedded in an insulator because they tend to blister and aid brush discharges under overloads. For these reasons, the *standard* type to be adopted, is the *plate* condenser made into convenient or desired units and imbedded in an insulator.

DETAILS.

The *glass* used may be had cut to size at any hardware or paint supply house and for voltages over 15,000 the use of double strength glass is advisable. Data regarding the sizes, thickness and so on may be had from the dealer and is useful in calculating capacity, estimating material, and similar purposes. Old photographic plates make very good condenser dielectric material when the emulsion is removed and may be had very cheap. The author once purchased two hundred 5x7 glass plates at 25c per hundred, and while the larger sizes are valued higher because of their use in picture frames, they may be had for a nominal sum. In fact, many photographers will gladly donate old glass plates if properly approached and told that they are for wireless experimental purposes. The emulsion can be removed by soaking the plates overnight in a strong solution of lye in water. Glass containing much lead is not suited for condensers, and all of the plates used should be of the *same thickness* throughout.

Just before using, it is advisable to again clean the plates with a rag dipped into alcohol, although warm water can be used if the plates are allowed to thoroughly dry afterwards. The glass should be thoroughly clean and dry before using.

MATERIAL FOR COATINGS.

Thin *copper sheet* or *heavy tin foil* should be used for the coatings and should be cut to size. If tin foil is used, it should be about No. 35 gauge if possible, and in any case it must be smoothed, by means of a print roller such as photographers use. In making condensers which are so large that a single width of tin foil will not suffice, two or three strips overlapping each other can be used. The size of the coatings should be such that a margin of one inch is left on all sides relative to the edge of the glass plate for every ten thousand volts to be used in the charging, though less may be used after a limit of two or three inches is reached, or when the plates are immersed in oil.

ARRANGEMENT.

The arrangement of the plates and coatings is shown in fig. 36. The lugs for the coatings are preferably in *one piece* with the coatings, but they may be separate pieces if they make good contact *electrically* with the coatings and are *mechanically* strong. The latter method is less expensive as there is practically no waste of material.

In soldering tinfoil, the foil to which a strip is to be soldered must be laid upon a piece of copper or aluminum sheet of some thickness, in order to conduct the heat

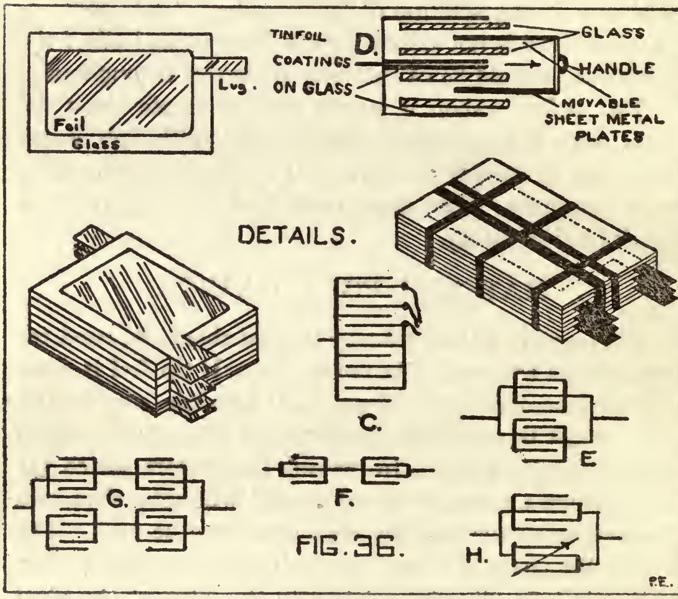


FIG. 36.

away, as the foil will melt or burn up, otherwise. When the condenser is to be used on high voltage, two or three thicknesses of the glass can be used between each sheet of foil to secure a greater disruptive strength, but the capacity is of course correspondingly less and the total thickness of the plates between the two coatings must be used to calculate the capacity.

The alternate lugs of the two coatings can be brought out on opposite sides of the plates or else suitably spaced on the same side. (See the figure.) It is a good plan to make the required condenser in several units, particularly if the capacity is large. Thus if twelve 8x10 plates are to be used, two units each having six plates are preferable. This arrangement makes repairs from damages or punctures easier, since only one of the units is liable to be punctured at a time, while with a single unit, the whole condenser would be temporarily disabled. It is good practice to provide an extra unit or two if this method is adopted, in order to meet emergencies.

In building the condenser, lay a sheet of glass on a flat table, then place a sheet of foil with its lug on top of it, so that it lies flat and is evenly spaced from the edge of the plate. Now lay a second glass plate on top of this, and place a second sheet of foil on it, spaced as before, but arranged so that its lug comes either at the *opposite* side of the plate or suitably *spaced* from the first lug, as shown in the figure. Proceed as before, placing alternate sheets of glass and foil until all of the plates have been assembled. An extra plate should then be used to cover the top sheet of foil. When this is done, the condenser will be a uniform unit, with two sets of insulated plates *alternately* arranged. The unit can then be bound together by large rubber bands, rubber tape or string, or any suitable form of clamp may be used provided too much pressure is not applied. If the plates are pressed together too tightly the glass will crack, ruining the condenser. The two respective sets of lugs should now be firmly clamped between brass or copper sheet, or soldered together and to a large lead. Test the unit for short circuits with a battery and telephone receiver, (the faint response does not indicate a short circuit, but is caused by the capacity of the plates). A few of the lugs can be left disconnected as shown at (c) fig. 36, and separate leads attached to them so that the capacity of the condenser can be varied a little. This method is useful particularly with spark coils since the exact capacity needed is difficult to predetermine.

The finished units should be placed in a suitable box or jar, (hard rubber or glass storage battery jars are excellent containers for this purpose), a hard rubber cover provided, connections brought to binding posts, and so on as desired. The jar or container should be liquid proof and should be filled with a good quality of transformer oil, boiled linseed oil, castor oil, vaseline, paraffine oil, or other non-explosive insulating oil. The condenser should be mounted or arranged in the jar so that it does not rattle and if the condenser is to be moved very much a thick insulator like vaseline should be used, so that the oil will not be continually running over or leaking. A good grade of lubricating oil can be used, the non-carbonizing oils used in automobiles being suitable and quite cheap. Oils which ignite easily or which carbonize or deteriorate quickly, as well as those which are poor insulators should not be used, since the function of the oil is to prevent leakage and brush discharges as well as to dissipate the heat caused by the hysteresis of the glass dielectric.

A condenser is really a very simple piece of apparatus, but too much care cannot be taken in constructing it if efficiency is desired. For experimental purposes, old bottles, placed in a dishpan containing salt water, and filled two-thirds full with a solution of common salt and water can be impressed into service as a condenser, connections being made to the dishpan and to wires entering into the bottles respectively. A large capacity is possible by this makeshift arrangement, but the capacity can of course not be accurately determined. Two rubber covered wires twisted together but insulated at the ends will form a condenser when connected about the secondary terminals of a small coil. There are many similar arrangements which will suggest themselves to the reader. There are other suitable forms for condensers, but since the type described is equal or superior to them and serves for all experimental purposes, these will not be described.

By using copper, zinc, or even tin sheets (iron coated with tin), of some thickness between glass plates, a variable condenser may be made. The capacity can be varied by moving the plates forming one set of coatings in or out of the vicinity of the glass plates and the other set of coatings, thus increasing or diminishing the capacity. The construction of such an arrangement is very simple and the details need no further comment. The diagram of this arrangement is shown in fig. 36 (d). It should be noted that this arrangement is just like an ordinary glass plate condenser except that rigid movable plates are substituted for the tinfoil in one of the sets of coatings. In fig. 36, (e) shows the manner of connecting condensers in *parallel* to *increase* the capacity, (f) shows the connections for *series* to *decrease* the capacity, and (g) shows a combination of the two, which *decreases* the capacity. Taking a single unit for comparison, the units being of the same size (e) will give *double* the capacity, (f) *one-half* the capacity, and (g) an *equal* capacity, but using four units. The series and series multiple connections are used when the voltage impressed on a single unit is more than it can stand without puncturing. (h) fig. 36 shows the method used to connect both a fixed and a variable condenser having the same form and size of dielectric in circuit. This method allows the exact capacity needed for a given transformer to be used. With this arrangement, the variable condenser need not have a very large capacity by itself since it is needed only to make up a small difference in most cases.

CHAPTER IX.

CALCULATION OF INDUCTANCE. CONSTRUCTION OF HELIX AND OSCILLATION TRANSFORMER.

Like the calculation of wave length and capacity, the calculation of inductance is quite simple provided the following formulas are used. The answer is of course only approximately correct, but this is quite accurate and may be used directly in supplying the proper inductance in the transmitting circuit. The calculation for self inductance takes into account the magnetic circuit of the coil and the number of turns of wire in the coil. Any change in the shape or size of a coil will alter the inductance and special shapes require special formulas. The following relation holds good, however, for cylindrical coils of one layer, as helixes or choke coils, and takes into account variable factors.

$$(1) \quad \frac{(5 \times D \times T)^2}{M + 1/3\,D} = \text{inductance in centimeters.}$$

In this formula,

D is the diameter of the coil in *inches*.

T is the total number of turns of wire.

M is the length of the coil in inches.

The result is expressed in centimeters, which may be changed into microhenrys by dividing the result by 1,000.

To illustrate the use of this formula, find the inductance of a coil nine inches in diameter, 10 inches long and having 10 turns of wire.

$$\frac{(5 \times 9 \times 10)^2}{10 + 1/3 \text{ of } 9} = \frac{450^2}{13} = \frac{202{,}500}{13}$$

or 15,580 cm. approximately, or 15.580 microhenrys.

Another formula which may be used to find the inductance of a helix in C. G. S. units is,

(2) Inductance (L) $= 1 \quad (3.1416 \text{ dn})^2$, where

1, is the length of the helix, d its diameter, and n the number of turns per unit length. Thus with this formula, a helix 5 cm. in diameter, 50 cm. long and having 2 turns to each cm., has an inductance of

$50\ (3.1416 \cdot 5.2)^2 = 50{,}000$ C. G. S.

1 henry is equal to 1,000,000,000 C. G. S. electromagnetic units.

To calculate the inductance of flat or doughnut helixes or coils (those having several layers wound over each other), the formula to use is,

(3)

$$\frac{(5 \times D \times T)^2}{1/3\, D + 3/2\, M + 5/4\, N} = \text{inductance in cms.,}$$

in which

D is the average diameter of the coil in inches.

M is the length of the coil in inches.

N is the depth of the coil in inches.

T is the total number of turns of the coil.

To illustrate: Given a flat type of helix of the following dimensions, calculate the inductance. 6 turns of copper strip 1 in. apart, depth of winding 6 in. Width of strip is 1 in. and average diameter 12 inches. (Inside 6 in., outside 18 in.)

$$\frac{(5 \times 12 \times 6)^2}{4 + 1\frac{1}{2} + 7\frac{1}{2}} = \frac{(360)^2}{13} = \frac{129{,}600}{13} \text{ or } 9970 \text{ cm.}$$

or 9.970 microhenrys.

MUTUAL INDUCTANCE.

In oscillation transformers, mutual induction must be considered. When the transformer is a long single layer coil having a lumped secondary wound about it, the formula is,

(4) $M = 4 \times 3.1416\ nNA$ C. G. S. units.

M is the mutual inductance, n the number of turns per cm. on the primary coil, N the total number of turns on the secondary coil, and A represents the area of cross section included within the primary coil. The length is to be measured in centimeters.

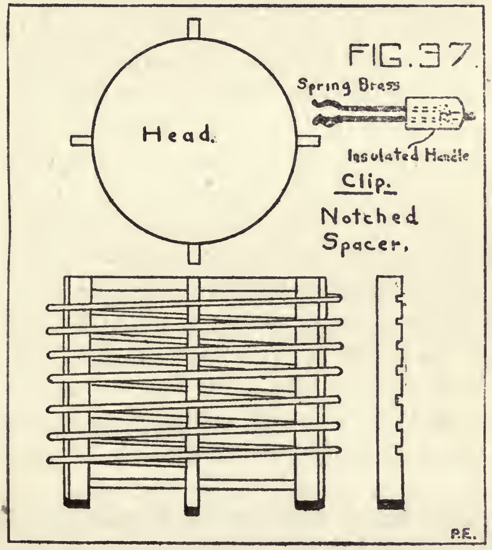
1 henry is equal to 1,000,000,000 C. G. S. electromagnetic units.

1 microhenry is one millionth of a henry.

STANDARD HELIX.

For small stations the helix is perhaps better suited than the oscillation transformer and since it is easier to calculate and construct, it will be described first. The arrangement and details of the helix are shown in fig. 37. The heads may be cut out of hardwood on a bandsaw or else turned out in a lathe, and should be eight inches in diameter and preferably ¾ of an inch thick. These heads are separated at a distance of 7 inches by four evenly spaced pieces, each ¾ of an inch thick by 1 inch wide by

9¼ inches long. These pieces should be smoothly finished. While the wire will stay on these pieces without artificial support, it is advisable to cut notches in these pieces to receive the wire. If possible, the outer surface of the pieces should be veneered with strips of hard rubber or fibre as extra insulation so that the wire does not make direct contact with the wood. The separating strips are arranged as shown so that they form legs ¾



of an inch high at the bottom. The construction is quite simple, and if possible insulators should be substituted for the wood legs, in which case, the upright pieces will be made ¾ of an inch shorter. The frame may be fastened together by screws and glue and should set true. The wire used is No. 4 B&S brass, aluminum or copper, and should be purchased already coiled to approximately 9 inches in diameter or a little less. When wound, the wire will have a diameter of 10 inches and will stay tight if of smaller diameter to begin with. The wire is wound on the notches, so that the turns are spaced ¾ of an inch apart in a uniform and even winding. Seven complete turns are required so that about 19½ feet of wire are necessary. This wire can be had at supply houses or hardware stores. The wire turns will start and end just a little less than one inch from each head, and the ends can be fastened down by large screw binding posts. The turns should be kept ¾ of an inch apart and 10 inches in diameter for the purpose of standardization. This arrangement will be most suited for the low wave length and will give fairly sharp tuning. If the turns are made larger in diameter, the tuning will be less definite, and if more turns are used the wave length is of course increased. However, if the inductance is made too large for the aerial, the *period* and the *radiation* are cut down. Small aerials must naturally have relatively *small helixes* to maintain the necessary balance. Flexible contacts or helix clips should be provided, as shown. Almost any desired size of inductance may be constructed along these same lines, and this standard is highly recommended for stations up to 1 K. W. using the low standard wave length.

This helix has a maximum inductance of approximately 14.28 microhenrys. One complete turn has an inductance of .291 microhenry. To find the inductance for any number of turns, multiply .291 by the square of the number of turns. Thus for three turns, multiply .291 by 9, for 3½ turns, by 12¼, and so on.

In practice, from one to three turns will be needed in the condenser circuit, according to the capacity of the condenser used, and while all of the seven turns may never be needed, the aerial circuit will generally include at least four or five turns, depending upon its dimensions.

Copper or brass ribbon or coiled strip is also suitable for helix construction.

STANDARD OSCILLATION TRANSFORMER.

The type to be adopted is the flat *pancake* form. The mutual inductance is readily adjustable with this type, and every part of the inductances can be readily reached. This transformer allows of very sharp and accurate tuning and is recommended for all stations using over 100 watts of energy. It will also be useful to smaller stations. Brass ribbon ½ inch wide is used in constructing both the primary and secondary and should be about 1-16 of an inch thick. This may be had at hardware stores. About 40 or 42 feet will be needed. Thinner ribbon may be used double or triple to make up the desired thickness.

Obtain four strips of rubber or fibre ¾x½ by 14½ inches long. These should be straight and smooth. Hardwood may be substituted. These should be joined as shown in fig. 38, with half joints at the center to form two sets of crossed pieces. Before gluing the joints the pieces should be taken apart, marked and cut as shown. The slots are best cut with a hacksaw or band saw; each slot being 1-16 of an inch wide and 3-8 of an inch deep. The slots are placed exactly ½ in. apart and begin ¼ of an inch from the end. Mark numbers 1 to 4 on the ends of the strips as shown in the figure so that when the two pieces are put together again the outside ends will be in order.

The slots are laid off beginning from the outside so that each slot is one-eighth of an inch closer to the center than the one before, the slots thus forming a spiral when the pieces are placed together. Proceed the same for both sets of cross pieces, except that slots for five turns are provided for the set which is to support the primary while the other set is slotted for nine turns, thus coming nearer the center. After the slotting is done, fasten the pieces at the joints and bore a hole three-eighths of an inch in diameter through each set exactly at the center.

Now fasten the two cross pieces down in a convenient place by means of one or two screws at the center hole and wind the ribbon in the slots. The ribbon should be either pressed or driven into the slots with a mallet. It is a good plan to begin at the inside to do this, taking care to make the curve of the spiral as uniform as poss-

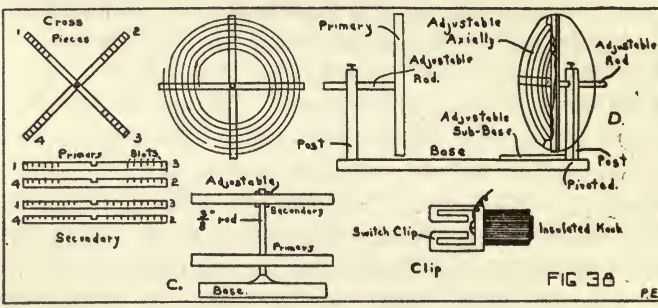


FIG 38

ible. Both forms should be wound in this manner, the ends of the ribbon being cut and smoothed off. The projecting ends should be sent slightly away from the adjacent turn of the ribbon. The ribbon should fit snugly in the slots so that it will stay in place indefinitely. The curve of the ribbon should not be too sharp at the support points, but should form a gradual symmetrical spiral. The completed coils may be mounted in a number of ways, suitable supports being shown at (c) and (d) of the figure. In the latter case, the primary is movable axially as well as longitudinally with respect to the secondary, this radial effect being useful in tuning very sharply. The details of mounting may be varied to suit the individual case, a threaded metallic rod, three-eighths of an inch through which the cross arms may pass and be fastened at an adjustable distance being suitable. The clip shown in the figure is made from an old 10 or 15 ampere switch contact. An electrose or hard rubber handle is screwed on its base end. Four of these should be used, two each for the two coils. Similar pieces may be easily made for the clips if an old switch is not obtainable, almost any piece which will make good contact with the ribbon, being suitable.

The inductance of the primary may be calculated for each turn, beginning with the center by using formula (3), taking first one turn, then the first two, then the first three, as though they were independent coils. Or if the inductance of each turn beginning with the outside is desired, a similar method may be employed. The inductance for the several turns is not constant on account of the difference in diameter between each turn. The values for the turns, beginning with the outside turn, are approximately.

First turn, .868 microhenry.

Two turns, 3.96 microhenrys.

Three turns, 5.7 microhenrys.

Four turns, 10.245 microhenrys.

Five turns (maximum inductance), 13.5 microhenrys.

When the coils are mounted to form a radial transformer, the secondary should not be turned out of a parallel plane unless very *sharp* tuning is required, as when it is necessary to work through considerable interference. The tuning is sharper, within limits, the greater the distance between the two coils, but for ordinary purposes they should not be too far apart because the *in-*

tensity of the transmitted signal is considerably less with a very loose coupling.

The secondary inductance may be similarly calculated, although this is not necessary, since after the primary or condenser circuit is tuned to a desired wave length, the antenna circuit can be brought into resonance with it by connecting a number of turns in the aerial circuit which experiment shows to be right.

A LOADING COIL.

A loading coil for the purpose of securing a high wave length for experimental purposes may be constructed like a helix and inserted in series with the aerial circuit, as has already been explained. This loading coil need not have quite as large wire as the sending helix, although this size is a desirable standard, in order to avoid undue resistance. No. 8 is a common size for this purpose. The loading must not be carried out too far with a given aerial, for after the ohmic *resistance* exceeds the square root of four times the inductance in henries, divided by the capacity in microfarads, the *oscillations* cannot take place. Any resistance impedes the oscillations considerably. If the long wave lengths are desired, a large aerial capacity must therefore be provided to begin with, if efficiency is desired. A small aerial, however, may be loaded for experiments.

Almost any circular coil of wire can be made to serve as a helix or loading coil as a makeshift arrangement, but the reader is strongly advised to adopt standardized instruments to make definite wave lengths, capacities, inductances, and adjustments possible. Sharp, accurate, scientific tuning and work can be attained in practically no other way. The best is not much harder to make than the other kinds and is certainly well worth the time taken, as no other kind is as easy and instructive to use.

CHAPTER X.

DESIGN AND CONSTRUCTION OF SPARK GAPS.

PURPOSE OF THE GAP.

A spark gap is inserted in the condenser circuit to allow the condenser to be discharged through it until the oscillations die out, and also to prevent the condenser from discharging until it is fully and properly charged. A spark gap, then, should be a good *insulator* while the condenser is charging and a good *conductor* while it is discharging. Now the resistance of the spark gap is one of the main factors which determine the damping of the oscillations, and unless properly constructed, considerable energy is wasted as heat in this part of the condenser circuit. The use of the proper amount of capacity in the condenser aids materially in keeping the length of the gap within efficient limits. Too long a gap causes an irregular stringy spark while too short a gap for the given condenser causes a wasteful arc to form in the gap. The gap should, therefore, be of adjustable length, able to conduct the energy without undue heating, and to make and break as an insulator and conductor with rapidity. A poorly constructed or poorly adjusted gap can cut down the efficiency of transmission materially. Three types of gaps are to be described, a common gap for small stations, a series gap for somewhat larger stations, and a rotary gap. The quenched spark system will be discussed in a later chapter.

A *simple gap* is shown in fig. 39. The electrodes may be mounted in almost any suitable manner, care being taken to keep the two parts well insulated from each other and from other bodies. Either a vertical or horizontal mounting can be used and if desired, only one of the electrodes need be adjustable. The construction is quite simple and further comment seems unnecessary. The insulation used is preferably hard rubber throughout, though other materials may be substituted. The parts are preferably made of brass and the electrodes from

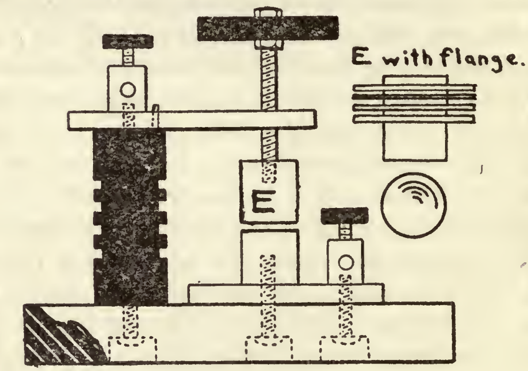


FIG. 39.

zinc or an alloy of zinc with 2 per cent aluminum. These electrodes should be made removable, as they pit after a time, and should be perfectly true. It is well to purchase these parts or have them made by a machinist, if no lathe is available. The electrodes should have plenty of surface, a diameter of ¼ inch for every hundred watts being suitable. If this type of gap is used with large power, *metallic radiating flanges* should be provided to take care of the heat. The handle should be well insulated so that the adjustment can be made while the coil or transformer is in operation. This form of gap can easily be muffled by placing a large glass jar over it, thus excluding the noise, or can be cooled by allowing a small fan to blow on to it, if desired.

A *series gap* is shown in fig. 40, which gives a smooth spark with many desirable features. It can readily be constructed in a desired size by referring to the figure. Too much care cannot be taken to insulate the electrodes well, and to provide large, true surfaces on the gap electrodes. While only a single dead electrode is shown in the figure, two or more dead electrodes may be used if

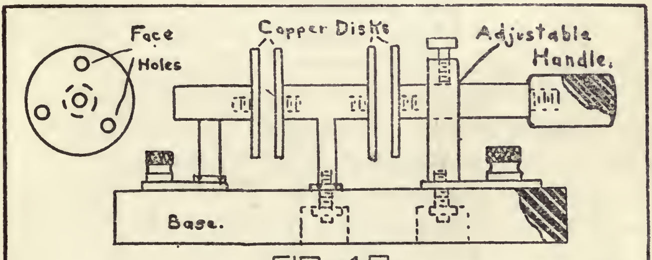


FIG. 40.

the sending coil or transformer is large. The electrode faces are made preferably of copper sheet, with *perforations* as shown to prevent uneven wear and made detachable as shown so that they can be cleaned or renewed. This type of gap has a large cooling surface and is to be commended for experimental use. The relative distances of the electrodes should be adjustable, but each part of the gap should be of uniform length. The total length of all the gaps should be about the same as would be used in a single gap.

The *rotary spark gap* is perhaps the most desirable of all the open discharge gaps and should be adopted whenever possible. Its advantages are many, among which may be mentioned its high spark frequency, (the discharge spark is broken up into a series of uniform sparks, which increase the effective transmission range), the well cooled electrodes, the uniform sparks, and others. There are many types and constructions for rotary gaps

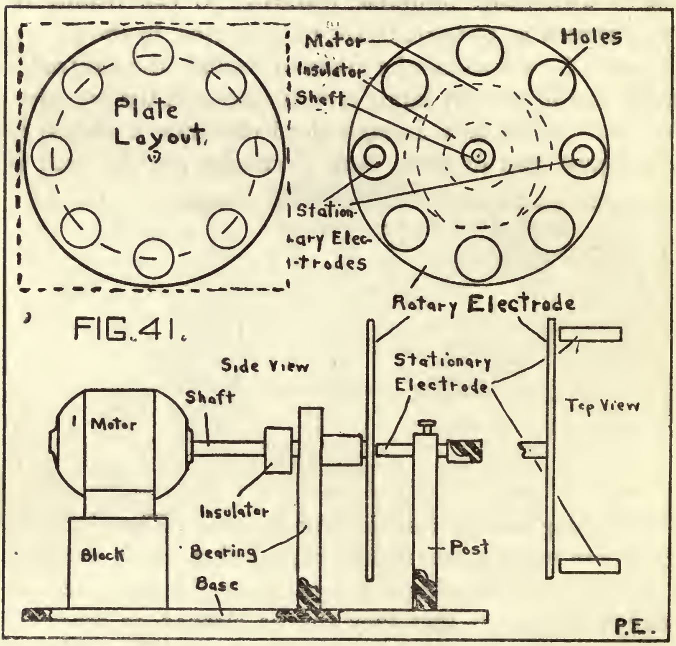


FIG. 41.

and while some of these are quite complicated, the reader will have little difficulty in constructing an efficient, inexpensive gap. A suitable construction is shown in fig. 41,* and while numerous variations may be used, this form

*This is not a hard and fast design, however, as many others are suitable.

will prove satisfactory in most cases. The revolving electrode as well as the stationary electrodes should be thoroughly insulated from each other and foreign bodies. The revolving electrode should be insulated from the drive shaft or motor. This is best accomplished by using a three-eighths inch shaft and bearing for the revolving electrode and making connection with the motor shaft by an insulated coupling, such as is used in electric light fixtures. These couplings may be had for a few cents. Another simple method is to use quite a long belt between the motor and a pulley on the rotary electrode shaft. The motor used may be an ordinary small battery motor or a small synchronous motor, preferably the latter. Fan motors are desirable for this purpose and the power need not be large, since the rotary electrode offers very little if any greater resistance to the power than a small fan. The stationary electrodes need no further comment and may be constructed with perforated surfaces to make them wear out evenly, as has been described for the series gap. This perforated feature may also be embodied in the rotary electrode. The rotary electrode is preferably made out of thick sheet aluminum, one-fourth of an inch being a suitable thickness. The size of the rotary electrode can be from four to ten or more inches in diameter, depending on the power to be used. An eight inch rotary electrode is a convenient size and may be used for stations up to ¾ K. W. or more. To make this electrode, proceed as follows:

CONSTRUCTION.

