Operator's Wireless Telegraph and Telephone Hand-Book

A COMPLETE TREATISE ON THE CONSTRUCTION AND OPERATION OF THE WIRELESS TELEGRAPH AND TELEPHONE, INCLUDING THE RULES OF NAVAL STATIONS, CODES, ABBREVIATIONS, ETC. : : : :

BY

VICTOR H. LAUGHTER

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PREFACE.

The writer has been long impressed with the fact that a book on the subject of Wireless was needed, which would not only explain the more simple working system but those of the more complicated design as well. Many good books are on the market relating to wireless telegraphy, but in the usual cases the subject is treated in either a rudimentary or a technical manner. The student soon passes over the experimental stage and desires to take up work with the more complicated instruments. This book has been written with the end in view of leading the student through the experimental stage, on up to the more complicated types of wireless telegraph and telephone instruments. Various rules and regulations as used at the present day have been inserted, as well as the different codes. At points where thought advisable the actual construction of the instruments used is gone into and all details given.

A statement made on page 105 reads as follows: "It is to be regretted that, as yet, we have no schools of wireless telegraphy which would serve to bring the student and the operating companies in closer relationship. However, the demand exists and such schools will ultimately follow." The truthfulness of this statement has already been proven, for since the pages of the book were set up the writer has become connected with an institute of this kind.

The writer wishes to extend his thanks to Mr. H. W.

Young, editor of *Popular Electricity;* Mr. F. E. Butler of the American Wireless Institute; Mr. H. Gernsback of the *Modern Electrics Publication,* and particularly to Mr. E. E. Burlingame, who supplied numerous photographs and much information.

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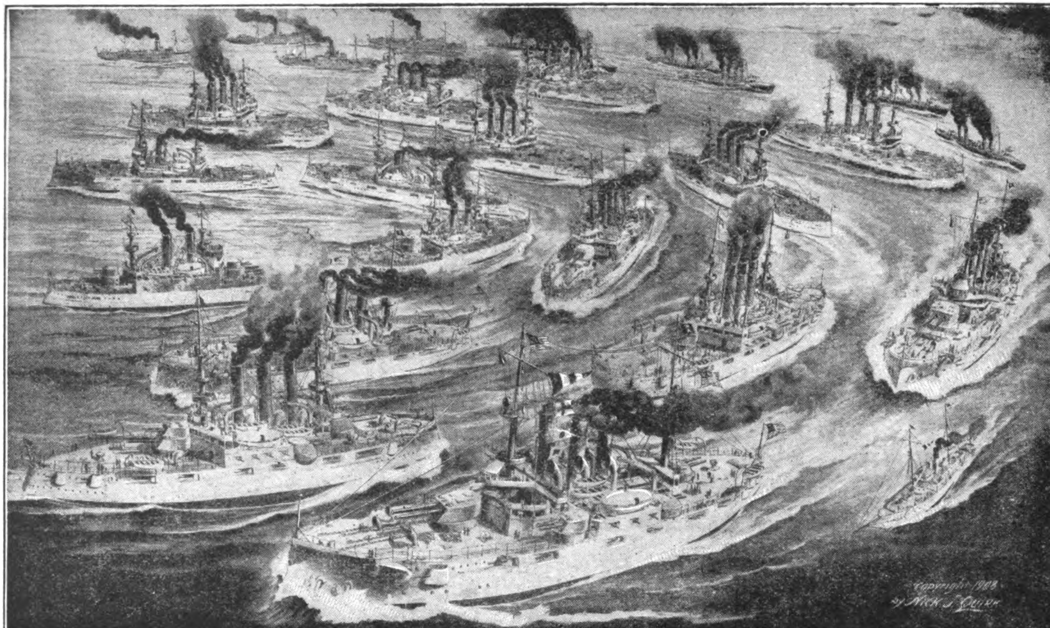
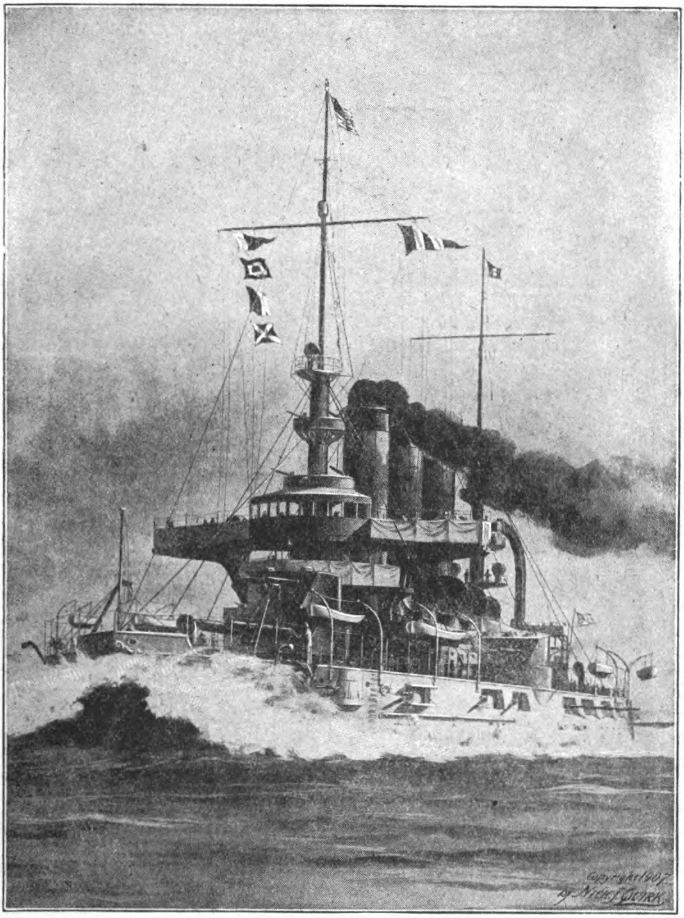
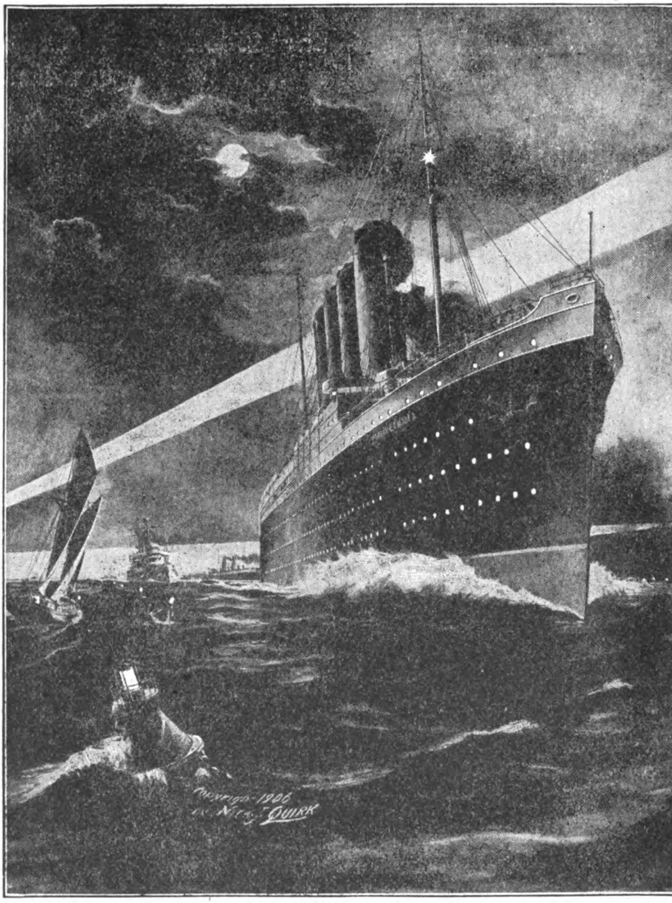


U. S. Fleet of 16 Battleships, 6 Torpedo Boat Destroyers and 5 Auxiliaries. (Wireless Telegraph and Telephone Equipment.)



U. S. Superposed Battleship "Virginia," First Warship to Use Wireless Telephone



Cunard Turbine S.S. "Mauretania" Entering New York Equipped with Marconi Wireless Telegraph System.

WIRELESS TELEGRAPHY.

BY VICTOR H. LAUGHTER.

CHAPTER I.

ELECTRICITY.

We do not know exactly what electricity is, yet the means for producing and utilizing it are well known and it can be found in the everyday passages of life; in the street railway, the electric light, the telephone and telegraph, and lastly the new arts of wireless telegraphy and telephony. It is of course evident that numerous other purposes and uses of the electric current could be given, this list however, would prove too large for the space allowed here. Since the earliest dawn of electricity well known scientists have devoted time and study to what might be termed the "eternal question." What is electricity? Many plausible theories have been advanced and reasons to sustain the theories, yet we are still in the dark as to its exact nature, and can only accept the results and continual growing scope as final. To follow out the progress of electricity, its continued growth, the utilization and means of producing would be impossible in the pages of this book, and besides it is only desired that the main features be given which are necessary to close understanding of wireless telegraphy.

FORMS OF ELECTRICITY.

The forms in which the electric current appear can come under the following headings: First static electricity, which appears as a charge on a body, such as a stick of sealing wax when rubbed with silk. The sealing wax has now undergone a change in state which can be described by saying that it is charged or electrified. The sealing wax stick if brought near the silk will attract to each other, but will repel a second stick of sealing wax like charged, the same rule applying to the silk. Hence, we have the law: "like charges repel and unlike attract." In this case the silk was positively charged indicated by the plus (+) sign and the wax negatively, indicated by the minus (—) sign. The principle of static electricity is farther extended in the electrophus and static machine, in each the charge being produced by frictional action.

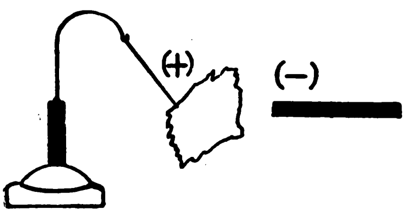


Fig. 1. Showing Attraction of Silk Handkerchief by Sealing Wax.

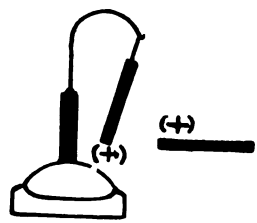


Fig. 2. Sealing Wax is Repelled by Sealing Wax Like Charged.

VOLTAIC ELECTRICITY.

Voltaic electricity in which the current is set up by chemical action is at once the most simple and efficient means for generating a continuous electrical current. The static current as noted above appears in the form of a charge caused by friction, while the voltaic cell sends out the current continuously until complete deterioration of the parts. The simplest form of voltaic cell is shown in Fig. 3 and consists of two plates, one of copper known as the positive pole and one of zinc known as the negative pole immersed in a dilute acid solution or better known electrolyte with wires connected to each plate and leading out at the top as shown. When the wires across the top are connected together or "closed," as the technical word is, the chemical action is started which continues so long as the circuit is closed and until the final eating away of the zinc. It is supposed that when the circuit is closed as explained the current flows out to the wire on the positive side, comes in again on the negative and completes the circuit through the solution. Thus it is one continuous circulation so long as the cell is connected for use.

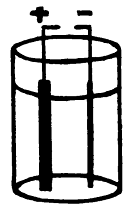


Fig. 3. Simple Form of Voltaic, Cell.

While this cell differs from the type in common use today yet the chemical action is nearly the same in all, and the same rules will apply to each.

DYNAMIC ELECTRICITY.

Dynamic electricity generated by the dynamo electric machine is the most economical means for generating the electric current when desired in large quantities such as for street railway and electric lighting use. The dynamo in action is very simple and consists of a coil of wire revolving in a strong magnetic field. The coil of wire is known as the armature and the magnetic field in the case cited, the termination of the N and S poles of a strong magnet. In Fig. 4 is shown the magnetic lines which circulate through the windings of the armature from the N and S poles of the magnet. In Fig. 5 is shown the armature being revolved and the distortion caused thereby in the magnetic field. The revolving of the armature in the magnetic field cutting in and out of the magnetic lines sets up the electric current in the winding of the armature which flows out by means of the brushes to the line wire.

The type of dynamo used here to illustrate the generation of the electric current is not of the type employed for common use, but the working principle and theory are the same.

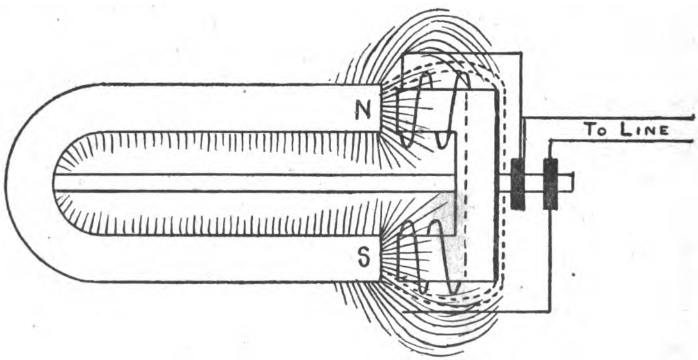


Fig. 4. Simple Type of Dynamo Showing Magnetic Lines.

ONE KIND OF ELECTRICITY.

From the above it should not be taken that three kinds of electricity exist. It has been repeatedly shown and proven that we have only one kind of electricity with different means for generating. In the static charge we have the silk positively electrified and the wax negatively charged. On bringing the two together a tiny spark will break across from the positive to the negative body, thus releasing the stress or potential difference between the two and showing that the negative body was the lesser charged. This same action is supposed to be present in lightning. A cloud heavily charged with positive elec-

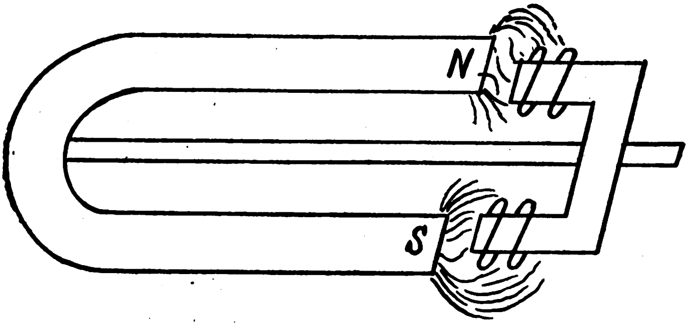


Fig. 5. Showing Distortion of Magnetic Lines when Armature is Revolved.

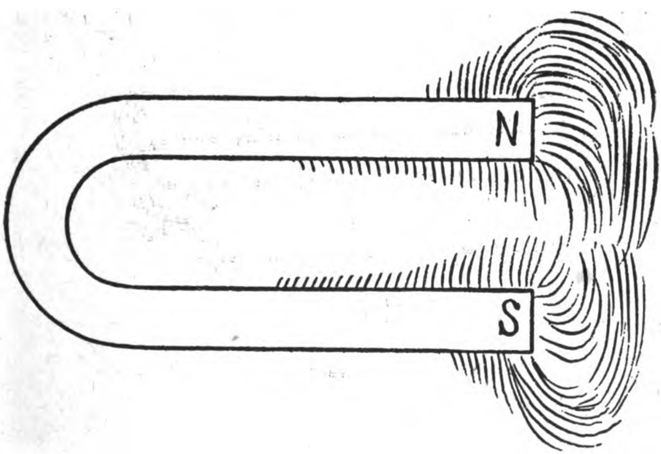


Fig. 6. Horse-shoe Magnet Showing Magnetic Lines.

tricity passes over an object lesser charged with negative, and in order to equalize the potential difference between the two a discharge takes place in the form of lightning.

On a smaller scale we have the same results in the voltaic cell. In this case, however, the discharge is continuous as the current constantly travels from the positive to the negative pole seeking the potential level.

MAGNETISM.

Magnetism in its natural state exists in the metal oxide of iron and is termed lodestone. Lodestone was first found by the Ancients in Magnesia, Asia Minor, from which the name of magnet is derived. Magnetism can be imparted to other metals such as steel, soft iron, etc., by rubbing over the surface of the metal with the magnet. Steel is found to be more retentive of this magnetism than any other metal and soft iron less retentive, hence each metal is employed where different effects are desired.

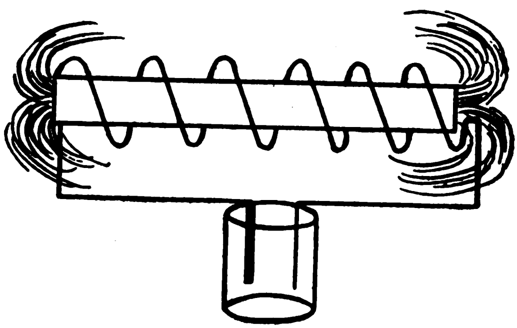


Fig. 7. Electro-Magnet.

ELECTRO-MAGNETISM.

Magnetic effects exist wherever there is a current bearing wire, the magnetism existing at right angles to the flow of the current. By winding a large number of turns of wire on a bar of soft iron we combine the magnetic effects of the entire length in this space and on sending the electric current through the winding the bar becomes magnetic, the magnetism existing however only as long as the current continues to flow. A magnet of this type is known as the electro-magnet. By replacing the bar of soft iron with one of steel and sending the current through as before the steel bar will retain the magnetism and will be capable of imparting the same effects to other objects. It is in this manner that the majority of small bar magnets are made.

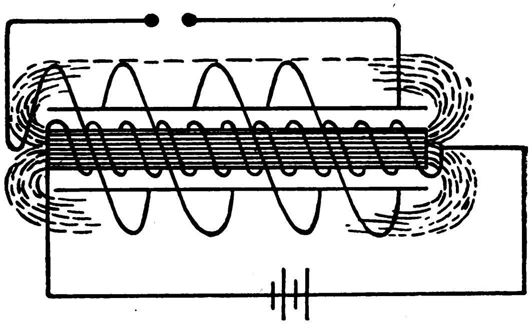


Fig. 8. Plan Showing Construction of Coil.

This electro-magnetism will extend to quite a distance beyond the winding and it is on this basic principle that the spark and induction coil are made. In Fig. 8 is shown the plan of the induction coil, which consists of the soft iron wires in the center known as the core, over which is usually wound two continuous layers of heavy wire known as the primary winding. On top of this winding and well insulated from it is wound several hundred layers of very fine wire known as the secondary. On sending the battery current through the primary winding magnetic lines are set up as shown, beginning at the end of the core and extending through the secondary winding. Now on quickly breaking this current the magnetism ceases to exist, thereby inducing a current of high voltage in the secondary winding, due to the large ratio of transformer winding employed. In the spark coil a device known as the vibrator is employed to "make and break" the current, both of which will be treated of in another chapter.

CHAPTER II.

HISTORY AND EARLY METHODS.

Signalling through space is an old art, if it may be so termed, and our records show that it has been practiced since the beginning of the ages in some crude form or other. It is said that the Ancient Romans used a semaphore signal system by which messages were spelled out and read by an observer on some distant hill or elevation in a direct visual line with the semaphore. Stanley tells us that the savages of South Africa used a beating noise made on "tom-toms" as signals, the sound being picked up and transferred from one tribe to another. Our history shows that the Indians used fires and clouds of smoke; while our forefathers of the revolution employed the same methods as the savages of Africa, only the more improved musket was used for setting up the sound waves.

Since the date of employing the above many revolutionary changes have been brought about, and many improved methods of signalling and communicating used; of these however, no special mention need be made as all were limited and could be employed only under certain conditions. The first radical change to take place in the way of quick and reliable signalling was on the adoption of the Morse telegraph; now we have the telegraph, the telephone, and lastly the new art of communicating through space without connecting wires, or more aptly called wireless telegraphy. Wireless telegraphy was proposed and theories worked out many years before its advent in 1896 by many well known scientists; however, Marconi was the first to place it on a practical basis and show the world the wonderful possibilities of such signalling.

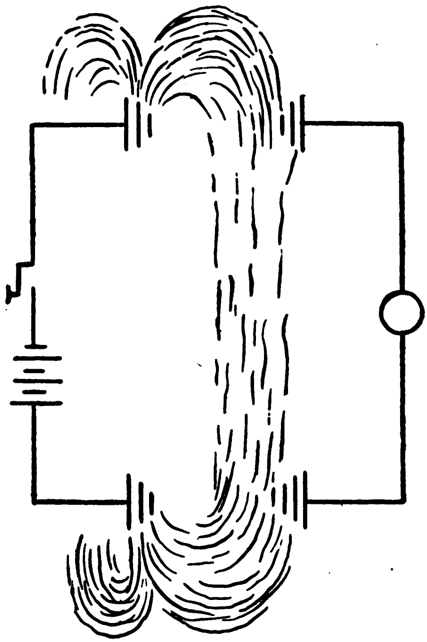


Fig. 9. Wireless Telephony by the Conductivity Method.

MEANS OF SIGNALLING-CONDUCTIVITY METHOD.

Before Marconi made his famous experiments and before the scientific world awoke to the possibilities of the Hertzian wave method, many investigators had found methods by which communication could be established over space without connecting wires.

One of the best known is the conductivity method first discovered by Steinheil of Bavaria and later on experimented with by Preece who was able to communicate over a distance of five miles. In the conductivity method the terminals of a strong battery in series with the key are grounded with the two legs of say a distance of fifty feet apart. Directly opposite at a distance fifty feet the receiving end is placed, the grounds being the same and the receiving device a telephone receiver or sensitive gal-

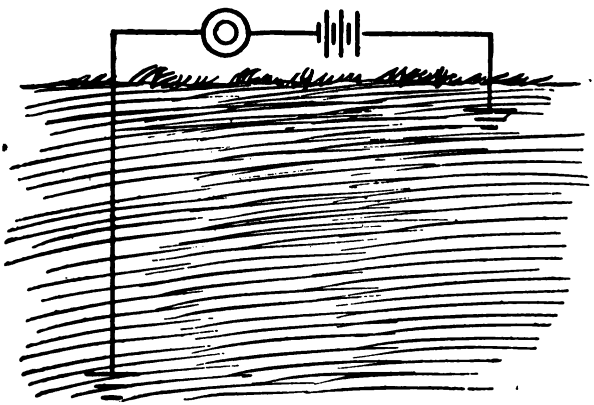


Fig. 10. Wireless Telephony. Second Plan Conductivity Method.

vanometer. On pressing the key the current is sent out in the ground and will cause indication at the receptive device. The best theory advanced for this action, is that current of the sending end in seeking the shortest path from one leg to the other disperses and spreads out, a certain portion being picked up by the ground legs opposite and conducted to the receiving device. The plan and arrangement of the conductive method is shown in Fig. 9.

Among the other investigators who have tried out the conductive method, which in some cases is different from the plans shown here, may be mentioned Armstrong-Orling, Laughter, Maiche of Paris and others, but no authentic record can be obtained of the actual results. In Fig. 10 is shown a second method of communicating by the conductive action. As noted in the plan one ground is embedded a few feet while the other is sunk to a much greater distance, it being the inventor's idea that the lower strata of earth would offer a good conducting medium, while the top would act as a partial ground, or on the same principle as the ground return telephone line using the lower strata as the conducting surface and the upper as the return or to complete the circuit. No record has yet been given of the results attained.

INDUCTIVE METHOD.

A later method is the inductive method, which operates on the same principle as the inductive effects between the primary and secondary of the spark coil. Two coils are used, one for the sending and one for the receiving. The sending coil consists of about a dozen turns of large wire wound in a circle three feet in diameter; the receiving about sixty turns of smaller wire wound in a circle two feet in diameter.

By supplying a current of 20 volts to the sending coil and including a telephone receiver in the receiving, messages can be picked up from a distance of 10 to 40 feet, in the open air and through solid walls, however, it is necessary to place the planes of the two coils in parallel to one another. By replacing the key in the sending circuit with a telephone transmitter the set can be used for wireless telephony up to possibly a distance of twenty feet. The method of connecting is shown in Fig. 11.

HERTZIAN WAVE METHOD.

We now come to the Hertzian wave method of signalling, the basic principle of wireless telegraphy today and a method that is perfect in theory and surprising in results.

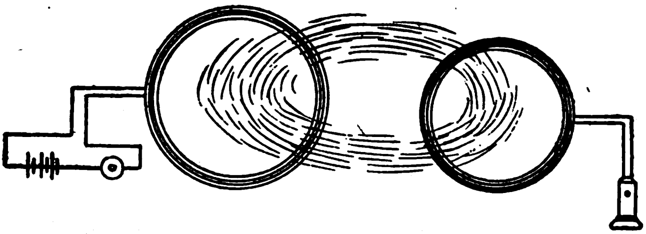


Fig. 11. Wireless Telephony by the Inductive Plan.