Find the center of a square sheet a trifle larger than the desired diameter and with it as a radius draw three circles. The outside circle will be for the finished diameter of the electrode, or eight inches in this case. The next circle will be a distance nearer the center, depending on the size of the electrode In this case a circle with a three inch radius will be used. The inner circle will be the size of the shaft used, or three-eighths of an inch in this case. Now the circle on the three inch radius is divided into eight parts by means of dividers, and these points are prick punched. Eight holes, each 1½ inch in diameter, are to be drilled at these points, either before or after the plate is turned down to the outside diameter. This size of hole leaves sufficient surface to care for power up to three-fourths of a kilowatt. The aluminum plate should be placed in a lathe and the shaft hole drilled out. The outside diameter should also be turned out. Aluminum should be worked slowly. Use plenty of kerosene oil. In drilling the holes, care should be taken to drill them true. It is advisable to trim the outer diameter after the plate has been placed on a mandril. The simple bearings and mountings need no further comment. The stationary electrodes should have a face diameter of five-eighths of an inch each, and should be mounted so that they are at the center of the electrode holes when at that position. The electrode should be mounted so that its face runs without wobbling. If a lathe is not available, a machinist can be found to do the work for you. The rotating electrode should be mounted in firm bearings to avoid undesired vibration.

Note.—The drawing is not to scale. The extra bearing can be dispensed with and the rotary electrode connected direct to the motor shaft, using an insulated coupling as a connector. In the rotary gap the sparking distance is best when it is relatively short. If this is not maintained as a short space, it will be necessary to use *less* capacity in the transmitting condenser. This last is not desirable, since the capacity in small stations is seldom any too large. Rotary gaps have a further advantage in that they care for heavy discharges without heating. *Synchronous* gaps are those rotated by means of a synchronous motor or those attached directly to the generator shaft so that sparks occur in accordance with the alternations of the supply current. Perfectly pure tones are produced in this manner. This is not always possible when the gap is not driven synchronously. With small aerials, the rotary gap allows larger quantities of energy to charge the antenna circuit.

The rotating electrode should be revolved at a high rate of speed, that resulting from a direct connection to a synchronous motor being suitable. The gap need only be rotated when in use, and may be stopped, while receiving, if desired.

A makeshift rotary gap can be made by driving evenly spaced brass headed tacks or screws into a wood disk mounted on a shaft and used as the gap just described. Just before the tacks are driven down, a twisted wire should be run between them for a continuous connection. This gap is not recommended for other than very small outfits, and then only as an experiment. The reader can doubtless make a more substantial modification along the same lines.

GAPS, IN GENERAL.

The surface of the electrodes should always be kept clean and bright. Emery cloth is useful for this purpose, but after the faces have become worn and pitted, new electrodes should be used. Many makeshift gaps are easily arranged for emergency or experimental purposes. Thus ordinary nails, dry battery zincs, brass pipes, and other similar metallic pieces can be mounted and used. Common porcelain insulators may be used for insulating standards. However, the reader is advised to make a substantial efficient gap, whenever possible.

It is interesting from the experimental standpoint to enclose a spark gap, preferably one of the series type, in an air tight container provided with an ordinary bicycle valve. Compressed air from a tire pump or carbon dioxid from a Presto tube can then be used to increase the number of molecules present between the electrodes, and under certain conditions surprisingly good results may be obtained.

The reason why a high spark rate is desirable is that it can be distinguished and read better than the ordinary discharge, and that the individual discharges have an additive effect in the receiver, building up a charge which results in a good signal. An ordinary discharge does not have this building effect upon the receiver, because the initial impulse is the actuating force. The subsequent impulses resulting from the charge, die out rapidly without materially affecting the receiving signal. All the commercial stations have adopted a high spark rate in one form or another, the rotary gap being quite generally used. The few which have not adopted high spark rates are the old style commercial stations, some of which are not even as good as the up-to-date experimental stations.

CHAPTER XI.

RADIATION INDICATORS. — HOT WIRE AMMETER.—SHUNT RESONATOR.—WAVE METER.

A radiation indicator is a device which indicates when the aerial is radiating the maximum amount of energy. It is essential to accurate effective wireless work, and is used to indicate when the circuits are in *resonance*. There are two types to be described here as standards. The first, the *hot wire ammeter,* is recommended. The *shunt resonator* is perhaps a little easier to construct, but is less reliable to use. In addition to the methods described, there is an instrument called a *wave meter,* which, while readily constructed, (it is a simple condenser and inductance of known dimensions), is unsuited to experimental use, because it is practically useless unless accurately calibrated. While this can be approximated by calculations, this method is tedious and unreliable. However, if a calibrated wave meter can be had for comparison, the reader is advised to construct a wave meter and calibrate it by comparison with the known standard, which is very simple. It may be remarked that almost any form of variable condenser can be used for the capacity and that a few turns of bell wire wound on a form about nine inches in diameter will do for the inductance. A telephone receiver and a detector serve to indicate well enough for experimental purposes.* In practice this instrument is placed so that the inductance is in a parallel plane to the sending helix or oscillation transformer. (See fig. 42.) It should not be placed too near, however, a distance of a few feet being desirable. Now, to find the primary wave length with this device, the arrangement is as shown at (a) with the aerial and ground out of the circuit. The capacity of the wave meter is varied until the telephone receiver indicates a maximum point. The wave length of the circuit measured is then very nearly the same as that indicated by the calibrated wave meter. The operation is essentially a comparison of a known wave length with an unknown one. The readings should

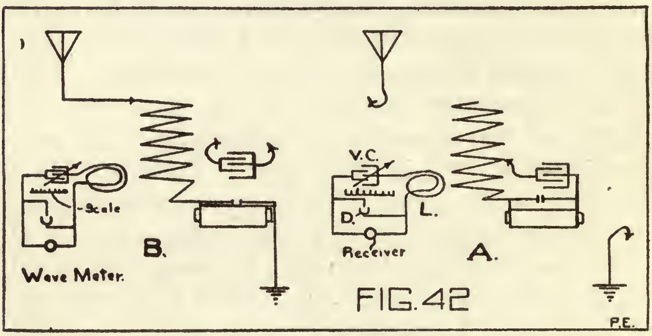


FIG. 42

be taken with different turns of the helix in the primary circuit until the wave length for the different amounts of inductance is ascertained. The wave length for the aerial circuit is obtained in the same way, the condenser being disconnected as shown at (b). The wave length using different amounts of inductance in the antenna cir-

* A calibrated shunt resistance, (as described on p. 180) may be used about the telephone receiver of the wave meter, and will materially aid accurate work.

cuit is then determined. In practice the two circuits are connected, so that both the aerial and condenser circuits are at the same wave length. Thus if the condenser circuit gives a wave length of 200 meters with one turn of the helix and the aerial circuit gives a wave length of 200 meters by itself when 4½ turns are in circuit, the connections should be made in this ratio. If the primary wave length is increased or decreased, the secondary or antenna wave length must be changed accordingly.

The *hot wire ammeter* is used in a somewhat different

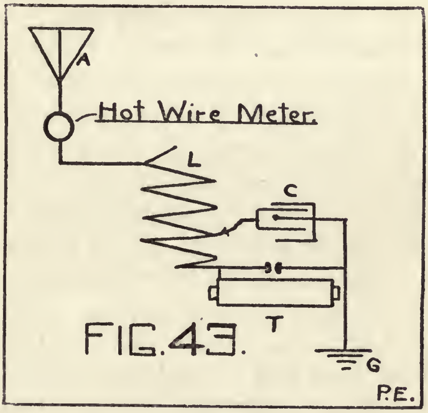


FIG. 43.

manner. The indicator of the meter is operated by the expansion and contraction of a fine wire according to the strength of the *oscillatory* current which passes through it, a maximum current causing a maximum deflection of the pointer. This meter is connected either in the aerial or ground conductor and is connected directly in circuit. After the adjustments have been made, it is preferably *short circuited* or removed as its *resistance* impedes the oscillations to some extent. The connections are shown in fig. 43. Now, since with a standard experimental outfit, the primary or condenser circuit is to operate at a wave length of 200 meters, and the proper relations are found by calculation, the hot wire *meter will be used* to bring the secondary or antenna circuit into resonance with the primary circuit, and also to indicate the proper adjustment for the spark gap. To operate then, connect the hot wire meter in the aerial or ground lead, and close the primary current. The condenser and inductance of the primary circuit are left so that they form a circuit having a wave length of 200 meters according to the calculations, and the aerial helix clip is placed at some arbitrary point on the helix. The deflection of the meter should be noted. Different amounts of the helix are then connected in the aerial circuit until a maximum deflection is obtained, indicating that the circuits are in resonance or nearly so. For a wave length of two hundred meters, the contact points should always remain at this point and the capacity in the condenser circuit should not be changed. If the primary condenser is made larger or smaller, the whole tuning operation will have to be repeated again. Now leaving the rest of the circuits fixed, adjust the length of the spark gap until the meter indicates a maximum deflection. With this done, the station is reasonably sure to be well tuned, and if there are no other troubles, such as leaks, short circuits, or brush discharges, the station is sure to radiate efficiently at the given wave length. Increased or decreased wave lengths may be obtained by changing the amount of the primary inductance, re-calculating the primary wave length with the new amount of inductance, and repeating the tuning operation with the wire meter until the secondary circuit is again in resonance. The spark gap need not be changed unless the capacity is varied, which is not recommended after the proper relations of the circuit are once found. Experiment will doubtless show that there is one wave length or range of wave lengths which will produce a greater deflection of the meter than the others at resonance and if this does not greatly exceed 200 meters it may be used, though the adjustment which gives a wave length of 200 meters or very nearly 200 meters, with a maximum deflection at that point, is to be preferred. When a loading coil is used for long wave lengths a similar plan is used, the loading coil being regarded as an extension to the secondary inductance.

CONSTRUCTION OF A HOT WIRE AMMETER.

A hot wire meter need not be a complicated piece of apparatus, since essentially it comprises a mechanical movement which will indicate the contraction and expansion of a fine wire through which the oscillatory current passes. The sensitive part, then, is the bearing and arrangement of the movement. The balance wheel of an old alarm clock is suitable for this purpose.

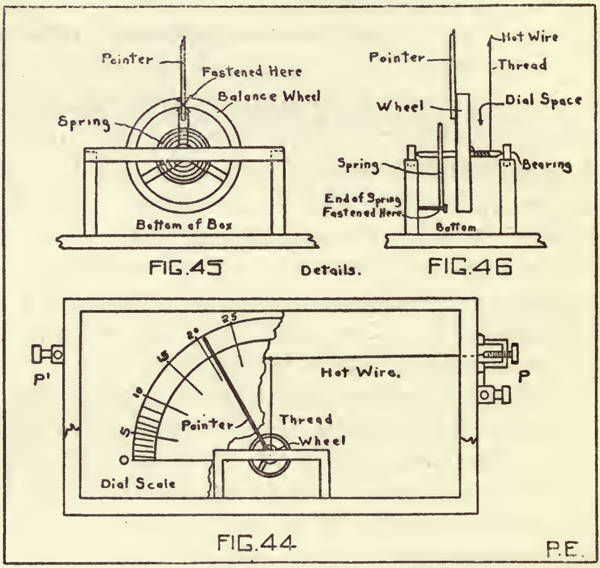
In taking the balance wheel and hair spring out of the old clock, leave enough of the framework to hold it together. This is all that is wanted from the clock and the remainder of the frame should be cut away with some heavy tin shears. It is well to clean the bearing out and oil the latter.

Mount the balance wheel with its bearings in a wooden frame, 8 inches long, 5 inches high and 2½ inches deep as shown in the figures, 44 to 46. The frame should be neatly and strongly made. The balance wheel should be mounted at the center of the bottom piece.

Put the balance wheel spring into tension by rotating the wheel a few turns.

Obtain a short piece of silk thread (size A or O is suitable), and after fastening it to the balance wheel, wind it five times around the axle of the wheel. The winding should be arranged so that the pull of the spring under tension is checked by holding the thread. That is, the thread should be wound in a direction which will maintain the tension of the wound up spring.

The hot wire itself is made from a small piece of No. 36 B&S bare platinum, resistance, or copper wire,



preferred in the order named. Nichrome or climax resistance wire serves very well for experimental purposes and copper wire will do. Stretch this wire between the two binding posts P and P1, so that it is in a plane above the point where the silk thread is wound on the axle. This will be clear from the illustrations. Either P or P' should be made adjustable so that the tension of the wire can be adjusted. This adjustment is necessary to counteract the natural expansion or contraction of the wire under varying weather conditions.

The pointer can be made either from a thin piece of aluminum sheet or a small piece of wood. This pointer should be made very light and is made 3½ inches long. The cross section of the pointer should not exceed one-sixteenth of an inch by one thirty-second of an inch, as it is essential to have a very light pointer. If this pointer is painted black the readings will be facilitated.

To fasten the pointer, pull the thread so that the spring is under tension and fasten one end of the pointer to one of the spokes of the balance wheel by means of a piece of No. 36 wire or of the silk thread left from the other parts.. A drop of hot wax or glue will serve to make the joint rigid. When fastened, the pointer should be in line with the center of the wheel.

The dial can be made on a piece of stiff paper and should be placed close to the back of the pointer so that it does not interfere with its movement. The divisions on the scale may be any desired number and are used only for comparative readings. Commercial instruments are generally calibrated direct in amperes or parts of an ampere, but for experimental purposes, comparative readings are all that are necessary. The dial should be of a size which will co-operate with the pointer and should be placed so that its center point is directly above the center of the balance wheel.

In putting the parts together, place the scale in position first, and tie the silk thread to the No. 36 wire at its middle point so that the pointer is moved to the 0 point of the scale. A glass cover and a suitable back can then be provided, making a neat instrument. This meter will give comparatively large readings for small stations, and if large power is used the fine wire should be shunted with a coil of No. 26 or 28 copper wire. This coil can be wound on a pencil and the amount of wire needed must be found by experiment. If this shunt is not provided, large coils or transformers will burn the fine wire out. A good plan is to start with only one or two turns in shunt and if the meter is not operated, add more turns until the proper amount is found. Part of the current goes through the shunt so that the fine wire is not overloaded.

When an oscillatory current passes from P to P1 the fine wire is heated and in expanding it leaves a slack in the silk thread which is taken up by the tension of the spring.

This causes the axle to wind up so that the balance wheel and pointer move. On account of the small diameter of the axle and the large leverage of the pointer, a very small movement of the thread makes a large movement of the pointer. When the wire is cooled, it contracts again and draws the pointer back to zero. It will always return to zero when the wire cools again, and if it does not on account of weather conditions, the wire may be adjusted by either P or P1 (made adjustable) so that it does.

The dimensions given need not necessarily be adhered to as long as the general principle is recognized and used. By using the balance wheel and hair spring of a watch with its delicate bearings, a much smaller and sensitive instrument can be made. In this case, a finer wire should be used, No. 40 being suitable for an ordinary watch spring. The remainder of the instrument should be correspondingly small, particular care being taken with the pointer.

The success of this instrument depends largely on the care taken in its construction, and though very simple, it should be regarded as a delicate instrument. The casing may be made round or any other shape and can be of metal if the parts are well insulated from each other and the metal.

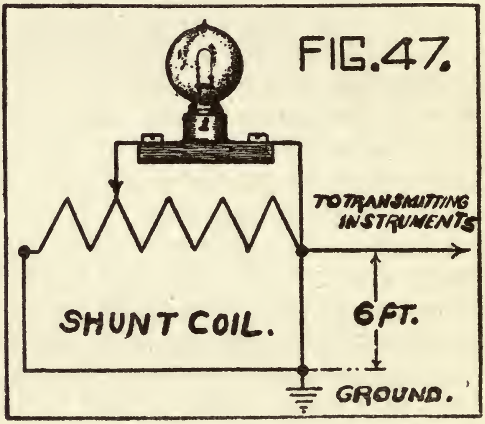
The hot wire ammeter is very desirable because it indicates the maximum radiation better than any other simple apparatus. While the wave meter does this to a certain extent, its use is limited to the actual measurement of wave lengths and is not very useful in determining the maximum radiation.

CONSTRUCTION OF A SHUNT RESONATOR.

This arrangement acts as a *radiation indicator* and serves the same purpose as the hot wire meter except that it is less delicate and sensitive in its indications. It has the advantage of not interfering with the oscillations and can be left in circuit continually. The arrangement is shown in fig. 47. The coil is constructed like a helix, about a dozen turns of No. 8 wire wound on a form three inches in diameter and spaced one-fourth inch apart, with a movable contact, being suitable. The lamp used is a small four or six volt carbon filament bulb, and may be had at any supply house. Whenever the transmitter is in operation the lamp lights up.

The coil is connected as shown in shunt around six or more feet of the ground wire, the proper amount to be determined by experiment. Only a part of the high frequency current is passed through the coil by this arrangement so that the resistance of the ground wire is not increased. It is really decreased to some extent. The effect is probably due to the resonant relation of the coil and the section of the ground wire.

To find the maximum radiation at a desired wave length, place the slider of the indicator coil so that all the turns are in circuit and adjust the antenna circuit until the lamp lights up the brightest. Now decrease the number of turns on the indicator coil, thus decreasing the brilliancy of the lamp, and adjust the transmitting circuits again. Continue this process until the lamp lights up brilliantly with the least possible number of turns of the indicator coil connected in circuit. The transmitting station will then have a maximum radiation for a given wave length. A similar arrangement can doubtless be



used by substituting a hot wire meter for the lamp, in which case, the radiation can be read directly. This is likely to be hard on the meter, however. Credit for this shunt indicator with a lamp is due to Mr. A. S. Hickley.

We have now considered the transmitter and its several details in some degree of thoroughness, paying particular attention to the resonant relations of the circuits and the design of standardized instruments. It is well to again remind, that all of the circuits should be well connected, contact points clean and of even surface, spark gaps clean and properly adjusted, and everything arranged in as workmanlike and businesslike a manner as is possible. Too much emphasis can hardly be placed on the necessity for sharply tuned resonant apparatus preferably operated at a low wave length.

A word as to *cost*. The cost of a station depends largely on the individual. Some experimenters are able to construct and operate efficient sets which cost only a few dollars while other less experienced or less fortunate workers may spend many times as much without better or even as good results The author believes that a good 250 watt station to operate at a wave length of 200 meters can be constructed at an average cost of about $25 for the transmitter, though the actual figures may be considerable more or less in each case. according to the circumstances involved. This figure does not consider the item of labor, transportation charges and many other variable factors, and indicates little more than the cost of the materials used. While larger stations (larger power) do not necessarily follow in the same ratio, the expense may be taken roughly as an additional $20 for every 150 additional watts. This amount is not to be taken as fixed or even accurate, as there are so many variable factors concerned. As an example, the hot wire meter described in this chapter will be made by many readers at a total expense of less than 25c, while others will doubtless spend up to a few dollars in its construction. In general, then, it is well to make the several parts as substantial and neat as possible without an excessive expenditure. After all, the "Works are more important than the looks," though good appearance is also desirable. Receiving stations can be made at a cost of perhaps 75c or up to as much as you wish. Designs for receiving apparatus will be found in later chapters.

The need of thorough *insulation* throughout is perhaps most important of all and all insulation should be quite *thick* in order to avoid the *dielectric* effect. In wireless transmission, a great deal of energy may pass through an insulator to a foreign body on account of the capacity which is formed. Thick insulation cuts down the capacity and consequently avoids this effect. With resonant, well adjusted circuits and a well insulated aerial, very good results may be expected. In fact with these precautions observed better results may often be had from a small outfit than from a much larger outfit in which the several points are not well carried out.

ACCURATE MEASUREMENTS—FREQUENCY.

Although many who read this volume are not directly concerned with accurate measurements in radio work it seems well to mention that one can determine a wealth of facts by using the wavemeter, the hot wire ammeter, or both. Knowing the wave length for instance one can immediately determine the frequency of the oscillations in the aerial. Thus *frequency* equals 1,000 million divided by *wave-length in feet*. A wave length of 10,000 feet (nearly two miles) for example means that the frequency is only 100,000 and it is evident that lower wave-lengths mean, under like conditions, higher frequencies. Other quantities such for instance as the decrement can also be obtained with accuracy and facility.

CHAPTER XII.

CONTINUOUS WAVES. WIRELESS TELEPHONE. QUENCHED SPARK. HIGH FREQUENCY ALTERNATORS.

The more advanced methods of wireless communication utilize continuous waves, produced either by an arc, quenched spark, or direct high frequency generator. Inasmuch as these methods are quite likely to be developed into the ultimate perfected wireless system, some consideration of the theory together with experimental operation is worthy of attention.

A simple system that may be used for telegraphy or telephony is shown in fig. 48. This arrangement will only operate on direct current of 110 or 220 volts, preferably the latter. The power supply should be capable of furnishing a uniform current of 10 amperes. The arc light may be an ordinary arc, but the lower electrode is preferably made of brass or copper and water cooled. This water cooled electrode may easily be made from a plumber's T connection, using a brass plug for the electrode end. Rubber tubing can be used to connect the T to a water supply. The arrows indicate the flow. The aerial, ground and oscillation transformer may be the same as for the spark system already described. The condenser should be variable, as the exact amount of capacity must be found by experiment. A hot wire meter in the aerial can be used to indicate the correct adjustment of the circuits. The impedance coil is made by forming an iron core 1½ in. square and 5x8 in. outside dimensions, as for a transformer, winding about four pounds of No. 12 D. C. C. wire on the long legs. The

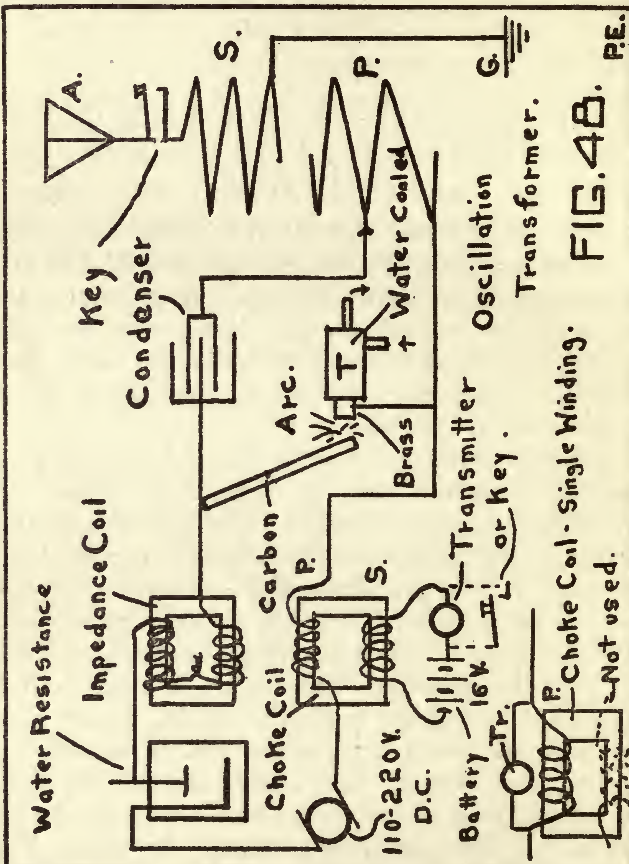


FIG. 48.

purpose of the impedance coil is to prevent the oscillations from surging back into the generator. The choke coil is made similar to the impedance coil, except that only two pounds of wire are used and wound on one leg. If desired, a secondary can be wound on the other leg. (See chapter on transformers.) A resistance for the arc should also be provided. This may be made by placing two electrodes an adjustable distance apart in a solution of salt and water. A transmitter or a key can be shunted around the choke coil, according to the use to be made of the set, or the key or transmitter may be used to vary other parts of either the primary or aerial circuit. A current through the secondary winding of the choke coil may also be used when it is modified by a transmitter.

It is understood, of course, that the transmitter in fig. 48 is used instead of a key when the circuit is used as a wireless telephone, or vice versa. That is, a key may be substituted for a transmitter to form an experimental arc telegraph. If the key or transmitter is used in the aerial, a duplicate in the main arc circuit is not needed. For telephone experiments the transmitter is best shunted around the choke coil as shown in the lower insert of fig. 48. Only the choke coil and transmitter (Tr.) are shown in this insert, as the circuit is the same in other respects. In this case only one winding is used. If the two windings are used as shown, the transmitter is connected to the secondary winding through a battery. In this method the variations caused by the transmitter are superposed on the line current by induction and in turn cause variations in the arc circuit. In the shunt method the transmitter carries part of the current directly, while in the inductive method it is only indirectly connected to the main circuit. Ordinary transmitters can be used. It is advisable to use two or three connected in parallel and grouped as a single unit. Larger currents can be cared for in this manner. The author has passed from 1 to 4 amperes through an ordinary transmitter with good results. The transmitter was heated by this treatment, however, and in some later trials, it was burned out. Indeed, the art is materially hindered at present, for want of a satisfactory transmitter.

It should be noted that the oscillatory circuit is formed by the condenser, oscillation transformer and arc. The circuit through the resistance, impedance coil, arc and choke coil is used to excite the arc.

In *operation,* the condenser is alternately charged and discharged at a very high rate, because the voltage between the arc terminals *decreases* with an *increase* of the current. The *condenser* takes current from the arc, causing an increase of the *voltage* between the terminals, and as a result more *current* flows into the condenser. Even after the condenser is charged to the same potential as that between the arc electrodes, the current in the condenser *continues* because of the *inductance* in series with it. The potential difference at the condenser thus becomes more than at the arc terminals, so that the condenser now begins to discharge through the arc. This immediately causes the voltage of the arc to drop, so that the discharge continues. Finally the condenser potential falls below that of the arc electrodes and the process reverses again. The condenser continues to charge and discharge in this manner and the resulting oscillatory current is utilized in the transmission. The arc is varied by the transmitter or key and in the former case, causes the arc to reproduce the sounds spoken into the transmitter. The resulting oscillations are similarly varied so that the receiver gets a more or less exact reproduction of the transmitted sound waves which are sent as *electromagnetic waves.*

The frequency produced in an arc system is very high, being from 100,000 to 1,000,000 per second, and can not be heard by the receiver except when modified as by a transmitter. Very close tuning is necessary to get results from this circuit, and the experimenter is quite safe in using any reasonable wave length with this arrangement, since for telegraphic purposes with a key used to make or break the aerial circuit, ordinary receiving stations are not interfered with. The Poulsen system operates along these lines.

A singing arc is made by connecting variable capacities in the shunt circuit of the arc. The pitch varies according to the capacity in this case, the highest pitch being obtained by the use of a very little capacity. If a telephone transmitter is also used the arrangement forms a *talking arc*. This is really a wireless telephone without helix, aerial and ground. It is also possible to omit the condenser for this purpose. Words spoken into the transmitter are reproduced by the variations in the arc. The sound will be louder as the length of the arc is increased. (Do not look at the arc too much, as it is very bad for the eyes.)

An arc system allows very sharp tuning to be carried out, and as a result it does not interfere with other stations, as much as ordinary spark sets do. The persistent train of oscillations produced by this method is a decided advance in the wireless art. The received signal is an accumulated impulse resulting from a series of the oscillations, as has been explained for the rotary gap. The arrangement described will only operate over short distances, however, as large power and specially designed arcs and apparatus are necessary for long distance work.

THE LEPEL ARC SYSTEM.

This arrangement is a *combination* of the arc and the quenched spark systems, and operates on either direct or alternating current of 500 or 1,000 volts. This voltage may be obtained from an ordinary alternating current supply by means of a step up transformer. A five hundred watt step up transformer with a ratio of 1 to 5 will serve nicely on 110 volts A. C. for experimental purposes. The arrangement is very simple and is shown in fig. 50.* The condenser used can be made of paraffined paper on account of the low voltage used, but glass is recommended. The remainder of the apparatus with the exception of the arc or gap itself is familiar and needs no further com-

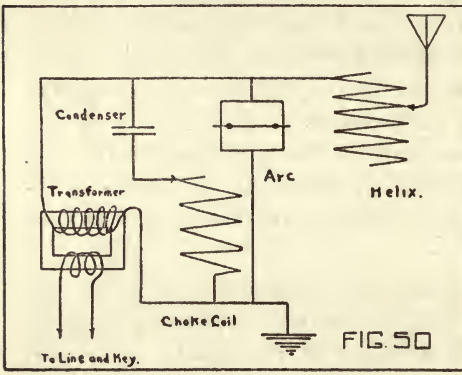


FIG. 50

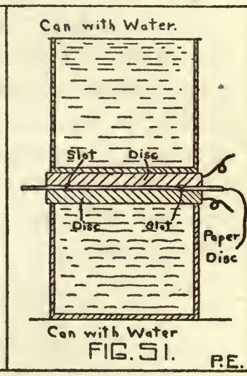


FIG. 51.

ment. A suitable construction for the gap for experimental purposes is illustrated in figure 51. Ordinary tin cans can be utilized, but the electrode faces should be of copper turned smooth and having a groove as shown. This groove serves to prevent the arc from reaching the outside of the gap. These copper disks should be from 3 to 5 inches in diameter, and can be arranged, after the cans are filled nearly full of water. The two electrodes

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* No chopper is needed at the receiver when A. C. is used with the transmitter.

are separated by a circular disk of paper, not more than .01 in. thick. A good bond paper will do. The disk

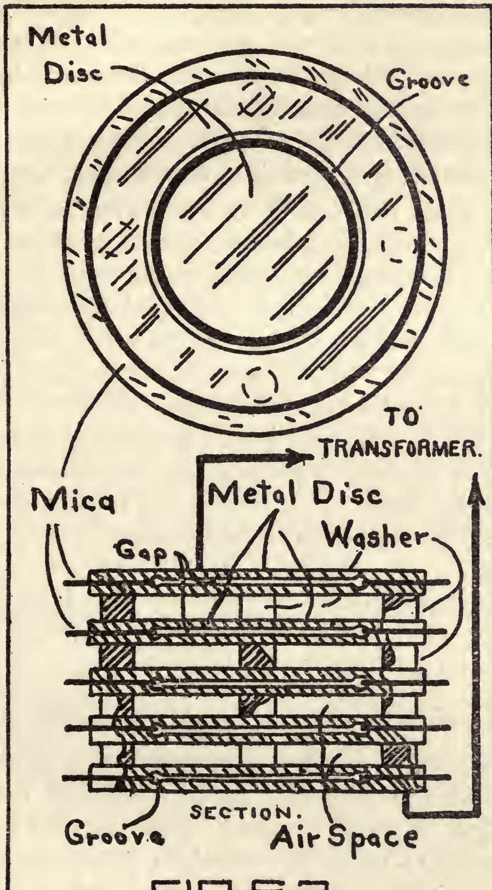


FIG. 52.

should have a small hole at its center to afford a starting point for the arc. The construction is very simple and needs no further comment.

In operation the arc starts at the center and gradually burns the paper away. As this burning occurs in an atmosphere lacking in oxygen, the paper does not burn all up until after a number of hours. It is essential to the arc, that the distance between the electrodes should be uniform and not over .01 inch, so that the arc occurs in an atmosphere lacking in oxygen. The products of combustion of the paper also aid the arc's efficiency.

The paper disc can be renewed after it is used up. This gap gives practically continuous oscillations and the circuits can be tuned by using a hot wire meter. The use of the shunt resonator described in Chapter 11 is advised with this arrangement as the spark or arc is practically inaudible.* This form of gap can be utilized for telephone purposes in much the same manner as described for the arc. Great care should be taken in handling the circuits as a shock from the line or secondary might easily prove fatal. Two or more of these gaps may be connected in series, this method being suitable for higher voltages.

A somewhat similar arrangement used on higher voltages and which does not need paper renewals is illustrated in fig. 52.

TELEFUNKEN (ARCO) QUENCHED GAP.

This is really a number of Lepel gaps connected in series. This arrangement can be substituted for the ordinary gap of a spark system. The discs are turned as shown from 3-16 or ¼ inch sheet brass to an outside diameter of 6½ or 7 inches and grooved 1 or 1½ inches in, so that the groove is about 3-8 of an inch wide at the face. Each plate is grooved on one side in this manner.

* When A. C. is used the discharge can be heard.

The mica rings used may be had at supply houses and should not extend further in than 1-8 inch beyond the outside diameter of the groove, so that the inside circumference of the mica comes within ¼ inch of the inside circumference of the groove. The groove is to prevent the spark from jumping to the mica as the latter becomes a conductor when heated by a high frequency discharge. The mica rings should not be more than .01 inch thick. The discs are assembled in pairs so that the grooved faces are next to each other, and washers are placed between the pairs so that the pairs are separated by a distance equal to the thickness of one of the plates. Thus if ¼ inch plates are used, the washers used should be ¼ inch thick. The assembled gap may be suitably mounted by using insulated supports, a sufficient number of pairs being used so that the combined length of the gaps is somewhat less than the length of a single gap, ordinarily used. When large power is used with this gap, it is well to have a small fan blow upon it to dissipate the heat which is generated.

THEORY AND ADVANTAGES OF THE QUENCHED SPARK.

The gaps described are not difficult to construct and operate and are recommended to the readers. The discharge is practically noiseless, almost 60 per cent more efficient than a common gap, and produces practically undamped waves. A high pitch note, which increases the effective transmission range, is also produced.

The operation of the quenched gap depends upon the fact that the spark quenches itself out after it has made a few oscillations, allowing the secondary oscillations to continue freely. The primary circuit is thus opened so that it does not interfere with the secondary or aerial oscillations. As a result the unwelcome beats common to open spark systems are avoided Returning to the parallel case of a gong, the quenched spark may be compared to a padded hammer, which after striking the gong (comparable to the antenna circuit in this case), a forceful blow, allows it to continue by itself with a clear, powerful vibration. The *short spark gap* when well cooled prevents the primary from *oscillating* by itself after the secondary circuit has been excited. That is, the spark is *active only long enough* to allow the secondary oscillations to reach a maximum, and the secondary oscillations are a maximum after the primary oscillations are reduced to a minimum. The number of primary oscillations necessary for this ideal operation is governed by the degree of coupling between the primary and secondary. It is desirable to use a close degree of coupling with the quenched spark for this reason. The energy ordinarily lost as heat in an ordinary spark gap is thus conserved and the wear on the primary apparatus is reduced. One of the chief causes of heat in the condensers and wear of the gap with an ordinary open gap is the useless continuance of the energy after the useful oscillations have been generated. The *quenched gap*. then, *prevents* undesirable oscillations from being set up in the primary by the reaction of the secondary, and makes the resulting radiations have a single wave length, for receiving purposes.

In constructing the quenched gap, it is essential that the electrodes be pressed with some force against each other. In the Lepel form of gap described the weight of the upper electrode suffices, but in the form of Arco gap described, a clamp should be provided. A quenched gap in connection with a resonant outfit as described in previous chapters is an ideal set for the experimenter. These arrangements are also known as ***shock excited*** systems, and are rapidly coming into increased favor

Note. If mica is not obtainable in the necessary size, rubber sheet of uniform thickness, .01 inch may be used, though the mica is to be preferred. Stove repair companies carry mica in stock as do commutator concerns. The latter use a mica mixture which is much cheaper than mica and which is suitable Smaller dimensions may be used for the electrodes for small stations, and for very small stations one or two sets of plates will suffice. By using soft rubber sheet instead of mica the length of the gaps can be varied by varying the pressure on the plates. Sheets of soft rubber can be had at dental supply houses. The quenched gap is of course used like a regular spark gap in an experimental set. Quenched gaps are made in both stationary and rotary forms, the latter having advantages similar to those of an ordinary rotary gap as well as those of the quenched gap.

The Goldschmidt high frequency generator is coming into some use for long distance work. Its operation depends upon the fact that an armature mechanically rotated in a rotating magnetic field gives an initial frequency—say 10,000—which can be further stepped up by carrying the current back through the field to produce a more rapidly rotating magnetic field; this new frequency current is again led back to still further increase the frequency, and so on until the desired frequency — say 40,000—is attained. The circuits must of course be nicely balanced electrically in order to obtain the necessary resonance, condensers being used for this purpose. To avoid eddy current losses, the armature is constructed of iron foil only .002 inch thick, each sheet being insulated from the next one. Substantially undamped waves are emitted by the use of this machine and since the frequency is above audibility, the method of beats is employed to get the intelligence at the receiving station.

Still another method for producing sustained oscillations has been devised by Galletti. Direct current is used as the primary source and a plurality of oscillatory circuits are automatically excited in succession, a common condenser being coupled to these circuits. An experimental alternator has also been constructed by the Telefunken Company in which the primary frequency is multiplied by means of a polarised transformer.

CHAPTER XIII.

THE RECEIVING STATION.

Having considered the transmitter and its details, the *receiving* station will now receive attention. The aerial and ground have already been discussed and since they are the same in most cases for both transmitter and receiver, they need no further attention.

We have seen that the transmitter emits *waves* of definite lengths and having definite characteristics, according to the adjustment of the transmitter and that these waves spread out in all directions at the speed of light. Now at the receiver, all that is necessary is some apparatus which will *detect* the waves which strike the receiving aerial and translate them into an intelligible signal.

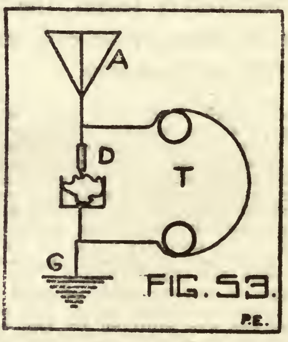


FIG. 53.

For this reason, the apparatus in its simplest form consists merely of a detector and a telephone receiver connected in the antenna circuit. This is shown in fig.

53. It will be understood that other sensitive recorders such as an Einthoven galvanometer can be used instead of the telephone receiver. The detector, however, is essential, because even the most sensitive telephone receiver or galvanometer cannot record signals without it.

In early experiments, a relay was used for the recording instrument. In its most sensitive form, however, a relay will only operate with about .001 of a volt at its terminals. Further, its action is slow, so that it has been discontinued for signalling purposes. Its use is limited to the field of telemechanics, the art of controlling motors, boats, etc., by wireless through a local relay. Its cooperating detector, the coherer, has also become obsolete except for the purpose mentioned.

The *telephone receiver* is the instrument in universal use for wireless receivers and is the form to be adopted as a standard for wireless purposes. The receivers for wireless purposes are made different than for ordinary purposes.

TELEPHONE RECEIVERS FOR WIRELESS RECEIVING.

Receivers for wireless purposes should be very *sensitive*. It has been found by experiments that the degree of sensitiveness depends largely on the *frequency* at which the received signals are sent. Thus, messages from a 900 cycle transmitter will produce an audible sound in the receiver when only 0.6 millionths of a volt is used, while impulses received from a 60 cycle set will only produce an audible sound when 620 millionths of a volt are used. These figures are according to Dr. Austin, and while they are taken for a particular set of receivers, with the use of a laboratory arrangement, the general relation holds good. It is for this reason that the transmitters operating at 500 to 1,000 cycles are more effective than those operating at low frequencies. The sensitiveness of a given receiver, then, depends on the frequency employed to operate it and also on the natural period of vibration of the diaphram. It is for this reason that thin diaphrams are employed in wireless receivers. The detailed requirements for receivers will receive attention later.

WHY A DETECTOR IS ESSENTIAL.

The detector (see fig. 53), is not of itself the most sensitive instrument at the receiving station, but in essential because the telephone receiver, while more sensitive, will not of itself respond to high frequency *oscillations* such as are received at a wireless station. The reason should be apparent, for the change first in one direction and then in the other, of the oscillations is so rapid that the successive changes neutralize each other and produce no effect in the receiver. To operate on these oscillations a telephone diaphram would have to move with frequency corresponding to approximately one-millionth of a second, which of course it cannot do. Again, we have seen that high frequency oscillations are greatly impeded by large inductance, so that the self inductance of the receiver would of itself prevent any except minute currents from operating it. The detector, then, *translates* the received oscillations into a current which will operate the receiver.

The oscillations coming in on the aerial A, fig. 53, are transformed by the detector into currents which operate the receiver. The nature of this transformation, the construction and operation of detectors, and similar matters will receive attention later.

THE RECEIVED SIGNAL.

The received signal, then, is made up of wave trains which set up an oscillatory current in the receiving station which corresponds to that sent by the transmitter. When it is remembered that the transmitted energy is sent out in all directions it is remarkable that one point such as a receiving station receives as much energy as it does. According to Mr. Pickard, measurements of the maximum energy received from a high power transmitting station 90 miles away, showed this energy to be .03 ergs per dot. The "erg" is equivalent to one ten-millionth of a watt. Inasmuch as a sensitive telephone receiver will operate with an audible sound on as little as one-millionth of an erg this leaves a considerable margin for the case at hand In any case, the received energy is many hundred times the actual energy necessary to produce an audible sound in the receiver, but since the receiver will not of itself operate efficiently on the high frequency oscillations, the detector employed limits the efficiency of the receiving station to a large extent.

Like other transformers, the detector represents a source of loss and although the modern detector is quite sensitive, (see table p. 160), a detector which would be at least as sensitive as a sensitive telephone receiver by itself would be of a great advance in the wireless art.

Now the simple circuit shown in fig. 53, comprises an untuned receiving set and is of little use without an auxiliary tuning apparatus if messages are to be received from modern transmitters.

Tuning. In order to receive signals from a transmitter, the receiver must be adjusted so that its circuits are in tune or resonance with those of the transmitter. Thus, if the receiver is to receive from a station sending

TABLE OF DETECTORS—SENSITIVENESS.

Type of Detector.	Energy required to operate. in ergs. per dot.
Electrolytic	.003640—.000400 *
	.007 §
Silicon	.000430—.000450 *
Magnetic hysteresis detector	.01 §
Hot-wire barretter	0.08 §
Carborundum	.009000—.014000 *

* According to Pickard.

§ According to Fessenden.

out a 300 meter wave it must be adjusted so that its wave length is very nearly 300 meters. However, if the transmitter is poorly tuned or very close to the receiver, it is a common occurrence to receive the message without careful tuning, or even without any tuning. (See chapter on resonance). The apparatus for tuning a receiver, consists, as at the transmitter, of adjustable circuits containing variable capacity and inductance. The whole subject is somewhat complex and will receive individual attention later.

The same receiving set may be used for either wireless telegraphy or telephony, since the conditions are identical in many respects. Indeed, both telephone and telegraph messages can be heard at the same time in some localities. This last is a special case of interference.

The requisites for the receiver then are:

1. Sensitive detector.
2. Sensitive telephone receiver or recorder.
3. Accurate auxiliary adjustable circuits for tuning.
4. A good aerial and ground, as for the transmitter.

The several items will receive attention presently, in some detail.

CHAPTER XIV.

DETECTORS SOLID RECTIFIERS.

Quite a number of different types of detectors have been discovered and developed and there are many forms for these. For the purpose of standardization, however, the types known as crystal or *solid rectifiers* are best adopted because of their sensitiveness, low cost, easy adjustment, portability and durability. Other forms which may be used are coherers, loose contacts, (almost any loose contact, as between a piece of carbon and a needle, being suitable), magnetic detectors, barretters or thermal detectors, electrolytic detectors, gaseous detectors, and vacuum detectors. Indeed, one might easily devote an entire book to a consideration of all types of detectors and their several details. Such a duplication seems unnecessary, however, since solid rectifiers can be used to as good advantage as the other types for all experimental purposes, whether for long or short distance receiving.

Solid rectifiers consist essentially of certain metallic compounds, such as oxides and sulphides, which have the property of *rectifying* the high frequency oscillations. That is, these metallic compounds when connected in a circuit, conduct the current better in one direction than in the other. This *unilateral* effect is quite marked, so that the detector acts as a valve, allowing the current to pass in one direction but practically preventing the oscillation from completion by *preventing* the current from passing in the reverse direction. In addition to this property it is necessary to have this rectifying effect carried on regularly so that the oscillations are rectified into a pulsating one way or direct current. The latter then serves to operate the telephone or other recorder. The metallic compounds used have this property also, so that a circuit which includes a solid rectifier is a good detector for the wireless receiving circuit. It is interesting to note that while a part of this phenomena was noticed as early as 1874, these metallic compounds were not understood and used as detectors until about 1906. A partial list of the elements and compounds which may be used for this purpose are:

Mineral Name.	Chemical Name.
Carborundum	Silicon Carbide
Fused Silicon	Silicon
Iron Pyrites	Iron Sulphides
Copper Pyrites	Copper Sulphide
Chalcopyrites	Copper Iron Sulphide
Hessite	Telluride of Silver and Gold
Zincite	Zinc Oxide
Octahedrite	Oxide of Titanum
Stibnite	Antimony Sulphide
Galena	Lead Sulphide
Molybdenite	Molybdenum Sulphide
Zirconium	Zirconium
Niccolite	Nickel Arsenide
Domeykite	Copper Arsenide
Sphalerite	Sulphide of Zinc
Pyrrholite	Iron Sulphide
Corundum	Oxide of Aluminum and Iron
Hematite	Iron Oxide
Cassiterite	Oxide of Tin
Siderite	Iron Carbonate
Malachite	Copper Carbonate
Cerusite	Lead Carbonate

With the exception of Carborundum these may all be used without a battery with good results. When two different crystals are used together to form a pericon detector, the use of a battery is optional.

In use, a small piece of the compound which will be hereafter called a *crystal* for convenience, is mounted between two metallic contacts. The exact nature of these contacts depends upon the particular crystal employed, and in nearly every case, it is desirable to make the contacts adjustable, so that the most *sensitive* part of the crystal can be used with the contacts at the most sensitive pressure. In practically every case it is desirable to make one of the terminals or contacts with a *large* area so that it makes very good contact with the crystal. This is to prevent the other contact from forming an opposing and undesirable second rectifier, which would greatly reduce the effect of the former. The crystal then, is mounted between a large and a small contact, to form an ordinary detector. *Silicon,* while a non-metallic element, is perhaps one of the most widely used solid rectifiers. The *iron pyrites* or pyron detector, the *galena* or lead sulphide detector, and the *molybdenite* detector, in the order named, are the other single crystal rectifiers in most general use and favor. Each has certain advantages and disadvantages and the various factors which determine the utility of a detector are so variable that direct comparison without exact comparative tests is not possible. In order to secure the necessary large contact for these detectors, the crystal is imbedded in a cup with a fusible alloy such as Woods, metal, (see constructional details), while the small point consist of a rounded adjustable point of brass, gold, platinum, or else a wire of these metals. When two or more of these crystals, one of which is preferably zincite, are used, this small metallic point is replaced by a fragment from another crystal. A small piece of chalco-pyrite is generally used for this purpose. This pericon detector is perhaps one of the best at present known as far as sensitiveness, portability, and durability are concerned. Small metal points are most suitable for polished crystals such as iron pyrites and galena. These two detectors are particularly free from injury from mechanical shocks or foreign electrical impulses.

For experimental purposes it is well to provide what is known as a *universal* detector stand so that any or all of the materials as well as new ones as yet undiscovered may be tried. There are plenty of unfound materials which may be much better than those now in use and a search for some of these would furnish enough excitement for the average experimenter for some little time. It is well to remark, however, that a mere duplication of detectors no better than those already in use will not be of much importance or use. What is wanted is something better, more sensitive, having less resistance, and which is more reliable and permanent.

CONSTRUCTIONAL DETAILS.

There are a great variety of constructions for solid rectifying detectors, almost every experimenter making a different kind or different form. Provided that the following general requirements are adhered to, the matter of size, adjustment (mechanical movement used), and form is of little consequence. The reader has unlimited latitude and opportunity to exercise his ingenuity. A few accepted forms which are similar to those in general use and favor will also be given.

MATERIALS.

The crystals in general use can be had from supply houses. Whenever possible tested crystals should be purchased, as this saves considerable time and trouble. For instance, it may happen that only a dozen or so suitable points will be obtained after trying out a pound of material, broken up into points. The silicon used should be *fused* silicon, the carborundum preferably *green* carborundum, and all of the others in the best grade obtainable. Cheap grades generally contain considerable foreign matter which is of course not desirable. Owing to the fact that the most commonly used crystals are mentioned in the claims of patents held practically by one holding company, many dealers in minerals and crystals are afraid to sell them for fear of infringement

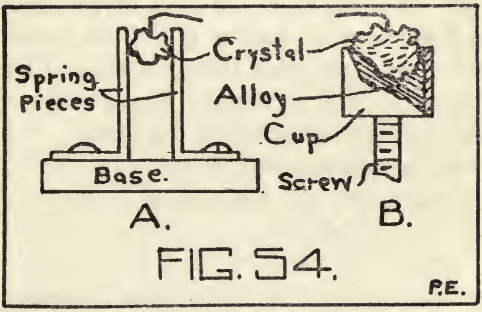


FIG. 54.

suits. (See chapter 19 on the experimenter's rights). The various cups, brass, screws, and other materials can also be had from supply houses.

Crystal mounting. Fig. 54 shows some suitable mountings for the crystals to form the large contact necessary. Two spring pieces fastened to a block of wood as at (a) will do. Perhaps the best mounting is that shown in the figure at (b), where the crystal is held in a cup containing a fusible alloy. This may be made by melting four parts of bismuth, one part of cadmium, two parts of lead, and one part of tin together; or three parts of a good grade of solder instead of the lead and tin, may be used. The melting point of this alloy is approximately 138 degrees F, and this mixture is used so that the resulting heat will not injure the crystal as ordinary solder would. The cup should be well cleaned before pouring the alloy in, and around the crystal. The metal is preferably poured into the cup and then the crystal is placed into the metal, and held in place until the alloy cools. A substitute for this method is to pack the crystal in the cup with tinfoil wads. This allows the crystal to be removed so that the sensitive part can be found. The cap from a round dry battery carbon can be used for a cup if it is well cleaned and polished. The tinfoil can be packed in so tight that the crystal will not fall out, and if the exposed part is found not to be sensitive, the crystal can be removed, turned over, and tried again, until a sensitive part is found. Many similar arrangements will suggest themselves to the reader. Almost any form of spring, clamp, or other contact which will make a large contact and hold the crystal in place is suitable. Use the crystal as follows.

The crystal used should be a small fragment as it will then work as well or better than a large piece. It should *not* be ground and should be left in its natural shape. Most of the materials are best used as small chunks. Molybdenite is best used as a thin sheet. The molybdenite may be easily copper plated so that connected wires can be directly soldered to it. When a pericon set is used, the zincite should have a larger surface than the other crystal. The latter may be a fragment of bornite or chalcopyrite, preferably with a definite point for contact.

In making a universal detector, it should be remembered that three types of contacts will be needed to include suitable contacts for all materials. Crystals like silicon work best with a blunt point and light contact, molybdenite with a blunt point and comparatively heavy contact, those like galena and iron pyrites require a fine light point, and those like carborundum require two large contacts with a comparatively large pressure. An ar-

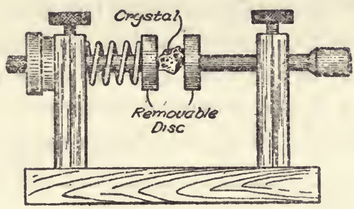


FIG. 55.

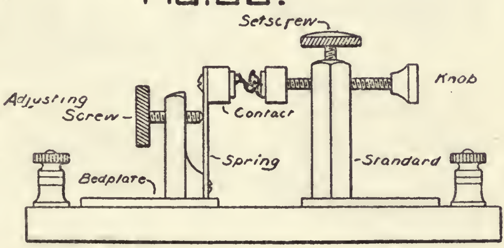


FIG. 56.

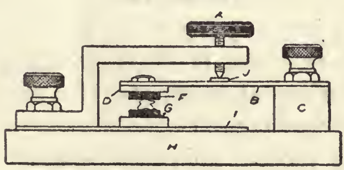


FIG. 57.

rangement which will provide for these variable conditions is, therefore, desirable. Some suitable mechanical arrangements are shown in figs. 55—62. In the clamp type, the crystal can be removed and another one replaced, while in the multi-crystal type the several crystals are mounted so that any one may be used at a time. Where compactness is no object it is perhaps a better plan to have a plurality of separate detector stands for each crystal. A duplicate detector is also desirable, so that when one crystal becames poorly adjusted, another sensitive detector can be immediately switched into circuit.

Referring to the figures, which were collected from various sources, figs 55, 56 and 57 show suitable constructions for a simple universal detector and require no further comment.* In fig. 57, A represents an insulated

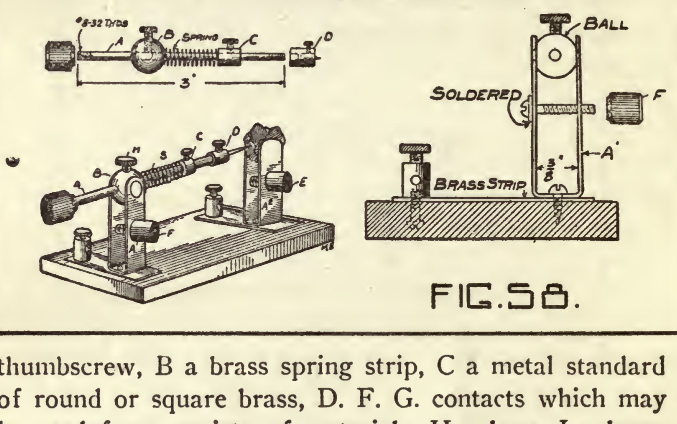


FIG. 58.

thumbscrew, B a brass spring strip, C a metal standard of round or square brass, D. F. G. contacts which may be used for a variety of materials, H a base, I a brass strap, and J a notched cup.

Fig. 58 shows another universal detector. The shaft A slides into a ball B, which is in turn held by the strips A1 with a pressure adjustable by F. The spring S keeps A in position. C is a simple screw chuck holding another

*Pop. Electricity. Modern Electrics. U. S. Pat. Specification.

chuck D in which a point is in turn held. Difficult shaped points may be used in this manner. The crystal is held adjustably in a clamp A2. The arrangement is quite simple and allows almost any desired adjustment and use.

The multi-cup arrangement of fig. 59 is taken from patent No. 1, 027,238, U. S., and is quite simple. The post C can be turned so that the contact G. makes con-

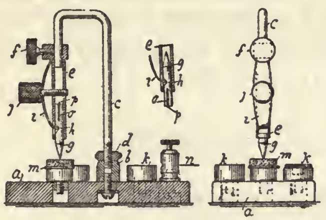


FIG. 59.

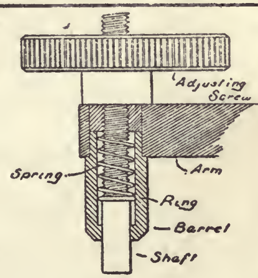


FIG. 61.

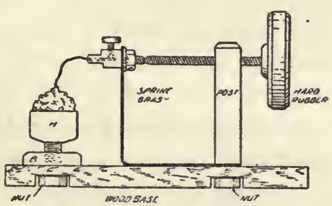


FIG. 60.

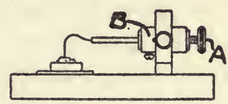


FIG. 62.

tact with any one of the cups arranged as a circle on the base. The contact G can be reversed so that the detector can be used as an electrolytic detector with one of the cups K. The spring I provides a mild, variable pressure, and the rough adjustment is made by the screw F clamping E to C after the proper length has been found. Fig. 60 shows a simple arrangement suitable for galena, iron pyrites and silicon, and needs no further comment.