The theory that electric waves could be set up and detected was advanced by a number of scientists before Hertz's time. Prof. Clerk Maxwell first laid the path in theory which Hertz followed up with the actual results in 1888. Such waves as proven by Hertz are always present on a sudden electric discharge as from the Leyden jar, a flash of lightning, induction coil or other high tension discharge. It was further proven that these waves had all the properties of those of light and heat and were capable of reflection, refraction, and diffraction. According to the authorities of the day and the best proof we have on the subject they vibrate at the rate of 230,-

000,000 per second and travel with the velocity of 186,-400 miles per second. Hertz showed that the oscillatory discharge of the Leyden jar was not only the leveling of the potential difference between the two but a continuous backward and forward surging, continually decreasing until a state of rest was reached and during the period of the surges a wave motion was sent out into free space. To better understand this action we will take the Leyden jar receiving a charge, the potential of one coating being raised above that of the other until the strain becomes too great and the discharge to the lesser charged coating takes place. In the sudden rush of current to the lesser charged coating a very curious but common action is the result, which could best be expressed by saying that it is over-rushed or stretched beyond its normal capacity and now has the greater charge which of course discharges back to the first coating only to repeat the operation over again. This oscillatory charging and discharging can be best represented by the action of a straight steel spring with one end screwed in a vise and the opposite end left free. Starting the free end in vibration it swings backward and forward, each swing decreasing until it reaches a state of rest. The first swing carries the end of the spring past the central division of rest and the distance which it passes this central division is called the amplitude. When the spring has reached its maximum amplitude, the force in that direction dies away and the backward or returning force comes in effect carrying the spring back passing the central position of rest, but falling short of the maximum amplitude from which it was first started, continuing and constantly falling from the maximum to zero. Thus the vibratory action of the spring and the oscillating charges of the Leyden jar are the same. The time used in making one complete swing from the central position of rest to the maximum amplitude at the right, to maximum at the left and back to the central position of rest is known as the "Period of time" while the number of such periods made in a second is the frequency. The same definitions and rules applying to the oscillatory action of the Leyden jar.

Hertz with aid of his oscillator and resonator was able to set up such waves and detect them in free space. The two are shown in Fig. 12 the oscillator consisting of a spark coil with two perfectly round and highly polished brass balls mounted on metal standards which are in turn connected to the secondary terminals. The brass

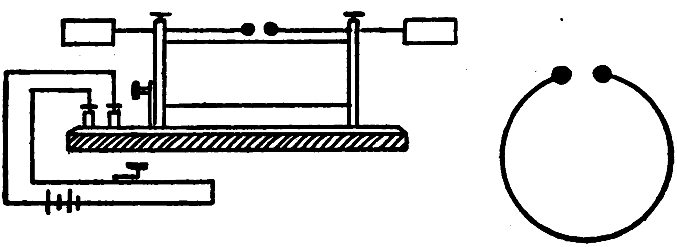


Fig. 12. Hertz Oscillator and Resonator.

balls are now known as oscillators and are adjusted to about 1/8" distance apart. At the free ends of the rods supporting the balls two metal plates are mounted which disperse the wave motion into space. The resonator, or "feeler," consists of a loop of wire terminating in two small brass balls with a minute air gap separating them. By starting the coil in operation and bringing the "feeler" in the wave range a tiny spark breaks across the gap thus showing that such waves were sent out and could be detected. It must be understood, however, that the "feeler'' had to be tuned or syntonized to the exact frequency of the oscillator, otherwise no results would be had. This can again be illustrated by the vibrating spring. If the spring is set in vibration and brought near a second spring of the same size the sound waves will set the second spring to vibrating, as the two are of the same size and respond to the same length sound wave. If of a different size it would not respond so readily as the tune would be different. Hence in the electric wave method of signalling we have the numerous methods for setting the sending and receiving end in close tune or syntony, desired for other reasons than as given here and explained in a later chapter.

To Sir Oliver Lodge is given the credit for first applying the syntonization of a set to practical use, and his experiments are simply those of Hertz carried out on a more improved scale.

Whether or not Hertz had in view a perfected system of wireless telegraphy is not known, for he died soon after giving the world the benefit of his long years of research and investigation. It is a certain fact, however, that we use the same methods and theories today as he set before us, and for which so many have claimed the credit.

THE COHERER.

Prof. Branly in 1890 discovered the peculiar action of coherence on a mass of metal filings when a Leyden jar was discharged in near proximity. To ''cohere'' means to cling together, and is caused by the magnetic effects of the electric current, whether in the form of a discharge or continuous flow, thus causing the mass of filings to ''cohere'' or arrange in this form.

To consider the coherer as a whole we have the loose mass of metal filings with electrodes resting in each edge. The filings are now in a jumbled mass without contiguity or order.

Send a battery current through the mass by touching the electrodes and the mass instantly takes on a continuous shape due to the magnetic effects of the current

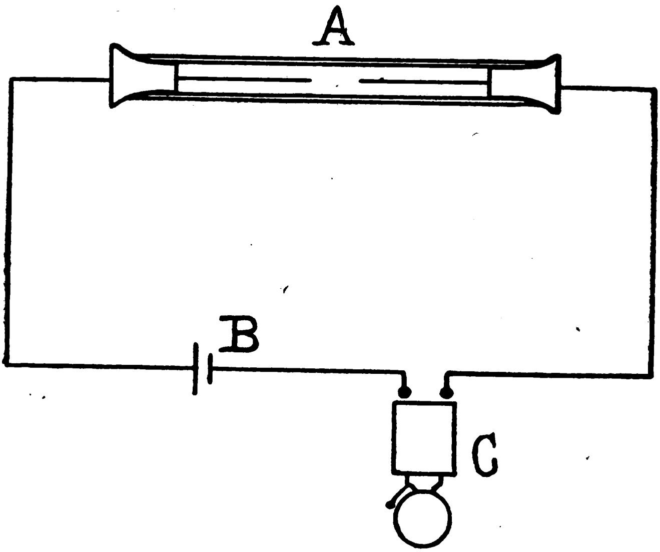


Fig. 13. Simple Type of Coherer.

as previously explained. It is evident that when the filings are in their jumbled state their resistance is very high and when the current flows through, causing the mass to cohere, the resistance is lowered to a large extent as a more continuous conducting surface is offered. By placing the filings in a glass tube and forcing conducting wires through corks at each end we have the type of coherer first used. To complete the circuit a common battery and electric bell are connected in series with it as shown in Fig. 13, in which A represents the coherer, B the battery, C the call bell. To adjust the coherer for use force the wires in at each end until the resistance across the mass of filings is broken down and the bell starts ringing, now draw the wires gradually apart until the bell ceases.

If a Leyden jar is now discharged near the coherer the filings will cohere as previously described, thereby lowering the resistance of the circuit and allowing the bell to ring, which continues until the mass of filings are restored to their original state of high resistance by tapping the tube with a pencil.

CHAPTER III.

CONSTRUCTION OF A SIMPLE WIRELESS SET.

To more fully understand the operation of a wireless telegraph set, the actual working of the parts involved and the plans to pursue to get the best results we should construct and operate a simple set as described here. This will enable the experimenter to more fully grasp the complicated points and prove of assistance when study is begun on the commercial sets as explained in later chapters.

The wireless telegraph set reduced to its simplest parts consists of the sending end for setting up the wave motion in ether and receptive device for picking up this wave motion and translating into the respective dots and dashes of the Morse code. In this case the ordinary induction coil is employed for setting up the wave motion and the coherer for the recepting device.

For sending up to a distance of a half mile it is estimated that the one-inch induction coil will answer. This estimate, however, cannot be relied on in all cases as the conditions under which a set works will cause large variations in the required energy at the sending end. Furthermore to say that a coil giving a certain spark length will send a certain distance is a very unsatisfactory method for the spark length does not in any way indicate the amount of energy given out. The majority of coils are wound with very small wire in the secondary, usually No. 36, this size being requisite for the coils up to the two-inch spark as the general dimensions of so small a coil would not allow of any special features for wireless work. To employ a coil of larger size for wireless work wound with the same size wire in the secondary will give a long stringy spark across the terminals with a small amount of energy, and of which no reliable estimate could be given of the sending distance. However, by winding this coil with No. 32 wire in place of the 36 a short, heavy and burning spark is the resultant which dissipates a large amount of energy and is especially desirable for wireless work. As previously stated no special dimensions are necessary for the smaller size coils, consequently the estimate of a half mile over which the one-inch coil can send will be found fairly reliable and under favorable conditions even a greater distance can be covered. The spark coil, which is simply a small transformer with a high wound ratio, consists of the following parts: Core, primary winding, insulating tube, secondary winding, vibrator and condenser. The exact dimensions of the above parts are given below, with points on the actual construction, it being understood that the coil may be purchased complete if so desired, and this plan is recommended as cheapest in the end, for the construction of a coil is a very difficult job and requires delicate handling.

THE CORE.

The core is made up of No. 22 soft iron wires formed into a bundle 7/8″ in diameter and 7″ long. The core wires should be bought especially for this purpose, cut to the right length and straight. The best method for forming the core is to roll a light flexible paper tube to the desired diameter and glue. Force the tube full of the core wires and roll with pressure between two boards which will cause the wires to fit more closely together and allow more to be forced in the tube. Keep this up until all the core wires possible have been forced in and the tube is perfectly round and tight. The core is now wrapped from end to end with black sewing thread.

THE PRIMARY WINDING.

The primary winding consists of two layers of No. 16 D. C. C. magnet wire wound on the core to within ½″ of each end. Care should be used in winding to make the respective turns fit together without kinks or additional space which causes unsightly work and to a certain extent impairs the efficiency of the coil. After winding on of the primary the whole is boiled out in paraffine wax until all bubbles cease to appear on the surface.

THE INSULATING TUBE.

The insulating tube should be of sufficient size in diameter to a neat fit over the completed primary winding, and of 1/16″ in thickness and 6½″ long. Hard rubber is preferred owing to the superior insulating qualities, although a composition tube will answer.

THE SECONDARY WINDING.

The secondary winding consists of one pound of No. 36 magnet wire wound in 4 sections and the total number of sections so connected that one continuous winding is formed. The simplest method of winding is to provide

4 spools, each spool having a central diameter large enough to slip over the insulating tube. After winding, boil out well in linseed oil and assemble on the insulating tube soldering all connections. The sectional view of the parts with the exact dimensions is shown in Fig. 14.

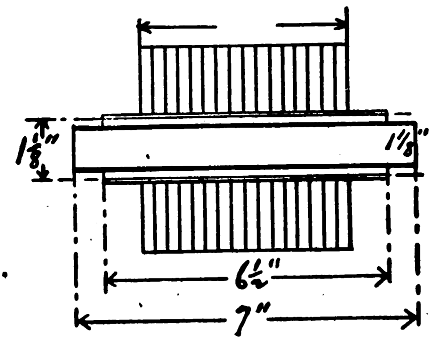


Fig. 14. Sectional View with Dimensions of Parts for Spark Coil.

THE CONDENSER.

The condenser should contain approximately 700 square inches of foil, or twenty-four 5"x6" sheets, which gives 720 square inches all as the total, allowing the extra amount for the loss in connecting, etc. The condenser is built up in the usual manner, using thin bond paper previously boiled out in paraffine wax, and cut in sheets of 6"x8" as the dielectric, or insulating medium to separate the foil sheets from one another.

Begin work by placing down a sheet of the bond paper and in the exact center a sheet of the foil which allows a one-inch margin around the edges. Roll the foil down with a squeege print roller. At the left hand end place a 1″x3″ foil connecting strip with one inch resting on the foil and one inch clear of the bond paper. Over this place a second sheet of bond paper and foil, rolling down as before and leading the connecting strip out to the right instead of the left. This method is followed throughout the construction, alternate layers of paper and foil with the connecting strips leading to the left on the odd sheets as 1:3:5 and those on the right to 2:4:6. In order to get the maximum spark length from the coil it will be necessary to divide the condenser up in banks, of six sheets to each bank, and connect more or less of the banks in the circuit, thereby increasing and decreasing the capacity until the best results are had.

THE VIBRATOR.

The vibrator for a spark coil offers quite a lot of difficulty in construction and it is recommended that it be purchased complete as the increased results will well repay us for the time and trouble spent in the construction.

MOUNTING.

The mounting of a coil is left more to the constructor's needs and means than actual dimensions. However, a good plan to follow is to use a wood case that will allow the insertion of the complete parts with a ¼″ space around the edges. The interior space being filled up with a mixture of paraffine and beeswax in the portions of half and half. At one end of the case the core is brought out ¼″ clear of the end against which the hammer of the vibrator works. The wiring diagram is shown in Fig. 15.

OPERATION OF THE COIL.

Before setting up the coil as a wireless transmitter it will be well to study out the action which takes place and the manner in which the high frequency current is induced in the secondary winding. As shown in Fig. 15 we have the complete wiring diagram and the parts with their relation to one another. A represents the core, B the primary winding, C the insulating tube, D the secondary winding, E the battery, F the telegraph key, H the vibrator and K the condenser.

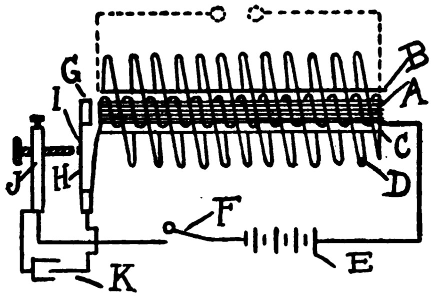


Fig. 15. Wiring Diagram of Spark Coil.

The complete vibrator consists of the post J, and the brass spring I with the soft iron disc G pivoted on the end and the disc resting 1/8″ clear of the end of the core. The contact screw of the post J is platinum tipped and works through the post to the platinum contact on the brass spring I. In Electro-Magnetism, Chapter I, we learned that on sending the electric current through a winding of wire over a bar of soft iron this central rod became magnetic and magnetic lines were set up beginning at the end of the core and extending through a second coil of wire wound over the first, this second winding being well insulated from the first and known as the secondary. On quickly breaking this current flow the magnetism ceases to exist and thereby induces a current of high voltage in the secondary winding. Thus in the spark coil, the strength of the current induced in the secondary winding depends not only on the general construction of the coil but the rapidity of the "make and break" in the primary circuit as well, and the device for bringing this about is known as the vibrator. In connection with the vibrator the condenser is employed, its purpose being to take up the spark at the vibrator contacts in the form of a charge and discharge back through the primary winding.

To follow out the operation of the coil as shown in Fig. 15 we press the key F, which closes the battery circuit and allows the current to circulate through the primary winding B around the core A, and completes the circuit through the contacts of J and I. The current circulating around the core makes it magnetic and this magnetic force attracts the soft iron disc G pivoted on the spring I. The disc is attracted to the exposed end of the core and in its forward move the spring I breaks the circuit which is completed through J and I. Here we have the sudden break and as the current no longer flows the magnetism ceases to exist, releasing the pull on the disc, allowing the spring to fly back to its original position, only to repeat the operation over again. The number of vibrations per minute which determines the spark length of the coil can best be found by regulating the screw which works through the post J. The condenser and its purpose has already been explained and need not be repeated.

THE TRANSMITTING END.

In addition to the spark coil there will be needed two brass balls or oscillators, the aerial wire and ground to complete the coil as a wireless sending end. The brass balls should be about ½″ or ¾″ in diameter perfectly round and highly polished. A small hole is drilled in each side and brass rods inserted. The rods are now mounted on the binding posts to which the secondary terminals are connected as shown at A, B, C, Fig. 16. The aerial should have an approximate height of 35 feet, suspended from a pole. This height, however, can be varied to suit the conditions as in a number of cases the aerial can be suspended from the roof of a house, which proves less expensive and no appreciable difference can be noted in the sending efficiency.

The aerial should be run the first half of the height with No. 14 insulated copper wire and finished out with the same size in bare. To suspend the aerial it is best to use two common porcelain knobs strung together with an oiled seagrass rope, one tied to the pole or from whatever object the suspension is made and the aerial to the lower one. This will serve to prevent the dispersion or leakage of the high frequency current which is the usual case when one knob is employed. Where the aerial is led in to the instruments care should be used in insulating as dispersion can occur here as well as at the termination. The usual method is to lead through a porcelain tube or hole drilled through a pane of glass, the latter method is the more preferable as better insulation is provided. The insulation is scraped off of the lower end of the aerial wire for about one inch and soldered to the rod as shown at B, Fig. 16.

The ground should consist of a metal sheet buried to a depth of five or six feet with an insulated wire soldered to it and led up and soldered to the brass rod opposite the one to which the aerial is attached. Both

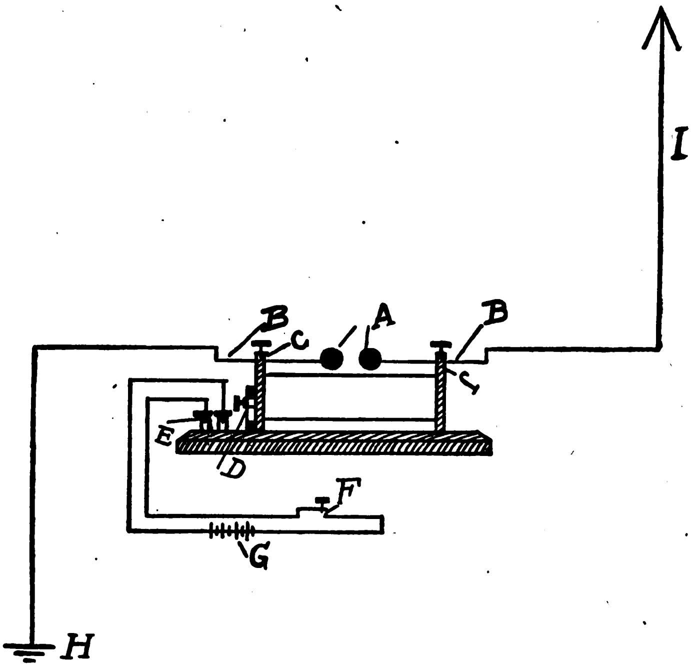


Fig. 16. Sending End of Experimental Wireless Set.

ground and aerial are shown in Fig. 16. By connecting up the battery in series with the telegraph key and the primary binding posts of the coil the sending end will be completed. The adjustment and operation will be taken up after work has been finished on the receiving end.

THE RECEIVING END.

The simplest form of coherer was the type originally used by Branly and was described in Chapter II. This type, however, would not answer for work over a few feet and a more improved and sensitive kind will be described. The coherer such as described here can be constructed at small expense and this method is recommended both from the point of economy and the fact that a better idea will be gained of the essential working features, which will prove of value in the final adjusting and operation. First two large binding posts are needed

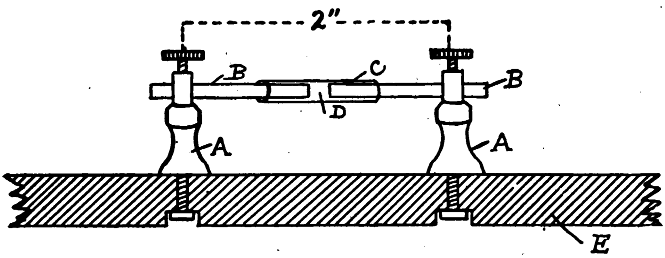


Fig. 17. Parts Used in Constructing Coherer.

as shown A-A Fig. 17. The exact size and style of the binding posts makes no difference so long as the hole at the top is of sufficient size to allow the insertion of a 1/8" brass rod. The binding posts are now mounted on a wood base 7" long by 3½" wide and 5/8" thick. In Fig. 18 is shown the method and position in which the binding posts are mounted. Two other binding posts are mounted and small V-shaped troughs cut as indicated by the dotted lines. Connecting wires are run down the troughs from the binding posts to binding post.

The brass rods or coherer arms are shown at B-B. These arms can be cut from a common ⅛" brass rod in lengths of two inches each, and well amalgamate the tips in mercury. In Fig. 17 is plainly shown the manner in which the rods are mounted and the glass tube which holds the filings in the space D. This space should be about 1/16" to ⅛" in length, the exact distance being best determined by actual experiments.

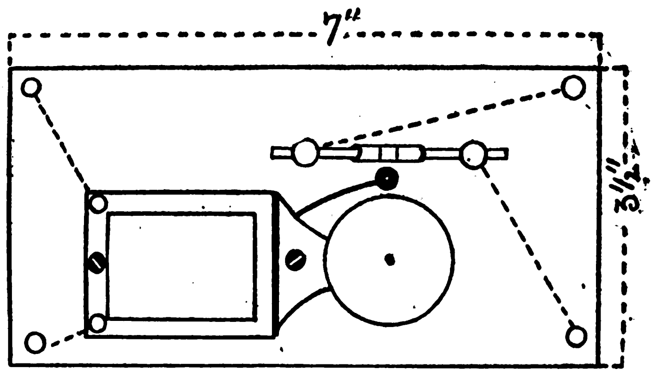


Fig. 18. Plan Showing Position in which Coherer and De-Coherer are Mounted.

The successful working of the coherer will depend to a large extent on the type of filings placed in the space D. No doubt but what a large number of experimenters have bad results with the coherer at the receiving end owing to the fact that they have adopted some formulæ from the numerous text-books or articles on this subject and which proves very unsatisfactory when applied to use. A mixture that the writer has found to give excellent results consists of 88 parts of steel to 12 of silver. The filings should be prepared with a coarse file and sifted in a thin cheese cloth which allows the dust to go through, retaining the larger and more coarse pieces which are placed in the space D between the coherer arms.

As previously explained, the filings when placed in the circuit of incoming wave current "cohere" which lowers

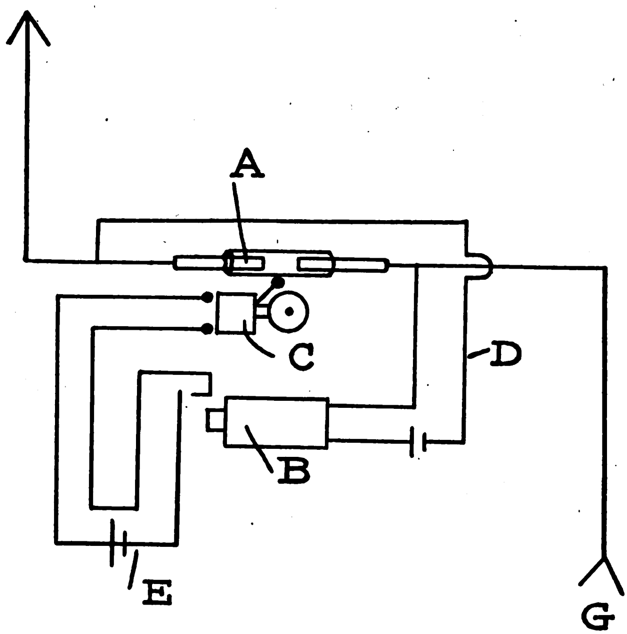


Fig. 19. Complete Receiving Set.

the resistance and allows the bell or other indicating device to be acted on by the battery. The current from the local battery will continue to flow, thereby giving indication until the filings are restored to their original state of high resistance, which in the first case was done by tapping the tube with a pencil. It was soon found necessary to provide other means for this tapping or de-coherering of the filings, a method whereby the de-coherering would continue in synchronism with the length of time the key was pressed at the sending end, and which is accomplished by use of the ordinary electric bell. The bell is mounted as shown in Fig. 18, with the hammer in such a position that it vibrates against the glass tube C when in operation. This completes the coherer and de-coherer. The manner of connecting up is shown in Fig. 19, in which A represents the coherer, B a 150 ohm relay, C the electric bell or de-coherer, D and E the batteries operating the respective circuits.

To adjust the receiving set for use considerable time and patience will be necessary. Begin by first turning the set screw which controls the bronze spring on the relay, until the relay armature, which is in turn controlled by the bronze spring, has fallen against the second contact, thereby closing the circuit with the battery E and starting the bell to ringing. Now gradually turn the set screw back until the tension on the spring has grown sufficient to pull the armature back and breaking the circuit with the bell E. The adjusting is continued on the relay contacts until the distance which separates the two is hardly visible to the naked eye; in fact, the writer has observed that the best results are had when the contacts are in this position. To adjust the coherer, begin by forcing in the coherer arms until enough current flows through the filings to attract the armature of the relay and start the bell to ringing.

The coherer arms are now pulled gradually apart until the bell stops, and lock the arms by turning the set screw on top. The receiving end is now adjusted for use and should be placed about ten feet from the sending end (without aerial or ground). Adjust the spark balls until about 1/8″ separates them and press the key which sets the vibrator in operation, discharging the spark across the gap and setting up the Hertzian waves.