Fig. 61 shows a delicate adjustment suitable for the small movable point of a universal detector. Fig. 62 shows a novel scheme for adjusting the pressure of the small point on the crystal. The piece B is mounted on a pivot so that it balances nicely. The pressure on the small contact can then be varied by screwing the nut A in or out, thus securing more or less weight on the fine point.

These forms are only reproduced as suggestions as the reader can easily make a detector according to his own design. Pericon crystals may be similarly mounted. the extra crystal replacing the fine point.

CARE AND ADJUSTMENT.

Detectors should be regarded as sensitive and delicate instruments. They should be kept out of the sunlight, away from dust and dirt, acid fumes, and similar places.

The crystals become less sensitive after a time, but can often be renewed by cleaning with gasoline or carbon bisulphide, using an old tooth brush and taking great care to avoid a fire or even a burning light, because both materials and particularly the bisulphide are very explosive. Heat alone if applied rationally will often restore an old crystal to sensitiveness again.

The actual *adjustment* is a matter which must be determined by experiment. A *buzzer test* is very valuable for this purpose and should be a part of every wireless receiving set. This is simply a common buzzer, such as may be had for about 25 cents, connected to a key and battery and to a short aerial wire as shown in fig 63. The wire need only be a few feet of number 18 bell wire. The connections can be arranged on the aerial switch so that when the switch is set for receiving, the transmitting key will operate the buzzer instead of the transformer. The noise of the buzzer should be deadened by covering it with old clothes or else by placing the buzzer outside of the building, since it is not desirable to hear the buzzing sound. This buzzer sets up weak wireless waves and the detector is in adjustment when the said waves are received and heard the loudest. Adjustment of the detector may also be carried out while

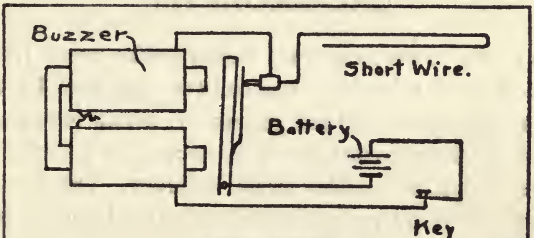


FIG. 63.

receiving from another station, provided that the copying of the message is of secondary importance while the adjustment is being carried out. The turning on and off of an electric light socket can also be used as a buzzer test, the resulting arc supplying the necessary waves. While we are on this subject it may be noted that a lamp on a lighting circuit near the transmitting station can be made to light up when the station is sending. Turn the lamp on and then unscrew the bulb until it just goes out. The transmitter will then cause it to light, when the key is pressed. This experiment illustrates the coherer principle to a certain extent and will only work when the light is in close proximity to the transmitter.

CHAPTER XV.

TELEPHONE RECEIVERS.—DETECTORS FOR CONTINUOUS WAVES.—EINTHOVEN GALVANOMETER.

In order to receive from a *continuous wave* transmitter such as a telegraph transmitter operated by an arc generator or quenched arc generator, which is not audibly altered at the transmitter, it is necessary to modify the received impulses audibly at the receiver. The human ear can only hear or recognize vibrations which do not exceed 35,000 or 40,000 per second, so that the waves sent out from an arc generator vibrating at many times this rate are inaudible. The only form of indicator which will efficiently record such inaudible waves without modifying them at the receiver by a vibrator or chopper is the Einthoven galvanometer, as far as the author is aware. While this is a delicate instrument, a brief account of it will be given so that it may be constructed by skilled workers.

EINTHOVEN GALVANOMETER.

This instrument consists essentially of a fine wire stretched between the pole pieces of a powerful electromagnet. This wire may be of platinum, silver, aluminum, or copper, and should be very fine. No. 40 or 50 such as is used for telephone receivers can be used. The construction and arrangement is shown in fig. 64. In the most sensitive forms, a thin quartz or glass fibre which has been platinized is used and if this can be had from a supply house, the reader is advised to purchase it. The fine wire is mounted on T shaped set screws C and F, so that the tension can be delicately adjusted. As shown, this is accomplished by having C attached to a rod having a cam K on its upper end and held in place by a spring L. When the lever K1 presses down on the rod, a very

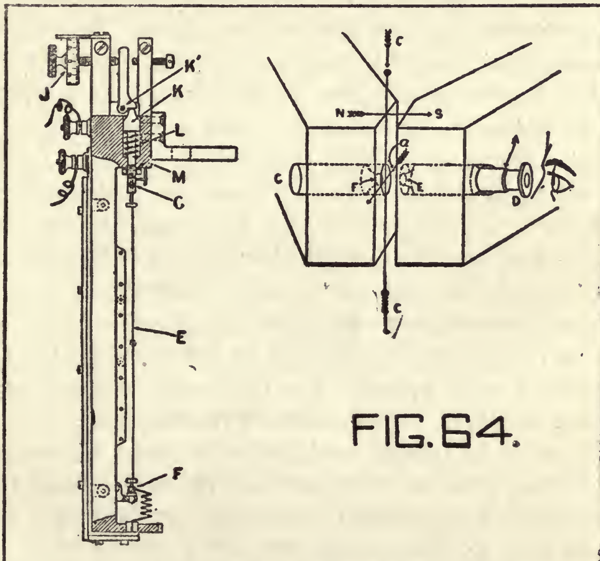


FIG. 64.

fine adjustment is secured. K1 is operated by a micrometer screw J, as shown. A more simple arrangement would also do, but the adjustment would then be less accurate, and more difficult to carry out.

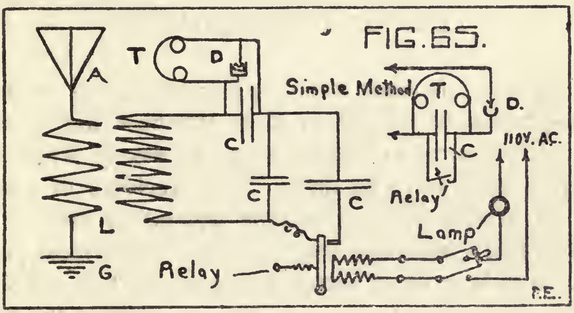
The smaller part of the figure shows the position of the wire and magnets and one method for observing the displacement of the wire. The eye piece AE is inserted in a hole in one of the magnet poles.* Light is projected by the tube C and lens F. When the current flows in the direction of the arrows, the wire stretched between CC has a deflection indicated by the arrow a. This displacement can be magnified by projection upon a screen, in which case the eye piece is removed and a strong light applied at C. This recorder is very sensitive and can be used for long distance work as well as for experimental measurements. The amount of deflection indicates the strength of the received signal. In practice, a photographic record is taken by means of a moving film, so that a permanent record of the message as a defined line according to the dots and dashes, is the result. The experimenter may dispense with the photographic record, however. The skilled reader should not find it difficult to make a duplicate from this brief description. The magnet used should consume about 250 to 500 watts, and it is not unlikely that ready wound magnet coils can be pressed into service for experimental purposes. The success of the instrument depends on the fact that the fine wire has a rapid period. The instrument will not be of any use, however, unless delicately constructed.

In order to receive unaltered continuous waves with an ordinary wireless telephone head receiver, the received impulses must be modified, interrupted or chopped. This can be done by the arrangement of fig. 65, in which the relay shown is a 20 ohm or 75 ohm telegraph relay, having its magnet connected to an alternating current line through a lamp. The secondary platinum terminals are used to alternately connect and disconnect a large fixed condenser in the receiving circuit as shown, thus balancing and unbalancing the circuit at an audible frequency so

* Old microscope parts can be used.

that the received signals are rendered audible. This arrangement also effectually cuts out a great deal of other interference. When ordinary stations are to be heard the relay is merely disconnected from the line. The remainder of the circuit is familiar or will soon be and needs no further comment. The relay acts as an interrupter and may be used to throw either capacity or inductance or both in and out of the circuit. The insert shows a simple method for the same purpose. In this case a single condenser is used in shunt about the tele-

FIG. 65.



phone receivers. The remainder of the circuit is not shown as it is the same as before.

Either the Einthoven galvanometer or this chopper arrangement will be satisfactory to detect the continuous waves. With this arrangement, experimenters may receive from the Poulsen stations provided that the circuits are properly tuned. In connection with the apparatus described in chapter 12 for telegraphy without modifying the continuous waves at an audible frequency at the transmitter, this form of detector forms an ideal one for the experimenter. A somewhat similar arrangement is sometimes incorporated directly in the detector, but since it is less efficient, it will not be described here.

The continuous wave system with a chopper at the receiving station is perhaps the most advanced system in the art at the present writing, and without a chopper, using the galvanometer, the messages can be permanently recorded as fast as they are sent. Sharper tuning is also possible and good transmission is possible on account of the accumulative effect at the receiving station.

If carefully constructed the galvanometer described will respond to a sufficient extent when operated by only .0001 volt.

TELEPHONE RECEIVERS.

Ordinary telephone receivers may be used as recorders for experimental work over short distances, but specially constructed wireless receivers are necessary when long distance work is to be done. The receivers in general use are of the watch case type and either one or two receivers on a headband may be used. Since most people are able to hear much better with one ear than the other, it is an advantage to use only one receiver on the headband and to block off the other ear from foreign sounds by a rubber pad. This method is less expensive than when two receivers are used on a headband. However, if two receivers are used they must be identical in their dimensions and windings as otherwise the one having the least resistance or other unequal dimension will not work in accordance with the other one. Many manufacturers are now making reliable light weight receivers suitable for the most exacting wireless work, and while the latter are perhaps a little expensive, they are essential to efficient work, particularly over long distances. The reason why a low resistance telephone receiver such as is used for telephone work is not suited for delicate wireless work is that it is made to give a loud response with a comparatively large amount of applied energy but will not give any response with very minute currents, such as are produced by a detector receiving from a distant station. An ordinary receiver can be rewound, however, with No. 40 or 50 enameled wire so that its utility will be much greater. When this is done a new and thinner diaphram should also be supplied, since the ordinary diaphram is too thick for wireless purposes. These thin diaphrams may be had at supply houses and are known as gold diaphrams because they are gold plated. A wireless receiver is not intended to give a loud response, but rather to give an audible and working response with very feeble currents. The resistance, however, is not the real delicate part of the receiver, and the mere statement that a receiver is wound to 1,500 ohms means little or nothing. What is desired is a large number of ampere turns, and since this is best secured by using fine copper wire, No. 38 or 40 is generally employed. Receivers are rated according to their resistance largely because this is a convenient measure, but as far as workability is concerned, the number of ampere turns is the essential factor which determines the actual utility. In any case, a resistance of over 1,500 ohms is no advantage, and a resistance of less than 800 ohms is not desirable when the receivers are to be used with solid rectifying detectors.

CARE AND ADJUSTMENT.

While a receiver seldom requires attention after it has been adjusted, it should be kept clean, and free from dust and moisture. When rewound receivers are used it is sometimes necessary to adjust the distance of the diaphram from the poles. This can be done by using a soft rubber cushion between the cap and the receiver case, and screwing the cap on with more or less pressure. thus adjusting the distance between the diaphram and the receiver's magnet pole. After long use, the permanent magnets should be tested and if the magnetic attraction is weak, the magnet should be strengthened by remagnetization. A common test is to judge by the distance between the receiver case and diaphram, which is necessary just before the diaphram (previously removed and laid on a table), is attracted to it.

Receivers are seldom burnt out. This may be the case after a station has been subjected to a heavy static or lightning discharge. The headband used should be comfortable and should keep the receiver tight against the ear. The receiver is very important and its sensitiveness together with the hearing ability of the operator is one of the largest factors which determine the receiving range of a station.

A word concerning *standard receivers* for wireless purposes. The magnets should be permanent and preferably of the consequent pole type, to prevent leakage about the pole pieces. The diaphram should be thin and uniform, but of sufficient thickness to absorb sufficient magnetic flux. The poles, case, and diaphram should be proportioned and made so that the maximum sensitiveness and least liability to injury and change is the result. Lightness and a good fit are important items as far as comfort is concerned, and if the receivers are to be used continually, this is a very important consideration. A suitable size for the wire used in the coils is No. 40 or wire .0031 thick. A standard thickness for the diaphram is .004 thick exclusive of the plate or varnish coat, which last is to prevent rust and corrosion.

HOW THE RECEIVER OPERATES.

It is well known to the readers that the telephone receiver depends upon simple magnetic phenomena, so an account of the action will be dispensed with. However, it is well to understand the action in a wireless receiving set.

We have seen that the detector rectifies the oscillatory current into a pulsating direct current. Now, this direct current passes through the windings of the receiver and causes the diaphram to be pulled according to the strength and changes in the current. While the current supplied to the telephone may have as much as a million pulsations in one second, the ear only hears a sound similar to that produced by a steady current on account of the regulation exerted by the *inductance* of the windings of the receiver. That is, each complete wave train after being rectified by the detector causes only one pull on the diaphram, so that the operator hears one sound corresponding to each transmitted wave train. However, a complete signal, even a dot, generally comprises several successive wave trains so that the received signal is heard as a succession of clicks corresponding to the spark rate and speed at which the message is sent. The receiver gets the message almost the same moment that it is sent, since the waves travel at the rate of 186,000 miles per second, and the frequency tone, wave length and other variable factors are practically the same as when the impulses leave the transmitting aerial.

MEASURING THE INTENSITY OF THE SIGNAL.*

For experimental work it is often desirable to compare the *relative strengths* of the signals received either from two stations or from the same station using different instruments or circuits. A suitable simple arrangement for this purpose is shown in figure 66, and consists simply of a calibrated shunt resistance about the phones. A non-inductive resistance box is suitable. The value of the received current in the telephone receiver is practically proportional to the energy of the incoming waves so that a rough table of values based on audibility is easily

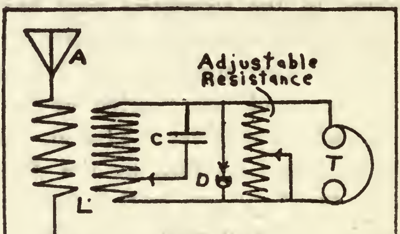


FIG. 66.

made. Thus a station which produces a sound just audible in the receivers when all the resistance is in circuit may be taken as a standard. If another station just produces an audible sound when one-half of the total resistance is in circuit, the new value can be compared with the standard. The calibration could just as well be the other way around so that the standard is audibility with no shunt resistance. The result is best expressed as a fraction of or so many times audibility, as the case may be.

* This method can also be used to eliminate interference from weak stations, but is carried out at the expense of a decrease in the intensity of the received signal. It can, however, be utilized in connection with a wave meter.

CHAPTER XVI.

TUNING—INTERFERENCE PREVENTION.

If the reader will bear in mind the discussions given for resonant circuits at the transmitting station, the requirements for tuning at the receiving station will not be difficult to understand. The two circuits are in fact quite similar in some respects. The detector corresponds to the spark gap and as the transmitter, this detector constitutes one of the greatest factors of resistance in the circuit. As in the case of the spark gap this *resistance damps* the oscillations and makes sharp tuning difficult. The resistance of the detector, then, prevents absolute tuning. As far as the rest of the apparatus and circuits are concerned, absolute tuning can be very nearly reached if desired. Now, the tuning apparatus and circuit to employ for experimental purposes will vary with the local conditions. In cities like New York, where the interference is considerable, very sharp tuning is desirable at both the transmitter and receiver, while in localities where there are only a few scattered stations, simple circuits with rough tuning will suffice, so that the intensity of the signal is about all that needs attention. In most of the present tuning methods, fine tuning is carried out at the expense of the intensity of the received signal, but for practical purposes all that is needed is a distinct audible signal. Close tuning has one disadvantage in that a message can easily be missed if the apparatus is at the wrong adjustment. In arranging a receiving set it is well to bear in mind the use to which the apparatus is to be put and to provide for the design accordingly. An *ideal set,* in the author's opinion, is one which provides two standby points and a variable close tuning or interference arrangement. One of the standby adjustments is for the standard 200 meter experimental wave length and the other standby adjustment is for the standard 300 meter commercial wave length. After the message has started, any interference which may arise or be in progress can then be tuned out or dissipated by the sharp tuning adjustments. There are several arrangements which will give this ideal outfit and the several parts will be described in some detail later. For the present, a close attention to the theory and design is of the first importance.

In localities where there is little or no interference, elaborate receiving apparatus is not necessary or even desirable. Aside from the extra expense, the complicated receiving circuits involve greater skill and require more experience to operate. Experimenters should spend much more time in tuning the transmitter than in tuning the receiver, in most cases, as the former is really more important and instructive. The item of interference will be taken up first.

INTERFERENCE.

If there was no interference in wireless work, all that would be necessary at the receiving station is a simple inductance with which to alter the receiving wave length so that the receiver can be brought into resonance with the transmitter. As it happens, however, the average station must be designed to work through both natural and artificial interferences. It may be explained that the term "interference" includes all foreign disturbances which impede or interfere with the regular reception of a desired message.

NATURAL INTERFERENCE.

Mechanical vibrations, waves received from street arc lights, induction from power and telephone lines, static and similar disturbances are natural causes of interference and can be overcome in nearly every case by the use of proper shunt circuits. A looped aerial is best to adopt when these disturbances are particularly marked. With the exception of strong static disturbances, these natural disturbances can be controlled and either dissipated or neutralized. Ordinary static disturbances result from the discharge of static electricity which accumulates on the aerial. This form of disturbance is particularly marked during the summer months and is very annoying. It can only be dissipated when not too strong and then, at the expense of the loss of intensity of the received signal. During electrical storms receiving becomes quite dangerous and impracticable. Experimenters are advised to abandon the use of the aerial during local electrical storms. Although the use of short aerials of low height does not ordinarily mean a liability to much danger, it is well to be on the safe side. Mechanical vibrations can be taken up by using cloth or rubber pads on the instruments.

ARTIFICIAL INTERFERENCE.

This is the form of interference resulting from regular wireless communication between several stations within the range of each other. The manner of overcoming this to a large extent, by the use of resonant transmitters having definite wave lengths, has already been pointed out in detail. If every station (this means both commercial and experimental) would use just enough power to transmit to the desired station, sharply tuned resonant circuits, a definite wave length and "wireless sense," the difficulty of the problem, even with simple instruments of the present design, would be much reduced. In its average or worst form, artificial interference means working through from four to a dozen or more other stations, simultaneously sending at approximately the same band of wave lengths and same intensity. The operator who receives, however, cannot regulate the coupling or adjustments of the several transmitting stations and must accept conditions as they exist. The several items must be successfully met and the interference dissipated without losing the desired message. While this is not always possible, it can generally be approximated. The worst item to overcome is the matter of forced waves, or those which seems to come in at every wave length on account of the proximity and heavy coupling of the transmitter. When the interference prevention methods to be described are employed, these forced wave disturbances can be practically eliminated in nearly every case. While the use of limited or restricted waves will prevent interference between commercial and experimental stations, the experimenters must still fight it out among themselves. In some respects the difficulty will be even more marked since short wave lengths are less immune from interference than the long wave lengths. However, the experimenter may receive from any and every station within range without difficulty, if the simple relations of a tuned receiving set are understood.

TUNING METHODS.

It must be remembered that the ordinary station emits at least two defined wave lengths. The sharper the two are defined, the better as far as the receiving operator is concerned.* With quenched spark or arc stations sharply tuned, practically a single sharp wave length is all that needs to be considered, but interference from other stations operating at the same wave length often complicates the matter. It may be stated right now that the number of possible connections for the receiving circuit is practically *unlimited,* but that many so called hook-ups are a mere duplication or fresh dressed forms for old circuits and really accomplish nothing. In building and arranging the apparatus for the receiving circuit, the actual factors concerned and the remedies should receive attention rather than a hit and miss elaboration of the circuits without conforming to the requirements. Bearing in mind that tuning the receiver means nothing more or less than altering the circuits by adjusting the amount of capacity and inductance used, (resistance is also a factor), the following summary will aid in designing a receiver.

FACTORS AND REQUIREMENTS FOR TUNING THE RECEIVER.

1. *Close coupling* at the receiver should be used when the transmitter is close coupled and vice versa.

2. With the receiver tuned to the desired transmitter, a large amount of the disturbance can be eliminated by *reducing the coupling,* until the strength of the signals is just distinct.

3. A shunt resistance as described in chapter 15 may be used as a substitute for or in addition to method 2.

* See diagrams in Chapter 4.

4. The two wave lengths sent by a transmitter being designated as *short* and *long,* tuning for either the long or the short wave (Detuning) to an extreme degree is often a marked advantage. Since the short wave is generally the least desirable, the aerial, circuit of the receiver is best thrown out of tune on the short wave side as much as is possible.

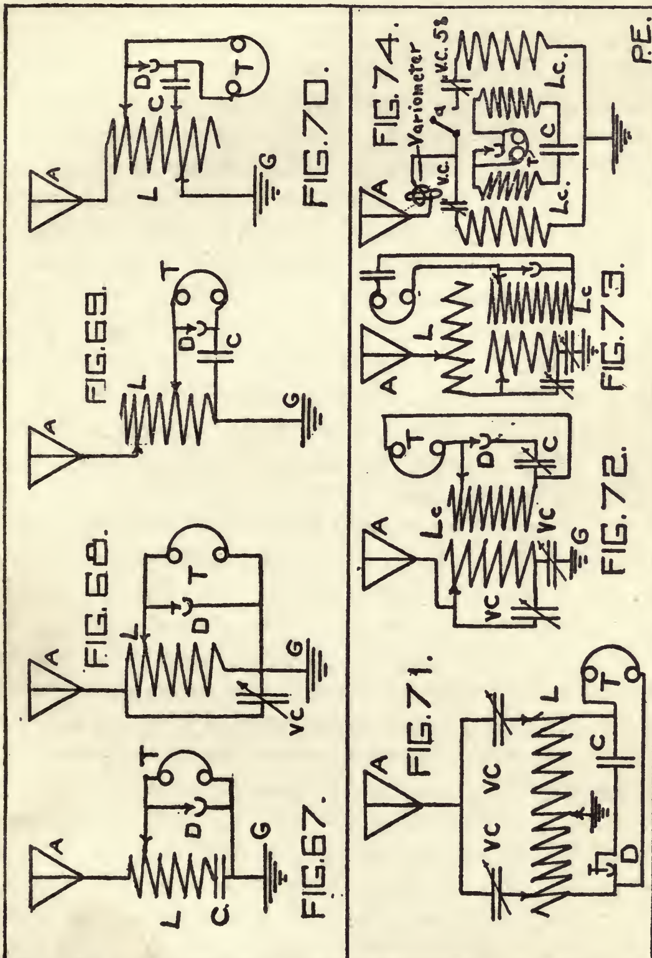
5. When the desired message comes in quite loud, the insertion of some resistance directly in the aerial circuit will often cut out disturbances, but at the expense of the intensity of the signal.

6. In tuning, remember, that an inductance in series with the aerial or a capacity in shunt with a series inductance in the aerial circuit, *increases* the receiving wave length. A series capacity in the aerial circuit on the other hand, *decreases* the receiving wave length.

7. A closed or looped aerial will eliminate most of the natural disturbances.

8. The disturbing impulses can be made to oppose and neutralize each other, while the desired signal, (at a reduced intensity), is received. (Differential method). (Bridge method). This is a very desirable method, and if the waves are in a sufficiently long train, it is possible to discriminate between them and undesired impulses. If the undesired impulses are more rapidly *damped* than the desired impulses they can be avoided, even when they are of the same period as the desired waves, under favorable conditions.

We shall now discuss approved circuits embodying the above principles, starting with the more simple ones. As has already been stated these may be varied almost at will, the essential forms being given wherever practicable. While a brief outline of the operation will be given, a close study of the diagrams will be necessary in at least part of the cases. The numbers which follow do not correspond with the numbers for the foregoing



summary.

1. Fig. 67. Simple tuned circuit with wave length

varied by adding more or less inductance to the antenna. The particular inductance indicated is known as a single slide tuner. The condenser in shunt about the detector increases the intensity of the received signal. While desirable, it may be dispensed with for short distance receiving. The coupling is fixed in this arrangement and while it is useful to bring a station to approximate resonance with the transmitter, close tuning or prevention of interference is not possible. In this and other diagrams the letter A denotes the aerial, G the ground, D the detector, C a fixed condenser, and T the receivers. L. represents the inductance.

2. Fig. 68. Same as before, except that a shunt variable condenser VC is provided. An increase of capacity of VC increases the wave length.

3. Fig. 69. Double slide tuner. Coupling of the circuit can be changed, but must be relatively close. Desirable where little interference is met with.

4. Fig. 70. Three slide tuner. Same as before, except that the coupling of the aerial and detector circuit can be varied to a larger extent. The position of the two circuits can be varied. Thus with the sliders including the detector circuit remaining a uniform distance apart, they can both be shifted up or down the turns of wire, while the ground slider remains fixed or also becomes changed. The relative positions of the aerial and detector circuits can thus be changed. The desired adjustment can only be found by trial and when once found should be noted before changes are made.

5. Fig. 71. Bridge. Three slide tuner with the detector circuit shunted around the terminals of the wire. Four or five slides would be better to use. When both branches of the divided circuit are maintained in a symmetrical condition the received impulses are *equally*

divided so that they have no effect on the detector. The arrangement is like a Wheatstone bridge, the detector corresponding to the galvanometer, and was devised by S. G. Brown. Now, to receive the desired signals, the ground contact is shifted to the right or left until the best position for the desired impulses is found. (See 8 of the foregoing summary.)

6. Fig. 72. Loose coupler, LC. Sharp tuning is possible because the coupling can be greatly varied. This is a very popular form of tuner, and while it derives its name from the fact that the secondary can be pulled away from the primary, the *heaviest coupling* is reached when the middle of the active primary turns is directly over the middle of the active secondary turns. When the sliding secondary is inserted farther in the primary after this point has been reached, the coupling again becomes loose. Since this form is best adopted as a standard because of its utility and comparative simplicity, its relations and pecularities will be more fully described. The following abridgement from an article in Popular Electricity by M. O. Andrews is of interest in this connection.

"1. Increasing the inductance of the primary increases the long wave length rapidly, but the short wave length is increased so slowly that it may be considered as remaining constant. The opposite is, of course, true when inductance is taken from the primary.

2. Increasing the inductance of the secondary increases both the long and the short wave lengths equally, or nearly so, and vice versa.

3. Loosening the coupling between the primary and secondary decreases the long wave length and increases the short wave length. Tightening the coupling increases the long and decreases the short wave lengths. In other words, its action is the same as the oscillation transformer of the transmitting set. As the coupling is loosened the two wave lengths approach the wave length to which each circuit is individually tuned, and as the coupling is closed the two wave lengths are driven farther from the natural wave length of the circuits.

4. Increasing the capacity in the primary circuit increases both wave lengths, and vice versa.

5. The variable capacity in the secondary circuit is used principally to put the secondary in resonance with the primary, thereby allowing looser coupling than would otherwise be possible. This allows atmospheric disturbances to be cut out to some extent without decreasing the audibility of the signals.

We have already observed that it is possible to hear a station radiating a double wave at two places on our tuner. In one case, we are in tune with the long wave and in the other with the short wave. We may also be in tune with both the long and the short waves at the same time. This is a decided advantage, as we will then receive energy from both waves, and the signals will consequently be much louder than when tuned to only one of the waves.

How may the different types of interference be avoided?

Case 1. When in tune with the long wave length of the transmitting station, there are four principle types of interference that we must dodge.

1. Another station may commence sending, whose long wave is of the same length as the one which we are receiving, but whose short wave is either longer or shorter than the short wave of the station from which we are receiving. For instance, suppose we are receiving from a station radiating waves of 1,500 and 500 meters respectively. We are tuned to 1,500 and 400 meters, and another station commences sending using waves of 1,500 and 600 meters. By referring to the effects of coupling on double waves we find that this type of interference may be tuned out by simply loosening the coupling which lowers our long wave length perhaps to 1,300 meters and raises our short wave length to 500 meters. The desired signals will then come in not on the long wave, but on the short wave, where there is no interference. If the coupling is loosened too much our short wave length will be raised to 600 meters, where the undesired signals will again be picked up.