The waves spread out equally, in space of which a certain portion flows through the mass of filings and causing them to "cohere," allowing the current from the battery to actuate the relay armature and starting the bell in operation. The distance between the two should now be lengthened until the limit has been reached, which is usually forty to fifty feet. By addition of the aerial and ground, communication can be held up to a half mile, as stated, with satisfactory results. The same rules apply to the erection of the aerial for the receiving as the sending end.

CHAPTER IV.

SPARK COILS AND TRANSFORMERS.

Spark coils and transformers are used to a large extent in wireless telegraphy and a chapter on this subject will no doubt prove beneficial to the reader, as it will serve to enlighten those who are not so familar with the subject and is necessary for an extended study of wireless telegraphy.

In Chapter II the operation and the parts necessary in the construction of a spark coil was explained and the reader is advised to refer to this chapter, as the construction of all spark coils is the same, the difference existing in the amount of insulation and the dimensions of the various parts used.

The most difficult and puzzling part which will arise before the layman in the construction of a coil is the winding of the secondary. This necessitates very delicate handling and careful work to get good results. To attempt to wind the secondary by hand would prove a very tedious job as the small size coils contain several miles of wire and it is next to impossible to make the respective turns run smooth and even, rendering the wound portion unsightly, and in the end giving bad results, as the uneven turns will allow of "air spaces" which frequently cause the "breakdowns," as explained farther on.

For winding the amateur will find the turning lathe excellent, as a good, steady speed can be maintained, which turns out a neatly wound section. The turning lathe, however, is not an adjunct to every amateur's laboratory and other means of winding must be supplied. The winding machine described here is very simple in construction and will wind sections for coils up to the 10″ size.

In winding the sections it is best to provide means whereby a certain portion of the insulating substance is placed on the wire as the winding proceeds. This will

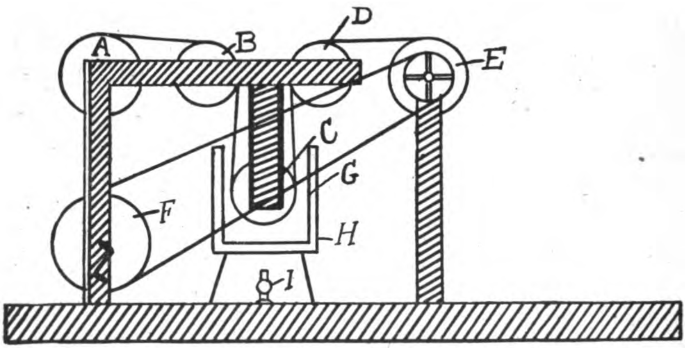


Fig. 20. View Showing Complete Winding Machine.

serve to hold the wire in place while the section is being handled and impart superior insulation to it. Several kinds of insulating substances are used, paraffine wax the most common and easily handled. The method of applying is given in the following description and illustrated in Fig. 20:

As shown in the figure we have a wood frame made up of strips and mounted on the base K. The height and dimensions of the various parts are of only momentary consideration, leaving the dimensions to the constructor's means, but retaining the same working features.

A represents the original spool of magnet wire, held in the top corner of the frame by a bolt run through its central hole and the strips. Common spools B-C-D are mounted on the frame as shown, their purpose being to guide the magnet wire through the paraffine wax solution and to the section former at E. A drive wheel F is placed on the frame and belted to the small wheel which is mounted on the same bolt as the section former E. The smaller drive wheel is shown at E. The paraffine wax receptacle is shown at G and consists of a small tin bucket placed inside the larger one H, and separated from it by water poured in the space between the two. The alcohol lamp at I serves to keep the two in a boiling state while the water serves to keep the paraffine from becoming overheated and catching fire.

Considering that the secondary for a one-inch coil is desired we turn to the table of dimensions, appended at the last of this chapter, and find that 1½ pounds of No. 36 S. S. C. magnet wire is necessary for the complete secondary, wound in four sections. As the total distance between the coil heads is 5¾″ this will allow 1 9/16″ for the thickness of each section.

The reason for winding the coil in sections, is that the current which is induced in the secondary runs up in the thousands of volts and it is a well known fact that the electric current, like running water, seeks the lowest path of resistance. Unless the precautions were taken of well insulating and dividing the secondary up in sections the current would naturally seek the lowest path of resistance, which would be directly across the secondary winding. What is known in the technical phrase as a "breakdown" has now occurred, which destroys the efficiency of the coil and makes a complete rewinding of the coil necessary. In fact, the "breakdown" is a "nightmare" to coil users and every factor in insulating, which is the only remedy, should be used against it. By dividing up the coil in sections each section will be made capable of carrying the current load and delivering to the secondary terminals. The number of sections to use will depend on the size coil in view. For instance, in the table we note that 6 sections are necessary for a 3″ coil, the number increasing as the length of the spark.

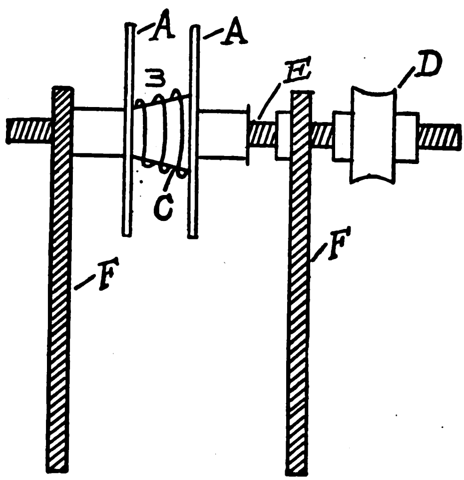


Fig. 21. Section Former and Manner of Holding.

For winding the individual sections, a device known as the section former is needed, and is shown in Fig. 21. The former consists of two brass plates A-A, about four inches in diameter, with holes drilled in the center large enough to slip over the bolt E. A second small hole is drilled in one of the plates as shown at B. The wood disc C, which is placed between the two plates, should have the same diameter at the smaller end as the insulating tube over the primary winding and 1/8" larger at the opposite end. The wood disc is made in this shape in order that it may be slipped from the wound section without disarranging the winding.

To begin winding draw the end of the magnet wire from the spool A around the guiding spools B-C-D up to the section former E and here lead through the small hole B, taking several turns around the bolt to hold the wire in place. Considering that the paraffine wax is in a boiling state, the crank handle of the wheel F is turned so that a fairly good speed is attained at the small drive wheel of the section former E and the wire guided as evenly as possible over the space by hand until the estimated amount has been wound on, which in this case would be 6 ounces, or one-quarter of the total amount. The only reliable method for determining the amount of wire wound on the section is to weigh the spool before the winding has been started and after a certain amount has been wound on, the difference between the two weights giving the amount on the section. To remove the section unscrew the taps and slip the bolt from the supporting strips.

The taps which hold the brass plates in position are now unscrewed and the plates taken from the sides of the sections next pushing the wood disc from the center. This section is marked No. 1 and laid aside.

In winding the next section the plate with the small hole B cut in it is faced in the opposite direction. That is, if this plate was to the left hand side when the first section was wound, face to the right for the second. This is necessary to make the sections coincide when connecting up. The third section is wound with the former facing in the same direction as the first, and the fourth same as the second, following this method throughout for winding any number. Each section should be marked as to its respective number when taken from the former.

The sections are next boiled out in linseed oil for at least one hour. This will drive out all traces of moisture and fill up the superfluous spaces, caused by irregularities in the winding. This same rule for boiling out in linseed oil will apply to all size coils, as the linseed oil provides an excellent insulating substance and it is seldom that a "breakdown" occurs where it is used.

In assembling the sections the inside terminals of each pair are connected together by twisting and soldering. It should be noted that the sections connect up so that one continuous winding is formed. In assembling, the sections should be separated from one another with four sheets of paraffined filter paper, which has been cut to the right diameter. In larger coils thin, hard rubber sheets are used for this purpose; however, paraffine paper will answer in coils up to the 4″ size. At this point it will also be of interest to note that in the large coils a different method is used in the winding. The sections which are to be used near the end of the secondary are wound with a lesser portion of wire and the diameter of the central hole increased. The extra space between the insulating tube and the central hole of the secondary is filled in with paraffine wax or some other insulating medium. This method of winding proves necessary as the greatest potential strain exists at each end of the secondary where the wires lead up to the terminals, and as the iron core is located in near proximity to the point of greatest strain, it is therefore necessary to increase the insulating qualities at this place, or otherwise the current would break across to the more conductive path of the iron core.

Slightly different rules are observed in winding coils for wireless use. No. 32 wire is usually employed in the secondary in place of the 36. The reason for this increase in size was partly explained in Chapter II. To restate, the energy radiated from a coil wound with fine wire is very low, yet the spark is much longer than it would be if the same coil was wound with the heavier wire. The second type of winding, however, gives a fat, hot and burning spark and radiates a large amount of energy. As an evidence of this fact, the writer has held communication up to a distance of 15 miles with a two-inch coil (spark length), and over this same distance an X-ray coil, giving a spark 6″ in length, failed to give anything like satisfactory results. A second advantage in using the larger wire is in the cost—and also in the insulation used. Where the No. 32 wire is employed the number of sections can be cut down at least one-half, as the larger size wire offers a better conducting surface, and therefore requires less insulation.

Equally as much care should be used in the construction of the other parts, for the spark coil, as true with other electrical apparatus, "is no stronger than its weakest part."

From the explanations which have been given the reader should be able to construct almost any desired size coil. By exercising care and patience the constructor may rest assured that the results will be satisfactory. The table of dimensions of various size coils is appended herewith and a description given of the various other instruments used in connection with the coil:

DIMENSIONS OF SPARK COILS FROM THOSE GIVING ½-INCH UP TO THE 4-INCH SIZE.

	½	1	1½	2	3	4
A	6½″	7½″	8″	9″	11″	10″
B	⅝″	⅞″	1″	1″	1⅛″	1⅛″
C	18	18	16	14	14	14
D	⅞″	1⅛″	1⅜″	1½″	1⅝″	1¾″
E	1⅛	1⅜″	1 11/16″	1⅞″	2″	2⅛″
F	2½″	3″	3½″	3¾″	4″	3¼″
G	4½″	5¾″	6½″	7½″	9″	7″
H	2	4	4	6	6	30
I	¾ lb.	1½lb.	2 lb.	2¼ lb.	3¼ lb.	4½ lb.
J (total in sq. in.)	700	1000	1500	1800	2300	3000

DIMENSIONS OF SPARK COILS FROM THOSE OF THE 6-INCH UP TO THE 12-14-INCH SIZE.

	6″	8-10″	12-14″
A	13″	17″	18″
B	1¼″	1½″	1 11/16″
C	4 lb.	7½lb.	8 lb.
D	12	12	12
E	1¾″	2″	2 3/16″
F	2¼″	2½″	2 11/16
G	4″	6″	6 to 7″
H	38	48	48
I	9″	12″	14″
J	6½ lb.	9 lb.	15 lb.
K	4000	8000	10,000

Note:—The dimensions of spark coils vary with the majority of manufacturers. The above tables are taken from the *"English Mechanic"* and have been compared with the tables of several makers, and according to the writer's opinon the above dimensions are the most reliable for general use.

The explanation of the letters is as follows:
Letter.

A—Length of core.
B—Diameter of core.
C—Gauge of primary wire.
D—Internal diameter of insulating tube.
E—External diameter of insulating tube.
F—Approximate diameter over secondary winding.
G—Distance between coil heads.
H—Number of sections in secondary.
I—Quantity of secondary wire. (Size No. 36 S. S. C.)
J—Total number of sq. in. of foil used in condenser.

Explanation of letters as used in second table:

A—Length of core.
B—Diameter of core.
C—Weight of core.
D—Gauge of primary wire.
E—Internal diameter of insulating tube.
F—External diameter of insulating tube.
G—Average diameter of secondary sections.
H—Number of sections.
I—Distance between coil heads.
J—Quantity of second wire. (No. 36 S. S. C.)
K—Condenser. Total area of foil.

If the coil is to be used for wireless telegraphy the dimensions of the core should be slightly increased. No. 32 wire should be used in the secondary in place of the 36 and the amount increased one-quarter above the amount given in the tables.

VIBRATORS AND INTERRUPTERS.

The type of vibrator shown and explained in Fig. 15 proves very efficient for the small size coil, but is useless for those above the 2″ spark, as the heavy primary current which is used with the larger coils soons melts the plat-

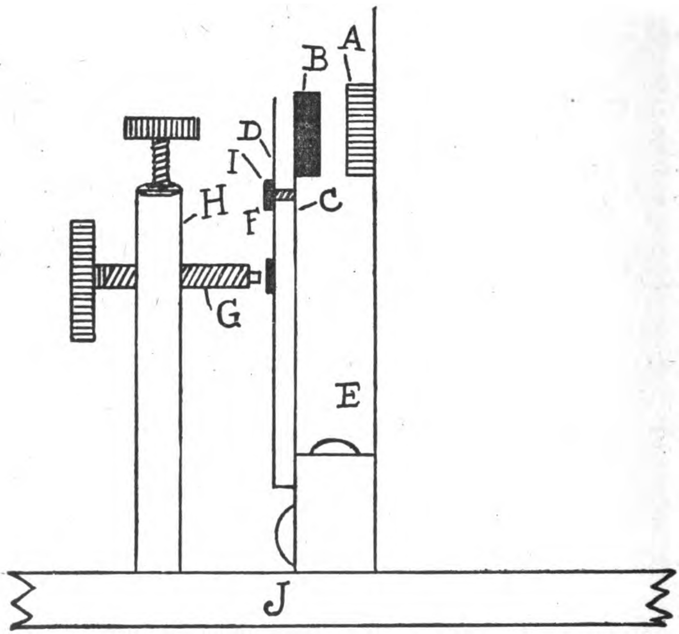


Fig. 22. Sectional View of Improved Vibrator.

inum and "pits" the surface, thereby increasing the resistance and reducing the primary current flow. This causes a weak and irregular spark, which can best be eliminated by the addition of one of the improved vibrators, as shown in Fig. 22.

In order to get the maximum results from the coil the vibrator should work at a good speed, yet allowing sufficient time at each make for the current to flow around the primary winding and fully magnetize the core. The break should be made very sudden in order that a full discharge may be made across the secondary terminals. In fact, the main working points of a vibrator is that it should have a long make and quick break.

The vibrator illustrated in Fig. 22 combines all the features named above and will give excellent results when used with the larger size coils. The exact dimensions of the parts are not given as this will depend on the size coil with which the vibrator is to be used. However, the working parts are shown and the amateur should have very little difficulty in constructing and assembling the parts.

The end of the core is shown at A and the complete vibrator comprises the rest of the figure. B is a soft iron disc mounted on the end of the spring C, with an auxiliary spring D mounted on the main spring and screwed to the metal block E. The tension of the auxiliary spring is controlled by the screw I, which works loosely through it, to the main piece C.

The brass standard H holds the screw G, which has the platinum contact F on the end, and makes contact with the platinum on the spring D.

When the soft iron disc B is attracted by the core A, it goes forward until the head of the screw I hits the second spring and breaks the circuit. The magnetic pull now ceases to exist and the screw which works loose in the slot allows the disc to fly back a considerable distance before the magnetic pull comes in effect. Thus the core is energized during the backward and forward motion of the spring C and until the screw I hits the second spring, which breaks the circuit, giving the long make and quick break.

Independent Vibrators. Vibrators used with some coils are known as the independent kind and are not operated by the magnetic action of the core, as previously explained, but by a separate coil which is included in the

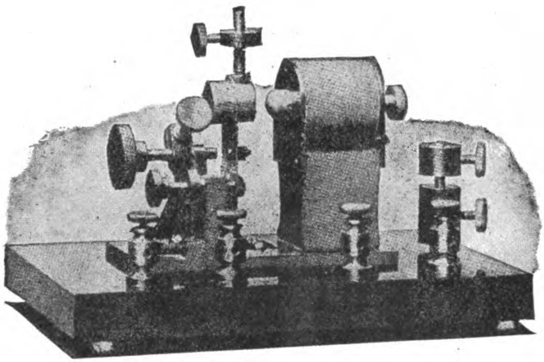


Fig. 23. Independent Vibrator.

primary circuit. The main features claimed for this type is the large range of adjustment which allows it to be used with almost any size coil. Such a vibrator is shown in Fig. 23, which combines, with the exception of the separate coil, the same working features as the type in Fig. 22.

Mercury Interrupters. Mercury interrupters are of numerous different kinds and types. Probably the most simple is the English kind, which consists of a triangle-shaped metal sheet mounted on the shaft of a small motor, which revolves at a high speed and cuts the corners of the triangle sheet in and out of a pot of mercury placed directly under it. The circuit is completed through the shaft of the motor and the pot of mercury.

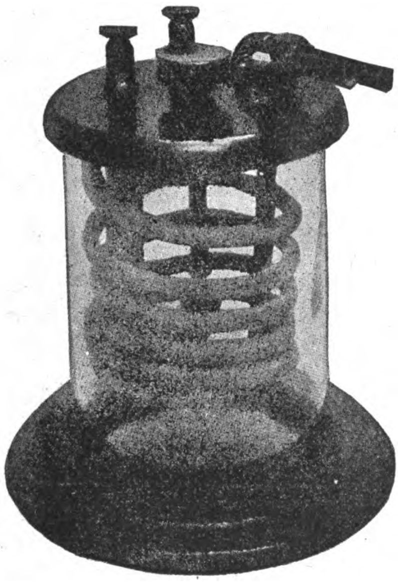


Fig. 24. Wehnelt Interrupter.

Wehnelt Interrupters. The Wehnelt interrupter shown in Fig. 24 is at once the most simple and efficient kind for general laboratory use. Excellent results are had when the proper adjustments are made. The Wehnelt interrupter consists of a platinum point and a lead plate immersed in a dilute solution of sulphuric acid, the positive side of the circuit being connected to the platinum electrode and completed through the primary of the coil, which is connected to the lead plate. The interruptions with this type of interrupter are extremly high, ranging from 100 to 1,000 per second. The coils used with this type of interrupter should be of the best insulated kind, as otherwise the rapid breaks will soon cause a breakdown in the secondary winding. In the type shown in Fig. 24 a tube is introduced in the jar through which water is circulated, keeping the solution cool.

Condensers. There is quite a number of types of condensers in use. One of the most easily constructed and cheapest kind is the paper type, which is used to a large extent across the vibrator contacts of small size spark coils. The paper type, however, proves useless for high tension work, as the paper insulating medium, or better known dielectric, is not capable of withstanding the high voltage, and in consequence the paper walls are pierced, which short circuits the current energy. To withstand the high tension currents a condenser with a dielectric of high insulating properties is necessary, of which glass is the most commonly used. The usual form of condenser employing glass as the dielectric is the Leyden jar, and is simply a glass jar coated to within three-quarters of the total height, inside and out, with tin foil. A second type that has been adopted to a large extent for wireless use is made by coating the opposite side of glass plates with the foil and placing in a suitable rack with contact points. This type is more portable than the Leyden jar kind and will allow of a very fine range of adjustment.

Among the other types in use are those where metal plates are separated by air, immersed in oil, placed in vacuum. Some special features are claimed by the makers of the different types, yet in actual working very little difference is noted.

Transformers. Transformers are now coming into wide use for wireless telegraphy and are found in the majority of the commercial stations. The advantages which the transformer holds over the spark coil are numerous and the entire points of favor would be too lengthy to be pointed out here.

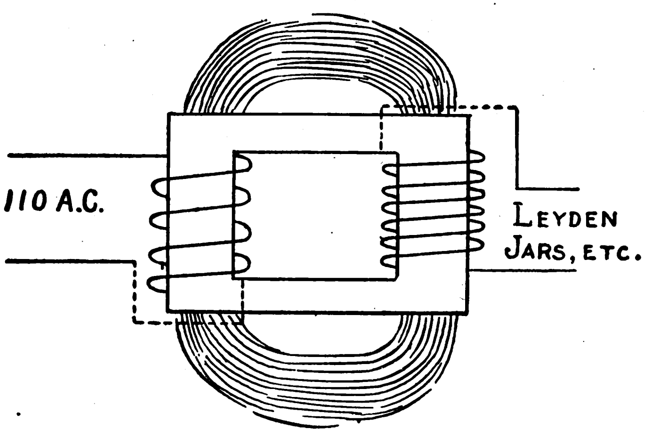


Fig. 25. Showing Plan Used in Constructing a Closed Core Transformer.

However, it may be stated that a wide difference exists in the cost. As an illustration we can take the ordinary 8″ spark coil, which usually costs in the neighborhood of $80.00, and this coil when used for sending would probably work up to fifteen miles. A 250-watt transformer costing $35.00 would send up to twenty miles and with far better results than the 8″ coil. It is considered that the coil mentioned above is of the ordinary X-ray kind, which is the type usually on the market.

The transformer can only be used where the required voltage (110 alternating) is at hand, and for a number of purposes, such as short distance experimenting, the spark coil is more desirable, as the expense in this case would be at a minimum. Among its other features the transformer does not include the delicate working parts such as the vibrator, condenser, etc., which are necessary adjuncts to every spark coil.

Transformers are of two general types, the closed core and the open core. In Fig. 25 is shown a sketch of the closed core type which comprises the primary winding of a few turns of heavy wire around the core, and the secondary winding of a large number of turns of small wire. The core is built up of soft iron sheets. The cycle of changes which takes place in the operation of the transformer is the same as for the induction coil with the exception that A C current is used and the natural reversals of the current cause the inductive discharge, thereby eliminating the use of the vibrator.

The opened core is identical with the primary and secondary of the spark coil in winding; the dimensions, however, are increased both in the amount of the primary wire and the amount and size of the wire used in the secondary.

CHAPTER V.

TUNING IN WIRELESS TELEGRAPHY.

Hertz in his original experiments found that his "Feeler" or detector, such as it may be termed, would have to be of a certain length before it would respond to the waves sent out by his resonator. From this fact and other experiments it was realized that all Hertzian waves are of some definite length, this length varying in proportion to the size of spark coil used and the amount of capacity included in the circuit. And the "Feeler" would have to be tuned or syntonized to this length before satisfactory indications were had.

In the analogy of the Leyden jar we have a straight steel spring with one end locked in a vise and one end left free. If a second spring locked in the same manner but of a greater length is brought near the first, and the first one started in vibration, the longer spring will pick up a certain portion of the sound waves and respond weakly. However, if we regulate the two springs until they are of the same length and one started in vibration the second will respond with the same musical note.

This same operation is had in wireless telegraphy. Waves are set up in the ether by means of the spark coil and oscillator, and the waves are in turn controlled by the tuning device. At the receiving end a second tuning device is employed, which is regulated until it responds to the same length of wave as sent out from the transmitting coil. Tuning is desired not only for the more efficient working of the system but secrecy as well.

Sir Oliver Lodge made the first applications of tuning and since that time constant developments have been made and at the present time several stations can work in near proximity to one another without interference, each station setting its wave length to the station desired to communicate with. However, tuning has not yet been developed to the point where absolute secrecy is had, for any station with a tuning device could cut in and listen. The open circuit set such as described in chapter 2 will pick up signals from any station, and in this case, what is known as "forced oscillations," take place, as the receiving end is forced with the incoming wave. The open circuit set, however, will not pick up the signals from distant stations or give as clear indication as the tuned set.

The main objections to the open circuit system as described in chapter 3 and originally employed by Marconi, is that the wave set up dies down very quickly and consequently is not suitable for long distance use. To explain this more clearly let us consider that a rock is dropped in a still body of water. This causes a disturbance in the form of waves which spread out equally over the surface and constantly die down as the distance increases.

The oscillations surging up and down the aerial strike such electrical blows on the ether, which spreads out in the form of the Hertzian waves and is picked up by the distant receiving end. The stronger the sending end the greater the disturbance and the distance covered. In the open circuit set the secondary of the spark coil is connected directly to the aerial and ground. Hence, the length of the aerial may be too great or too short for the amount of energy radiated from the coil and the oscillations are quickly damped out, giving very little indication at the receiving end. In the operation of tuning the energy from the coil is set in harmony with the length of the aerial and as all parts are in harmony the maximum results are had. The tuned set is commonly known as the "closed circuit set."

The Tuning Coil for the Sending End. The tuned set complete comprises a battery of Leyden jars connected across the spark gap of the coil through the tuning coil.

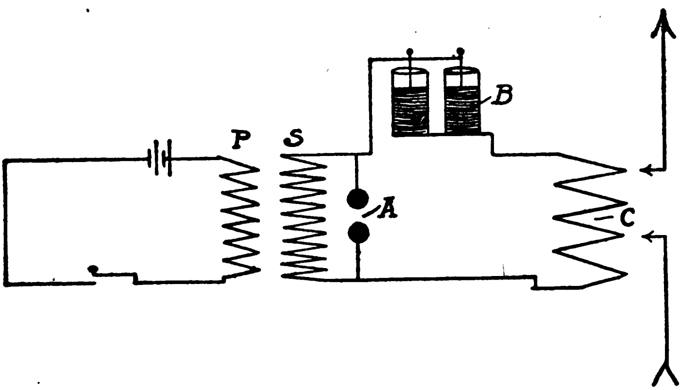


Fig. 26. Tuned Wireless Sending Circuit.

In Fig. 26 is shown the complete arrangement: P represents the primary of the coil or transformer, S the secondary, B the condensers, C the tuning coil, and A the spark gap. The tuning coil is simply a few turns of heavy wire wound on a hard rubber or polished wood frame. The coil is now known as an inductive resistance. Direct current will flow through such a resistance impeded only by the natural resistance of the wire, which is very small. However, when the high tension alternating current flows through such a winding the rapid alternations set up little waves of magnetism around the wire, which opposes the current flow and makes the resistance offered to the alternating current very high, consequently quite a large range of regulation can be had by winding only a few turns of wire on the frame.

A very good size of tuning coil can be made for experimental use by winding 10 turns of No. 8 tinned copper wire on a frame 10″ high and 12″ in diameter. This type is shown in Fig. 27. The exact size given here can be changed, as almost any type will answer.

The Leyden jars, considering that this type of condensers are to be used, are connected as shown in the figure. The number of jars to use will depend on the strength of the induction coil or transformer and the number of turns in the tuning coil. However, a very good plan to follow out is to connect 10 jars in the circuit, decrease and increase this number, also connecting to the different portions of the tuning coil until the best results are had.

By referring to Fig. 26 we see that the lead from the Leyden jars to the tuning coil has the arrow tip. This indicates that this is made of flexible cord, provided with clamp connection so that any portion of the tuning coil may be connected in the circuit to increase or decrease the capacity. Like contacts are provided for the aerial and ground, as it is also desired that these two be connected to the different portions of the frame.

In operation the key is pressed which sets up transforming action between the primary and secondary of the coil. The high tension current flows through the inductive resistance and begins charging the condensers. One side of the condenser takes up the majority of the charge until the potential strain becomes too great and

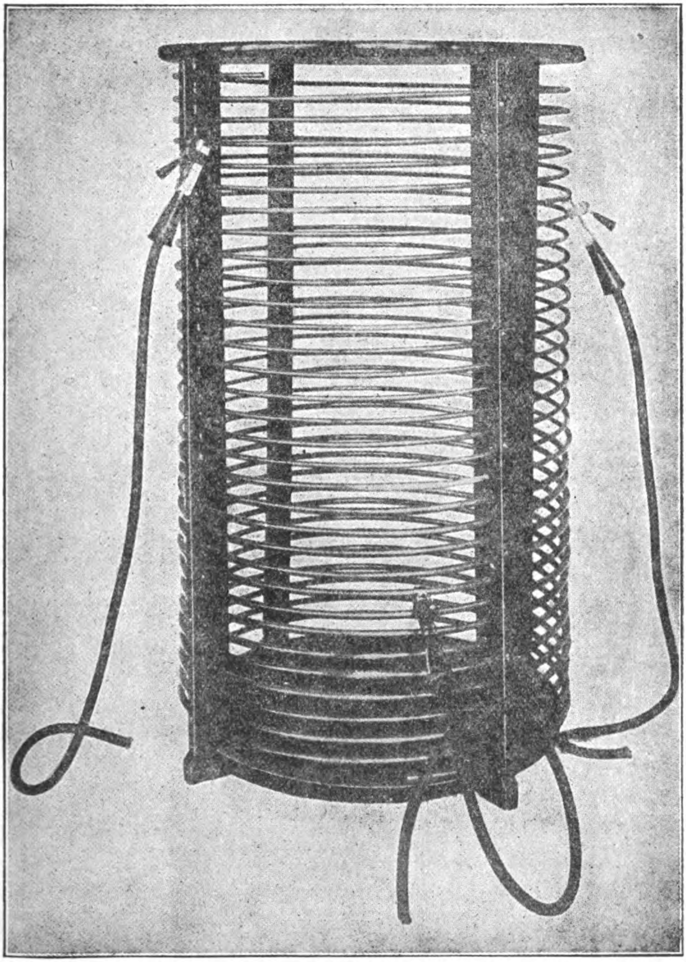


Fig. 27. De Forest Type of Tuning Coil.

the discharge across the spark gap takes place. When this discharge takes place an oscillatory charging action is the resultant continually surging backward and forward until a state of rest is reached. This action of the Leyden jar has been fully explained in Chapter II. It is, of course, evident that in the meantime the vibrator of the coil is in operation and the condensers are continually charged.

As the closed circuit set and aerial are in harmony the aerial will take up the oscillations and radiate with the maximum results. The oscillations in this case are known as "sustained," deriving this word from the fact that the condensers charge and recharge, ranging from the maximum to zero, and during this period of action send an oscillation of like character surging up and down the aerial. The disadvantage of the open circuit set is obvious when we consider that the indication is set up by one "crash" of the spark coil, which has none of the "sustained" features as evident with the "closed circuit" set. Hence, the difference between the closed circuit and the open circuit set in working, is that the closed circuit set sends out a sustained oscillation which is capable of breaking down the more distant indicating device and is susceptible of tuning; whereas, the open circuit set has none of the above features and is only suitable for experimental work.

The Tuned Receiving End and Tuning Coil. The tuned receiving end is simply the detecting device provided with suitable instruments for setting to the same wave length as the sending end. The instruments which comprise the complete set are as follows: The detecting device, the telephone receiver, the battery, the potentiometer, the tuning coil and condensers. The complete set and how it is connected in relation with the various instruments is shown in Fig. 28. Of the instruments, the tuning coil will first be taken in consideration. The receiving tuning coil differs broadly from the sending coil. The sending coil is made of a few turns of heavy wire, while the receiving coil is made of a large number of turns of very small wire. The tuning coil is shown in Fig. 29, and it will be noted that two sliding contacts

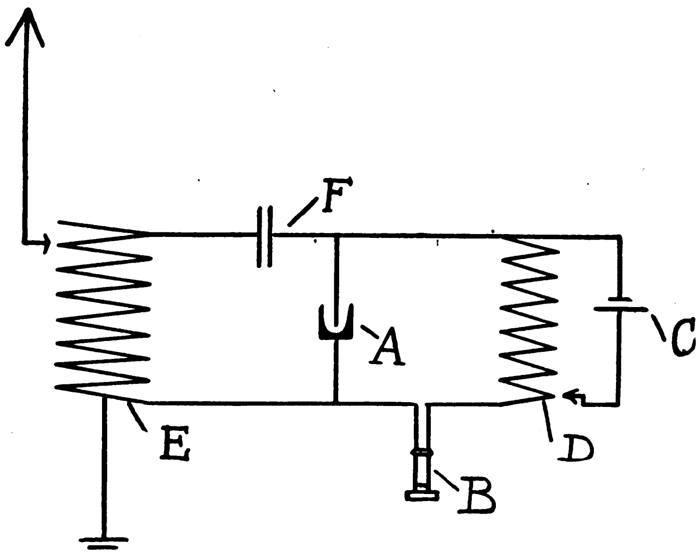


Fig. 28. Tuned Receiving Circuit with Liquid Detector.

are provided, which work up and down the frame, throwing in more or less of the turns of the winding. A scale is usually provided over which the contacts work, thereby indicating the number of turns used for receiving from a certain station. The tuning coil in size is usually about 10″ in diameter and 12″ to 14″ high, wound with several hundred turns of wire.

Taken approximately each turn of wire will represent a wave 4 meters in length and if wound with 110 turns of wire it will be adjustable up to a wave 440 meters in

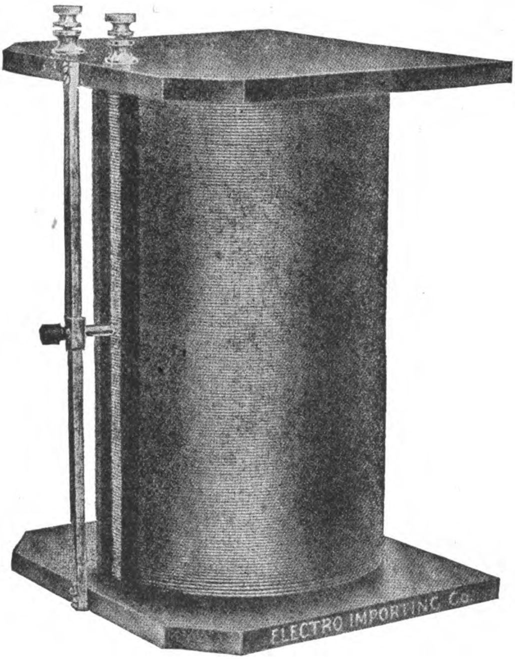


Fig. 29. Tuning Coil with Slide Contact.

length. There is quite a variety of methods for connecting up the tuning coil with the other instruments; the plan shown in Fig. 28, however, will be found simple and easy to use.

The condenser F is made by building up with three or four sheets of tinfoil 2″ by 4″ in size, and separating with paraffine paper. The detecting device A is the liquid detector which will be described in operation here, the actual construction being taken up in a later chapter. The telephone receiver B is of the double head-band high wound type, as it is only with this type that good results can be had. The potentiometer D should have an approximate resistance of 300 ohms, while the battery C is of the ordinary dry cell kind.

The regulation of the set for sensitiveness lies in the adjusting of the detector A, and the potentiometer D, which controls the battery current C. This does not set the receiving end in tune with the sending end, which is a different operation, and will be taken up at a later point. To more fully understand the adjusting of this set a short description of the liquid detector will be given. The liquid detector consists of a small Wollaston wire, about .0004 in size, mounted in a slit cut in the end of a thumb screw, the thumb screw working through a metal standard. Directly under this standard holding the Wollaston wire, is placed a glass cup with a platinum contact wire sealed therein, also a dilute solution of nitric acid. To adjust, connect up as shown, and place the head receivers to the ear, run the variable contact of the potentiometer out to the last turn and turn the thumb screw which holds the Wollaston wire in the slit until it tips the solution. At this point a roaring noise will be heard in the telephone receiver. Begin bringing the variable contact of the potentiometer in to the center until the noise ceases. The detector is now at the critical point and is ready to receive. The adjustment can still be made more sensitive after the set has been put in use and the operator learns the more essential features, as the adjustments arising from necessity will give clearer idea of the operation than by any other method. However, at this point the adjusting of the instruments can be stopped and the operation of tuning the sending and receiving sets taken up.

Tuning. The tuning is first begun by getting the proper adjustment of the sending end. Considering that all connections have been made at the sending end, as shown in Fig. 26, the first move is to place the lead from the condenser on the fifth or middle turn of wire of the tuning coil. The aerial and ground contacts are connected to the top and bottom turns of the coil. Press the key and note the character of spark which jumps the gap, the gap being separated a distance of ¼″ to ½″, depending on the strength of the coil or transformer. If the spark breaks cross the gap fat and heavy, with a crackling noise, the set is working at the maximum point; however, it will be well to continue adjusting, as still better results may be had. In some cases where the spark gap has been made too short a noiseless arc will flow across it, which radiates no energy from the aerial. To remedy, increase the length of the spark gap and include one more turn of the tuning coil in the circuit by carrying the contact one turn higher.

The aerial and ground are connected to the different turns of the coil; the variable lead from the condenser connected to the different turns; the length of the spark gap varied and the number of condensers in the circuit increased and decreased until the spark breaks across the gap with the desideratum given above. After putting the set in use the operator will find the point at which the set works best can be determined by the character of spark across the gap. In fact, this method is largely used by commercial operators.

When the above adjustments have been made the operator can begin setting the receiving tuning coil to the same wave length as the sending. The tuning can be more accurately accomplished by use of the hot wire ammeter. The hot wire ammeter derives its action from a coiled wire, which is inside of the instrument, and heats as the electrical current passes through, thereby contracting and elongating the wire, the wire in turn so arranged that it moves an indicating needle over a scale. The ammeter is introduced in the aerial wire and the surging of the oscillation through the winding moving the indicating needle. The sending set is now worked and adjustment carried on until the indicating needle rests at the highest value. At this point the aerial radiating wire is in tune with the oscillating circuit. A more simple method, but hardly so reliable, is had by introducing a Geissler tube in the aerial in place of the ammeter. The writer is indebted to Mr. H. Gernsback for this plan.

As a well known fact the Geissler tube lights up when an oscillating current surges through it, and such tubes offer comparatively small resistance to an oscillating current. The adjusting is carried on the same as for the hot wire ammeter until the tube lights up at the brightest point. It is advisable to use at least three tubes of constantly increasing size, introducing the smaller tube first, then the second, and lastly the third, continuing the adjusting all the way through, and when the third tube is made bright, a very high degree of syntony is had.

Of the above methods the first is, of course, more reliable and sensitive, but, owing to the expense attached, the second method will be adopted. The final adjusting of the sending end has been made and the remaining operation is to set the receiving tuning coil to this same wave length where the maximum results will be had.

Taken approximately, the wave emitted from any ordinary closed circuit sending set, is four times the length of the aerial in meters. Hence, with an aerial 30 meters in height, the wave emitted will be 120 meters.

For this wave to produce the best results at the receiving end, the receiving tuning coil should be set to where it responds to a wave of 120 meters in length. As previously explained each turn of winding on the tuning coil represents a wave 4 meters in length; therefore, the aerial lead should be set on the thirtieth turn of the tuning coil, which will be approximate to a wave 120 meters in length.

However, this plan alone will not serve to set the two in sharp syntony. The operator at the sending end should send out some predetermined signal of, say, the letter M, at certain intervals. The operator at the receiving end moves the slide contacts over the tuning coil and changes the other adjustments until the point is reached where the clearest indications are had. This should be repeated several times in order that the best adjustments will be had.

While the above method is not the most approved in general use, yet it proves very easy to carry out, and is within the reach of the ordinary experimenter. The other methods in use combine quite a lot of theoretical matter, which only serves to puzzle the layman, and the increased results are small.

CHAPTER VI.

DETECTORS AND DETECTING INSTRUMENTS.

The coherer originally invented by Branly, improved on and put in practical use by Marconi, has had only slight improvements since its introduction. Among the leading wireless systems the coherer has become almost obsolete; the only system at the present employing it for commercial use is the Slaby-Arco. As the Slaby-Arco coherer is of the most improved type it can be taken as the standard. This coherer consists of two plugs inserted in a glass tube and exhausted. By sealing the plugs in the exhausted tube oxidization of the filings is

Fig. 30. Improved Type of Slaby-Arco Coherer.

prevented to a certain extent. The inside ends of the plugs are of a sloping shape which will allow of different adjustments to be had by revolving the tube in the fingers. Platinum wires are soldered to the ends of the plugs and led out of the tube. The filings employed are of the oxidized nickel silver alloy which have been found to give excellent results.

The main feature of the Slaby-Arco coherer is that it can be employed with the Morse register, thereby giving a written record of the incoming signals. However, in operation the coherer is more sluggish than the self-restoring types, such as the liquid detector, and less sensitive. When used in connection with the Morse register the coherer is especially slow in operation, as sufficient time has to be allowed between each dot and dash for the decohering action to take place, allowing the inker of the register to arise from the tape. This requires very careful adjusting. In case the incoming signals are rapid and the decoherer works slow, a continuous mark will be made on the tape.

The adjusting and operation of a simple coherer was given in Chapter III and need not be repeated here.

The coherer receiving set is recommended to all taking up the study of wireless, as with it, the essential features of accurate adjusting so necessary to the operation of wireless instruments is brought out and will prove beneficial later on.

The coherer can also be used for exhibition purposes in wireless, such as the lighting up of miniature lamps, starting motors, firing cannons, etc. The circuit of such a set is shown in Figure 31 and consists of the following parts: Metal filing coherer A, battery B, relays C and D, battery E, which operates the decoherer F, battery G, which operates the miniature lamp motors, etc. The relays C and D should be accurately adjusted, of the same resistance, and exert the same tension on the bronze springs of the respective coherers; the bronze spring in turn controlling the armature that closes the second circuit.

In operation the incoming signal "coheres" the filings and allows the battery current to flow through, thereby attracting the armatures of the relays C and D and closing the second circuits. The decohering device will start in operation and continue so long as the key is pressed at the sending end. If the handle of the key H is set on one of the points, the instrument connected to this point will start in operation as well. By pressing the key at the sending end and running the handle

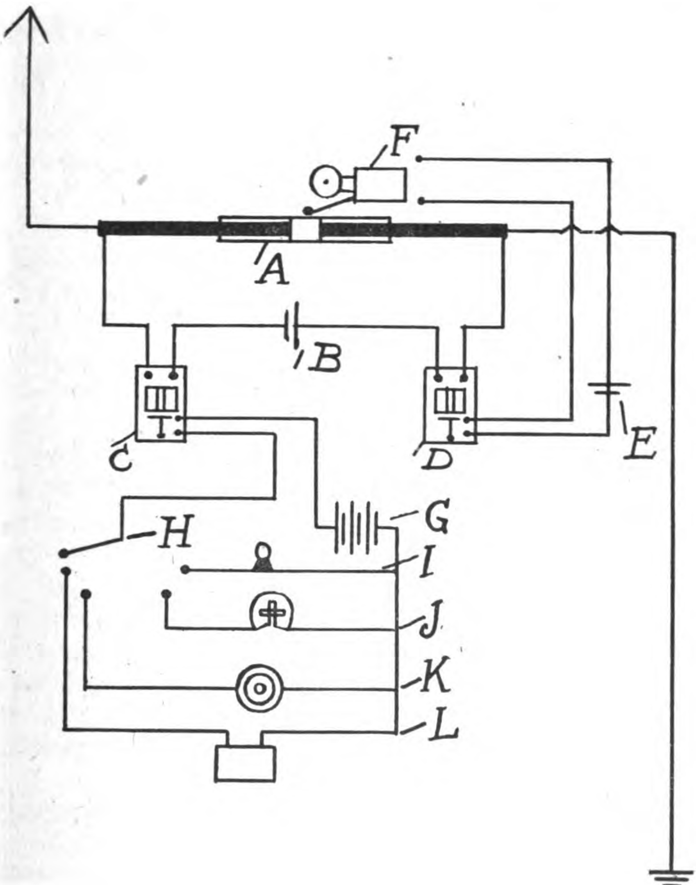


Fig. 31. Wireless Telegraph Exhibition Set.

over the points, the various instruments will be cut in the circuit and different effects produced.

For the successful working of coherer receptors the following suggestions will prove of value:

Be sure that the filings are perfectly dry before placing in the tube, and never touch with the fingers.

Have the ends of the coherer arms well amalgamated.

Screw all nuts down well.

In closing, it is recommended that the operator study the adjusting and operation of the instruments, and observe the rules as given previously.

THE LIQUID DETECTOR.—We now come to the liquid detector invented by Prof. R. A. Fessenden, and which is one of the most sensitive recepting instruments known. It may be said that the liquid detector brought about a broad change in wireless telegraphy, as the coherer and other types were limited in their working distance and slow in operation. From the data that the writer has at hand, the liquid detector has proven the most sensitive detecting instrument in use and has been adopted to a large extent. However, there are other more simple and easily handled types which will be described in this chapter.

As explained in the chapter on tuning, the detector consists of a small platinum wire tipping the edge of an acid solution, the acid solution being placed in a glass cup with a second platinum contact sealed therein. This detector is known as the self-restoring type and consequently it does not have to be tapped in synchronism with incoming wave. The resistance of the detector is very high, but is reduced slightly by the incoming wave impinging on it; this reduction in resistance, however, is not great enough to allow sufficient current to flow through it and affect the relay, therefore we employ in connection the detector, the most sensitive known recorder of the electric current or the telephone receiver.

As the detector is self restoring, and the telephone receiver likewise, we have a combination in the two that will respond to signals as fast as can be sent.

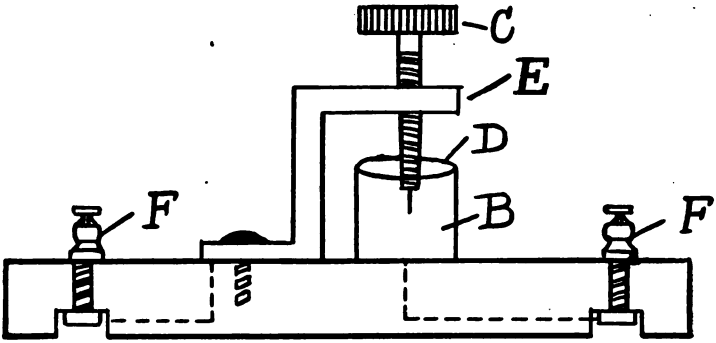


Fig. 32. Simple Type of Fessenden Detector.

The detector is shown in Figure 32 and consists of the wood base A, the glass cup B with the platinum contact soldered in, the thumbscrew holding the Wollaston wire D in the slit, the metal standard E, the binding posts F-F. In construction the detector is very simple and the dimensions are as follows: Wood base 5″ by 3″ in length and width and ½″ thick, metal standard E ½″ wide, ⅛″ thick bent to the shape shown and standing about 1¼″ clear of the base, glass cup B ½″ in diameter and ¾″ high, with platinum wire soldered in, screw C 1″ long with slit cut in end and of very fine thread, Wollaston wire D ¼″ long, .0004″ diameter, electrolyte to be placed in cup 20% solution of nitric acid.

A simple receiving set for experimental work is shown in Figure 33 and consists of the detector A, the telephone receiver B and battery C. The positive pole of the battery should always be connected to the terminal which leads to the platinum point, as otherwise the detector is inoperative. The adjustment is made by turning the thumbscrew until the Wollaston wire tips the

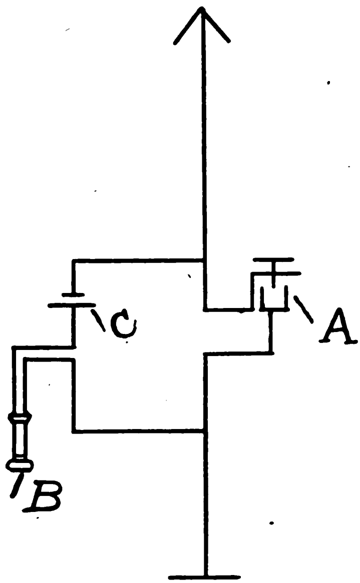


Fig. 33. Circuits of Simple Receiving Set.

solution. The roaring noise will be heard in the telephone receiver and the dots and dashes of the code will come in the form of a short or long buzz, as the indication may be. The depth to which the point is immersed in the solution will also affect the sensitiveness, the exact depth being best determined by actual experiments.

A second type of liquid detector is shown in Figure 34. In this type the Wollaston wire is sealed in the end of a small glass tube, the tube and point ground off flush with one another. The tube is next run through a hole in the center of a cork, the cork having a second small hole run through it for the escapement of gases from the solution. The cork is now placed in the mouth of a second tube which contains the electrolyte and contact, as shown in the figure. Mercury is poured in the

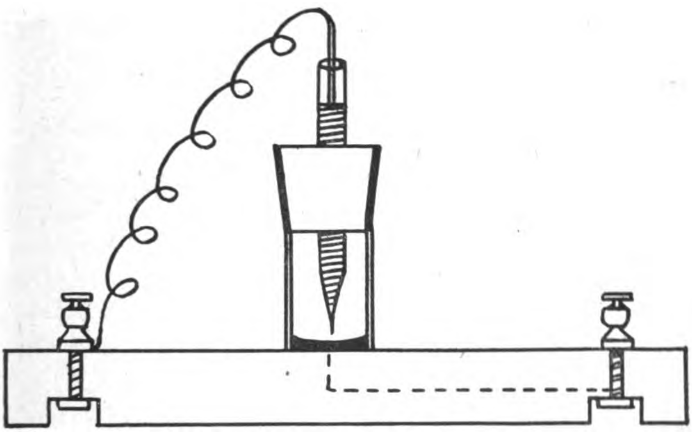


Fig. 34. Second Type Liquid Detector.

tube holding the Wollaston wire and a coiled wire run from one of the binding posts and the exposed end placed in the tube with the mercury, thereby making contact with the point.