2. While we are still tuned to 1,500 and 400 meters, and are receiving from a station radiating waves of 1,500 and 500 meters, another station may begin sending, using a short wave of 400 meters and a long wave, either longer or shorter than 1,500 meters. It may be tuned out by adding capacity to the primary circuit, which increases both wave lengths to 1,700 and 600 meters, then by loosening the coupling our long wave length is again brought back to 1,500 meters and our short wave length driven still farther from the interference at 400 meters. The desired signals will again come in on the long wave, but our short wave length has been raised to 800 meters, where it is comparatively safe from interference, as there are very few stations using wave lengths of from 600 to 900 meters.

3. Tuned as before to 1,500 and 400 meters and receiving from waves of 1,500 and 500 meters, we may get interference from waves 1,500 and 400 meters. In this case, we are in tune with both waves of the interference and the desired signals may be entirely drowned out. This may be overcome by simply

adding inductance in the secondary or capacity in the primary circuit, either of which raises both our wave lengths to 1,600 and 500 meters. We will then get our station on the short wave where there is no interference.

4. Under the same conditions as before, suppose a station begins sending, both waves of which are of exactly the same length as those of the station from which we are receiving. If there is no difference in the tone or intensity of the signals, we must wait our turn, as there is positively no way of getting around this type of interference. However, this is, fortunately, a very rare case and will not often be encountered.

Case 2. When in tune with the short wave length of the transmitting station, the types of interference are similar to those under Case 1, but the remedies are slightly different. One example will be given here, and the reader may work out the rest for himself.

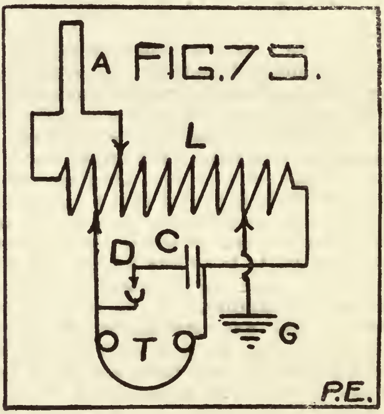
1. We are tuned to 1,500 and 400 meters, and are receiving from waves of 1,600 and 400 meters. Interference of 1,400 and 400 meters may be tuned out by adding inductance in the secondary circuit or capacity in the primary, either of which will raise our wave lengths to 1,600 and 500 meters. The desired signals will then come in on the 1,600 meter wave.

Questions now begin to come up. How can we tell to which wave we are tuned? This sounds well on paper, but in practice how are we to determine whether we are tuned to the long, to the short, or to both waves? Nothing could possibly be more simple. All we have to do is to add inductance to the primary and observe the result upon the intensity of the signals. If the signals are cut out altogether, we are in tune with the long wave, if the signals are not affected or are only slightly decreased in audibility, we are in tune with the short wave, and if they are not cut out entirely, but their audibility is considerably diminished, we are in tune with both waves.

Is it not possible to strengthen weak signals by these methods? It certainly is. For instance, suppose we are receiving from 1,500 and 500 meter waves and are tuned to 1,500 and 400 meters. If the signals are weak, they may be strengthened by first increasing the inductance in the secondary until we are tuned to 1,600 and 500 meters. The signals will then come in on the 500 meter waves. Then, by taking half as much inductance from the secondary as was added to it, and loosening the coupling, we become tuned to 1,500 and 500 meters and are getting energy from both waves and consequently stronger signals."

7. Fig. 73. Small stations will find it an advantage to use the series inductance in the primary circuit as shown when receiving from stations using long wave lengths. This corresponds to the use of a loading coil at the transmitter.

8. Fig. 74. Differential (Fessenden) Method. Two identical loose couplers connected as shown are used. The variometer is a form of tuner which will be described later, and a single slide tuner may be used instead. In operation the switch "a" is opened and the set is tuned to the desired signals. A is then closed and the variometer or single slide tuner adjusted until the signals are received the loudest. The condenser marked 5% must be



adjusted so that its capacity is nearly 5 per cent more than the other one. The interfering impulses are not in tune with either half of the circuit, so that they go through both sides very nearly equally. As in the bridge method, they become neutralized and do not affect the receiver.

9. Fig. 75. Simple loop aerial connection. Eliminates natural disturbances and short interfering waves. When a looped aerial is used it is used as an ordinary aerial for transmitting and a loop for receiving.

CHAPTER XVII.

CONSTRUCTION OF RECEIVING CONDENSERS. FIXED AND VARIABLE.

The discussion which has already been given for sending condensers applies, for the most part, to receiving condensers. The main difference is that the insulation for receiving condensers does not need to be so heavy because of the lower potential and currents used. The coatings of receiving condensers are, therefore, placed very close together so as to secure a large capacity in a small space. Air is used for variable condensers to a large extent because it provides a convenient dielectric which has no hysteresis losses. On account of the low dielectric constant, however, other dielectric materials, such as castor oil, mica, paraffine paper, and glass are used when large capacity is desired. The capacities necessary for the receiving circuits, however, are generally small. The laws for parallel and series connections as stated for transmitting condensers apply to receiving condensers as well, and as has already been pointed out a fixed and variable condenser can be used in parallel, the fixed condenser to approximate the desired capacity and the variable condenser to make up the difference. This is perhaps the most satisfactory and economical arrangement as large variable capacities are then unnecessary. In making fixed condensers, the proper capacity must be approximated, and can be calculated by the formulas already given for transmitting condensers. It is well to make several units which may be connected in or out of the circuit to secure a variable step condenser.

The proper capacity necessary for each set must be determined experimentally, though the approximate amount can be found by calculation. This is essential because of the variable quantities concerned, such as the other apparatus employed, the size of the aerial, etc., which is a different problem than when the transmitting condenser is calculated for a definite size and kind of transformer. The use of too little capacity can generally be told by the *weakness* of the received signal. Capacity should be added until the maximum sound is received. If however, an excess of capacity is used, the signals, will become muddy and indistinct. The capacity should then be lessened until the ragged sound disappears and is clear.

There are many suitable constructions for both fixed and variable condensers, the designs here described being those most generally used.

FIXED CONDENSER.

These are used as shunts around the detector or phones to increase the intensity of the received signal. When tuning inductances having adjustable coils are used, the secondary or detector circuit condenser can be of the fixed or fixed step-by-step type. A variable condenser is hardly necessary except in the primary or aerial circuit, and since it is more expensive, particularly in the large sizes, the step by step type is best to use in parallel with a small balancing variable condenser as has already been pointed out. Aside from intensifying the received signals, a condenser, if of the adjustable type, allows of fine selective tuning.

A convenient condenser unit which may be connected together with duplicate units or variable capacity to secure almost any capacity is made as follows:

CONSTRUCTION.

Obtain a good grade of bond paper about .004 or .005 (measure with a micrometer), of an inch thick and soak several sheets in a pot of clean melted paraffine until the air bubbles are driven out. When air bubbles no longer rise, hang the sheets up to dry and cut them into pieces 2 inches by 3 inches.

The coatings are made from tinfoil cut to pieces 1 5-8 of an inch by 3 inches long, and smoothed out by a roller as described for transmitting condensers.

ASSEMBLING.

Lay a strip of tinfoil upon a strip of paraffined paper so that 3-8 of an inch of one end of the foil projects beyond one of the long ends of the paper. Now lay a sheet of paper on top of this and again place a sheet of the foil, but projecting the 3-8 of an inch on the other end of the paper. Repeat, until the desired number of sheets and foil have been alternately arranged, six or eight sheets being a desired number. The foil should be arranged evenly between the paper, so that the margin on three sides is nearly equal. When done, the condenser should consist of alternate layers of foil and paper with every other foil projection on an opposite end of the paper. Now place the assembled condenser between two temporary boards and a clamp and squeeze together under the influence of heat. This may be accomplished over a hot air or steam register or open oven which is just hot enough to soften the paraffine of the paper sheets. Tighten up the clamps and remove them after the wax cools. The two sets of connecters are then soldered or clamped to a conductor of stranded copper wire, and may be mounted in almost any desired manner. The condenser used as a detector shunt may be mounted in the base of the detector stand. Switches should be provided for connecting several of these units in series, parallel, or series multiple. About three of these units in parallel will be the right amount for the chopper condenser of the continuous wave receiving set, while a single unit will suffice for most of the secondary or detector circuits. *Test* as described for the transmitting condenser. The condenser should hold the battery charge for some little time and should be capable of discharging through the telephone receiver with an audible click several seconds after the battery terminals have been disconnected from it. It is seldom that this kind of condenser is burnt out or injured, so that once made, it is practically permanent. The primary condenser for the spark coils already described is built in the same manner, except that the larger dimensions given are used. A shunt condenser around a telegraph key used for sending, should have a large capacity similar to that used around the vibrator contacts of a coil. Paraffined tissue paper such as is used to wrap eatables and instruments may be had ready paraffined and is desirable because of the uniform thickness. The condenser can also be assembled by applying the foil to the paper while the wax is still soft and warm, making the after-warming and pressure unnecessary.

KORDA AIR CONDENSER.

This type of variable condenser is in general use for wireless receiving sets, wave meters, and is particularly desirable in the primary or aerial circuit for tuning purposes. Fine adjustment is possible and when properly made there is little or no loss in the condenser. The construction is somewhat difficult, however, but since the plates may be had already cut and smoothed, the main

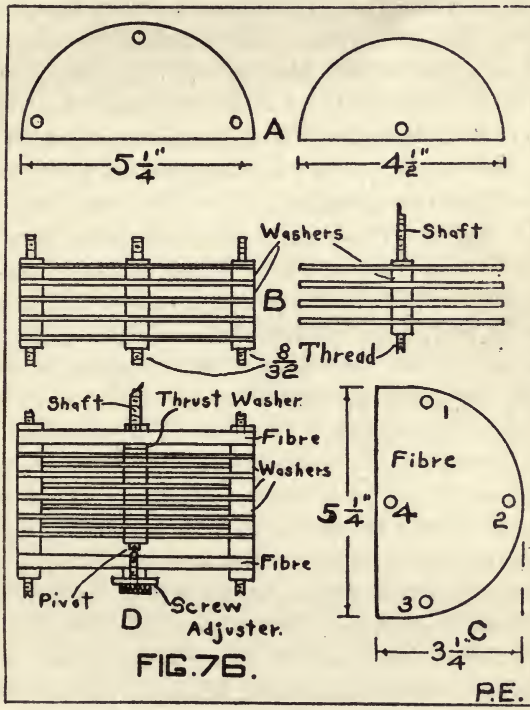


FIG. 76.

difficulty is limited to the arrangement of the plates. It is not necessary to use a large number of plates provided the arrangement with a parallel step by step condenser is adopted. Such a step by step condenser should not have more than one or two sheets of foil and dielectric to each unit or step and the switch contacts used, should be good and well cleaned.

The plates used should be of brass or aluminum of about No. 20 B&S gauge and since the cutting is difficult to do by hand, they are preferably purchased already stamped from supply houses or else turned out in a lathe by a machinist. It is essential that the plates be perfectly flat and even. The number of plates used need not be more than four or six if a fixed condenser in parallel is also used, but if the condenser is to be used alone, from twenty-four to twelve plates should be used. This is for the larger or stationary plates, one less being used for the rotary plates. Five fixed and four rotary plates make a convenient size for a variable unit.

The five fixed plates should be semi-circles 5¼ inches in diameter and the rotary plates of which four are needed should be 4½ inches in diameter, as these are standard sizes. It will be understood that larger units may be made in the same manner, using more plates. The several details are shown in fig. 76. The five large semi-circles should be placed together and three 5-32 in. holes drilled near the edge as shown at (A). The four small plates are placed in the same manner, except that only one 5-32 inch hole is bored as shown.

Obtain brass or copper washers 5-32 inch thick, 3-8 of an inch in diameter and with a 5-32 inch hole at the center. These may be had at a supply house or hardware store. Also obtain some 5-32 inch brass rods.

ASSEMBLING THE ROTARY PLATES.

The plates are assembled after the holes have been smoothed and burrs removed, by passing a piece of the 5-32 inch rod alternately through a plate and then a washer. The ends of the rod should be threaded with an eight thirty-two die and the rod cut so that a short extension is left beyond the plates for a handle. The plates are held together on the rod by two threaded washers or nuts ½ inch in diameter and 9-32 of an inch thick. The nuts should be turned tightly so that the plates can not move after they are placed in alignment.

ASSEMBLING THE FIXED PLATES.

A similar plan is used with the fixed plates, a rod being inserted in each of the three holes, and threaded 8-32 at the ends as before, care being taken to keep the plates in alignment. The washers between the plates are placed at all three positions. A longer extension should be left on these rods for fastening purposes. The appearance of the assembled plates is shown at (B) of the figure.

Obtain two pieces of fibre 3-16 of an inch thick and cut out two pieces with the shape and having holes as shown at (C). The holes 1, 2, 3, correspond to the holes of the large plates, and the hole 4 is bored so that when the shaft of the movable plates is in place in it and the fibre is assembled on the rods, the brass washers of the movable plates will not touch or make contact with the fixed plates. This is important, as a short circuit would result otherwise. About ½ inch will be sufficient extension for this hole. The lower fibre piece is held in place on the rods by 8-32 nuts. It is preferably spaced a little distance from the lower plate by washers. The upper fibre piece is similarly placed after the plates have been placed in position.

ASSEMBLING AND MOUNTING.

The assembled plates must not rub or touch each other and must be brought into alignment, the adjustable screw bearing at the bottom shown at (D) being a suitable means. The rotary plates can be raised or lowered by this arrangement. The condenser may be suitably mounted in a box or case, and the connections, one from a washer on the fixed plates and one from a brass strip or brush bearing on the rotary shaft near the top, may be brought to binding posts. The excess length of the rods can then be cut off, and a handle provided for the rotary shaft. A scale and pointer can also be arranged on the cover, to suit. Electrose or composition knobs such as are used for typewriter platens (obtainable at supply houses) make good handles for this purpose. The scale may be calibrated by comparison with a known standard, using a wave meter, or may be arbitrary, using equal divisions. A brass protractor such as is used by draughtsmen may be had for a few cents and makes a convenient scale. The pointer can be cut out of a strip of brass or aluminum. Two or more of these units may be mounted in a common case or box and switches provided for changing the connections. Moving washers are preferably provided at the upper bearing to take up the thrust, so that the condenser may be used in any position.* When neatly carried out this type of condenser will be of business like appearance as well as operation.

MAKESHIFTS.

It is often desired to have a simple makeshift variable condenser for experiments. Almost any two conductors

* A horizontal position for the axis is not desirable.

in any shape separated by any dielectric, so that more or less surface may be brought into relation to form capacity, are suitable. Such common things as tin cans may be utilized, the insulation being provided by using paper or even a coat of shellac or asphaltum. A can painted in this manner and suspended so that its height in a jar of salt water can be altered, connections being made to the can and to a plate inserted in the solution, is suitable, provided that every part of the exposed surface is covered by a thin coat of the insulating varnish. Sliding plates similar to those described for a variable sending condenser may also be used. Two tin cans having diameters so that one just slides into the other after a layer of paper has been shellaced on the inner or sliding one may be used. Similar arrangements will doubtless suggest themselves to the reader and if carried out carefully may serve quite well. The series capacity used in the aerial circuit should have a comparatively large capacity. This is best obtained by using a fixed and a variable capacity in parallel, in which case a makeshift arrangement carefully constructed will generally have sufficient capacity to make it of considerable use.

The Korda condenser described is desirable, however, and if immersed in a can of transformer or castor oil, preferably the latter, its capacity will be considerably increased. (See chapter on the calculation of capacity). The maximum capacity of such a condenser is readily calculated when the area is taken by using the formula.

Area of a circle $= 3.1416\ R^2$ taking the radius R for the rotary plates, and dividing by 2 to find the area of the half circle.

CHAPTER XVIII.

CONSTRUCTION OF TUNING INDUCTANCES. LOOSE COUPLERS, VARIOMETERS, TUNERS.

GENERAL REQUIREMENTS.

Whatever type of tuning is adopted, the inductances used should be *carefully* constructed with accurate and delicate adjustments. Every part should be nicely made and great care taken with the *insulation* and contacts. The cores and ends used are preferably made from hard rubber, fibre or molded composition, but wood and paper when dry and carefully shellaced may be substituted. The wire used should be uniform, and may either be bare or insulated. Bare wire is spaced by means of a thread or a groove cut into the core, while insulated wire is separated naturally. Contact is best made when bare wire is used. Enameled wire is neat and useful since a contact portion is readily scraped from the wire. Cotton and silk insulations are difficult to scrape for contact with sliders, so that the job is neat and effective. The only objection to enameled wire seems to be that the turns are brought too close together, so that an undesirable electrostatic capacity is formed between the adjacent turns. Wood may be used for bases. All metallic parts including connecting wires should be carefully insulated from each other and even from wood, by using hard rubber sheeting and tubes. In receiving delicate and minute oscillations from distance stations, every detail counts for efficiency and too much care cannot be taken if the maximum results are desired. Holes are preferably filled up with tar or wax, and shields provided to prevent injury or leakage to or from the wires. In the following designs, descriptions will be given for inductances of standard design and merit and while there are varied forms for the detailed constructions, and much ingenuity can be exercised, the main dimensions and design should generally be adhered to, to secure efficient instruments.

TUNERS, SLIDE TYPE.

This form is commonly employed for tuning, bridge, loading, and similar methods as has already been described. While only one slider is described, it will be understood that duplicate sliders can be provided on other parts of the circumference of the core and wire It is well to provide binding posts for the wire terminals in every case so that a variety of utility is the result. (See fig. 77.)

Core. This may be turned out from hard wood, but since wood shrinks, a rubber, fibre, composition, or even a shellaced paper tube is much prefered. Suitable tubes may be had from supply houses. Paper or fibre tubes can be made by rolling up and gluing a sheet of the thin fibre into the desired size. Hollow tubes have the additional advantage of light weight. The diameter of the tube may be any convenient size between 2½ inches and 6 inches, the smaller diameters providing sharper adjustment. 3½ inches is a desirable diameter. If bare wire is to be used on the fibre, rubber or composition tube, it is very desirable to turn or have a machinist turn a thread on the core. About 18 threads to the inch makes a suitable thread for use with No 22 wire, which is a common size in favor. The threads can be cut to within ½ inch or so from each end. The length of the tube used may be from 3 inches to 12 inches or more as desired.

The winding. Use soft copper wire of not more than No. 24 in fineness, nor less than No. 18 in coarseness, No. 20 or 22 being preferred. The winding can be done by hand if care is taken, but a lathe or makeshift lathe

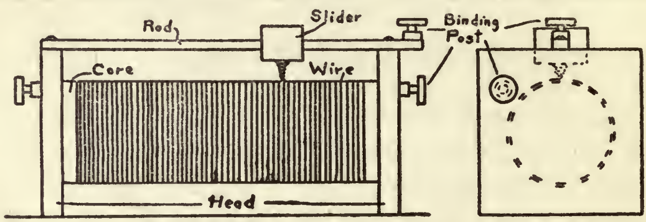


FIG. 77.

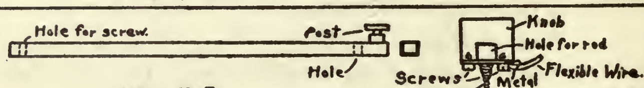


FIG. 78.

is best to use. The wire should be wound tightly and evenly, avoiding kinks. When the core is threaded, this is easy. If bare wire is used without threading the core, the turns should be spaced by winding the wire with a turn of heavy linen thread, so that each turn is spaced by the thickness of the thread and the adjacent turns of wire do not touch each other. Enameled wire is wound without spacing. Cotton or silk insulation is not recommended for wire for tuners of this type. The bare wire is preferred. Then ends of the wire can be fastened by means of a small hole drilled at the end of the core or else by means of a small screw. If hard drawn copper wire, such as may be had at hardware stores, is available, it is preferred as it is more durable and easier to wind.

CORE ENDS.—BASE

While the core ends must be of a size corresponding to the diameter of the tube used, which may vary from 2 in. to 6 in, a margin should be provided to allow for clearance from a base, sliders, and so on. The ends are preferably square and may be easily fastened to the cores in any desired manner. For solid wood cores, wood screws may be used. Tubings are best fastened by turning a recess in the inner end of the core end which will fit over the tube snugly. Another method is to provide plug ends for the tube, which are then screwed on the core ends. When assembled, the tuner should set true. The use of a base is optional and is hardly necessary, except for appearance and possibly convenience. The binding posts can be brought out on the core ends.

SLIDERS.

(See fig. 78). These may be any suitable type which will make a step by step contact with the several turns of wire without undue friction. The slider rods are preferably of square or rectangular shape, as round rods must be used doubly to prevent undesired turning. The rod is cut as long as the length of the core plus the thickness of the core ends, which should not be over ¾ inch, plus a little extra for connections or a binding post. While only one form of slider is shown, to avoid unnecessary duplication, it will be understood that many other forms may be used. The essential feature of sliders is that they should make *good contact* with only *one turn* of wire at a time and without too much friction. If the slider touches two turns at once (which will happen if care is not taken), the turn is short circuited. This is not desirable as the intensity of the received signals is thus lessened. The spiral spring shown can be coiled from No 22 spring brass, and a round piece of copper wire smoothed off to a round surface is soldered on the tip. The length of the spiral should be enough to make contact with the wire after the slider is in place. While connection with the slider can be made through the rod by the sliding contact which results, this method is not desirable and a flexible insulated wire is best soldered directly to the slider. The knob is for convenience in handling, and can be made from hard rubber or purchased already molded. Sliders and rods may be had in the open market. The slider should slide on the rod without sticking. Loading coils may be made without sliders, by taking taps off from every ten or twenty turns and using multi-point switches. The wire when wound on smooth forms should be coated with two coats of shellac and allowed to dry. The portion for contact is then scraped clean for a distance along the length of the coil and under the slider, of about ½ inch. This may be accomplished by using a knife or a small block of wood covered with emery cloth. The wire should be scraped until it shows clean and bright. Two wooden strips may be temporarily fastened on the core the desired distance apart to serve as a guide so that the scraped portion will be of uniform width. If several sliders are used, two may be taken from the top or one from each side, or all, as desired. The use of bare wire wound in a threaded tube core is best adopted for a standard, the diameter being 3 inches and length 10 inches, as this will give a serviceable instrument with a wide range of utility. Wires wound on smooth cores or wood cores, particularly enamelled wire, tend to loosen after a time, in which case it is best to either rewind the coil or make a new one.

VARIOMETER.

A variometer is a form of tuner without any sliding or variable contacts and depends solely on the variable coupling between its two parts which are connected together. It is quite easily made and is very useful in

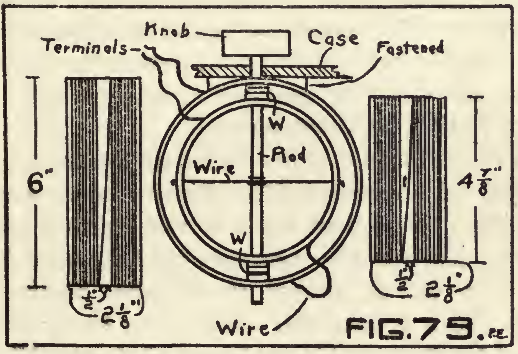


FIG. 79.

connection with other apparatus, particularly as a loading coil. It may be used alone for short wave lengths.

A suitable construction is indicated in fig. 79. The cores are of hollow fibre, rubber, composition or paper and may be made as has already been described. One core (the stationary core) is 6 in. in diameter and 2 1-8 inches wide, while the inner and movable core is 4 7-8 inches in diameter and 2 1-8 inches wide. The larger core is wound with about forty feet of No. 22 insulated wire, so that a space of ½ inch is left at the center. This will make about 24 turns on each side of the space. The small core is wound in the same way, except that 28 turns are wound on each side of the space. Both parts of each core should have the same number of turns.

¼ in. holes are now bored or punched, at opposite points of the two cores, in the center of the ½ inch bare band, for a rod. This rod is a piece of ¼ inch round brass 7½ inches long, and is passed through the holes as shown in the figure. Now take a piece of No. 18 bare wire about 5½ inches long and fasten it as shown, soldering it at the center to the ¼ inch rod and bringing the ends through the small core. This is to make the inner coil fast to the rod so that it may be rotated. Rubber or fibre washers (W) should be placed as shown, so that the inner coil is free to rotate within the outer coil. The two coils are connected together as shown with a short length of flexible insulated wire.

Mounting. This may be carried out as desired, a box 6½ inches cube being suitable. Binding posts should be provided and connections made so that starting with the end of one coil, the wire continues until the opposite end of the other coil is reached at the other binding post. A knob with a pointer and a scale may be provided as described for the variable condenser of chapter 17. Use like a tuning or loading coil. When at right angles the two coils are neutral, while when concentric the closest coupling adjustment is reached. About 75 feet of the wire will be needed. The coils may be shellaced and the instrument finished as desired. In mounting the instrument, the outer coil is fastened rigidly to the case or cover so that only the inner coil is rotable.

LOOSE COUPLER.

The loose coupler is in general favor at the present time, as with it and condensers, a wide variety of tuning and coupling is possible. The set can be tuned to either the long or short waves or both and when the maximum point is found the interfering stations can often be tuned out by making the coupling very small. (That is, pulling the primary far away from the secondary or vice versa.) The following design and data is for one of these instruments and two will be required if the Fessenden differential method is employed. (See fig. 80.)

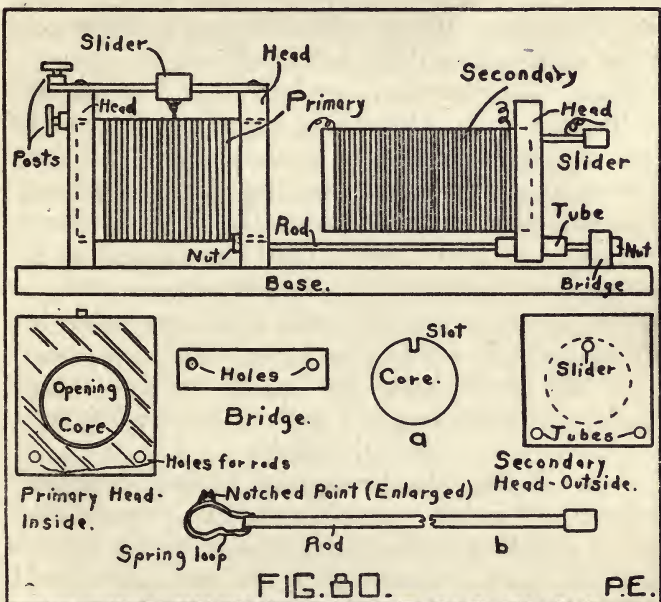


FIG. 80.

PRIMARY.

Core: Insulating tube 3 inches in diameter and 4 5-8 long. The wall should not be more than 1-8 inch thick. Wind as directed for tuner, using either No. 20 or 22 B&S gauge bare or enameled wire, preferably the former, in threaded grooves. Start winding 9-16 of an inch from one end and wind until within 9-16 of the other end.

Heads for Primary. ½ in. thick, 4x4½ in., smoothed on all sides. Find the center of each piece (two needed). These pieces are now centered in a chuck in a lathe so that the lathe center is ¼ inch below the marked center of the pieces. One piece is made with a hole 3 inches in diameter through it, while the other piece is only bored, with this same size, to have a depth of 3-8 of an inch. When done, one piece will have a hole 3 inches in diameter through it while the other will have a smaller hole coming within 1-8 inch of the other surface.