Action of the Liquid Detector.—The action which takes place in the operation of the liquid detector is very interesting and when once made clear is easily understood. When the current from the battery in the circuit flows through the liquid detector what is known as polarization is set up. This polarization is simply the liberation of oxygen at the anode, caused by the electric current decomposing the solution. The polarization continues until sufficient oxygen has accumulated at the Wollaston wire and insulates it from the solution, thereby stopping the current flow. The detector is now at the critical point and a slight increase in the current, such as an incoming wave, would break down this insulation and allow the current from the battery to flow through it and the telephone receiver, the receiver giving the indication so long as the incoming wave breaks down the insulating resistance. This action, however, is seldom had with good results when the circuit as shown in Figure 33 is employed. The local battery in this case will usually keep the insulation broke down around the anode and the roaring noise in the receiver is the result, and a loss of sensitiveness. To overcome this the potentiometer is introduced in the circuit as shown in Figure 28, and the current so regulated that the detector remains just below the breaking point. The receivers are now silent until the incoming wave breaks down the insulation as explained.

Marconi Magnetic Detector.—The magnetic detector was first put in use by Rutherford. His detector, however, was very crude, but was improved on by Marconi and is the type described here. The detector proper consists of the following parts: A small induction coil with the usual primary and secondary winding; however, the primary is wound over a small glass tube in place of the usual iron core; a soft iron wire that moves continuously through the tube over which the primary is wound, the wire being held in place in the slot of two wheels and revolved by clockwork or motor; a permanent horseshoe magnet is so placed that its "N" pole nearly touches the top of the secondary winding, a telephone receiver connected to the secondary terminals, the aerial and ground connected to the primary leads.

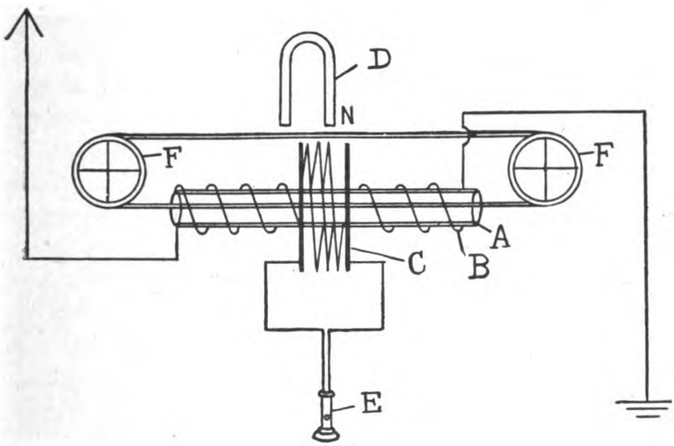


Fig. 35. Marconi Magnetic Detector.

The various parts are shown in Figure 35 and consist of the glass tube A, the primary winding B, the secondary winding C, permanent magnet D, telephone E, wheels F, which revolve and carry the soft iron wire through the glass tube A.

The most commonly accepted theory of the working of the Magnetic Detector is that the magnetizing of the core lags behind the magnetic effects of the permanent magnet, and any changes in the field such as would be produced by the incoming wave, would produce a second increased change in the secondary, resulting in the indication in the telephone receiver.

This detector when properly constructed requires very little adjustment and is fairly sensitive. However, the magnetic detector has never come into wide use, and like the coherer it is almost obsolete.

SHOEMAKER DETECTOR.—The Shoemaker Detector is the ordinary electrolytic kind, but differs from others in the fact that it is a battery itself and therefore requires no local current. The detector comprises a glass tube with the platinum point sealed in, according to the plan given for Figure 34, but employs a zinc strip in the solution in the place of the platinum point. This detector is very sensitive and is employed by a number of commercial companies. The amount of current set up by such a cell is of course small, yet it is sufficient to give indication in the telephone receiver.

MASSIE OSCILLAPHONE.—The Massie Oscillaphone is a very simple type of detecting instrument and has been adopted by a large number of amateur experimenters. This detector is of the loose contact type and consists of two carbon blocks mounted on a wood base with a light sewing needle laid across the top. As this detector is of the self-restoring type, it is used in connection with the telephone receiver. The connectors and adjustments are the same as given for Figures 33 and 28.

The amateur who is contemplating wireless experiments is advised to try this type, as it is very easy to construct and handle. The complete detector and dimensions of the various parts is shown in Figure 36. The dimensions of the base is the same as for the liquid detector given in Figure 32. A wood block B, which is 1½″ long, 1″ wide and ½″ thick, is glued down to the base as shown. The carbon blocks C-C can be cut from an old battery carbon and are 1″ in height, 1″ wide and

¼″ thick. The ends are filed to a knifelike edge and a hole drilled through, in which screws are inserted, and the blocks screwed to the base facing one another. Under the heads of these screws is placed the exposed end of a coiled wire, which is led back and connected to the binding posts E-E.

The tops of the carbons are now wiped carefully with a woolen rag and a light sewing needle laid across.

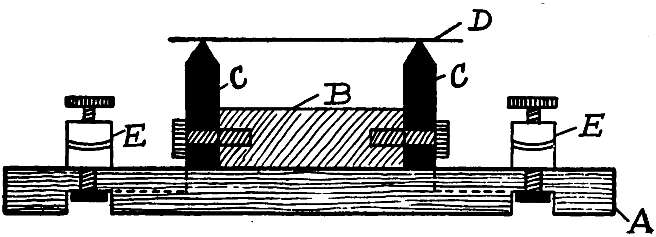


Fig. 36. Massie Oscillaphone.

By connecting the telephone receiver and battery in the circuit and the aerial and ground to the posts E-E, the set is ready for use. A roaring noise will be heard in the telephone receiver, and when the incoming wave flows across the high resistance contact offered by the needle laid across the carbon blocks the needle will adhere more closely to the blocks, lowering the resistance, thereby allowing more current from the local cell to flow through and giving an increased sound in the receiver which is proportional to the length of the incoming signal. In case where the needle is too light the roaring noise will be so great that any incoming signals will be drowned out. This can be overcome by attaching a small weight to the center of the needle. In the original Massie Oscillaphone the varying degrees of sensitiveness were had by placing a small horseshoe magnet directly under the needle, and by raising or lowering the magnet the pull on the needle was decreased and increased, regulating the receiving effects to the same proportion.

LODGE-MUIRHEAD DETECTOR.—The Lodge-Muirhead Detector or coherer is used to a large extent among the English experimenters, but is practically unknown in

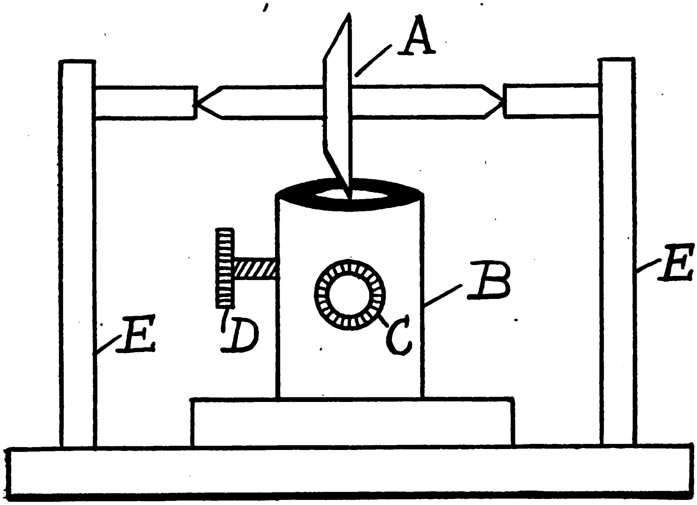


Fig. 37. Lodge-Muirhead Coherer.

America. The reason no doubt lies in the fact that the American experimenters prefer to use the more sensitive and simple types such as previously described, and which do not require the accurate work in constructing and adjusting as does the Lodge-Muirhead type. The schematic arrangement of a Lodge-Muirhead detector is shown in Figure 37. While this type differs broadly from the more accurate kind supplied for commercial use, yet the actual working features are the same.

The detector consists of a small steel wheel A, which is sharpened to a knifelike edge and revolves on the metal rod which is supported by the slots of the frame posts E-E. A small motor or other power is used to revolve the wheel, but is not shown in the drawing. The containing cup B is made of hard rubber with a central slot cut in the top. The tip of the metal wheel A rests in the center of this slot. Mercury is poured in the slot of the cup B. The thumbscrew D works in the side of the cup and raises or lowers the surface of the mercury. C represents a binding post, which makes contact with the mercury and to which one of the terminals is connected.

In use the wheel A is revolved at a high speed and the screw D regulated until the wheel tips the edge of the mercury. By means of a brush connection the wheel leads to the aerial and the binding post C to the ground. The other connections are made to the battery and indicating instrument, which is usually a galvanometer. It is necessary to include a potentiometer in the circuit with the battery, as otherwise the device will operate with poor results. This coherer has the advantage of being self-restoring and can also be used in connection with a telephone receiver. When the telephone is employed the coherer has to be very accurately constructed or the signals will be heard in unreadable form, this being caused by the slow action of the coherer in decohering and not giving a distinct break between the dots and dashes, the telephone giving one continuous record. This trouble will not be experienced when the less sensitive galvanometer is used, as it is not so susceptible to the changes of the current.

Delaney Lamp Detector.—When a very sensitive liquid detector such as the Fessenden type is operated in the vicinity of a strong wireless telegraph station, the Wollaston wire point soon burns out, owing to the strength of the incoming signal. A detector that will respond to signals not sent over a great distance and is capable of withstanding the oscillations from any wireless station can be constructed by breaking a hole in the top of an ordinary incandescent lamp, removing the filament and place therein a 20% solution of nitric acid. This type of detector was invented by Chief Electrician Delaney of the U. S. N.

The Silicon Detector.—One of the latest innovations in detecting instruments is the Silicon. The silicon detector has gained quite a wide adoption since its introduction, owing to the fact that it is very sensitive, easy of adjustment and requires no local battery.

In construction the silicon detector in certain parts resembles the liquid type. In the liquid type very accurate adjustment is required between the tip of the Wollaston wire and the electrolyte, while in the silicon the adjustment is had between the point of the thumbscrew and the block of silicon. A very simple type for experimental use could be made from a liquid detector by removing the Wollaston wire and filing the end of the thumbscrew to a sharp point. Pour the electrolyte from the cup and place therein a block of fused silicon so that contact is made with the platinum wire. The thumbscrew is now run down until it rests with pressure on the silicon, where the device is ready for operation. The silicon, as all other detectors, requires quite a lot of adjusting before the most sensitive point has been reached. However, the method given above is not recommended as the adjustment between the point and the silicon does not remain constant, and requires constant readjusting to get results. The best results are had where the point is controlled by spring action, the spring exerting an equal and steady pressure on the point at all times, and the proper adjustment when once secured will remain constant.

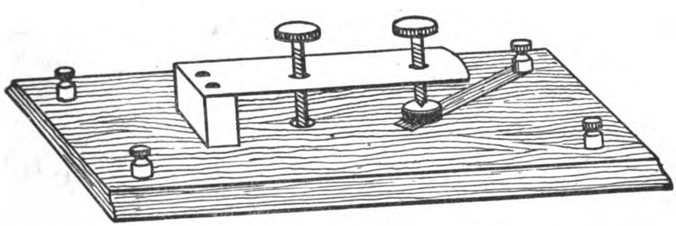


Fig. 38. Simple Type of Silicon Detector.

In Fig. 38 is shown the view of a silicon detector with the above requirements. Such a detector is very simple in construction and the time expended will be well repaid by the results.

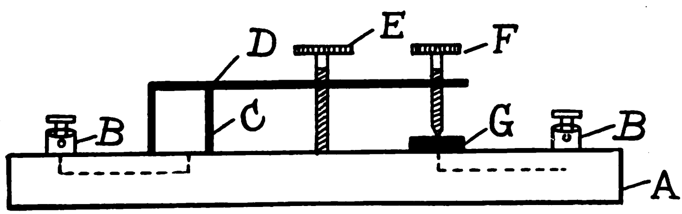


Fig. 39. Parts of Silicon Detector.

The detailed view is shown in Fig. 39. A represents the wood base, which is 5″ by 3″ by ½″ thick in size, BB binding posts, C a brass block ½″ by ¾″ square screwed to the base, D a brass strip 1-64″ thick and 3″ long by ½″ wide screwed to the block C, E thumbscrew which works through hole cut in strip D down to the threaded eyelet placed in the base, F thumbscrew with fine point, G metal cup which holds the silicon. The bottom plan of the base is shown in Fig. 40. Countersunk holes are drilled for four binding posts in the corners of the base. Small V-shaped troughs are cut across as shown and the connecting wire placed therein.

The metal cup G should be ¾″ or 1″ in diameter and about ¼″ deep. A piece of fused silicon is now ground

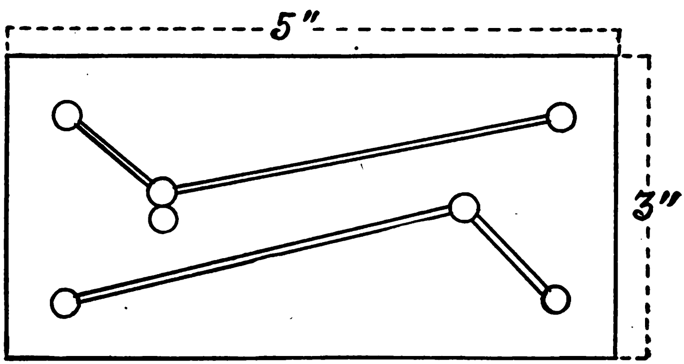


Fig. 40. Plan of Base for Silicon Detector.

down until it will make a neat fit in the cup. It will be impossible to make the surface of the silicon smooth, but the job should be done as neatly as possible. Next place a lump of solder in the cup with a small amount of soldering flux. Hold the flame of an alcoholic lamp on it until the solder melts, and place therein the lump of silicon. When the silicon has set in the cup the final assembling and adjusting can be taken up. First screw a brass strip 1″ wide and 2″ long under the binding post

B so that it rests flat on the base and comes directly under the thumbscrew F. Place the cup containing the silicon on this strip and adjust the thumbscrew F until the point tips the edge. A high-wound receiver is next connected across the detector according to Figure 41.

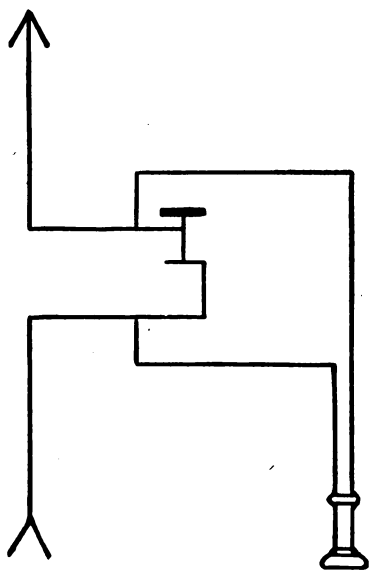


Fig. 41. Simple Receiving Circuit Employing the Silicon Detector.

The high-wound type is necessary, as it is only with this kind that successful results can be had. The adjustment is had by turning the thumbscrew E and thereby increasing the pressure on the tip of F and the silicon block, and at the same time moving the cup around so that the different portions are brought in contact, listen-ing in the receiver and noting at what point the best indications are had. This testing is carried on for some time and until the operator is positive that the most sensitive point has been reached. As silicon varies greatly in its sensitiveness, several cups should be made up and the most sensitive one adopted.

The working of the silicon detector is based on thermo-electric action. It is a well-known fact that when two dissimilar metals are joined and heated, a minute electric current will be set up. Likewise on passing an electric current through the couple the inverse action of heating will take place. This action is more marked with some metals than others.

The surging of the incoming wave through the brass point and the silicon block sets up minute heating effects, which in turn set up the minute electric current and is registered in the telephone receiver.

THE CARBORUNDUM DETECTOR.—A very simple and inexpensive type of detector is the carborundum. In this type the carborundum crystals are placed between two electrodes and the other connections made as for the other kinds of self-restoring detectors. In fact, it will be noted, that with the exception of the Silicon and Shoemaker types, which require no local battery, the connection for all detectors are identically the same. Any form of adjusting device which has two electrodes for holding the crystals will answer as a carborundum detector.

DETECTORS OF THE FLAME TYPE.—Prof. Ernest Ruhmer in his experiments found that a very simple detecting device could be made by employing a gas flame and inserting therein two contacts which were suitably connected to the receiving circuit. A conducting flame of gas is exceedingly delicate and will be instantly "shattered" when impinged on by an incoming wave. The current from a local battery flows through the partial conducting medium, the flame, with a telephone receiver in series. On the flame being "shattered" the circuit is changed and this change registers in the telephone receiver to the same proportion.

A simple and fairly efficient form of flame detector is made by employing the flame from a Bunsen burner. Two platinum contacts are inserted in the flame, the lower one being placed in the central part where the coolest portion is, and the upper at the apex of the flame or the point of the greatest heat. The lower contact has a small trough in which is placed a pinch of some kind of alkaline salts, the heat constantly vaporizing the salt and keeping the flame saturated with gas.

The plan for connecting is shown in Fig. 42. It is necessary to use a very heavy battery current, of at least 30 volts. To adjust, vary the position of the contacts in the flame and throw in more or less of the batteries in the circuit. When once adjusted the detector will prove wonderfully sensitive. However, it has never proven successful in use, as any outside disturbances such as a breath of air, etc., will "shatter" the flame and give an indication in the receiver which would drown out the incoming signal.

A second type consists of an arc formed between two cored carbons, the current being supplied by a local battery with a platinum contact inserted in the flame of the arc. The platinum contact leads to the aerial and the remaining connection to the positive carbon. This type proves slightly more sensitive than the above, but has the same objectionable features, that is, the registering of indications caused by some outside source.

THE AUDION.—Dr. DeForest has improved on the above-named types of flame detectors and perfected the Audion, which at the present date represents the flame detector at its highest stage of development.

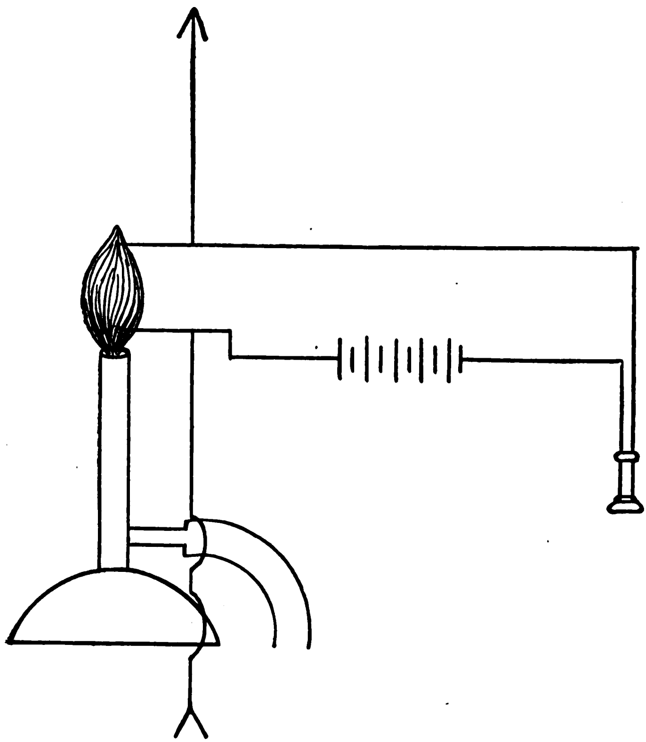


Fig. 42. Simple Type of Flame Detector.

The Audion is based on the fact that when a filament and plate are sealed in an evacuated glass globe, a current can pass from the filament to the plate, while the filament is burning, but not from the plate to the filament. By connecting a local battery to the plate and filament a flow of ions are set up which flow from the filament to the plate, and any change in the battery current will make a consequent change in the flow of ions. This fact is taken advantage of and the flow of ions made to change in accordance with the incoming wave.

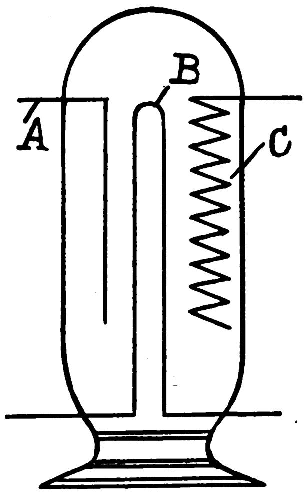


Fig. 43. De Forest Audion Detector.

The DeForest Audion proper consists of a low voltage tantalum lamp with a gird, filament and wing sealed inside, such as shown in Fig. 43. The lamp is burnt by two storage cells in circuit with a rheostat for regulating the flow of the current. The gird is connected to the aerial lead and the filament to the ground. The telephone receiver is included in the circuit with the wing, the extra set of batteries and the remaining terminal leading to the tantalum filament. This is all brought out clearly in Fig. 44.

In use the flow of ions are changed by the incoming wave and this change increases and decreases the flow of battery current through the telephone receiver, resulting in the indication.

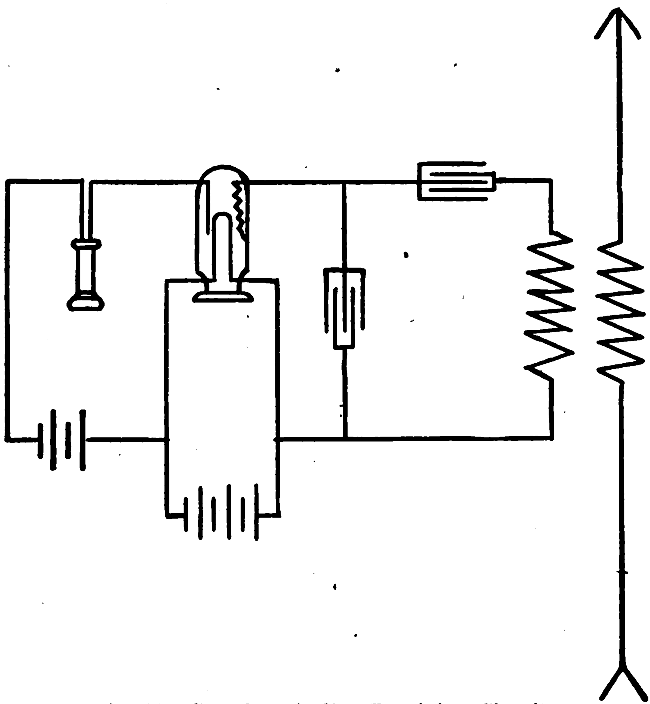


Fig. 44. Complete Audion Receiving Circuit.

The Audion has proven very sensitive for use in wireless telephony, yet it is doubtful if it will ever come into wide use, owing to the difficulty in manufacture and short life. Usually quite a number of Audions have to be tested out before one sensitive enough for general use is found.

CHAPTER VII.

AERIALS.

The aerial, or technically called antennæ elevation, consists of a wire or number of wires strung in the air to intercept the wave and conduct down to the receiving instruments, or radiate the energy as set up by the transforming apparatus. Aerials are of numerous different types and kinds. The original Marconi elevation con-

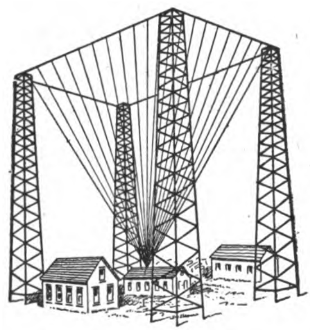


Fig. 45. Marconi Aerial Elevation.

sisted of a single vertical wire suspended as explained in Chapter III. This type is excellent for use with small size coils, but where it is desired to cover greater distances, involving the use of large power transformers, aerials of larger spread and elevated to a greater height become necessary. Marconi later used a large spread or network suspended by four masts, as shown in Figure 45. This type of elevation is excellent for long distance work, but owing to the large expense in erecting it has never come into wide use, and at the present only a few elevations of this type remain.

Following the network aerial is the four-wire type, consisting of four wires strung in the air according to some one of the plans given below. Of the plans in common use we have the "T" type, the inverted "L" type, the "U" or loop type. The above styles are taken on more through convenience in erecting than any other point. For instance, on board ship the "T" type is commonly used, as the position of the masts and location of the operating room made the erection of this type more convenient. Numerous other types are in use involving some theoretical features and need not be treated of here.

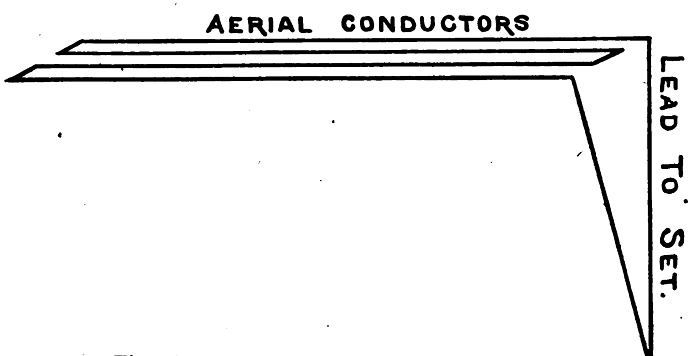


Fig. 46. Inverted "L" Type Aerial Elevation.

The standard aerial conductors as employed for commercial use consists of stranded phosphor-bronze wire, each strand composing seven No. 20 bare wires, and four such strands fastened to insulated stringers and supported from the masts. Owing to the lead-in taking on the shapes as shown in Figures 46 and 47, the "T" and "L" types are formed.

The description of a "T" type elevation is given here with all the essential points on construction which will enable the amateur to erect any type, as the changes from one type to another involves only a few changes in the manner of connecting.

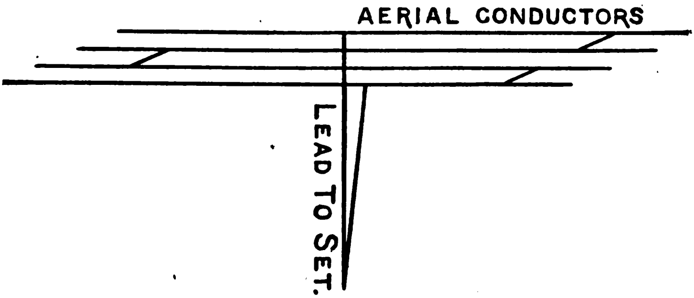


Fig. 47. "T" Type Aerial Elevation.

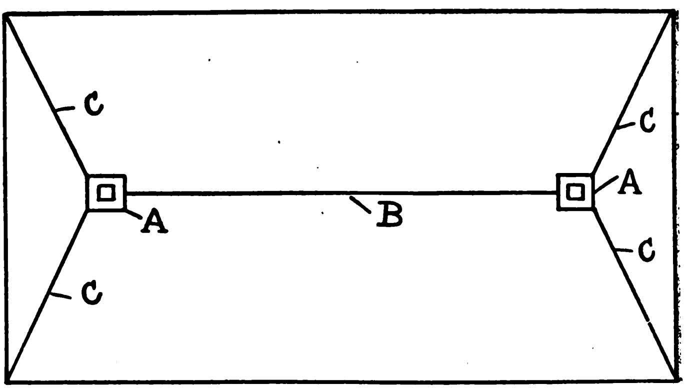


Fig. 48. Plan of Roof on Which Masts for Supporting Aerials Are Elevated.

The complete elevation is shown in Figure 49. The "T" type was used in this special case, owing to the location of the operating room, which was on the lower floor in the front of the building, and it was desired to make the lead-in as direct as possible, the building not having sufficient length to use the inverted "L" type. The aerial can of course be built up to suit the conditions, but the same manner of elevating should be followed out. The exact height of the masts will depend on the height of the building on which they are placed, and the distance it is desired to cover. In the elevation illustrated the height of the building was 60 feet and the masts 15 feet, giving a total of 75 feet from the top of the aerial wires to the ground. A set made up of a 250-watt transformer and tuned receiving equipment was connected to this aerial and communication held

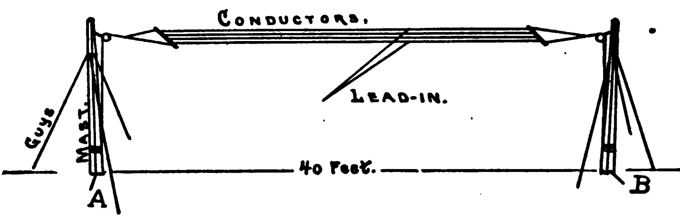


Fig. 49. Complete Aerial Elevation Showing Masts and Aerial Spread.

daily over a distance of 25 miles overland, and at times this distance was doubled. For reliable and accurate work, however, the distance of 25 miles overland would be the proper range for a set composing the above equipment.

The mast used for supporting the aerial wires should be of sufficient size to withstand any ordinary strain and guyed to the different portions of the building. The masts in the elevation shown, measured 3″ by 3″ at the butt, and 2″ by 2″ at the top, sawed from long leaf yellow pine. Although any other kind of hardwood will answer, the pine was simply used because it was more convenient.

Before the erection of the masts two wood bases measuring 2″ by 12″ by 12″, with a 3″ by 3″ hole cut 1″ deep in the center, were placed on the building 40 feet apart at the points where the masts were to be erected. As it was the part of the bases to hold the butt of the masts from the roof of the building, they were guyed together and to the four corners of the building, as shown in Figure 48. In the figure, A-A represents the wood bases, B the central guy wire running from base to base, and C the corner guys. For guying, No. 14 iron wire was used. a nail being drove in the corners of the base at the point where it is desired to make the lead from, and the wire wrapped around this nail and led over to the corners, where they are drawn tight and wrapped around a nail driven in the edge of the roof.

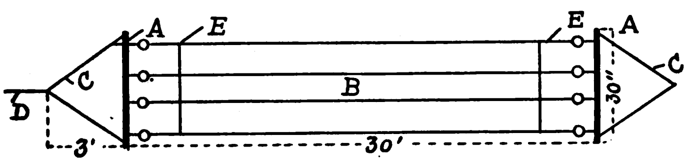


Fig. 50. Plan of Aerial Arrangement.

Four guys are placed on each mast one foot from the top, and of sufficient length to reach to the objects to which they are to be fastened. Two small pulleys are next suspended from the top of the masts by means of a strong cord, and about 30 feet of bell cord run through each pulley. The masts are now ready to be placed in position. If the masts are no larger than the sizes given here they can be easily set in position by one person, while a second takes the guys and wraps around the various objects provided for this purpose. Draw up all guys until the mast stands up rigidly.

After the masts have been erected work is begun on the aerial spread. The most important feature in the aerial spread is to have the wires well insulated from the supporting objects, for the current as sent out by the transforming apparatus is of exceedingly high potential and will leak through to the ground, destroying a certain portion of the sending efficiency, unless the insulation is made to withstand this strain. A number of different kinds of insulators can be used, but probably the most available to the average experimenter is the ordinary porcelain knob kind. This type is shown in Fig-

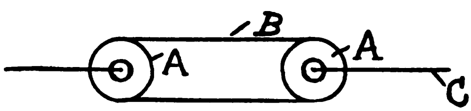


Fig. 51. Insulator for Supporting Aerial Wires.

ure 51 and consists of two porcelain knobs tied together from groove to groove with a well oiled sea-grass rope. One of the knobs is now tied back to the stringer, while through the center groove of the front is inserted the aerial wire and wrapped.

The stringers are made from oak strips and should measure 30″ in length and 2″ by 2″ square. Beginning at the end, tie on the porcelain knob insulators every 10″, which will allow four to be tied on each stringer. Tie on each end of the stringers a piece of well-oiled rope of sufficient length to form a V three feet in length, as shown at C, Figure 50. To the middle portions of C-C is tied the ends of the bell cords which run through the small pulleys at the top of the masts.

As previously noted, the aerial conductors as employed by the commercial stations are composed of stranded phosphor-bronze wires. This type of wire, however, cannot always be secured by the experimenter, so a substitute will be made by using No. 12 bare copper wire, which makes a fairly good aerial for experimental work. The distance from stringer to stringer is 30 feet, and as this distance is to be covered four times, 120 feet will be required. It will be well, however, to get 130 feet to allow for loss in cutting and connecting. Cut four pieces of sufficient length to run the distance and lead the ends through the respective knobs and tie by taking several turns around the wire. A straight piece of wire is now soldered across the ends, as shown at E-E, Figure 50.

The lead-in wires can either be No. 14 or No. 12 bare copper wire, soldered to the middle portion of the two outer conductors and led down to where they will be even with the roof when the aerial spread is pulled in place. The ends of the two lead-in wires are now soldered to the exposed ends of a high-tension cable, the cable in turn being led over the roof, as shown, and supported by means of a high-tension insulator. The cable is led down the side of the wall to the instruments, and wherever it would come in contact with the building a high tension insulator is placed.

To elevate the aerial spread, pull equally on the two ends of the bell cord until the spread is at the greatest height and tie the ends of the cord around the mast.

The Lead-in.—Where the high-tension cable leads into the instruments care should be used in insulating, as dispersion or leakage of the current can occur here as well as at the other points. The usual method where small power sending instruments are in use is to bore a hole through the wall and place therein a porcelain tube, leading the lead-in wire through this tube. While this method would answer for the small power sending instruments, but if a greater was used, the current would leak through to the wall and offer a partial ground. A very efficient method is to bore a hole through a pane of glass and lead the wire through, but this plan is not possible in every case, as very few experimenters have the proper means for boring the hole, which is a difficult operation.

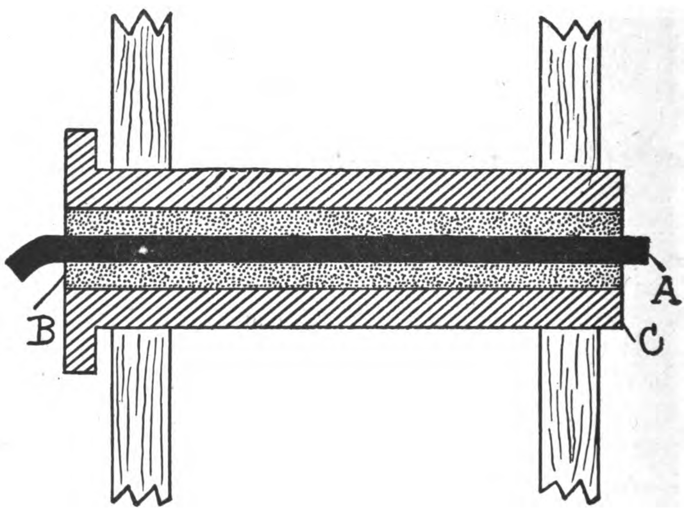


Fig. 52. Lead-in for Aerial Wire.

A method that the writer has adopted is shown in Figure 52. In this case a porcelain tube with an external diameter of 2″ and an internal diameter of 1″ is needed. A hole is drilled through the wall of sufficient size to allow the porcelain tube to slip through. The point at which the lead-in cable passes through the tube is marked, and the tube withdrawn from the hole and the cable held in the exact center of the tube at the point previously marked. One end of the tube is now stopped up with putty. Boiling paraffin wax is poured in at the opposite end of the tube until full, and when the wax sets the putty is pulled off, which leaves the lead-in wire incased in the paraffin bed. In Figure 52 A represents the lead-in wire, B the paraffin, and C the porcelain tube. This type of lead-in can be constructed at very low cost and is very efficient.

Aerial Switch.—The termination of the lead-in wire is usually connected to a double-pole double-throw switch so that the aerial can be either thrown to sending or receiving side. Such a switch, however, is not necessary where it is only desired to operate a receiving set, and in this instance the insulation of the aerial need not be so perfect.

The different systems use different types of switches, but all have the same working features as the kind shown in Figure 53. In the figure the aerial is shown at A, the ground at B, sending side at C, and receiving side at D. During a storm a jumper can be placed across the contacts A and B to protect the instruments from lightning. At this point a word might be said regarding lightning arresters. For wireless telegraphy the ordinary form of lightning arrester is useless, for whatever would offer a path for lightning to the ground would also offer a path to the high potential current from the sending set. Therefore the only safe method is to connect the aerial to the ground by means of the jumper, which of course renders the instruments inoperative.

The Ground Wire.—The ground wire is a very important adjunct to a wireless set, and to it very careful attention should be directed. The exact depth to which a ground should be placed can be largely determined by the character of the soil around the station. However, the ground should always be placed deep enough to make contact with the permanently damp earth. Where the

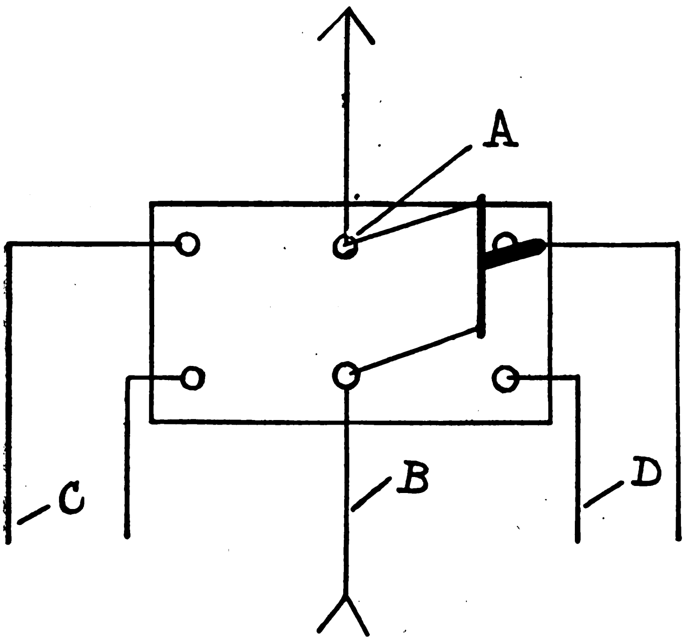


Fig. 53. Aerial Switch.

soil is dry and sandy it will be necessary to go to quite a depth, while at stations where the earth remains damp at all periods, only a few feet will be necessary. Zinc or copper sheets from 25 to 100 feet square are usually employed as the ground plates. They are buried to the desired depth with a horizontal projecting strip to which the lead from the switch is soldered. In portable sets the ground is secured by dragging a square of wire netting over grass or the damp earth.

The wire leading up to the switch should be well insulated, for the slightest conducting path would allow a certain portion of the current to escape.

On board ship the ground is a very easy matter, as it is only necessary to solder the lead to the bed plate of the engine.

MASTS.—Where the station is isolated from high buildings or other means of support, the erection of a mast becomes necessary, which is a very difficult matter and requires careful handling. However, by following out the direction as given here for erecting an 80-foot mast, no difficulty should be experienced, and after the first attempt the work should become easier, as a better idea will be had of the difficulties to overcome.

For the complete mast will be required three spars, the first 5″ by 5″ in diameter and 35 feet high, the second 4″ by 4″ and 25 feet high, the third 3″ by 3″ and 20 feet high. The masts are spliced together by half-grooving and wrapping with No. 10 steel wire and screwed together with two steel bolts to each joint. After all joints have been securely spliced the mast is laid flat with the butt to the hole in which it will slide as it goes up. Three guys are placed on each splice, making a total of nine in all. At the top is placed a small crossarm, well braced with braces, and a small pulley with sufficient bell cord run through to reach to the ground. A "dummy" pole about 20 feet in height is now erected. The mast is placed with butt to butt of the dummy pole. Three double blocks are now tied to the top of the dummy pole and led down and tied to the top of each spar of the mast. This is necessary in order that the pull will be equally divided, as otherwise the strain would become too great and possibly break the mast. To erect, first begin raising the mast with pike poles such as

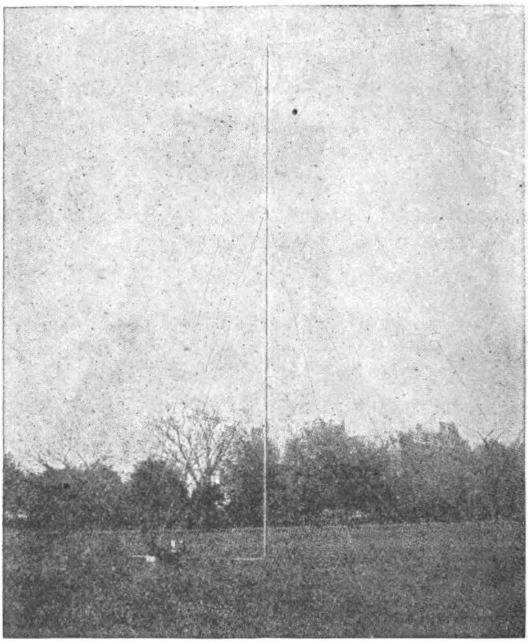


Fig. 54. Portable Aerial Arrangement as Supplied by the United Wireless Company.

linemen use, taking up the slack in the ropes of the blocks at the same time. Assistants are stationed at different points with the guy wires to hold the mast in position. When the mast has been erected to the greatest height with the blocks and pike poles, the guy wires are

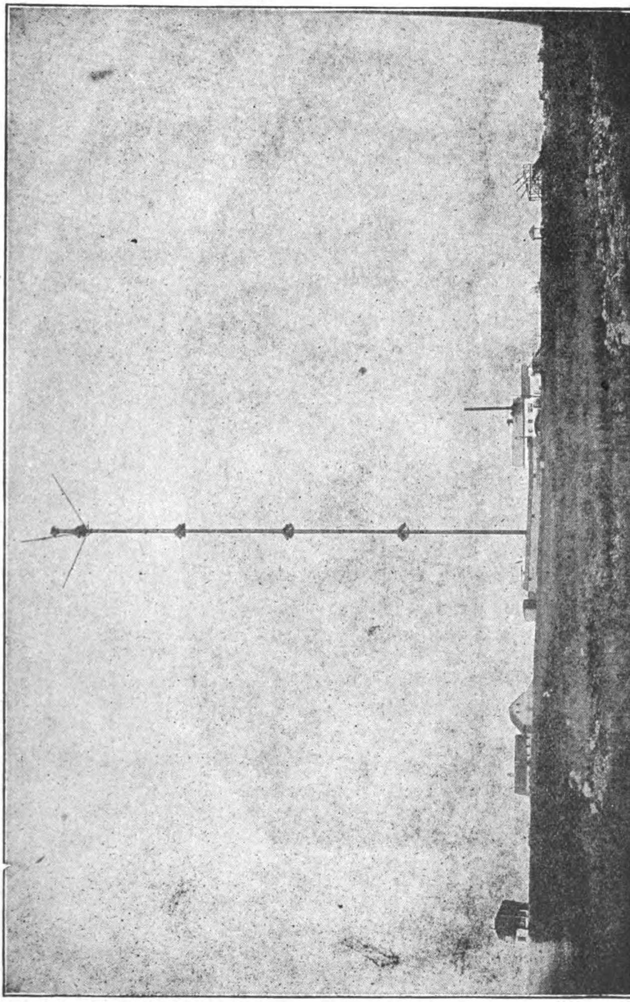


Fig. 55. Fessenden Station at Brant Rock, Mass.

taken in hand and pulled until the mast is standing in an upright position. The guys are now led off to the respective stubs, pulled tight and wrapped. The guy wires can be made of No. 10 iron wire divided up into sections with porcelain knob insulators, the insulators being interposed according to the method shown in Figure 51, using one insulator instead of two. The aerial arrangement is constructed according to the plan given for Figure 49, and pulled into place by means of the bell cord. In this instance the aerial is of the four-wire vertical type.

PORTABLE AERIAL ARRANGEMENTS.—Quite a lot of attention is being devoted to the perfection of portable wireless sets. The United Wireless Company has just put out a new design which is readily portable on horseback, wagon, or landing boat and can be unpacked and put in operation in 15 minutes. The aerial of such an arrangement is shown in Figure 54, the set having a sending range of from twenty to thirty miles.

MASTS FOR LONG DISTANCE USE.—One of the highest masts in use at the present day is shown in Figure 55. This mast is over 400 feet high and is employed at the Fessenden station at Brant Rock, Mass. The mast, or tower, as it may be termed, is built up of cylindrical steel sections, the largest three feet in diameter and resting on an insulated base. The aerial radiating wires, from their fineness, are not shown, the black dots indicating the insulator interposed in the guy wires.

CHAPTER VIII.

THE STUDY OF WIRELESS TELEGRAPHY.

General Remarks. Before going into the details on the study of wireless telegraphy a few general remarks will be made on the results accomplished up to the present date and the present day limitations, so that the student will understand the field that he is confronted with, and the difficulties that will arise in actual practice. Since the first introduction of wireless telegraphy experimenters in all parts of the country have been constructing and operating sets, and at the present those interested in the art will number up in the thousands. That these students or experimenters have accomplished wonderful results is plainly evident. Many took up the study without any previous knowledge of electricity or its applications and in a short while mastered the details of the most intricate working sets from theory to actual practice. While this statement may sound broad to some of the uninitiated, yet by glancing over the pages of some of the publications which have devoted special departments to the wireless experimenter, all doubts will be removed, for here, one will find numerous proofs of the statement in articles, photographs, and other interesting matter as contributed by this class of workers. Furthermore, it is pleasing to note that the greatest number of wireless experimenters live in the United States and some of the most important inventions and improvements pertaining to wireless have been brought out by American investigators. In this respect wireless communication is only following the path of wire communication. It is a well known fact that America leads all other countries in the number of telephone and telegraph instruments installed, and the number who are given employment in such service. While of course the writer will make no attempt to compare wireless communication with ordinary wire means, it is a positive fact that wireless even at the present stage of development occupies a field which can never be covered by the wire system, namely, communication over water. To predict the end of wireless development would be impossible, for the new developments bring out some new use heretofore undreamed of. As an illustration we can take the new system of *sparkless* telegraphy which has been adopted by Dr. DeForest in his system of wireless communication. One of the greatest drawbacks to wireless telegraphy up to the present date has been the inability to properly tune the sets. Tuning has been developed to a high degree with the spark system, but when put in actual practice it is found that interference is an important factor to overcome, and according to the opinion of some of the best known investigators, tuning will never be on a practical basis when employed with the spark system. Realizing this fact, Dr. DeForest has brought out the sparkless system which is susceptible of very fine tuning and which to a certain extent has changed the entire outlook of wireless telegraphy, as the sparkless system can be employed equally as well for wireless telephony and can be tuned to the point where several stations can be used in near range to one another without interference. This new system is fully described in a later chapter. Considering the widespread interest shown in this art, and the broad field for development, one can realize that it is only a matter of a short while before wireless communication will be as necessary as the wire means which now extends to every portion of the country.

To give a complete list of the results which have been accomplished by means of wireless would be impossible within the pages of this book, nor is it necessary for the main point is to give such information as will help the student in a practical way.

The recent wreck of the Republic, with which the majority of readers are familiar, has probably done more to awaken the public to the actual utility of wireless than any other feature. Since that date several bills have been introduced to the effect that all ships be equipped with wireless sets. This rapid development will call for wireless operators and even at the present the demand for wireless operators is greater than the supply. At this point some of the readers might question the statement regarding the large number of students already interested and why the more advanced experimenters could not fill the positions. In some instances this would be possible, but usually the amateur experimenter has satisfied his ambition by simply erecting a station, adding new instruments from time to time, and studying out the theory of various parts as described in technical publications. He deserts the practical work and seldom learns the code. The erection and working of an experimental set is a very necessary requirement to the study of wireless telegraphy but the student should not stop at this point. To learn the practical side it is of course best that one should become connected with an actual operating company. However, the theory should be studied as well for it is only by combining the two that we can hope to gain a deep insight in the art. In the usual cases it is not possible to become connected with an operating company which has neither the time nor inclination to instruct, and the student must depend on his own ability. The student selects such text books as he can secure, which are usually devoted more to theory than practice and useless to the beginner. With the object of offering a practical source of instruction the writer has prepared this book and included all matter that would assist the student in becoming a proficient wireless operator.

At this point it may be pertinent to give a few words concerning the numerous wireless concerns which have been organized in the past with the only end in view of selling stock. While this point has no direct bearing on the subject, but as the development of wireless has been held back by such projects due to a loss of public confidence in general, a few words will clear up the matter to those who are not familiar with the inside details. The names of such concerns are too well known to be given space here. The stock was sold out promiscuously with many claims for quick and large profits. On the awakening the stockholders found that they had only the worthless certificates left. Such methods of course caused the general public to brand wireless telegraphy as simply a stock brokers' harvest, with the result that the legitimate companies were retarded in development owing to their inability to secure capital. However, from the broad strides which are found at present one can realize that the retardation caused by such projects was only momentary, and that wireless telegraphy and other wireless means of communication is now on a solid basis where it can command the respect of the American people. It will only be a matter of time before all the "get rich quick" wireless concerns will be forced out of existence, due to the fact that the investors will demand some proof of the concerns being able to substantiate their claims and show actual operating stations. Among the more prominent investigators, however, no doubt was ever held as to the ultimate success of wireless communication. They have worked quietly along, step by step, and are now in position to realize the fruits of their labor. In face of the fact, however, that many years' research has been given to wireless and many improvements brought out, still the field is unlimited for new and useful inventions and for this reason it offers many opportunities to those who take up the study.