Base. Three-fourths of an inch thick, 6 inches wide and 16 inches long. (Hardwood.) Mount the primary at one end so that it sets true and is nicely spaced, using screws driven from the bottom of the base into the heads, the screws being countersunk. A single slider may now be provided, as shown and as has been described for tuners. It is understood that the primary core with the winding, is mounted in the heads, using cement, so that the core and wire are held in the openings in the heads and so that the head with the hole all the way through it faces toward the long end of the base. (See figure.)

SECONDARY.

Core. Hardwood cylinder turned from dry wood.* Diameter, 2½ inches. Length, 5 inches. (See fig. 80.) Have a machinist mill a slot 3-16 wide by 3-8 deep as shown at (a) the whole length of the core. This should be smooth when done. Inasmuch as bare wire is to be used, it would be well to have threads turned on the cylinder before the milling is done. These should be 20 to the inch, and very light. Wind with No. 26 B&S hard drawn copper wire. Threads may be used, spacing the turns with linen thread, if the machine threads cannot

* A hollow tube may be used if a frame is provided for the slot.

be cut. Use considerable pressure in winding, as the contact is to be made from below. The linen thread used should be about as thick as the wire used. Start ¾ inch from one end and wind to 3-8 inch of the other.

Head. One needed. ¾ inch stock, cut 3¾ inches square with a hole bored in center to a depth of 3-8 of an inch. This hole is 2½ inches in diameter and is turned as before.

Attach the head to the secondary core at the ¾ in. end by small screws started from the back of the head and screwed into the core. The secondary *slider* is made so that more or less wire is included in the circuit when the rod (See b) is moved in or out, and allows of adjustment after the secondary is within the primary coil. This slider is made from a piece of 5-32 inch brass rod, 7 inches long, to one end of which a small loop of thin spring brass 5-32 inch wide, is soldered, as shown. A rounded point is then soldered on the upper part of this spring to make contact with a single turn of wire at a time. Note the notch. This is made by a few strokes with a fine three cornered file. A handle is provided at the other end of the rod. The slider is mounted in the milled slot and extends through the head through a small hole.

MOUNTINGS.

The mountings are shown clearly in the figure. Binding posts should be provided and flexible insulated wires should be brought to the slider rods. The inner end of the secondary coil can be brought to the back by either boring a hole through the cylinder or else making a groove in one side of the milled slot so that the wire imbedded in it cannot possibly make contact with the slider. Both ends of both primary and secondary should be brought out to binding posts. The two pieces of tubing which act as bearings to support the secondary have an internal diameter of ¼ inch and are 1½ inches long. They are forced into holes drilled in the secondary head. The rods on which the secondary slides are 10½ inches long and are supported as shown, one end being fastened by passing through holes in the inner head of the primary and the other end being fastened to a small bridge fastened to the base. The latter is 1x1x4 inches long. Small nuts serve to hold the rods in place. The coils should be mounted so that the secondary will slide freely into the primary. The remainder of the instrument is left to the individual worker and presents no difficulty. Provided that the general dimensions are preserved, any suitable mounting may be used. In using two of these with a Fessenden interference preventing circuit, the condenser marked 5 per cent must be calibrated so that it is always 5 per cent different in capacity than the other one. This may be accomplished by arranging the scale on this capacity so that when the pointer is on zero, the condenser will really be in mesh to approximately 5 per cent. This need only be approximated.

A receiving loose coupler can be made on the pancake plan using two flat spirals of wire, one of which is adjustable with respect to the other, as for the transmitting oscillation transformer. The spacing, however, is accomplished by using a thin insulated wire strip such as is used for transformer coils, and the turns can be close together on account of the low potentials used. Such an arrangement has very little if any advantage over the loose coupler described, particularly if a variometer is also used, so the duplicated description will be omitted. The method of using the apparatus described has already been fully set forth.

The reader with limited tools can, of course, make a simpler arrangement. It is possible to make tuning instruments with little or no facilities and tools.

CHAPTER XIX.

CONCLUSION. THE RIGHTS OF THE EXPERIMENTER.

The completed receiver, of whatever type adopted can all be mounted together if desired. In any case the connections used should be of stranded insulated conductors, kept free from each other, well insulated from wood and other matter, the switch contacts clean, and so on. The descriptions have been made as clear and concise as possible, though the details have been purposely left to the individual in many cases where the design is optional. Such items as cases, boxes or mountings are well within the limits of every reader, and even in the other apparatus and parts considerable ingenuity may be used. Duplication of apparatus has been avoided wherever possible, though in some cases all forms have been described. The author believes that when one piece of apparatus will do the work of two, there is little use in using two. Every piece of apparatus should be made with care and should always be understood. Learn to *know* your apparatus, master its peculiarities, note the good and bad adjustments, always be on the lookout for possible phenomena, and keep a record of your experiments. While the apparatus described is intended particularly for stations it can be easily made portable. Stations may be readily set up on small boats, in the field, camp, and so on. There is hardly a limit to the use to which a wireless set may be put.

The experimenter generally plans to receive over a much greater distance than he expects to send. Indeed, with the present network of high-powered stations, there are few readers who may not do long distance work with even simple apparatus. The new Arlington station, for instance, should be heard by every experimenter within 1,000 to 3,000 miles under favorable conditions. It is surprising to learn what can be done with even home made apparatus. A list of wireless stations may be obtained for 15c by addressing the Superintendent of Documents, Washington, D. C.

If you have not already done so, join a local wireless club. Nearly every locality has one or is forming one and there is little or no expense attached. If you have not yet learned a code, start now. The continental code is in general favor and it is well to master it first. There are so many messages which can be read with a simple receiving set, that the code can be mastered in a short time. In practice, it is well to start with the letters first, then with short words, and finally with simple sentences and paragraphs. The average person finds it much easier to send than to receive. Acquire a free, easy and clear movement in making the dots and dashes. Speed is a secondary matter, as it will come with practice. It is worth while to keep a record of all messages in a small note book.

THE EXPERIMENTER'S RIGHTS.

All of the leading countries have laws regulating radiocommunication. The wireless law enacted on December 13, 1912, makes the following restrictions upon experimenters:

1. The law recognizes the experimenter, gives him rights, and licenses are to be given provided that,

2. The experimenter does not use a wave length over 200 meters long for transmission nor a greater power in either a coil or transformer than 1 K. W., if he is farther than 5 nautical miles away from a government station, or not more than ½ K. W. if he is within 5 nautical miles of a government station.

3. Experimenters having apparatus which is not powerful enough to transmit farther than the boundaries of the state in which the station is situated, and which cannot interfere with the reception of signals from outside the state, need not take out a license unless they desire to do so. This means practically that if you live in the heart of say Texas, you may use large power without license provided, stations in other states cannot hear you, but if you live near the border of another state you must use very weak power or else obtain a license.

4. It is not necessary to have a license for a receiving station only.

5. If the experimenter wishes to use a high wave length or high power, permission will be granted by the Secretary of Commerce and Labor, upon proper application, provided the applicant shows cause why the additional power and wave length is desired.

6. The operator is required to preserve the secrecy of all messages sent or received upon the penalty of a fine and imprisonment.

7. The experimenters must use sharp and pure waves.

8. The penalty for sending a false message of any kind will be a fine up to $1,000 or imprisonment up to two years or both. (Distress signal, $2,500—5 years.)

9. The operation of wireless instruments for either sending or receiving except as before stated, without a license, will be punishable by a fine of not more than $500 and the forfeiture of the apparatus. This does not apply to receiving apparatus only.

These are simple, boiled down accounts of the main requirements and provisions of the law as far as the experimenter is concerned. Information will be furnished by the Secretary of Commerce and Labor, without expense, upon your request.

The licensing is free and even advantageous to experimenters. The apparatus described in this book will enable the reader to comply with every feature of the law without difficulty, provided that the aerial used for transmitting purposes is not made longer than 70 feet by itself,* allowing for lead-ins to make up the remainder of the effective length. The plan of using a duplex aerial will be found particularly valuable in accordance with the law, so that long distance messages may be received. The two aerials should be placed at right angles to each other if possible in order to avoid unnecessary absorption of the transmitted energy. There is no cause for alarm over the new law.

The Department of Commerce and Labor has formed certain rules and regulations which must be adhered to. Administration districts have been established, with offices at the customhouses. Classifications have been made for the purpose of administration. Full particulars can be obtained gratis by addressing the Commissioner of Navigation. The first thing to do is to write for forms No. 756 and 757. Full instructions will be sent at the same time. There will not be any difficulties in obtaining a license, but it is imperative that you apply for the license at once.

PATENTS.

While most of the wireless apparatus is covered more or less completely by patents, the experimenter need have no concern. While the experimenter is legally an infringer when he uses patented apparatus without permission from the patentee, it is generally recognized that experimenters may use patented articles for purely noncommercial purposes without liability. This educational idea seems to be so fixed that even manufacturers and dealers in patented experimental goods not made under license or permission of the patentee, are for the most part perfectly safe, since the patent rights are seldom pushed into this realm. The author feels a little on the subject and certainly does not advise the open and wilful infringement of patents, but also believes that for educational and experimental purposes where no commercial

* This allows a height of 50 to 70 feet for leads, etc.

profits are realized from such use, the use of patented articles is recognized as legitimate in effect if not in the legal sense. The readers need have little concern on this points as long as they do not make or sell or rent the apparatus for commercial gain. Even then, if in moderation, it is not likely that there will be any great difficulty.

While there is a large field for improvement in the new art, the reader is not advised to take out or apply for patents unless he is sure that the device has merit, is a real improvement, and is needed, as otherwise failure in one form or another will generally result. There are at the present time something like 1,500 or 2,000 patents in full force which cover wireless apparatus and systems. While a part of these are useless and obsolete, it is not unlikely that the very improvement you have in mind is embodied in one or more of these, so that it is well to have a search made into the records before spending money for applications, models, etc. This is not intended to discourage but rather to encourage in the right direction. The author has treated the matter of inventions and patents quite fully in another volume which is soon to be published.

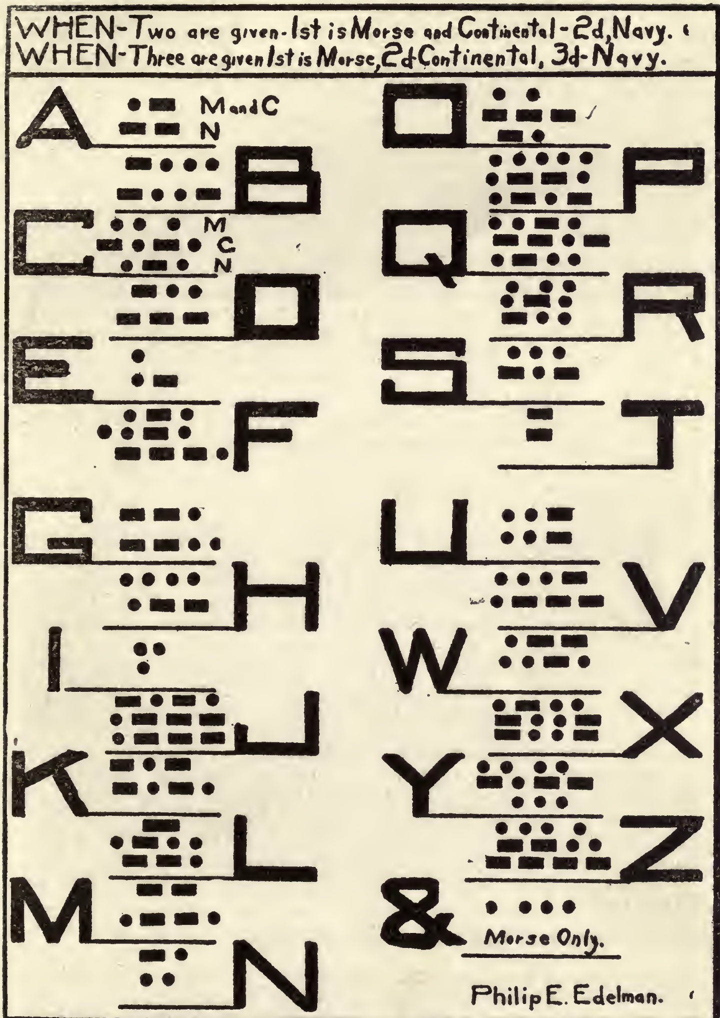
In conclusion it seems well to remark that the present tendency in the art is toward the permanent establishment of large chains of powerful land stations employing directive aerials, the simplification of ship, train, and portable stations, the use of long wave lengths for large power radiation, the employment of high pitch musical tones for transmission, the transmission methods which make reception inaudible except when the principle of beats is employed at the receiving station, the use of amplifiers to increase the effective intensity of the received energy, and a beginning toward early standardization. Among the new developments some brief mention of the Edelman Differential Wave System will doubtless be of interest. Experiments by the author have already shown that all of the common disturbances—undesired signals as well as atmospherics—do not interfere with this system. The promising experiments with pin point gaps, liquid transmitters, stepped-up-frequency-alternators, and low aerials also deserve to be mentioned.

The reader will do well to continue with the study, as much interesting and useful material of an advanced nature is to be had.

And so, we come to the end of the book but, it is hoped,

Only the Beginning of a Study of the Wonderful New Art.

WIRELESS CODES.



Note: The Navy code has been superseded by the Continental code, and is no longer used.

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1916 SUPPLEMENT.

AUTHOR'S NOTE.—Previous editions of Experimental Wireless Stations have been distributed to and welcomed in all parts of the world. Thousands of readers have been kind enough to say that they have gained much from the book. Many, indeed, have voluntarily sent photographs and descriptions of their success after following the directions. The book has won on its merits and has attained a wide influence.

The radio art is still in the process of evolution. Experimental work continues to keep well ahead of commercial practice. What appears wonderfully important today may be of only historical interest tomorrow. Still the fundamental principles remain. Behind the novel forms of commercial apparatus continually brought out and inside of the nicely polished boxes you will find the same coils, condensers and simple apparatus described in this book.

The present supplement aims to append notes which will bring the book right up to the present time. Much of the material here presented has not been published before in any form. Attention is called to the patent index, which demanded considerable expense and labor from the author. It should, however, save the readers much time and money. Copies of the patents may be found in all large public libraries or can be purchased for 5 cents each. They are the key to the art, and often a single paper will contain all that is known about a particular subject.

CONTENTS.

1916 SUPPLEMENT.

RAILROAD WIRELESS.

Railroad wireless telegraphy and telephony differs in no way from radiocommunication for other purposes except that the aerial consists of two or three wires suspended just a little above the train car while the ground is through the trucks to the rails. Couplings are provided for the aerial between cars. The Delaware and Lackawanna Railroad has had much success with such moving stations in conjunction with a few fixed land stations and communication is regularly established with the moving trains both ways, even when the train is passing through a tunnel.

AUTOMOBILE WIRELESS.

Successful communication may be established over several miles with a small wireless station on an automobile, using a small aerial suspended a few feet above or within the top and using the metal body of the car as a counterbalance in lieu of a ground. For army use, the automobile is merely used to transport and contain the apparatus and a portable aerial is rapidly erected when communication is to be established.

AEROPLANE WIRELESS.

Wireless communication is successfully used on aeroplanes to communicate to military bases from the air or enemy territory. The apparatus comprises a small sending and receiving station of light weight. The receivers are provided with sound protectors but receiving is less successful than sending because of propellor noise. The aerial is generally mounted on the planes and a counterpoise or additional aerial is used instead of a ground. Hanging aerials from reels, etc., are considered dangerous and obsolete. The total weight of the equipment need not be over 50 pounds. Use of the wireless to direct gun fire and report troop movements has been tried with some success.

WIRELESS COMPASS.

The Bellini and Tosi compass, of which a very few made by the Marconi Co., are at present in use, utilizes an almost closed triangular oscillating antenna which radiates and also receives the strongest in its own plane and the least at right angles thereto. Two partially closed looped aerials are placed at right angles to each other and each is connected to a primary of a loose coupler having two primaries at right angles to each other and a single secondary winding which is rotatable therein. For any position of this secondary winding the received energy will be proportionately due to the two primaries so that by observing when the received signals are strongest the sending station can be located within two or three degrees. This is most useful in foggy weather. For sending the same arrangement is used with a transmitting oscillator connected to the two aerials in the same manner so that signals can be sent out strongest in a desired direction. International radio regulations require such stations to use small power and low wavelengths, this being necessary in order to avoid interference with other communications.

The set uses no ground connection and is shown in figure 82. The aerials A, B, respectively are connected to the primaries A′, B′, respectively of a loose coupler

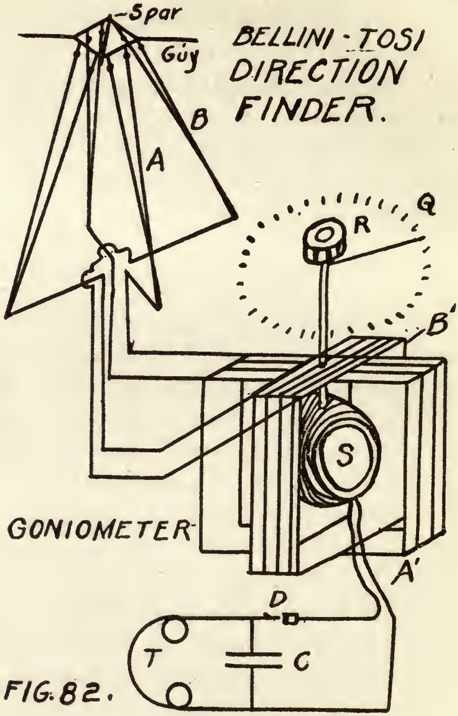


FIG. 82.

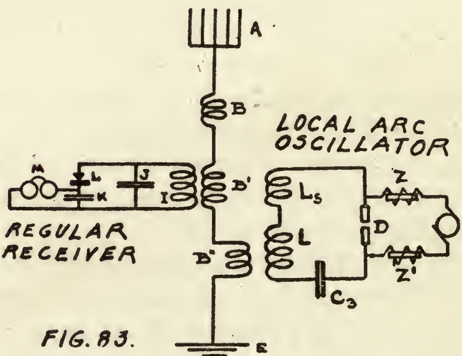


FIG. 83.

HETERODYNE RECEIVER

called a goniometer. The secondary S, wound on a spherical core connects to an ordinary detector circuit and is movable by means on handle R which carries a pointer so that degrees may be read on a scale Q. In practice a slightly elaborated arrangement is used. For purposes of demonstration it is not difficult to rig up an outfit of this kind.

With the Telefunken compass an ordinary antenna on a ship may be used in conjunction with shore stations. Thirty-two separate aerials arranged in the form of an umbrella are used at the shore station for sending, a rotatable switch being provided so that each antenna may be separately and successively connected to the sending apparatus. Aboard the ship the direction is determined by comparing signal strengths. Various other arrangements have also been proposed but none appear to have come into use up to the present time.

HETERODYNE RECEIVER.

This receiving method originated by R. Fessenden permits the tone of the received signals to be varied at will, thus aiding in overcoming interference, and also slightly increases the sensitiveness of the received signals. It consists (Fig. 83) essentially of an ordinary receiving set which is coupled with a local miniature sending set such as an arc or audion high frequency oscillator. If for example the incoming signals have a frequency of 300,000 and the local oscillator is adjusted to a frequency of 300,516 the interaction sets up beats by interference which give a musical tone of 516 frequency in the head receivers. This method is particularly useful for reception from undamped wave stations but may also be used with spark oscillations.

TELEMECHANICS.

Wireless controlled torpedoes, boats, fog guns, etc., have been successfully experimented with so that applications may be expected to come into use soon. Most of this work has been done with the use of a coheror receptor and various mechanical switch and tuning arrangements. It is now possible, however, to use the more sensitive audion and amplified circuits already mentioned for this purpose. A simply made outfit for demonstrating the various possible applications is described in chapter 13 of the book "Experiments" by the author which may be obtained for $1.50. Reference to the patent index in this supplement will give the reader the key to the results of previous workers on this subject.

BALANCING AERIALS.

The new Marconi duplex stations are to use a balancing aerial at the receiving station to overcome interference from the sending end of the station a number of miles away which is in simultaneous use. This is simply an aerial placed at right angles to the receiving aerial and of lesser height which is coupled to the main aerial through a loose coupler in such a way that the energy received by the one aerial is neutralized by that received by the other from the strong nearby station. The large aerial receives the long distance signals as usual but the balancing aerial being both lower and at right angles does not receive enough energy from the distant station to deter the reception of signals therefrom. A single horizontal wire suffices for the balancing aerial.

GROUND AERIALS.

Experiments with grounded aerials show that signals may be received for distances of at least 3,000 miles with an ordinary receiving set by simply using a bare or insulated wire spread upon or supported a few feet above the ground as an aerial with a counterpoise. A single wire has been found to be the best especially if a Y is connected to its ends and such an antenna has also been found to be directive. The counterpoise is best made exactly like the aerial and arranged opposite it so that the receiving set is at the middle of a symmetrically placed conductor adjacent to the ground. For sending purposes such an arrangement has not been found effective except over a short distance.

RADIATION RESISTANCE.

This term originated with J. S. Stone and means the equivalent resistance which would consume the same energy as that withdrawn from the sending antenna by radiation. It is often used and according to R. Ruedenberg is approximately equal to

$$\frac{1{,}600\ (\text{height from earth to center of capacity of antenna})^2}{(\text{wave length})^2}$$

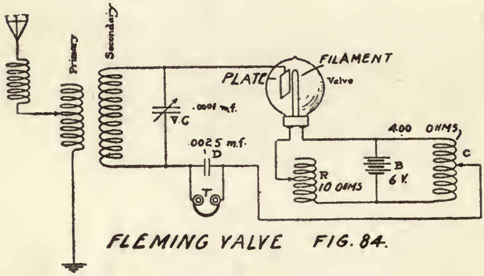
ohms, the meter being the unit of length.

VACUUM VALVES—AMPLIFIERS, DETECTORS, AND OSCILLATORS.

Recently vacuum valves have come into general use for detecting and amplifying signals. There are several types of these bulbs, all of which depend substantially on the same operating principles, the difference being in the details of construction and degree of vacuum employed.

FLEMING VALVE.

The Fleming valve, one of the first of these, consists simply of a miniature electric light bulb with a filament and a metal plate near it as shown in fig. 84. In use,



FLEMING VALVE FIG. 84.

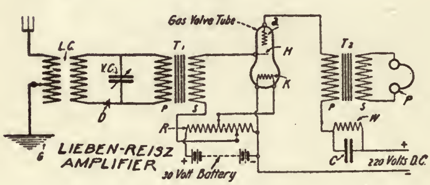


FIG 86.

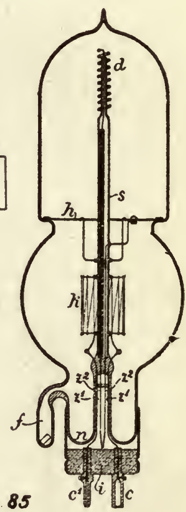


FIG 85

current may pass from the filament to the plate but not reversely so that the device acts as a rectifier. It is not very sensitive and relatively few are in use now. The kenotron is a similar device which is evacuated so that less gas is left in the bulb. The kenotron is very highly evacuated and built for larger current but is not used for wireless purposes at present.

AUDION.

The audion (fig. 89) is like the previously described device except that a grid, which is simply a piece of bent wire or metal screen or plate with holes, is placed be-

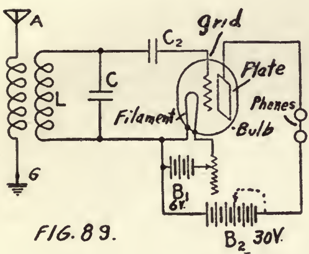


FIG. 89.

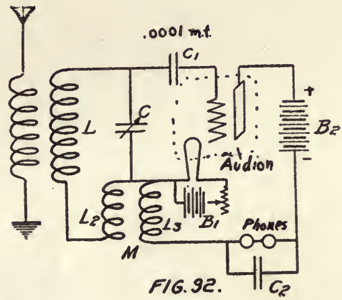


FIG. 92.

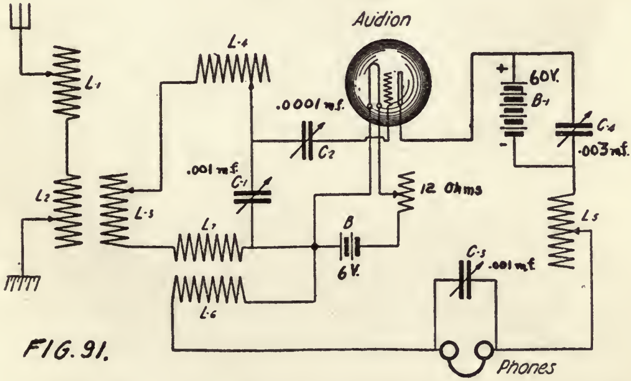


FIG. 91.

tween the filament and the metal plate or wing. The audion has a double filament, only one filament of which is heated at a time, the other being saved for use when the first burns out. This filament is usually connected to a 6 volt storage battery through a small rheostat.

Separated from the filament by about 1/8 inch is the plate and between the two at the middle and insulated from both is the grid. The plate is about 1/2 inch square and of sheet nickel in the size used as a detector. The whole is sealed in a glass bulb and evacuated so that only a little gas is left. Various other forms have been made with two plates and grids, in larger sizes, with cylindrical plates, etc., but the principle of operation is the same in all types. The device called the pliotron is similar in all respects except that the bulb is very highly evacuated. Experimental bulbs have also been made in which mercury vapor is introduced into the bulb after it has been evacuated.

LIEBEN-REISZ AMPLIFIER.

The Reisz gas tube as described in U. S. patent 1,142,625 is shown in fig. 85. The circuit in which it is used is given in fig. 86. T^1 and T^2 are iron core step up transformers. The device is analogous to the audion which is better known and will be understood from discussions of the latter device.

PLIOTRON. CASCADE AMPLIFIER.

This device has two plates, a grid of fine wire wrapped around a support F (fig. 87) and a filament held in this support. It is very highly evacuated so that much higher voltages must be used with it than in the case of the audion. It can be built in larger sizes than the audion for use as an undamped wave generator or relay and is more constant, so that whereas audions vary widely in characteristics, these more highly evacuated bulbs are nearly identical and many of them may be connected in parallel. Two such devices connected in cascade for receiving radio signals with an amplification as high as 1,000 times are shown in fig. 88. L^1 and L^2 are the primary and secondary of an air core

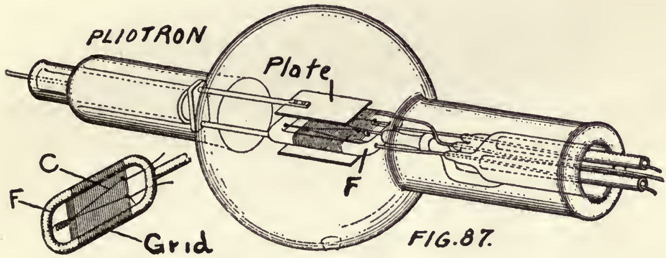


FIG. 87.

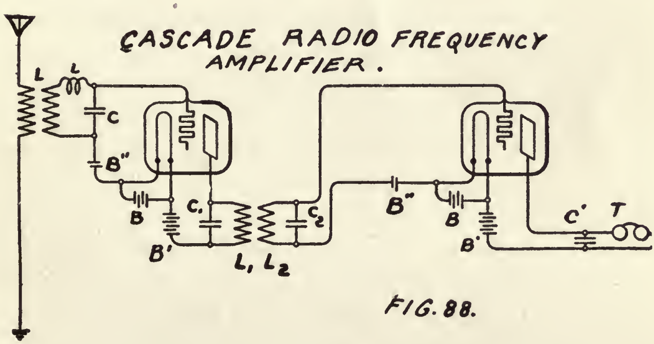


FIG. 88.

transformer. The first bulb detects and amplifies the incoming oscillations and the second bulb again amplifies the previously amplified oscillations. The battery B′ must afford several hundred volts and the battery B″ is required to charge the grid. A similar circuit may be used with ordinary audion bulbs except that batteries B″ are not required.