The Study of Wireless Telegraphy.—Probably the first questions to come in consideration to those taking up the study would be: what preparation must be had and what kind and type of instruments must be used? In wireless telegraphy, as in the study of any other art, the more preparation we have along that special line the more simplified will be the course. The writer has known several to take up the study who had no previous experience or knowledge of electricity and are now expert operators. While this can not be accomplished by all, yet one may rest assured that by careful and close study, a knowledge will be gained that will prove of ultimate benefit whether one intends to follow this as an occupation or not. An experienced electrician could make more rapid steps than one just embarking in the field, for the electrician would have his previous knowledge to draw from which would prove of assistance. In the end, however, the beginner might prove the more able for such knowledge as he gained would be from his own resources and ability and not from any previous learning. Therefore in wireless telegraphy it is impossible to judge what one can do until they have shown results, but constant work and study as in everything else is sure to bring success.

It is absolutely necessary that the student should be able to send and receive messages over the wire line by the Morse code. This if possible should be learned by the student before taking up the study of wireless telegraphy. When one has learned how to send and receive over the Morse instruments he may rest assured of his ability to send and receive over the wireless set, for in wireless telegraphy the indications are much slower than over the wire line. As many valuable books are on the market relating to instruction to those who desire to become wire operators the writer will give no further explanations on this point.

It being considered that the student has had no previous experience the necessary instruments should constitute a Morse set for learning the code and a short distance wireless telegraph set. A very simple set was described in detail in Chapter III. If the student has sufficient ability he is advised to construct the set, for in this way he can gain a close insight into the working details. However, the student may not have the time or ability to construct the set, and if so the whole can be purchased at low cost. Such a set is shown in figure 56 and consists of the spark coil, oscillators, etc., at the sending end, and the coherer with automatic de-coherer at the receiving end. The coherer receptor is described in use in the above mentioned chapter, but it is evident that it can be replaced with the liquid detector or any other type of detecting device. The main feature of the coherer is that it gives out an audible signal, while with the liquid and other self-restoring types of detectors the

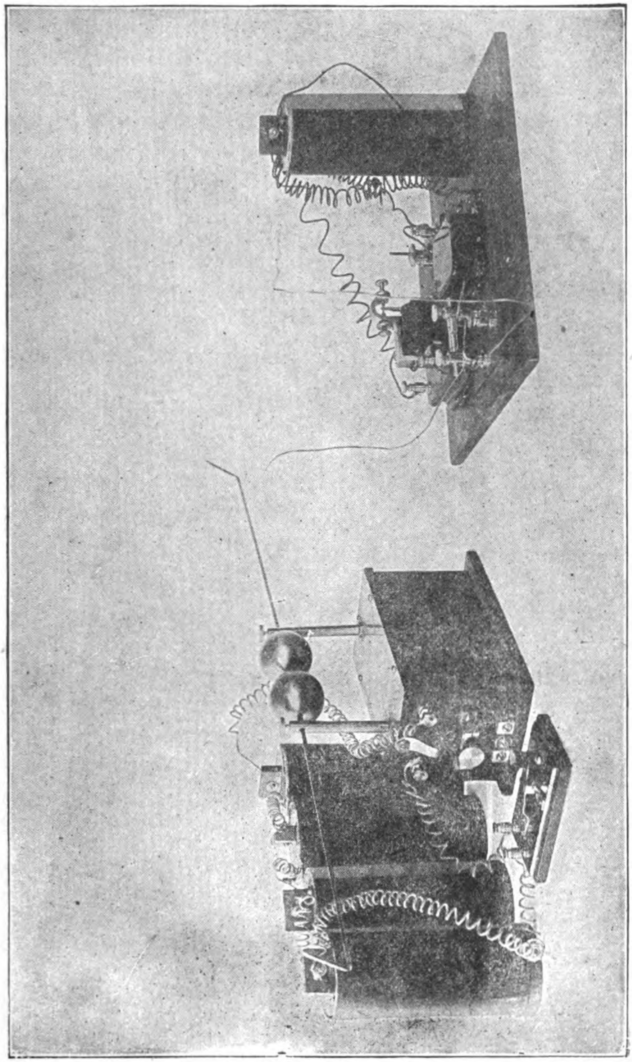


Fig. 56. Experimental Wireless Telegraph Set.

signals are read in a telephone receiver by buzzing sounds corresponding to the code. The coherer is also difficult of adjustment, and for this reason is recommended to the amateur, as the adjustment when once made perfect will give an idea of the delicate features involved in the other types.

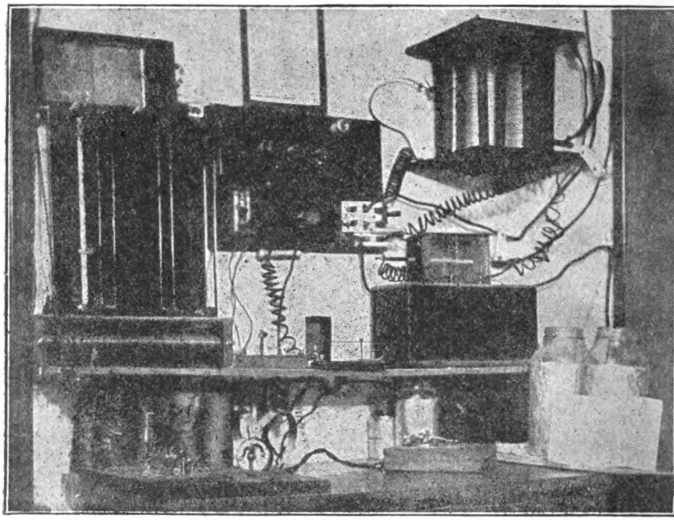


Fig. 57. Amateur's Wireless Station.

The remaining points which could be explained are very few and furthermore it is only by putting a set in actual use that a clear idea can be gained of the essential details. A number of puzzling problems will no doubt arise when the work is first begun, but by depending on his own ingenuity the student will be able to find the solution, and advance step by step to the working of the tuned sets which are slightly different in operation.

When the student has advanced to the stage where he can send and receive readable messages and is familiar with the working of the tuned sets he may consider himself an operator with sufficient ability to take charge of a station. The operation of the tuned and open circuit sets has been described in previous chapters which the student can refer to as he advances in the study. However, the student will find that a broad channel exists between his ability to handle an experimental set, and that of taking charge of an actual operating station. It is to be regretted that as yet, we have no schools of wireless telegraphy which would serve to bring the student and operating company in closer relationship. However, the demand exists and such schools will ultimately follow.

Below are given the Naval Rules and Regulations for wireless stations, which should be carefully read over and applied to use wherever possible. Some of the rules will not be clear to the beginner, but after going further in the study he will be able to grasp all the points, as the rules have been made as simple and concise as possible.

NAVAL RULES GOVERNING WIRELESS STATIONS.

"For installation ample room is available at all shore stations.

"On board ship a room, having about 60 square feet of floor space, with no dimensions less than 5 feet, should be provided for the installation and operation of a wireless-telegraph set. The operating room should be well ventilated and lighted, as nearly sound proof as practicable, and free from vibration. The exact location of the operating room is not of great importance, provided a good lead to it for the aerial can be obtained. The farther this lead is from large conducting bodies the better. Operating rooms below the water line, where long leads to the aerial are necessary, are decidedly less efficient than those on the upper deck.

"The room should have a well insulated entrance for the aerial and should be fitted with an operating table about 2½ feet wide, not less than 7 feet long, and of convenient height for working the sending key while sitting down.

"The table should be strongly built of dry, well-seasoned wood."

"The instruments should be mounted on the table so that they are at safe sparking distance from each other and from any part of the operating room."

"The receiving instruments should be as far away from the sending instruments as practicable. The induction coil or transformer may be mounted on the bulkhead or under the table. In any case it should be where its terminals are not likely to be touched accidentally. The motor generator is preferably installed near the operating room, but outside of it. It may be installed in the operating room or in the dynamo room."

"The connections between all parts of sending and receiving instruments should be as direct as possible and in the case of the sending instruments they should be of large surface and well insulated by air or other nonconductors. Sharp turns in connecting wires should be avoided on account of brush discharges, which always start at corners. The effect is the same as if electricity were travelling too fast to turn corners."

"The necessity for bringing a number of leads to the combination switch for sending or receiving detracts considerably from the simplicity of the installation and to a slight extent from the efficiency of the set as a whole."

"High potential leads should be kept away from low potential leads and where they cross it should be nearly at right angles."

"The ground connection should be electrically good and of large area. The diagram of connections and the purpose and use of each connection should be familiar to every operator. They should be well made and kept clean at all times."

"Wireless telegraph instruments, like all others, depend for their efficiency on their good condition and amply repay good care."

"Sending-key contacts should be kept clean and smooth and with faces parallel to each other."

"All sliding contacts, especially in receiver tuning coils, should be clean and bright and free from foreign matter."

"Detector points should be kept in their most sensitive condition and frequently tested by means of the buzzer furnished for the purpose."

"The best adjustment for receiving different stations should be recorded or memorized by all operators."

"A sending set working at low power with all connections good, closed and open circuit in resonance, no sparking from edge of condenser, jar, or plates, nor glow from aerial and no sparking to rigging, is utilizing its power much more efficiently and will probably be heard farther than the same set pushed to the limit, but out of resonance or with high-resistance connections and sparking at all points."

"In any case use only current and gap necessary for good readable signals when sending to stations at known distances."

"Tuning curves for open and closed circuits are only correct for the capacity and inductance in each at the time the measurements are taken, and the radiation shown on the hot-wire ammeter after coupling the two circuits is that for the particular period and coupling, as well as for the primary current, frequency, and spark gap then used."

"These conditions should be reproduced as nearly as possible and the hot-wire ammeter tests made daily. The cause of decreased radiation should be searched for until it is found and then remedied. The condensers should be carefully examined weekly, as well as all contacts on all circuits, special attention being given to the ground connection."

"The insulation resistance of the aerial should be tested monthly or more frequently when leaks are suspected, and all insulation aloft should be frequently examined."

"Porcelain or glass insulators are preferred. Hard rubber insulators char on the surface from leaks in wet weather and become less effective as insulators."

"Except where a number of tunes are ordered to be used the operators should not alter the capacity or inductance in either circuit, except when absolutely necessary, and when, while sending, any part of the condenser is injured it should be immediately replaced or repaired, and if this can not be done on the account of lack of spare parts the two circuits should be readjusted to resonance with the best means available."

"Operators must avoid a short or jerky style of sending. Dots and dashes must be firm and of proper relative lengths, as must also the intervals between parts of a letter and the spaces between letters and words. The spark must be kept white and crackling and have considerable volume."

"At all stations, ship and shore, the best results are invariably obtained and the most satisfactory service given by alert and careful operators who take pride in the conditions of their instruments."

CODES.

Both the Morse and Continental Morse Code are used for wireless telegraph service. The Morse Code is used for overland service, while between the ships of the Navy and shore stations the Continental is used. The two are given as follows:

MORSE ALPHABET.

A · —	B — · · ·	C · · ·	D — · ·	E ·	F · — ·	G — — ·
H · · · ·	I · ·	J — · — ·	K — · —	L ⸺	M — —	N — ·
O · ·	P · · · · ·	Q · · — ·	R · · ·	S · · ·	T —	U · · —
V · · · —	W · — —	X · — · ·	Y · · · ·	Z · · · ·	& · · · ·	
1 · — — ·	2 · · — · ·	3 · · · — ·	4 · · · · —	PERIOD · · — — · ·	INTERROGATION — · · — ·	
5 — — —	6 · · · · · ·	7 — — · ·	8 — · · · ·	COMMA · — · —	EXCLAMATION — — — ·	
9 — · · —	0 ⸺					

CONTINENTAL WIRELESS TELEGRAPH CODE.

A .-	B -...	C -.-.	D -..	E .	F ..-.
G --.	H	I ..	J .---	K -.-	L .-..
M --	N -.	O ---	P .--.	Q --.-	R .-.
S ...	T -	U ..-	V ...-	W .--	X -..-
Y -.--	Z --..	WAIT .-...	UNDERSTAND ...-.	DONT UNDERSTAND -....-.	
PERIOD		INTERROGATION ..--..		EXCLAMATION --..--	
1 .----	2 ..---	3 ...--	4 ....-	5	
6 -....	7 --...	8 ---..	9 ----.		
0 -----	CALL -.-.-	FINISH .-.-.			

ABBREVIATIONS USED IN WIRELESS TELEGRAPHY.

An.—Answer.
Arv.—Arrive.
Atk.—Attack.
Atl.—Atlantic.
Awa.—Away.
Awi.—Awhile.
Ax.—Ask.
Ay.—Any.
B.—Be.
Bal.—Balance.
Bd.—Board.
Bld.—Bundle.
Bf.—Before.
Bg.—Being.
Bn.—Been.
Bot.—Bought.
Byd.—Beyond.
Bz.—Business.
Bat.—Battery.
Bbl.—Barrel.
C.—See.
Ca.—Came.
Cg.—Seeing.
Chg.—Charge.
Cr.—Care.
Ct.—Connect.
Cty.—City.
Cvl.—Civil.
Cx.—Capital letter.
Col.—Collect.
Ck.—Check.
Da.—Day.
Dd.—Did.
Deg.—Degree.
Dld.—Delivered.
Dr.—Doctor.
Drk.—Dark.
Dux.—Duplex.
DH.—Deadhead.
Ea.—Each.
Ed.—Editor.
Eng.—Engine.
Etc.—Et cetera.
Ev.—Ever.
Evn.—Even.
Exą.—Extra.
Fl.—Feel.
Fld.—Field.
Flg.—Feeling.
Flo.—Flow.
Flt.—Felt.
Fm.—From.
Fri.—Friday.
Frt.—Freight.
Gr.—Ground.
G.B.A.—Give better address.
G.A.—Go ahead.
G.S.A.—Give some address.
G.M.—Good morning.
G.E.—Good evening.
G.N.—Good night.
Gen.—General.
Ger.—German.
Gg.—Going.
Gu.—Guard.
Gv.—Give.
Gvg.—Giving.
Hb.—Has been.
Hhd.—Hogshead.
Hld.—Held.
Hlm.—Helm.
Hm.—Him.
Hnd.—Hundred.
Hon.—Honorable.

Hpn.—Happen.
Hqrs.—Headquarters.
Hr.—Here.
Hs.—His.
Hu.—House.
Hv.—Have.
Hw.—How.
Ify.—Infantry.
Imp.—Import.
Ix.—It is.
Ixu.—It is understood.
Kp.—Keep.
Kpg.—Keeping.
Kpt.—Kept.
Kw.—Know.
Kwg.—Knowing.
Kws.—Knows.
Las.—Last.
Lat.—Latitude.
Lft.—Left.
Lit.—Little.
Lk.—Like.
Lt.—Lieutenant.
Lv.—Leave.
Lvg.—Leaving.
Lvs.—Leaves.
Lyg.—Lying.
Ma.—May.
Mab.—May be.
Maj.—Major.
Mar.—March.
Mas.—Master.
Mat.—Material.
Max.—Maximum.
Mch.—Machine.
Mcy.—Machinery.
Md.—Made.
Mem.—Member.
Mfd.—Manufactured.
Mgr.—Manager.
Mh.—Much.
Mil.—Military.
Min.—Minute.
Mk.—Make.
Mkg.—Making.
Mkr.—Maker.
Mks.—Makes.
Mkt.—Market.
Ml.—Mail.
Mng.—Morning.
Mny.—Many.
Mo.—Month.
Mrl.—Marshal.
Msg.—Message.
Msk.—Mistake.
Mst.—Must.
Mv.—Move.
Myn.—Million.
Na.—Name.
Nd.—Need.
Nec.—Necessary.
Neg.—Negative.
Ni.—Night.
No.—No, and New Orleans.
Nun.—None.
Nv.—Never.
Nw.—Now.
Nx.—Next.
N.M.—No more.
Ofc.—Officer.
Ofr.—Offer.
Ofs.—Office.
Opr.—Operator.
Ot.—Out.
Otr.—Other.
Ov.—Over.
O.K.—All right.
Pc.—Per cent.
Pd.—Paid.
Ph.—Perhaps.

Pha.—Philadelphia.
Pm.—Postmaster.
Po.—Post-office.
Pod.—Post-Office Department.
Pot.—President of the.
Potus.—President of the United States.
Pr.—President.
Pra.—Pray.
Prt.—Part.
Pt.—Present.
Qk.—Quick.
Qmg.—Quartermaster-General.
Qr.—Quarter.
R.—Are.
Rc.—Receive.
Rcd.—Received.
Rcg.—Receiving.
Rcr.—Receiver.
Rcs.—Receives.
Rct.—Receipt.
Rek.—Wreck.
Rht.—Right.
Rlf.—Relief.
Rp.—Report.
Rpt.—Repeat.
Rr.—Railroad.
Ru.—Are you.
Ruf.—Rough.
Ry.—Railway.
Sa.—Senate.
Scotus.—Supreme Court of the United States.
Sd.—Should.
Sdn.—Sudden.
Sec.—Section.
Sed.—Said.
Sem.—Seem.
Sen.—Seen.
Sh.—Such.
Shf.—Sheriff.
Shl.—Shall.
Sig.—Signature.
Sik.—Sick.
Sis.—Sister.
Slf.—Self.
Slo.—Slow.
Slr.—Sailor.
Sm.—Some.
Sma.—Small.
Sn.—Soon.
Snc.—Since.
Snd.—Send.
Snr.—Sooner.
Snt.—Sent.
Sor.—Soldier.
Sp.—Ship.
Spfy.—Specify.
Spl.—Special.
Spo.—Suppose.
Ss.—Steamship.
St.—Street.
Sta.—State.
Stn.—Station.
Sto.—Store.
Str.—Steamer.
Sud.—Surround.
Sv.—Seven.
Svc.—Service.
Svd.—Served.
Sve.—Serve.
Svg.—Serving.
Svl.—Several.
Swo.—Swore.
Sx.—Dollar mark.
Sy.—Say.
S.Y.S.—See your service.
T.—The.
Tan.—Than.

Tg.—Thing.
Tgh.—Telegraph.
Tgm.—Telegram.
Tgr.—Together.
Tgy.—Telegraphy.
Th.—Those.
Thk.—Thanks.
Tho.—Through.
Thr.—Their.
Ti.—Time.
Tk.—Take.
Thk.—Taking.
Tkn.—Taken.
Tkt.—Ticket.
Tlk.—Talk.
Tm.—Them.
Tn.—Then.
Tnd.—Thousand.
Tni.—To-night.
Tnk.—Think.
Tr.—There.
Tru.—Through.
Ts.—This.
Tse.—These.
Tt.—That.
Ttt.—That the (5)
Tuf.—Tough.
Tw.—To-morrow.
Ty.—They.
U.—You.
Uc.—You see.
Un.—Until.
Uni.—United.
Upn.—Upon.
Ur.—Your.
Urg.—Urge.
Val.—Value.
Vy.—Very.
W.—With.
Wa.—Way.
Wat.—Water.
Wd.—Would.
Wea.—Weather.
Wg.—Wrong.
Wh.—Which.
Wi.—Will.
Wit.—Witness.
Wl.—Well.
Wlk.—Walk.
Wn.—When.
Wnt.—Want.
Wo.—Who.
Wom.—Whom.
Wos.—Whose.
Wr.—Were.
Ws.—Was.
Wt.—What.
Wu.—Western Union.
Wy.—Why.
Y.—Year.
Ya.—Yesterday.
4.—Please start me, or where.
5.—Have you anything for me?
9.—Important official message.
13.—Understand.
25.—I am busy now.
30.—No more.
73.—Accept best regards.
77.—Message for you.
92.—Deliver.
"Wire."—Give instant possession of line for test.

LIST OF OTHER INSTRUMENTS EMPLOYED.

The buzzer test mentioned in the Naval Rules can be made to an advantage with all sets, whether of the experimental or long distance type. The rule reads: "Detector points should be kept in their most sensitive condition and frequently tested by means of the buzzer furnished for this purpose." From this rule the amateur should not understand that the buzzer test is only to be made with the liquid detector, for it can be used equally as well with any other type of self-restoring detecting instrument such as the silicon, oscillaphone, etc.

The test in question is made by use of the ordinary electrical buzzer. Two common dry cells are connected to the buzzer to operate it, with a telegraph key seriesed in the circuit. A ground wire is connected to one of the binding posts of the buzzer, and the ground made within a few feet of the ground of the telegraph set. The buzzer should be placed far enough away so that the noise from it will not interfere with the operator reading the signals in the telephone receiver.

The arrangement for connecting is shown in Fig. 58 with the buzzer to the right and the detecting set to the left. To test: have party to press key which starts the buzzer in operation. Listen-in at the receiver and adjust the thumb screw until the point is reached where the indication is the clearest. The operator will soon be able to find the most sensitive point with little adjusting, as he becomes more familiar with the working of the set.

If the indication is not heard, all connections should be closely examined, and loose nuts screwed up, as a loose connection often proves a source of trouble. If the Wollaston wire point is broken off, which is often the case, replace and test as before. In actual practice the operator will find many other tests that can be utilized, the majority of which are embodied in the Naval Rules previously given.

Condensers. The Leyden jar is one of the best known types of condensers. The oscillatory action which takes place in the charging and discharging of a condenser was explained in Chapter II. The uses to which a condenser

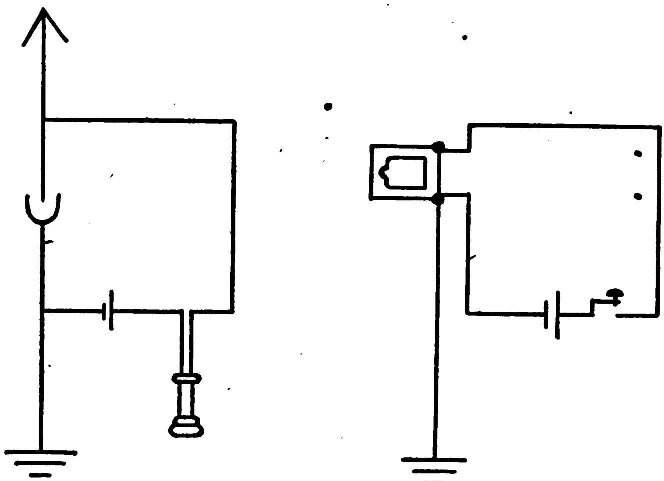


Fig. 58. Showing Method of Making the Buzzer Test.

is put, and the method of manufacture, varies with the special conditions to meet. The insulating medium which separates the two conductors is known as the dielectric. When the condenser is designed for use in the sending circuit of a wireless telegraph set, the dielectric should have high insulating properties. This is necessary in order that the condenser can be charged to the maximum point, and discharge with the minimum loss across the spark gap. If the dielectric is not capable of withstanding the charge the current will jump through to the opposite conducting plate, forming a puncture. If the condenser is of the kind where some solid insulating substance is used as the dielectric, the puncture will ruin its efficiency, making it necessary to replace with another; but if the dielectric is the open air or in liquid form, no repairs will be needed, as the insulating medium in this case remains constant. A condenser of this type is known as the self-healing kind. Various dielectrics are used in condensers, such as mica, glass, paper, oils, and the open air. Mica is the best known insulator, but is seldom used, owing to the expense.

Condensers employed in the receiving circuit do not have such high insulating properties, as the currents of the receiving circuit are of very low tension. Paper, glass, and mica are commonly used as the dielectric for condensers of the fixed type, to be used in the receiving circuit, and for the variable kind metal sheets are employed separated by the open air. In construction the sheets are so arranged that they can be run backward and forward, thereby increasing and decreasing the conducting surfaces offered and in a like manner varying the capacity.

Condensers are often referred to as capacities. In the electrical sense the capacity of a condenser depends on the square of the conducting surface and the thickness of the dielectric.

Theoretically, doubling the thickness of the dielectric doubles the capacity; however, this does not prove to be a fact in actual practice. By connecting two condensers in series we reduce the capacity to one-half of one, or by connecting two in parallel we double the capacity. A very common condenser circuit is shown in Fig. 59, in which the condensers are connected in series-parallel. This method of connecting proves very efficient for wireless telegraph work. As a well known fact wherever there is electrical work a certain amount of heat is generated. When condensers are charged and discharged this heat is generated and is known as dielectric hysteresis. To overcome such effects the condensers are con-

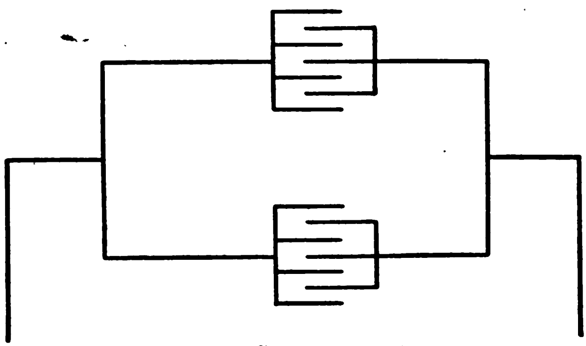


Fig. 59. Condensers Connected in Series-Parallel.

nected according to the plan shown in Fig. 59, which divides up the load and spreads the charge equally over the conducting surfaces. This method of connecting, however, is not absolutely necessary, but is more efficient for the reasons set forth.