PRINCIPLE OF OPERATION.

It should be remembered that there are two distinct actions of this class of valves, the one holding for bulbs containing appreciable gas so that ionization can occur by collision and the other taking place in bulbs so highly evacuated as to be almost free from gas so that a purely electronic action occurs. The first class of bulbs may be recognized by the blue glow which occurs just beyond the sensitive and operating adjustment as in the audion. The Lieben-Reisz, Audio-tron and similar tubes are also of the first class. The second class embraces bulbs such as the pliotron in which a pure electron discharge occurs from the heated cathode or filament. The second class does not rely upon residual gas as a conducting medium as in devices of the first class.

The hot filament in these devices emits electrons. In elementary static electricity it will be remembered that like charges repel and unlike attract; negative repels negative for instance. The electron may be considered as the smallest possible particle of electricity, the atom of electricity so to speak, and furthermore it is always negative. Hence if an electron comes near a negative charge or a piece of metal charged negatively by a battery the electron will be repelled, or on the other hand the same piece of metal if charged positively will attract the electron to it.

Now in a highly evacuated bulb containing filament, grid, and plate, the resistance between the filament and grid or plate when the filament is cold is very high, and a pressure of 100 volts for example can send no current across such a path. As soon as the filament is heated, however, electrons are emitted from the hot cathode and fill the surrounding space. As soon as the space is filled, however, additional electrons which are emitted by the filament cathode are repelled by the electrons already in the space and are absorbed again by the cathode. If now the grid, which is between the plate and the filament is negatively charged by a battery still more electrons will be repelled and sent back to the filament, but on the other hand if this grid is positively charged the electrons will be attracted to it and a larger current will flow from the filament. This is the case for the pliotron.

When, however, there is gas present, as in the audion, the electrons in passing from the filament to the plate ionize the gas, that is split it up into elementary parts carrying electric charges so that the gas becomes a conductor. Now some of the charges of the ionized gas are positive and these partly neutralize the electrons which have been projected into the space by the filament. Also if a positive charge is applied to the grid the electrons from the filament will be attracted and pass more rapidly. In so doing they produce more ions in the gas and the action continues—more electrons pass the grid and more ionization takes place. Now every time ionization occurs or increases the electrons in the space are reduced so that a much larger current can flow from the filament. Only a small amount of gas need be present for this purpose. In fact if too much gas is present there will be too much ionization and too large a current will flow giving a blue glow and spoiling the relaying effect.

On such a basis we can understand what happens in the tube. Fig. 89 shows the ordinary audion circuit. Both detection as in a crystal rectifier and amplification of the received energy by trigger action occur. In use the filament is brought to incandescence and tuning adjustments are made until the desired signals are brought in. The incoming signals are embodied in oscillations and these are rectified between the filament and grid. One-half cycle passes, the other cannot because the hot filament—cold grid is uni-directional. In the Fleming valve this is all, but in the audion under consideration amplification now occurs. The battery B^2 causes current to pass from the plate to the filament but by the action already explained the negatively charged grid decreases it. When this current decreases the change registers on the head phones and a loud response results which is much stronger than would result from the rectification alone. The potential on the grid caused by the incoming oscillations controls the larger current passing from the plate to the filament and through the phones to give the signal. A small increase of the potential on the grid means in practice a large change in the current passing between the grid and filament, and this in turn causes a corresponding change in the current passing through the phones by way of the plate to filament circuit.

This device generally works best just below the point which causes a blue glow to appear. The filament should not be lighted when the set is not in use because this results in a waste of current from the high voltage battery and deteriorates the filament. When the filament is lighted and the device is ready to use, the high voltage battery causes a continual flow of current through the bulb: the incoming oscillations merely cause this current to vary.

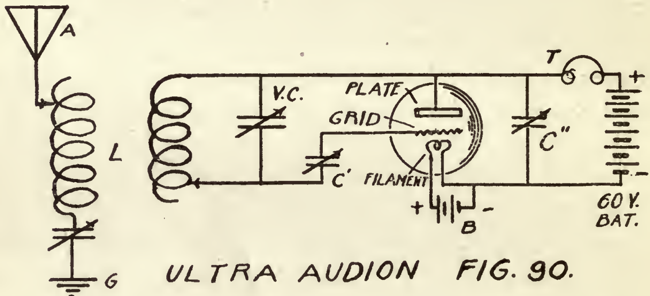
EFFECT OF MAGNET ON AUDION.

If a magnet, permanent or electromagnet, is brought near an audion in operation various effects may be produced. Sometimes this merely causes the blue glow to appear. In other cases the bulb starts to send pulsations through the phones at a rate which gives musical tones which may be made to run all the way up and down the scale by proper motion of the magnet. If, however, the magnet is brought in the proper plane the thermionic stream can be concentrated so that in very many cases the bulb will work better than ever and give an increased amplification. This may be quickly found by trial.

THE ULTRA-AUDION RECEIVER.

De Forests' ultra-audion is a form of heterodyne circuit combined in one instrument. It is an ordinary audion detector with a receiving circuit (fig. 90) in which the inductance L is large (secondary of loose coupler wound with many turns of No. 30 to 36 wire) while the condenser C′ is only about .0002 microfarad in capacity. The condenser VC is also made small. The electron flow in the audion used in this circuit is automatically unbalanced because of this system of inductance and capacity so that continuous oscillations are set up. These oscillations are strengthened by the variable condenser C″. Any audion bulb may be connected up in this manner to receive undamped wave signals, for when the capacities are adjusted so that the audion sets up oscillations slightly differing in frequency from those received, beats result which are heard in the head receivers.

Often an ordinary audion in a common receiving set will oscillate in such manner if only the filament is burned slightly brighter than usual. One may ascertain that the bulb is oscillating by touching any portion of the metallic circuit between L and C′ whereupon a sound will be heard in the telephone receivers if the bulb is oscillating. For receiving from spark stations the bulb is often best when in the non-oscillating condition as when oscillating in the above manner the musical tone



ULTRA AUDION FIG. 90.

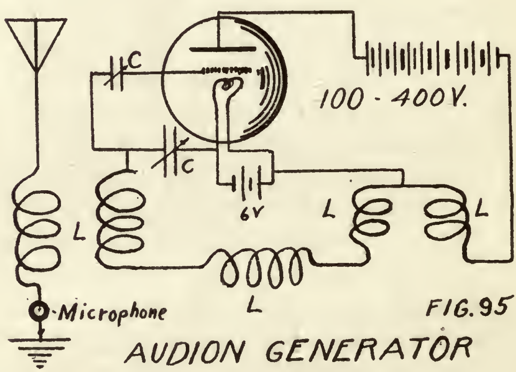


FIG. 95

AUDION GENERATOR

of the sending spark becomes ragged so that a louder but indistinct sound results. This is perhaps the most sensitive arrangement for detection which is at present available as it affords a combined detector and amplifier as well as a local oscillator.

AUDION AS UNDAMPED WAVE GENERATOR.

A suitable circuit for obtaining undamped waves from an audion bulb is shown in fig. 95. A microphone may be employed as shown so that for demonstration purposes the arrangement shown may serve as a wireless telephone transmitter for some little distance. The filament of a bulb intended for a detector will, however, rapidly waste away, so it is best to obtain a bulb constructed for this purpose. Any frequency can be obtained over a wide range by adjustments of the condenser capacity.

ARMSTRONG CIRCUIT.

The Armstrong circuit combines the principle of the singing microphone with the audion so that a part of the amplified current reacts on the current between the grid and filament and thus causes a still further amplification. This is best accomplished by means of a coupling coil built like a loose coupler. If this coil is made with an air core (no iron) the radio frequency oscillations will be amplified. Similarly by the use of an iron core induction coil the audio frequency current through the telephone will be amplified. It is possible to amplify either or both at the same time. In fig. 91 the complete circuit for a long wave set using the oscillating and amplifying audion is given. Either spark or undamped wave sets can be heard with this arrangement. A less complicated circuit which will serve about as well is shown in fig. 92. Compare with the ultra-audion, fig. 90.

CONSTRUCTION. LONG WAVE UNDAMPED WAVE RECEPTOR. RANGE 14,000 METERS.

Few of the readers have the facilities to construct the bulbs, but if one has a bulb the amplifying circuit may be readily made at small cost. When properly adjusted a single bulb amplifier of this type is as good or better than the usual two step amplifier employing two bulbs.

The values of the condenser capacities and maximum battery voltages are given in the diagram of fig. 91. The inductances are made by winding a single layer of silk covered wire on paper tubes and for the various coils suitable dimensions follow.

L^1; core 6" diameter by 25" long wound with No. 24 S. C. C. wire, with taps taken at ten, five, and then every inch of length.

Loose coupler L^2, L^3. Primary L^2; 12" long by 6" diameter with No. 24 S. C. C. Secondary L^3; 12" long by 5½" diameter wound with No. 32 S. C. C.

L^4 and L^5 are each 5" in diameter and 30" long, and wound full of No. 32 S. C. C. Taps are taken every inch at the last 5 inches.

Loose coupler L^7, L^6. L^7 is 8" long by 5" diameter. L^6 is 7½" long by 4½" diameter. Both cores are wound full of No. 30 S. C. C. wire.

The condensers should be of the rotary plate type and C^2 which is used at very small values should have a streak of graphite rubbed between its binding posts to serve as a high resistance shunt which dissipates high voltage accumulations on the condenser from static disturbances.

ADJUSTMENT.

Short circuit L^5 and place C^3 at its maximum capacity. Have L^2, L^3 all in and vary L^4 and the other condensers, also L^1 until the signals are brought in best. Now place L^5 in and adjust the number of turns used as well as C^3 until the loudest signal strength is obtained. Mark the adjustments for future reference and make any other necessary changes by means of L^1, L^2, L^3, C^3, and C^1. When the bulb is replaced with a new one, the adjustments may have to be repeated as new valves will be required. If siren effects bother, ground one terminal of battery B.

Fig. 92 will now be readily understood. The loose coupler L^2, L^3 is made with variable coupling, L^2 is 5″ in diameter by 4½″ long. L^3 is 4½″ in diameter by 5″ long. Both cores are wound full of No. 28 S. C. C. B^2 should be adjustable up to 40 volts. The range will depend on the loose coupler used between the aerial and detecting circuit and is more suited to wave lengths under 6,000 meters.

CASCADE CIRCUITS.

Audions may also be used in cascade to amplify either the audio or radio frequency currents. Pliotrons can also be used in a similar manner. There is a limit to the number of steps that can be used, however, as the amplified current soon causes distortion, so in practice not more than three bulbs in cascade have been found to be practicable. In the cascade circuits it will be noted that the first step is the familiar circuit while the amplified current of this step (at audio frequency in the audion arrangement) operates the grid filament circuit of the next step through an iron core inductive coupling; then this is repeated in the next step in the same manner. The final current may be large enough to operate a loud speaking telephone or even a relay or milliameter. Often signals with any of the audion circuits have been so loud that they could be directly recorded on a wax cylinder phonograph by simply holding the telephone receiver against the recording diaphram.

CASCADE CIRCUIT CONSTRUCTION.

Fig. 93 shows how to connect two ordinary audion bulbs in cascade to amplify the audio frequency. Compare with fig. 88 and note that these two figures could be combined to still further increase the magnification. The transformer consists of a core 1" in diameter and 10" long made up of a bundle of soft iron wires wound with tape. The primary winding consists of one pound of No. 36 S. S. C. wire. Over this the secondary of one and one-half pounds No. 36 S. C. C. wire is wound. Amplification up to about 100 may be expected.

DISADVANTAGES OF AUDION. COMPARISON WITH CRYSTAL DETECTOR.

The audion detector as now sold is bulky, fragile, and requires frequent care and renewal of batteries, bulb, etc. Many bulbs are not constant and some give annoying siren effects. In very many cases there really is no need to employ any such device for a crystal detector will do as well or better. A well adjusted crystal detector is very nearly as sensitive as the best audion detector and will bring in most if not all the stations that an audion will. A crystal detector such as galena will even detect signals from arc and undamped wave sets under favorable conditions and the author has heard such signals when using such a detector in a receiving circuit containing a variometer coupler which caused the necessary reaction in the circuits. The tone, however, was not musical.

The audion as an amplifier, is superior, as the usual received signals are amplified to advantage. Indeed the

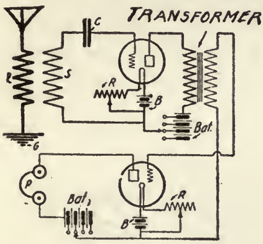


FIG. 93

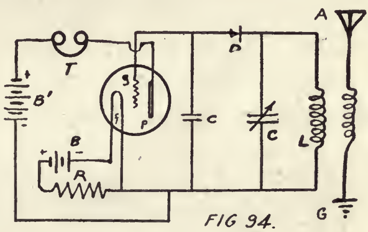


FIG 94.

audion may be combined with a good crystal detector to advantage, the one rectifying, the other amplifying the rectified current.

AUDION WITH CRYSTAL DETECTOR.

The connections for using an audion with a crystal detector such as galena are shown in fig. 94 and afford an amplification of about 10 times the signal strength obtained with the detector alone.

OTHER AMPLIFIERS.

Brown's microphone relay has found slight use. It is connected in place of the phones and amplifies through a microphone contact which controls a local circuit. The telefunken amplifier is similar but employs a number of such telephone-transmitters of special reed type in cascade so that the amplified current of one circuit actuates the next, etc. A similar device employing a liquid microphone instead of a contact device has been brought out by L. Bishop and a few are in use. Microphonic arrangements give amplifications of 20 upwards but are difficult to keep in adjustment and in general unreliable.

TRANSCONTINENTAL WIRELESS TELEPHONE.

In 1915 wireless telephone, one way communication was established from Arlington, Va., to Paris, France; Honolulu, Hawaii; Colon, Panama, and a few other

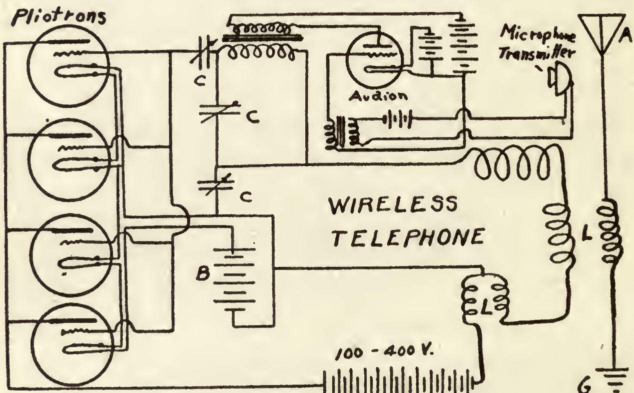


FIG. 96.

points. No details of the circuits used have been published at this writing, but on the basis of the author's own independent experiments, previous to the above mentioned tests, it is probable that the circuits employed were of the type shown in fig. 96. There are various modifications for the same result.

In this figure the current from a telephone line is amplified through an audion bulb in the manner already set forth and this amplified current is used to actuate the grid-filament circuit of a large number of highly evacuated bulbs connected in parallel and arranged to generate undamped waves after the manner already set forth. An ordinary telephone transmitter may thus be used to vary the strength of the high frequency oscillations set up in several hundred bulbs and where one bulb is shown in the diagram it will be understood that any suitable number of bulbs may be substituted in a similar manner to secure higher power. Continuous radiation occurs in the aerial-ground circuit and this is modified in exact accordance with the voice which causes the original variations of the electrical current which are amplified and made to control the larger current at radio-frequency. This will be readily understood by bearing in mind the previous discussions of the parts here combined. Any receiving station with a sensitive detector such as an audion with amplifying circuit can receive from such a wireless telephone station and the voice reproduction will be even better than over land lines.

LONG WAVE LENGTH STATIONS.

There are only a few stations of very long wave length now in operation and a number of these are of the undamped wave type. Wave lengths of 6,000 to 14,000 meters may be employed, though 12,000 meters is the most recent limit for long distance work. It is considered quite a feat for an amateur to hear such stations. This may be easily done, however, either by constructing a long receiving aerial or by loading an ordinary aerial with inductance. A suitable long wave receiving aerial may consist of a single No. 14 wire supported about thirty feet from the ground and 1,000, 3,000 or even 5,000 feet long, preferably running in a straight line and insulated at the supports. Another method which may work if conditions are right is to simply connect the aerial terminal of the receiving set to one binding post of a small variable condenser, the other binding post of which is connected to one of the wires of a telephone line. When this is done no telephone conversation can be heard, but the telephone system is used as an aerial and brought to a suitable wave length by means of the series variable condenser. All the other connections and tuning are the same as usual.

LOOSE COUPLERS FOR LONG WAVE LENGTHS.

Tuners for long wave lengths simply are made larger with more turns of wire and should be constructed with taps at intervals so that adjustments may be made. To say that a certain tuner has a certain wave length is misleading, as wave length depends upon the product of capacity and inductance as pointed out in the text whereas the tuner itself is only used to supply a portion of the inductance.

The accompanying table gives data which will serve as a guide in constructing loose couplers of correct dimensions. These were calculated by taking the average capacity of a large number of aerials from the smallest to the largest into account. The variable condenser to be used in the secondary circuit should have a maximum capacity of about .0009 Mfds. If a crystal detector is to be used and about one-third of this if an audion detector is to be employed. In practice only about three-tenths of the condenser capacity may be needed. More turns are used for the secondary in the case of audion detectors because they are potentially operated devices of high resistance and work best with large secondary inductance and small capacity. In any case it is desirable to add to the wave length by means of series inductance rather than shunt capacity as Dr. Austin has found that the efficiency is decreased by the parallel condenser. When considerable inductance is added in this manner the circuit is said to be "stiffened" and this is supposed to slightly reduce trouble from static. See fig. 97.

Loading coils for long wave lengths may be constructed in the same way as the primary coils given in the table. In loading a small aerial to a long wave length both the primary and secondary circuits should be loaded as the ordinary secondary of the receiving loose coupler alone is not large enough. The loading coils in the two circuits may be coupled together like loose couplers or separated like straight tuners. The large cores may be made by wrapping many layers of paraffined paper around a cylinder and removing this tube when cold.

Wave lengths less than the maximum capacity may be had by taking out taps at intervals to a switch.

TABLE FOR LOOSE COUPLERS AND LOADING COILS.

WAVE LENGTH. 3,000 METERS.

Primary: core 4½" long by 4" diameter, tightly wound with a single full layer of No. 26 S. S. C. wire.

Secondary: core 3½" diameter by 4" long, wound tightly with a single layer of No. 28 S. C. C. wire for use with crystal detector or with No. 34 for use with audion.

WAVE LENGTH. 6,000 METERS.

Primary: core 8" long by 5" diameter wound with single layer of No. 24 S. C. C. wire.

Secondary: core 7½" long by 4½" diameter, wound with a single layer of No. 30 S. C. C. wire for use with crystal detector or with No. 34 wire for use with audion.

WAVE LENGTH. 14,000 METERS.

Primary: core 7½" diameter by 12" long wound tightly with single layer of No. 24 S. C. C. wire.

Secondary: core 11½" long by 7" diameter wound with single tight layer of No. 30 S. C. C. wire for crystal detector use or with No. 34 wire for audion circuit.

With small aerials an additional primary loading coil of similar dimensions may be required in series with the primary coil. An aerial intended for only 200 meters has been successfully loaded to 8,000 meters and has received signals over 4,000 miles with the aid of an amplifying audion detector.

DEAD ENDS.

The unused portion of a tuning coil or cover is said to be "dead" and may absorb some energy thus reducing the efficiency. This is almost eliminated by switching arrangements which entirely cut out the unused turns. The principle is shown in figure 98 which shows diagrammatically a form of switch constructed by the author for this purpose. Only the primary is here shown as the secondary winding may be arranged in the same way.

A wide range of wave lengths is thus possible in a single receiving set. The coil is divided into a number of insulated series of turns O, O, etc., which are connected to a switch built like a commutator so that con-

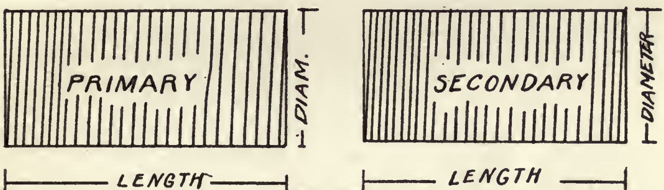


FIG. 97

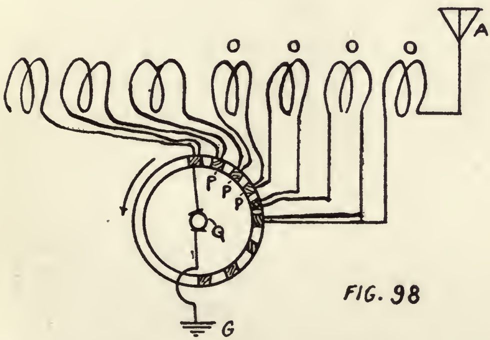


FIG. 98

tacts P, P, P, etc., may successively cause additional turns to be included in the circuit while at the same time unused turns at the other end of the coil are open circuited so that they cannot absorb the energy. Contact with the ground is made through slip ring Q which rotates with the switch. Each contact P, P, is of course insulated from the others and all are placed at equal intervals.

PLURAL RECEIVING SETS.

Another plan is to make a number of separate and independent receiving sets or couplers, each exactly right to receive at a certain wave length or from a certain station. A switch is then made to put the desired set in and the others are not in use at such time.

TRANSMISSION OF TIME SIGNALS BY NAVAL RADIO STATIONS.

To receive time signals an aerial about 500 feet long is desirable though a much smaller one will do. Apparatus described in this book will bring in the signals with either a crystal or audion type of detector. The following new advice is given by the U. S. Dept. of Commerce:

Time signals are now sent out on the Atlantic coast only through the radio stations at Arlington, Key West, and New Orleans. Signals from Arlington and Key West, which reach a zone formerly served by other coast stations, are sent out every day in the year twice a day, viz, from 11:55 a. m. to noon and from 9.55 to 10 p. m., seventy-fifth meridian time. Time signals from New Orleans are sent out daily, including Sundays and holidays, commencing at 11.55 a. m., seventy-fifth meridian time, and ending at noon.

On the Pacific coast the time signals are sent broadcast to sea through the naval radio stations at Mare Island, Eureka, Point Arguello, and San Diego, Cal., and at North Head, Wash. The controlling clock for each station is in the naval observatory at the Mare Island Navy Yard. Signals from Mare Island are sent out every day from 11.55 to noon, and from 9.55 to 10 p. m., one hundred and twentieth meridian standard time.

Those from North Head, Eureka, Point Arguello, and San Diego are sent out daily, excluding Sundays and holidays, from 11.55 to noon, one hundred and twentieth meridian standard time.

To get the maximum clearness of signals, the receiving circuit should be tuned to that of the sending station. Arlington and Mare Island send on a 2,500-meter wave length, North Head and San Diego on a 2,000-meter wave length, Eureka on a 1,400-meter wave length, Key West and New Orleans on a 1,000-meter wave length, and Point Arguello on a 750-meter wave length.

TRANSMISSION OF WEATHER REPORTS BY NAVAL RADIO STATIONS.

Through co-operation with local offices of the United States Weather Bureau, weather forecasts are sent broadcast to sea through naval coast radio stations at certain times, varying with the locality. Storm warnings are sent whenever received and the daily weather bulletins are distributed by the naval radio stations at Arlington, Va., and Key West, Fla., a few minutes after the 10 p. m. time signal. These bulletins consist of two parts.

The first part contains code letters and figures which express the actual weather conditions at 8 p. m., seventy-fifth meridian time, on the day of distribution, at certain points along the eastern coast of North America, one point along the Gulf of Mexico, and one at Bermuda.

The second part of the bulletin contains a special forecast of the probable winds to be experienced a hundred miles or so off shore, made by the United States Weather Bureau, for distribution to shipmasters. The second part of the bulletin also contains warnings of severe storms along the coasts, as occasions for such warnings may arise.

Immediately following this bulletin, a weather bulletin for certain points along the Great Lakes is sent broadcast by the naval radio station at Arlington, Va., consisting of two parts. The first part contains code letters and figures which express the actual weather conditions at 8 p. m., seventy-fifth meridian time, on the day of distribution, at certain points along the lakes. The second part of the bulletin contains a special forecast of the probable winds to be experienced on the lakes, during the season of navigation—about April 15 to December 10.

The points for which weather reports are furnished are designated as follows: *For Atlantic coast and Gulf points,* S=Sydney, T=Nantucket, DB=Delaware Breakwater, H=Hatteras, C=Charleston, K=Key West, P=Pensacola, and B=Bermuda; *for points on the Great Lakes,* Du=Duluth, M=Marquette, U=Sault Ste. Marie, G=Green Bay, Ch=Chicago, L=Alpena, D=Detroit, V=Cleveland, and F=Buffalo.

All bulletins begin with the letters U. S. W. B. (United States Weather Bureau) and the weather conditions follow. The first three figures of a report represent the barometric pressure in inches (002=30.02); the next figure, the fourth in sequence, represents the direction of the wind to the eight points of the compass: 1=north, 2=northeast, 3=east, 4=southeast, 5=south, 6=southwest, 7=west, 8=northwest, and 0=calm. The fifth figure represents the force of the wind on the Beaufort Scale, given on page 255.

Beaufort Scale of Wind Force.

Number and designation.	Statute miles per hour.	Nautical miles per hour.
0 Calm	0 to 3	0 to 2.6
1 Light air	8	6.9
2 Light breeze	13	11.3
3 Gentle breeze	18	15.6
4 Moderate breeze	23	20.0
5 Fresh breeze	28	24.3
6 Strong breeze	34	29.5
7 Moderate gale	40	34.7
8 Fresh gale	48	41.6
9 Strong gale	56	48.6
10 Whole gale	65	56.4
11 Storm	75	65.1
12 Hurricane	90 and over.	78.1 and over.

In order to simplify the code, no provision has been made for wind force greater than 9, strong gale, on the Beaufort Scale. Whenever winds of force greater than 9 occur, the number representing them is given in words instead of figures, thus: Ten, eleven, etc.

Example of Code.

U S W B Du 95826 M 97635 U 00443 G 96046 Ch 95667 L 00644 D 00842 V 01054 F 01656.

Translation.

United States Weather Bureau.

Station.	Pressure.	Wind.	
		Direction.	Force.[1]
Duluth	29.58	NE	6
Marquette	29.76	E	5
Sault Ste. Marie	30.04	SE	3
Green Bay	29.60	SE	6
Chicago	29.56	SW	7
Alpena	30.06	SE	2
Detroit	30.08	SE	4
Cleveland	30.10	S	4
Buffalo	30.16	S	6

[1] See Beaufort scale.

U. S. PATENTS ON WIRELESS TELEGRAPHY, TELEPHONY, AND CONTROL.

This is the most complete list obtainable. It should be invaluable to the reader. Patents from 1881 to January 1, 1916, are included.

HOW TO USE THE LIST.

Look for the subject of interest or the headings that might contain it. Patents considered of particular importance have been designated with a * mark. Copies complete of any of these patents can be obtained for 5 cents each by addressing the Commissioner of Patents, Washington, D. C.

GENERAL APPARATUS AND SYSTEMS, BOTH TRANSMITTING AND SENDING.

For any other apparatus or arrangement of circuits consult also this general list, as it includes patents treating of more than one related idea.

Patents numbered:

586,193	716,334	1,123,118*	1,120,054	711,266	711,184	717,773
717,769	717,771	717,772	711,183	711,182	749,584	748,597*
734,048	730,247*	743,999	749,370	749,131	737,170*	800,854
12,073	758,842	706,718	756,904	730,819*	756,719*	802,981
805,412	716,334	765,298	706,742*	710,355	710,354	703,842
768,301*	710,122	706,746*	706,745	706,743	706,500	763,893
706,741*	671,406	711,132*	11,952	700,250*	671,407	680,001
757,559*	687,440	737,072	699,158	795,762	682,974	684,706
706,736*	684,467	758,005*	750,496	753,863*	720,568*	708,071
609,154*	711,130	708,072	12,168	703,712	706,737*	706,740
707,064	717,766	743,056*	750,429*	671,732	696,715	685,742
741,622	763,772*	716,203	717,765	768,003*	674,846*	664,869
377,879	691,176	550,510	657,224	651,361	651,362	650,255
651,014	650,110*	650,109	647,009*	657,222	711,174*	644,497
627,650*	647,007*	647,008*	643,018	673,553	673,418	716,203
671,403	929,745	783,923*	781,823	716,000	962,014*	934,883*
935,721	842,910	837,616	837,901*	841,386	889,790	889,792
884,109*	889,791	884,070	884,076	957,282*	884,108	884,106*
962,017	884,071	899,239	899,243	1,129,821	728,243	701,256
884,986*	729,797	768,778	1,006,786	1,128,210	730,246	897,278*
879,409	913,718	998,567*	908,815*	994,191	706,738	717,770
894,378	754,058	727,329	727,330	730,753	767,979*	767,983
927,641	770,668*	752,895	874,745	768,000	884,987*	802,430
783,992*	786,132*	770,229	759,216	767,984	759,825	711,444
760,463*	725,635	749,434	749,178	742,779	1,162,830	12,169

General Systems, Continued.

Patents numbered:

706,737	767,990*	767,985*	767,991*	725,634*	767,989*	767,988*
734,476	753,864	808,641*	768,003	818,236	771,818	767,978
923,963	764,093	974,762*	966,705*	764,094	1,111,777	929,145
926,936	879,532	997,515	1,059,666*	1,106,875	1,038,506	1,106,874
899,240	986,651	935,382*	916,307	827,524	884,107	858,569
1,020,032*	1,132,568*	1,019,236*	1,080,271*	1,018,555	813,914*	954,640*
979,276	808,594*	802,432*	1,074,423*	996,090	996,088	1,001,227
706,740	1,157,094	767,987*	767,980*	767,986	767,981	767,975
725,636	767,977*	767,982*	767,976*	758,517	781,873	813,975
802,417	768,005	768,002	767,996*	929,349	1,018,555	759,826
768,004	884,989*	864,272	884,110	935,383	956,165	706,735*
793,650	913,528	793,652	1,014,002*	946,168	934,875	929,487
1,031,698	1,101,915*	824,003	899,242	889,289	822,936	937,281
1,010,669	924,560*	928,962	1,016,003	1,101,533*	1,015,881	1,003,375
1,006,635	1,006,636	1,012,456	758,527	761,450	802,418	739,287*
1,020,032	797,544*	730,753*	742,780	1,002,049	958,006	749,372
824,676	767,995	768,001	767,997	767,992	767,998	767,993
829,787	908,742	901,649	992,042	711,131	785,803	711,445
962,018	624,516*	797,169*	1,128,210	1,045,781	1,132,569*	1,114,840
1,138,652	928,371*	956,489	946,166	851,621	854,813	869,714
899,241	714,648	1,050,728	1,074,456	1,059,665	1,082,221	1,035,334*
716,334	730,819	1,123,119	1,139,226	14,012	806,966	756,720
788,477	843,733	776,337	782,181	787,780	755,846	771,819
792,528*	767,999*	767,994	943,969	935,386	946,167	965,060
1,002,051*	915,280	996,580	995,339	929,145	711,181	1,127,921*
1,101,914*	1,014,002*	802,431	802,421	802,420*	802,419*	444,678*
818,363	840,909	992,791	676,332*	680,002	716,000	713,700
758,004	714,246	960,304	850,917	1,021,132	1,045,782	1,080,544
1,050,441	1,022,540*	750,216	918,306	918,307	777,014	1,158,123

RECEIVING DEVICES, SYSTEMS, AND CIRCUITS.

Includes selective arrangements, interference compensators, beat receivers, audio-tuning, bridge circuits, apparatus arrangements, static shields, etc. See also related headings. Includes some detectors.

Patents numbered:

1,895,342	1,138,147	1,144,968	1,116,183	1,116,588	1,019,236*	657,223
1,113,149*	997,516*	1,134,593	1,132,588*	1,139,632	1,143,799	1,123,910
1,127,368	727,327	762,829	767,971	801,118	796,800	767,922
761,258	712,764	806,052	962,417	668,315*	974,838	793,648*
921,531*	727,331*	995,312	936,258	12,115	962,016	665,957
780,842	902,613	897,779	962,015	962,016	845,316	836,531
883,437	936,258	962,015*	958,181*	974,986	974,538	921,531*
902,613	936,163	912,726	974,985	892,312	706,742	730,246
761,258	727,331	884,988	748,306	796,403	12,115	749,371*
727,328*	746,557*	745,463	737,271	744,936	756,219	755,586
773,171	773,340	774,922	775,050	782,422	793,648	780,842
783,712	961,645*	1,002,150	758,468	905,537	897,779*	924,827
888,191	959,510	892,312	896,130	877,451*	883,241	886,154
1,009,317	963,173	916,429*	918,618	974,927	1,012,496	952,403
784,762	931,586*	925,921	802,428*	824,682*	930,508	846,414
852,381*	853,929	839,029*	706,745	730,247	802,423*	802,422*
923,699*	857,375	994,426	858,668	846,081*	785,276	1,009,106
812,557	820,169	816,205	962,417	1,093,240	1,087,113*	1,104,256*
1,089,091	13,798	1,042,778	1,097,974	1,027,238	1,091,127	1,099,865
1,059,391*	1,022,539	1,044,637*	1,087,892	1,087,549*	1,132,568	916,429
897,278	752,894	752,895	1,018,155	1,012,496	716,135	167,970
1,156,677	1,163,839					

SELECTIVE SECRECY SYSTEMS.

(See also others.)

Patents numbered:

1,102,442	1,091,768	714,384	715,203	717,978	714,756	795,840
752,894	727,326	12,149	714,831	12,141	1,123,119*	777,014
913,718	768,001*	1,091,768				

DETECTORS.

Oscillation Responding Devices, Rectifiers, Electrolytic, Heat, Contact, Capillary Devices, etc.

(For circuit arrangements, etc., see Receiving Apparatus and Systems.)

OSCILLAPHONE.

Patents numbered: 769,005 819,779

MAGNETIC DETECTOR.

Patents numbered:

772,878	877,069	917,104	930,780	711,182	917,104	749,371
715,043						

ELECTRO-CAPILLARY DEVICES.

Patents numbered:

844,080	798,484	798,483	798,482	798,481	848,083

ELECTROLYTIC.

Patents numbered:

706,742	716,334	929,784	894,317*	875,105	902,569	795,312
894,317	875,105	962,014*	783,712	716,203	727,331	716,000
731,029	706,744	916,428	793,648	768,003		

HEAT DETECTOR.

Patents numbered: 800,856 767,996 767,997

BOLOMETER.

Patents numbered:

778,275	767,992	767,980	767,971	767,981	767,972

CRYSTAL AND MISCELLANEOUS—ALL TYPES.

Patents numbered:

879,062	879,117	923,700	924,827	837,616	886,154	912,613
912,726	1,159,969	1,152,444	1,158,112	1,162,765	1,080,681	1,052,355
1,096,142*	1,048,117	1,102,184	1,104,065	1,104,073*	867,876*	899,264
824,637*	824,638*	927,314	1,013,223	986,806	966,855	954,619
959,967	867,878	867,877	912,613	879,062	917,574	1,004,784
904,222	906,991	811,654	776,359	757,802	741,570	1,003,210
905,781	901,942	962,262	836,070*	836,071*	1,155,338	879,061
820,258	902,569	706,744	707,266	711,123	756,676	787,412
1,003,374	902,569	1,136,044	1,136,045	1,137,714	1,136,046	1,136,047
1,122,558	1,128,552	1,118,228	1,115,902	1,112,411	1,145,658	1,144,399*
1,008,977*	933,263	770,228	917,574	706,735	706,736	767,985
837,616	706,735					

MERCURY AUDION, VACUUM VALVES, AUDIONS, THERMIONIC RELAYS, AND DETECTORS.

Patents numbered:

1,130,008	1,142,625	837,878	836,070	879,532	841,386	979,275
837,901	867,876	995,126	836,071	979,275*	803,689*	1,130,043*
1,127,371*	1,430,008	1,128,817	1,130,009	1,130,042*	1,128,280	1,137,275
1,145,735	1,144,596	1,159,307	1,138,652	1,113,149	841,397	1,156,625
943,969	824,637	824,638	867,071	915,280	824,637	803,684
837,901	841,387	867,877	867,878			

COHERORS.

(See Radio-Mechanical Control.)

Patents numbered:

1,019,260	932,799*	700,708	691,815	993,024	886,983	794,459*
800,119*	908,504	985,854	775,113	742,298	763,894	759,835
968,007	670,711	708,070	755,840	722,139*	710,372	1,019,260
741,767	1,118,410	1,150,111				

WAVE METERS.

Patents numbered:

804,189,	1,064,325	1,018,769	804,190	932,819	846,675	918,256
892,311	993,316	1,152,632				

GALVANOSCOPE.

Patent numbered 798,152

SYNCHRONIZER.

Patent numbered 717,768

RANGE FINDER.

(See also Direction Finders.)

Patents numbered: 749,436* 1,135,604*

SPARK GAPS, INCLUDING MUFFLED, COOLING AND TONE TYPES.

Patents numbered:

1,073,371	1,051,744	1,075,075*	834,054	926,933	971,935*	1,132,589*
1,117,681	750,180	750,005	1,163,586	792,014	706,741	768,000*
1,148,521*	1,161,520	1,152,272	1,162,659			

WIRELESS TELEPHONY.

(See also Oscillation Producers, Transmitting and Sending Systems, etc.)

Patents numbered:

1,118,004	1,125,496*	1,122,594	1,139,413	1,062,179*	1,086,530	1,108,895*
1,044,798	1,052,849	1,088,686	803,199*	836,015*	814,942	836,072*
803,513*	1,006,429	923,962	753,863	793,649	793,750	1,148,827

RADIO-MECHANICAL CONTROL. TORPEDOES, TYPEWRITERS, ETC., CONTROLLED BY WIRELESS. COHERORS.

(See also Detectors and Systems.)

715,803	1,115,530*	1,097,871	1,072,152	1,987,966	625,823	1,029,573
789,618	976,500	828,864	907,488	1,098,379*	957,001	663,400
723,176	913,814	1,155,653	1,154,628	1,149,874		

RECEIVING RECORDER.

Patent numbered 766,743

RELAYS AND RELAY SYSTEMS.

Patents numbered:

717,514*	786,696*	657,221*	718,535	717,513	717,509	717,570
1,106,729	655,716					

AUTOMATIC TICKER.

(See also Receiving Devices.)

Patents numbered: 1,098,380 1,161,142

TUNING DEVICES AND COUPLINGS.

(See also Receiving Systems, Transmitting Systems, Wavemeters.)

Patents numbered:

1,116,130	978,604	802,425	1,070,376	1,014,722	1,014,722*	1,083,085
1,096,065	719,005	707,056	763,345*	717,511*	934,296	803,569
956,936	996,092	717,512*	1,132,568	1,127,921	714,756	714,831
1,151,098	1,148,279					

AMPLIFIERS FOR RECEIVING.

(See also Receiving Systems, and Audions.)

Patents numbered:

965,884	714,832	1,041,210	12,151	12,152	1,163,180	751,818
714,833	1,165,454					

ALARM SYSTEM.

(See Coherors, and Radio-Mechanical Control.)

Patent numbered 606,405

CONDUCTION AND EARTH SYSTEMS.

(See general system list.)

Patents numbered: 1,051,443* 690,151

COMBINATION SETS. RECEIVING AND TRANSMITTING. LINE AND RADIO.

Patents numbered: 996,089 1,104,712 1,092,294 916,483 972,721

PORTABLE STATIONS.

(See general list and Aerials.)

Patents numbered: 1,145,066 958,209

COMBINATION TRANSMITTING AND RECEIVING SETS.

(See also general list.)

Patents numbered:

1,116,111	1,141,453	1,141,386	751,294	777,014	736,483	726,413
840,908	979,144	916,895	876,281	794,334	798,158	810,150
793,652						

TRANSFORMERS RESONANT WITH CAPACITY, FOR TRANSMITTING STATIONS.

Patents numbered: 965,168* 835,023*

DIRECTION AND DISTANCE FINDERS.

Patents numbered:

736,432	744,897	716,135	1,069,355	899,272	12,148	941,565
943,960*	961,265	984,108	948,086*	945,440*	894,318	1,002,141
833,034	716,134	758,517	1,149,123	1,149,122		

STATIONARY AND PORTABLE ANTENNA—AEROPLANE, AERIALS.

Patents numbered:

1,141,387	918,255	919,115	930,746	898,197	945,475	972,004
959,100	1,005,471*	793,718	793,651	948,068	860,051	1,106,945
1,101,175	1,063,671	1,132,569	767,973	717,511	706,737	1,147,010
770,229	749,436	749,131	748,597	771,819	707,746	706,738

Aerials, Continued.

706,739	716,136	899,272	1,158,124	717,512	793,718	753,864
802,981	802,982	806,966	822,936	824,003	767,986	767,988
767,998	767,999	716,177	1,165,412			

BREAKING SYSTEMS AND KEYS—SENDING TO RECEIVING.

Patents numbered: 827,523 842,134 1,016,564* 1,073,624

MASTS—AERIAL SUPPORTS, INCLUDING AEROPLANE AERIAL DEVICES.

Patents numbered: 1,116,059 857,152 1,034,760 1,099,861 768,005

AUTOMATIC CHANGE-OVER SWITCH—SENDING TO RECEIVING.

Patent numbered 1,074,057

CLEARING ICE FROM ANTENNAS.

Patent numbered 750,181

PROTECTING DEVICES.

Patents numbered: 771,820 978,607 1,035,958

CONDUCTOR FOR WIRELESS TELEGRAPHY.

Patent numbered 706,739

CURRENT INTERRUPTER.

(General interrupters not included.)

Patent numbered 1,039,011

KEYS, CIRCUIT CLOSERS AND CONTROLLERS.

Patents numbered:

917,749 792,020* 792,015 769,228 934,716 749,178 792,015

TRANSMISSION OF MUSIC.

(See Radiotelephony.)

Patent numbered 1,025,908

PUNCHED TAPE SYSTEMS.

Patents numbered:

725,634 725,635 725,636 767,978 767,991 767,932 767,995

STATIC VALVE. STATIC PREVENTION.

Patents numbered: 823,402 825,402

METHOD OF UTILIZING ENERGY OF WAVES.

(See general list.)

Patent numbered 731,029

VISIBLE AND AUDIBLE SIGNAL.

(See Coherors, Radio-Mechanical Control, etc.)

Patent numbered 805,714

COMMUNICATION BY WAVE COMPONENTS.

(See also General Systems.)

Patent numbered 876,996

PRODUCTION OF TONE EFFECTS.

(See also Spark Gaps, General Systems, Transmitters.)

Patents numbered: 1,056,892* 1,056,893*

AUTOMATIC COMMUTATOR FOR WIRELESS TELEGRAPHY.

(See General Systems also for similar arrangements.)

Patent numbered 1,105,029

RELAYING HIGH FREQUENCY CURRENTS.

(See also Audions, Detectors, Oscillation Producers, etc.)

Patent numbered 1,042,069*

DETERMINATION OF FREQUENCY.

(See also Wavemeters.)

Patent numbered 1,022,584

SYSTEMS OF HIGH FREQUENCY DISTRIBUTION.

(See also General Systems, Transmitters, Oscillation Producers.)

Patents numbered:

1,123,098* 1,122,027* 856,149* 856,150* 1,043,104* 1,043,766*

CONTROL OF SPARK PRODUCTION.

(See also Radiotelephony and General Systems.)

Patents numbered: 750,180 802,850

TELEPHONE RECEIVER.

(General telephone list not included.)

Patent numbered 936,684

DUPLEX, MULTIPLEX, SYSTEMS.

(See General Systems.)

Patents numbered:

716,136	772,829	802,429	802,426	717,767	767,970	924,168*
1,116,309*	1,076,312	1,042,205	749,434	720,568	716,134	772,879
767,980	716,134	793,652				

SUBMARINE SIGNALLING SYSTEMS, COLLISION PREVENTION, ETC.

Patents numbered:

711,386	1,126,095	1,073,088	749,694	802,020	914,483	913,910
526,609	1,099,998					

PHOTOPHONES.

(See General Systems.)

Patents numbered:

235,120	680,614	796,254	766,355	241,909*	235,496*	235,199
341,213						

CONDENSERS, PAPER, GLASS, AIR, COMPOSITION, ETC.

(For complete list see general electrical classification omitted here.)

Patents numbered:

1,127,513	793,647*	786,578	793,777	1,033,095	1,150,895	1,108,793
1,063,105	1,094,178	1,116,013	1,111,289*	1,112,397	1,114,626	1,139,976
814,951	793,647	793,651	767,977	1,151,824		

DIRECTIVE SYSTEMS.

Patents numbered:

795,762	749,131	720,568	716,134	716,135	771,818	771,819

TRANSMISSION SYSTEMS AND APPARATUS.

(General list. See also detail lists, as they are not repeated here. See General Systems.)

Patents numbered:

1,145,239—Polyphase		974,169	1,119,952	247,127	255,305	11,913
586,193*	657,363	465,971	932,821	926,900	767,974*	767,973*
749,435	685,953	685,954	685,957	785,956	754,737	767,977
755,132	775,416	776,876	876,165	792,014	787,056	910,430
935,381	950,258	932,820	921,293	1,005,338	986,405*	918,208
1,119,732	749,372	802,850	768,004	758,004	1,148,279	966,539
953,635	927,433	802,427*	851,336*	991,837	834,497	966,475
917,103	858,554	1,015,881*	921,013	1,136,411*	1,139,226	1,140,150*
1,141,717	1,126,966*	723,188	685,958	685,955	714,832	714,833
714,837	767,990	767,975	767,976,	767,984	767,989	767,975
767,979	1,153,717*					

OSCILLATION PRODUCERS, ARC CONTROLS, PRODUCTION OF HIGH FREQUENCY CURRENTS AND ALL KNOWN TYPES OF WAVES.

(See Audions and General systems. This list includes mercury vapor devices applied to the art, except such as are listed elsewhere.)

Patents numbered:

550,630	1,115,823	1,118,174	1,121,360	1,120,306	829,447	829,934
1,097,872	1,087,126	1,152,675	500,630	1,122,975	1,131,190	1,123,120
1,139,673	790,250	1,023,135	1,043,117	1,101,148	1,159,209	1,142,496
717,774	685,012	925,060	1,047,643	1,103,822	1,101,491	1,061,717
921,526	979,277	780,997	773,069	1,096,717	1,105,984	1,092,398
1,110,253	781,606	817,137	932,111	966,560	1,077,733	1,028,204
1,109,909	923,963	730,755	758,004	706,742	897,279	767,983
767,993						

RELAY OF MESSAGE.

Patents numbered: 717,509 717,513 717,514 717,516

NOTES ON LIST.

As a guide to date of issue, the number of the first patent for a period is given herewith:

247,127-1881	691,176-1902	730,247-1903	749,131-1904	802,417-1905
808,641-1906	840,909-1907	876,165-1908	908,742-1909	945,440-1910
984,108-1911	1,014,002-1912	1,050,728-1913	1,083,677-1914	1,123,910-1915

Numbers of five figures, as 12,073, are for re-issued patents.

The author assumes no liability for the accuracy of the list, but it is thought to include all of the U. S. patents granted in the art. The general list of electrical patents which overlaps the radio list in many instances has not been included because it alone is far larger than the entire wireless list.

DISCUSSION OF U. S. PATENTS FOR 1914 AND 1915.

By way of pointing out indications of recent progress a few recent patents may be mentioned. Patents numbered 1,087,113 and 1,104,256 describe the tone wheel ticker receiving system of Rudolf Goldschmidt. Patents numbered 1,098,379, 1,154,628 and 1,115,530 describe the control system of J. H. Hammond, Jr. An improved audion circuit is given in patent 1,113,149 of E. H. Armstrong. An arc oscillator using an arc between cooled electrodes immersed in alcohol and said to have transmitted telephone communication 600 miles is set forth in Dwyer's patent No. 1,109,909. A multiphase transmitter is described in patent 1,114,840. A practical arrangement of an aerial on an aeroplane is given in patent numbered 1,116,059. The duplex system of Marconi using two aerials at right angles is explained in patent numbered 1,116,309. A receiving set which is selective and obviates the use of the loose coupler by a practical arrangement of inductance and capacity is described in Cohen's patent No. 1,123,098. A proposed secrecy system is describe by De Forest in patent numbered 1,123,119.

A suitable system for radiotelephony over about fifteen miles is described by De Forest in patent 1,125,496. His arrangement uses a quenched spark gap oscillator. A balanced receiving circuit which attempts to prevent interference is described in patent 1,127,368. A good tuning circuit for receiving with both tight and loose coupling is described in Tronchon's patent 1,129,821. Weintraub furnishes much information on mercury vapor tubes as oscillation producers in patent numbered 1,131,190. Tape sending and phonographic recording is illustrated in Fessenden's patent 1,132,568. Marconi describes a plural circuit rotary gap method of generating continuous waves in patent 1,136,477. R. C. Galletti shows a system utilizing high frequency unidirectional impulses in patent 1,140,150. A novel aerial loaded with inductance and capacity to give a large wavelength range in a small space is illustrated by Franklin in patent 1,141,387. A good exposition of the heterodyne system is given in patent 1,141,717. Patent 1,144,969 shows a method of using a crystal detector to receive from undamped wave stations. P. C. Hewitt describes his mercury vapor receiving system in detail in patent 1,144,596. Marconi explains his disc discharger in patent 1,148,521. An improved coheror is illustrated in patent 1,150,111 and a new manner of using it for radio control is shown in patent 1,155,653. Seibt describes a practical quenched spark transmitter in patent 1,153,717. Vreeland illustrates his mercury arc generator cooled by water in patent 1,152,675. An antimony and ferrosilicon detector is shown in patent 1,158,112. A secrecy method is shown in patent 14,012 of Nov. 16, 1915. The receiving ticker used by the Federal Telegraph Co. is shown in patent 1,161,142. Quenched spark gap construction is the subject of Pfund's patent 1,161,520. In patent 1,152,272 H. Boas makes the practical suggestion of using tungsten for spark gaps. One form of the plural receiving tuner mentioned on page 252 is described in patent 1,151,098. A practical quenched spark system is described in patent 1,162,830. Amplification by means of microphones in cascade is explained in patent 1,163,180. Patent 1,127,371 shows how an audion may be used in connection with a relay circuit for wireless control purposes. Patent 1,165,412 shows a practical installation of a wireless set on an aeroplane, but employs the objectionable hanging wire antenna.

AERIALS RECOMMENDED FOR VARIOUS WAVELENGTHS.

The following dimensions are suitable for four-wire aerials of the "L" type with spacing between wires not less than 0.02 of the length. The length here means only the flat top length, as the lead-in length will vary with the location of the set. To find the amount of wire needed multiply the length of the aerial and lead-in by four, which gives the number of feet required. As regards range in miles which such an aerial can in each case cover, it should be understood that the size is no limit in this respect. The values given are the approximate natural wavelengths in meters and can be increased by loading with inductance or decreased by means of a condenser in series.

Meters.	Height above ground—feet.	Length in feet.
150	30	75
200	50	80
200	60	50
200	30	90
250	40	100
300	60	100
400	80	130
500	60	180
600	80	230

For long wavelengths see page 247. The second 200 meter aerial is recommended for amateur transmitting.

Wavelength of Any Aerial.

This is best found with a wavemeter, but may be roughly calculated from—

$W = \left(V + \frac{L}{4}\right) 4.2$, where W is the wavelength in meters, V the height of the flat top in feet, and L the length of the four-wire aerial in feet.

WHEN THE WIRELESS SET REFUSES TO WORK.

Probably a majority of the difficulties arise from a misconception or ignorance of the fundamental principles involved; for example, (1) the use of a single wire for a lead-in from an aerial composed of six such wires, (2) the use of too small or too large a condenser for the transmitting circuit, (3) faulty insulation or design of instrument, such as using a helix or oscillation transformer for a ½ kilowatt set which has No. 14 wire for its primary.

"I get a good spark, but cannot radiate any energy." Probable causes are a broken conductor in the aerial circuit, an overheated gap, too short or too long a gap, poor or practically no ground connection, enormous resistance due to loose contact, a broken wire, dry earth connection, a broken condenser plate, punctured insulation, too much or too little primary or secondary inductance or both, causing a lack of resonance, a broken aerial insulator, grounded lead-in wire, coupling too loose, or again, the values of capacity, inductance, frequency, voltage or resistance may be such as to prevent free radiation. Occasionally an aerial will really radiate, the apparent failure being due to a burned out hot wire ammeter, which is used as an indicator. The proper relation of the values for capacity, inductance, resistance, voltage, amperage, frequency, and the coupling used are fundamental and any variation will cause some degree of loss or failure. Total failure is generally due to a definite leakage caused by a breakdown in the circuits.

"I am using one kilowatt of power, but cannot reach a friend fifteen miles away." The cause may be one already given, but in a case in mind the difficulty was due to the use of too small an aerial, a poor ground and very poor tuning.

"I cannot get a good spark discharge." This is often due to the use of too small electrodes, too much power for the size of the gap, lack of cooling, too short a gap, a leaking or broken condenser; or again, it may be due to the use of long connecting wires of small cross section, such as were found in one particular case where the connecting wires were heated hot.

"I cannot get my set down to 200 meters and radiate enough energy to affect my hot wire meter." A variety of causes may include the use of too large a condenser, an inductance consisting of a coil of too great diameter, a poor design of oscillation transformer, too long wires for connections, loose contacts of the clips, or connecting wires of too small a cross section. In many cases, an inductance coil of the cylinder type will give better results with a smaller diameter, say six inches or less, and a large conductor, say No. 0 to 4, than is ordinarily used. The aim should be to use a condenser and inductance which will allow at least one complete turn of the inductance to be included in the primary 200 meter circuit. A pancake type of oscillation transformer embodying this principle of small diameter and large conducting surface is also suitable.

"I can hear NAX clearly, why cannot I get Arlington?" The usual reason for this is that a small station has insufficient wire in use to attain the necessary high wave length. It is a simple matter to construct a large loading coil, with taps, to bring a small set up to the longest wave length now in general use.

"A station 150 miles from here formerly came in very strong, but now I can hardly hear it." It was found that the station mentioned had changed its wave length, but the cause might have been poor contact of the sliders or coupler switches or a non-sensitive detector. Often, after some months, a conductor used in the circuits will become grounded or broken.

"My set tests out fine with a buzzer, but I cannot get even static." This failure is due to a poor ground or no ground, or a grounded aerial, or a broken lead-in, or a broken wire in the primary inductance (usually near the binding posts), or it may be merely a case requiring intelligent tuning.

"I am operating a ship station using a motor generator set, but I have to connect a battery across the fields to get the generator started." This often happens with small generators because of a loss of magnetism due to a variety of causes, such as faulty connection, the iron used in construction, etc. A few dry cells are generally sufficient to supply the starting energizing current, after which the fields build up rapidly.

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