TUNING INDUCTANCE—TUNING COIL.

The tuning coil and its purpose has been previously described and here will be explained a few of the different types in use. The tuning coil which is used in the sending circuit is commonly called an inductance. By combining the tuning inductance, condenser capacity, and spark gap in series with the secondary of the transformer, the tuned sending end is completed. By varying either the inductance or capacity we vary the wave length of the station. It is in this manner that the set is adjusted to the proper wave length. Numerous types of inductances are used of which the most common is shown in Fig. 27. Another very efficient type consists of a ribbon of copper wound in a spiral form and mounted flat on a board. The advantage of the last named type lies in the fact that it will offer a better conducting surface to the high tension current than the same amount of wire if in the circular form. The high tension current as set up in the oscillating circuit of a wireless telegraph set, does not sink down in the wire as would a slow direct current, but flows over the outer surface.

This is known as skin effects. Therefore, it is necessary to wind tuning inductances with a much larger size wire, than it would be if the current employed were direct. The metal ribbon type proves more efficient as it offers a larger surface over which the current can spread. Stranded wires are better conductors than single wire having the same cross section. For this reason stranded conductors are often used in wireless telegraphy.

Tuning coils employed at the receiving end are divided up into more different types than those for the sending end. In Fig. 29 is shown a type that is employed in common use, consisting of enameled wire wound on a circular frame, with a certain width of the winding scraped bare all the way down the frame. The slide contact is mounted on the brass rod so that it can be run up and down and make contact with the different

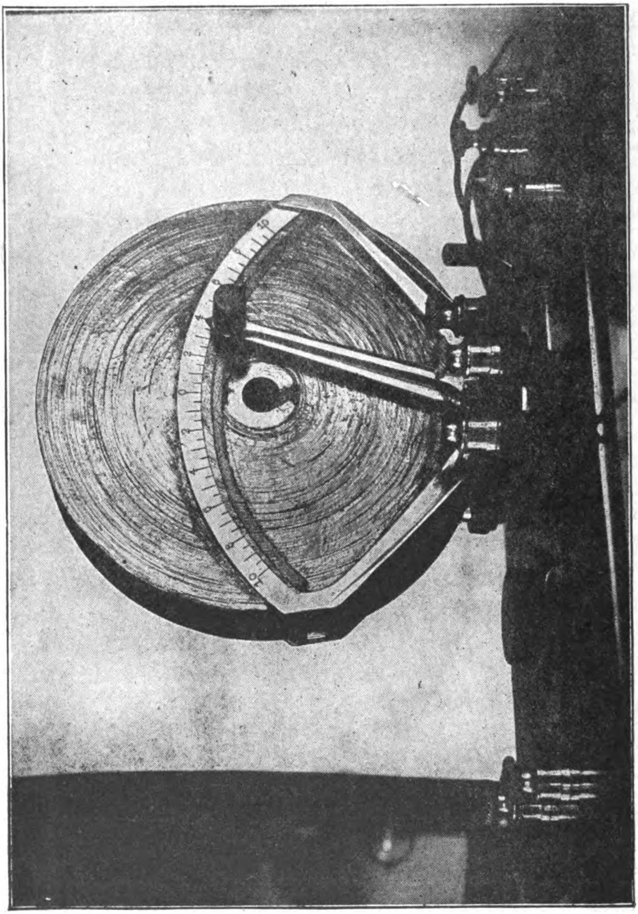


Fig. 60. De Forest "Pancake" Tuner.

turns of the winding, as exposed by the bare portion. A later type evolved by Dr. DeForrest known as the "pancake" tuner is shown in Fig. 60. This type is very unique in operation and construction. It consists of metal ribbon wound with the successive turns on top of each other and separated by a suitable insulating substance. The lever works over the exposed portion and makes contact with the different turns. A scale is provided as shown, which reads from zero at the center to 10 in each direction. The tuner is mounted on top of the audion receiving set, which facilitates the handling. The special feature of this type is the fineness to which the regulation can be carried and ease in handling.

A second type which gives fully as fine a degree of regulation as the type explained above is the Fessenden double roller type. This type is shown in Fig. 61 and consists of two cylinders mounted side by side and revolved simultaneously. This reels the winding from one cylinder to the other.

WAVE LENGTH CALCULATION.

In this calculation it is necessary to know the capacity and inductance of the entire oscillating system, including antenna, lead-in and tuning coil. When the dimensions of the coil are known, its inductance may be calculated by formula (1):

$$L = \frac{(5 \times D \times N)^2}{S + \frac{D}{3}}$$

where L = inductance in centimeters; D = diameter of coil in inches; N = number of turns; 5 = a constant; S = length of coil in inches; 3 = a constant.

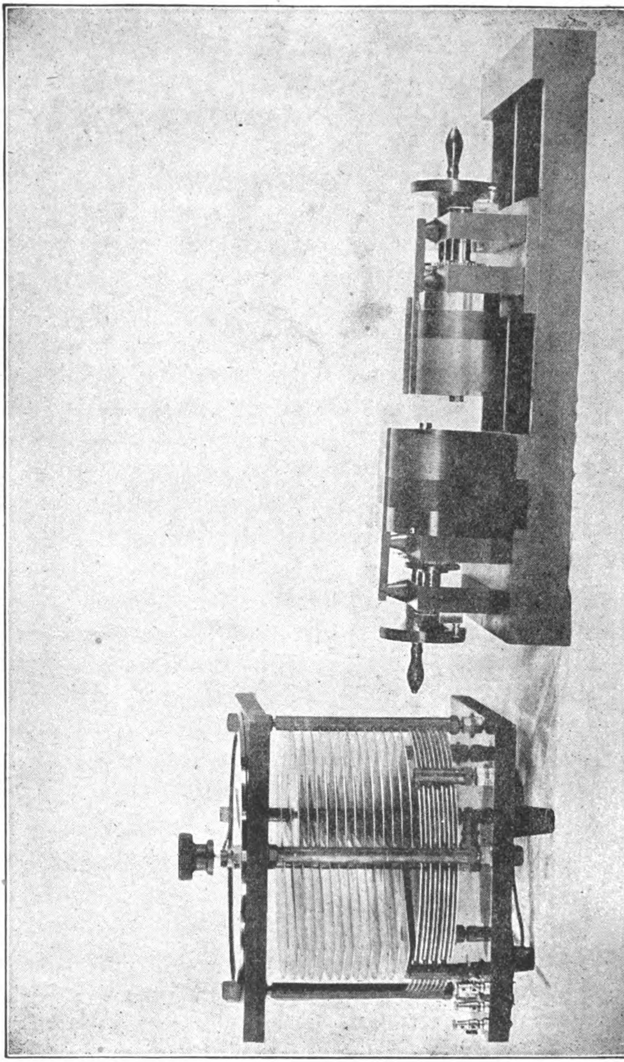


Fig. 61. Fessenden Double Roller Tuner and Variable Condenser.

Example: A coil is 10 in. long, 2 in. in diameter and is wound with 235 turns of No. 18 wire. What is its inductance?

Ans.: $L = \dfrac{(5 \times 2 \times 235)^2}{10 + \frac{2}{3}}$ = 518000 centimeters = 518 micro-henrys.

The following table gives antenna and condenser capacities in micro-farads for inverted "*L*" aerials of various heights and lengths (see page 84); wires spaced 2 to 3 feet.

Height in Feet	Length of Flat-top in Feet 60	80	100	120
40	.00033	.00042	.00051	.00060
50	.00035	.00043	.00050	.00058
60	.00036	.00044	.00051	.00059
70	.00037	.00045	.00052	.00059
80	.00039	.00046	.00053	.00060
90	.00040	.00048	.00055	.00061
100	.00042	.00049	.00056	.00062

Knowing the inductance and capacity values of a given system, the wave length may be calculated by formula (2):

$$W.\,L. = 38\sqrt{L \times C}$$

where $W.\,L.$ = wave length in meters; L = inductance in centimeters; C = capacity in micro-farads; 38 = a constant.

Assume a four-wire inverted "*L*" antenna; height 70 feet; length of flat top 60 feet; equipped with a tuning coil of the dimensions given above. Reference to table above shows its capacity to be .00037 micro-farads.

The wave length in this case will be

$$W.\,L. = 38\sqrt{518000 \times .00037} = 525 \text{ meters.}$$

WAVE METERS.

Wave meters are simply some form of indicating which shows the strength of the oscillations surging up and down the aerial wire. The hot wire ammeter, as previously described, is connected in series with the aerial wire. With the following types no direct connection is made, the currents being set up in the wave meter circuit inductively. That is, the wave meter with a suitable indicating device affixed, is placed in near proximity to the aerial radiating wire. The current surging up and down the aerial wire sets up lines of force. These lines of force cut into a suitable coil connected to the wave meter indicating device, and set up a second inductive current, which registers on the indicator. The reading from the indicator will be in proportion to the amount of current flowing through the aerial, and when the aerial circuit is in resonance the indicator will be at the maximum reading.

Several different types of wave meters are used, of which we have the Donitz type, Slaby measuring rods, Fleming cymometer.

TELEPHONE RECEIVERS.

Special features are embodied in telephone receivers for use in wireless telegraphy. The ordinary low wound receivers are not suitable, as there is not sufficient turns on the winding to make the weak currents energize the pole ends and affect the diaphragm.

The receivers are usually wound with No. 40 silk covered magnet wire, which size will allow of a large number of turns to be placed in a small space. The standard resistance for each receiver is 1,000 ohms. The diaphragm is made very thin as it has been found that the best results from weak currents is given with this type.

CHAPTER IX.

WIRELESS TELEGRAPH SYSTEMS.

Quite a number of wireless telegraph systems are in use in this country and abroad. Among the best known American systems we have the DeForest, Massie, Fessenden, and Stone. Each of the respective systems employ some special means for connecting up of the various circuits, and for which broad theoretical claims are made. However, the student will find that little difference exists in the various systems, and when he becomes familiar with the tuned set, no difficulty will be had in studying out the other circuits as they are all based on the same general plan.

For connecting up of the tuned set two common circuits are used, known as the direct connected type and the inductively connected type. The direct connected plan is the ordinary tuned set and is used with slight variations by the DeForest, Fessenden, and Massie sets. The inductive plan is utilized in the Stone system. In the tuned set of the direct connected type the inductance coil can be said to act as an auto-transformer. In the inductive type two coils are used, a primary and secondary. The primary is connected to the Leyden jars, spark gap, etc., and the secondary leads to the aerial and ground. The current surging through the primary coil induces a current of high voltage in the secondary, which is in turn led to the aerial and ground, and produces the wave effect. There is quite a difference of opinion as to which type is more efficient, but this has not yet been

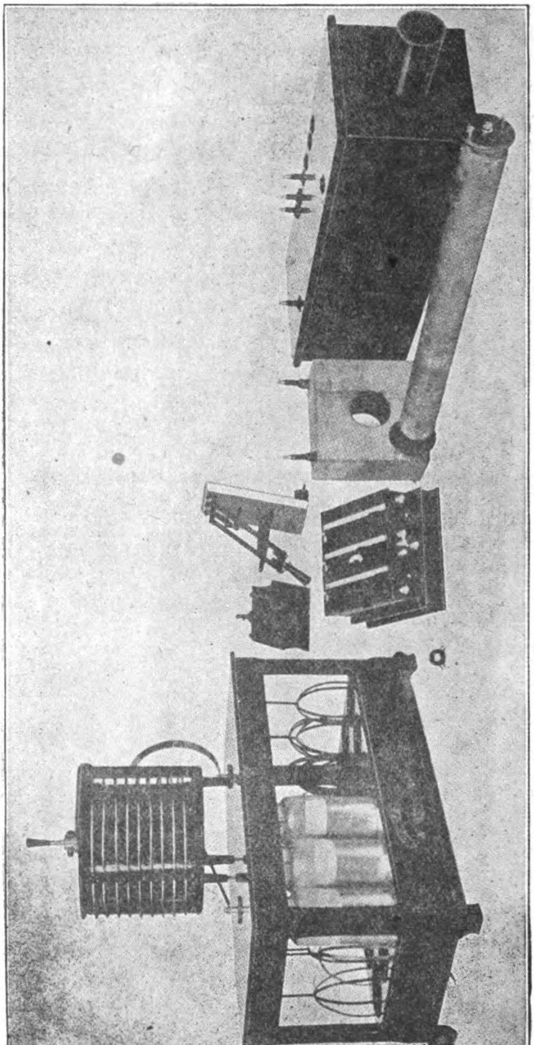


Fig. 62. Parts Used in the De Forest Set.

actually determined. However, each type possesses distinct advantages and will be treated of at the proper point.

By comparing the receiving circuit with the sending it will be noted that they are identical in several respects, the difference existing in the placing of the detector which occupies the same position as the spark gap, and the proportional size of the parts.

DE FOREST SYSTEM.

One of the best known American systems is that invented and put in practical use by Dr. Lee DeForest. The DeForest instruments will be found in use in the principal cities in the United States and on the majority of the steamers. Some of the parts used in the DeForest system is shown in Fig. 62. To the left of the figure is illustrated the case containing the Leyden jar battery, with the tuning inductance mounted on top, spark gap working through the central portion of the frame on which the tuning inductance is wound. To the right is shown the transformer. The aerial switch and other instruments are shown in the center. In Fig. 63 is shown the plan for connecting up. A represents the transformer which is supplied by a 110-volt alternating current generator, the current being broken up into the dots and dashes of the code by the key. When the key is pressed the current circulates through the primary winding of the transformer and induces a second current of 25,000 volts in the secondary, which charges the condenser B to the maximum point, the condensers in turn discharging through the winding of the inductance coil C, and jumping the spark gap D. The ground is made direct to the inductance. The aerial lead is provided with a clamp contact so that different numbers of the turns can be included in the circuit. At J is shown the anchor gap.

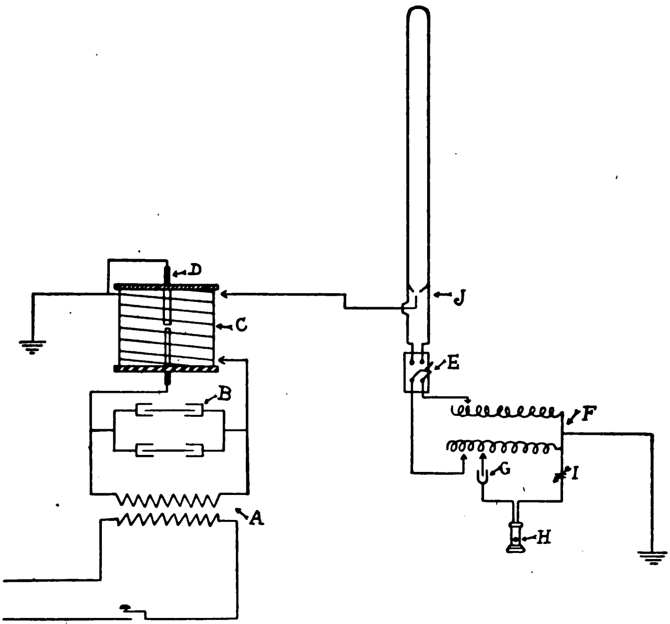


Fig. 63. De Forest Wireless Telegraph Circuit.

The receiving circuit is shown to the right of the figure. The aerial is of the inverted "U" or loop type and leads to the anchor gap J, on to the aerial switch E. A double coil syntonizer is employed and shown at F. G represents the detecting device, I the variable condenser, and H the telephone receiver. The set is sometimes equipped with a three-coil syntonizer instead of the two coil type shown at F.

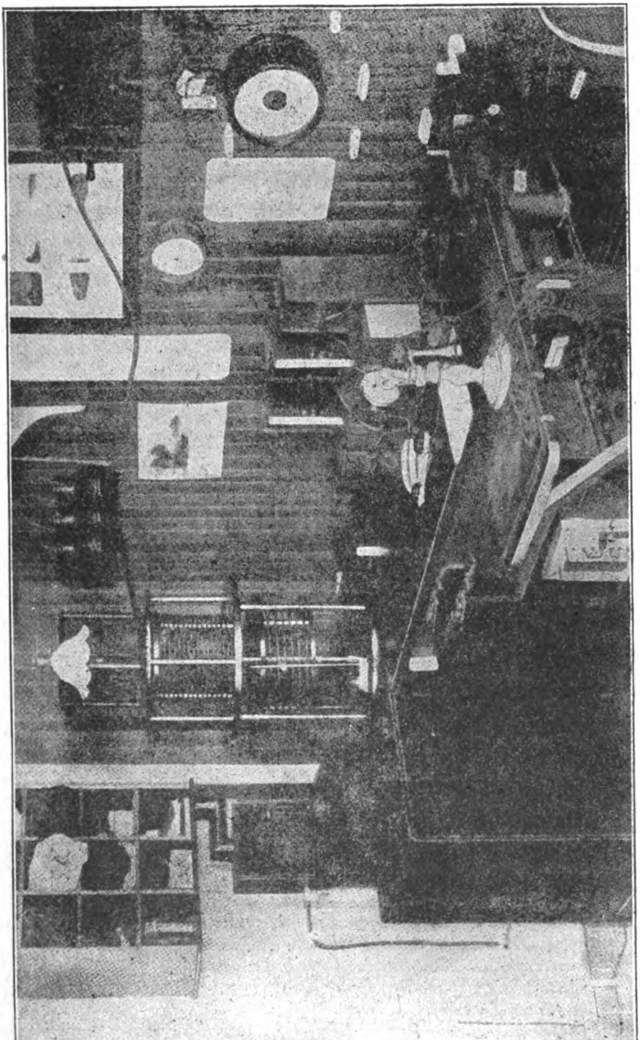


Fig. 64. Interior View of Stone Station.

Such a receiving arrangement allows of a very high degree of selectivity. The different wave lengths are had by varying the contacts over the coil F. The anchor gap obviates the use of a double pole double throw switch, and is an essential feature where the "U" type elevation is employed.

In practice the DeForest system has proven to be one of the most efficient yet designed and a large number of sets have been supplied to the United States and foreign governments. Dr. DeForest is at the present devoting his time to the perfection of a system of wireless telephony which bears his name.

THE STONE SYSTEM.

The Stone system embodies a number of unique features. The main feature, however, may be said to lie in the fact that the set is of the inductive connected type. The complete set is shown in Fig. 64. To the left of the figure is shown the inductance coils, transformer, and spark gap, and to the right the receiving instruments. The complete transmitting and receiving circuits are shown in Fig. 65.

In the Fig. A represents the inductance coil, B the spark gap, C the condensers, D the transformer, E protecting instruments, F the rheostat, and K the key.

The remaining part of the figure represents the receiving circuit. H is a low capacity fixed condenser, G-G small transformer coils, I potentiometer, and J the detector.

No aerial switch is required in this set as the key automatically breaks the circuit when operated. This is

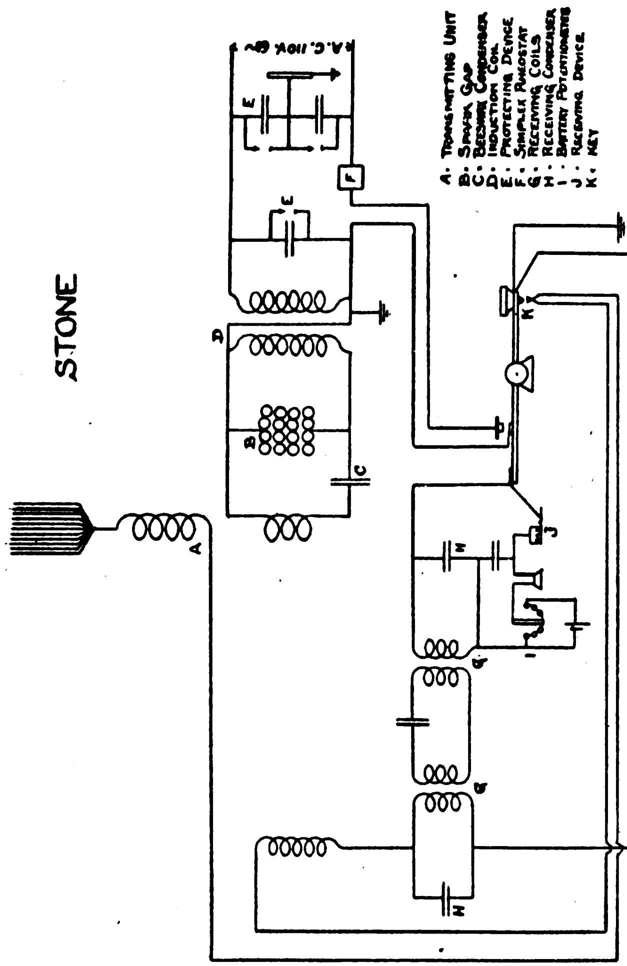


Fig. 65. Complete Sending and Receiving Circuit of the Stone System.

made clear by reference to the diagram. When the key is pressed the back part of the lever is raised and the circuit closed with the 110 volt A. C. generator. The current flowing through the primary of the transformer D raises an inductive current in the secondary. The current now flows through the lower inductance A and charges the condensers C, and breaking across the air gap of the spark balls B, this sets up an oscillating current of high frequency which flows through the lower inductance, and induces a current of much greater potential in the upper inductance.

As will be noted the key K, when pressed down also spreads open the contacts which rest directly under the button. This connects one leg of the circuit to the ground and allows the high voltage current to flow to the ground without damage to the detecting instruments. In this respect the Stone system possesses one distinct advantage over all others, namely, the operator can be broken in on while sending, whereas in the other systems the operator must first signal the desired station and then listen-in.

The spark gap consists of six brass balls arranged in multiple. The condenser C is built up of glass plates coated with tinfoil and sealed in beeswax.

A difference will be noted in the manner of connecting up the spark gap and the condenser in the DeForest and Stone systems. In the DeForest set the gap is seriesed in the circuit with the inductance coil, and the condensers bridged across the secondary terminals. The Stone method of connecting is the reverse. The spark gap is bridged across the secondary terminals and the condenser placed in series with the inductance.

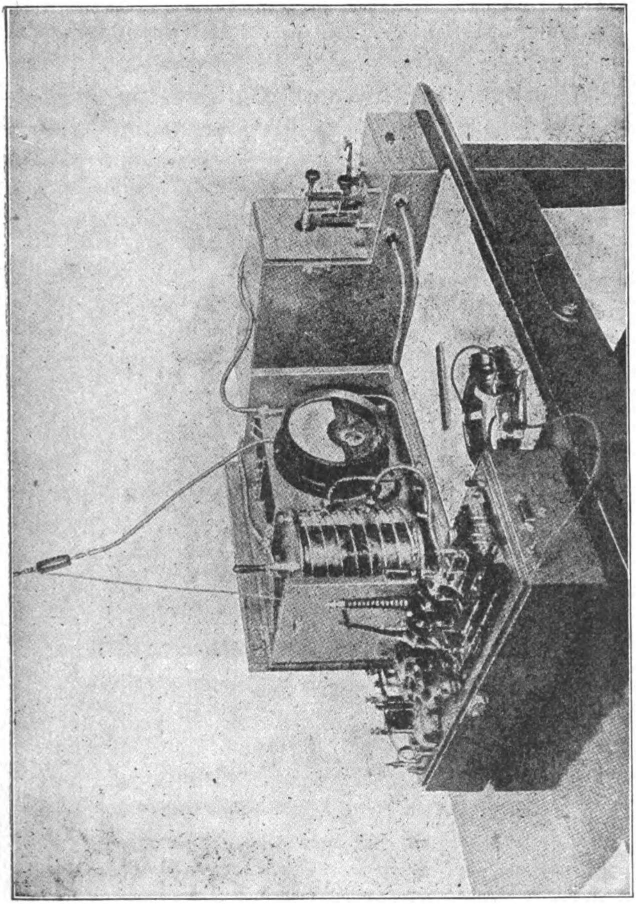


Fig. 66. Massie Wireless Telegraph Set.

THE MASSIE SYSTEM.

The Massie system invented by Mr. Walter W. Massie of Providence, R. I., has developed to a high practical stage and a number of sets are at the present in Government use, as well as several long distance stations and equipment for private concerns. The complete set is shown in Fig. 66. To the left is shown the receiving set, in the center the inductance coil, spark gap, hot wire ammeter, and head receivers, and to the right the transformer.

Mr. Massie as will be remembered is the inventor of the oscillaphone, a wonderfully simple and sensitive detecting device, which has been widely used by wireless telegraph experimenters. However, for long distance use the Massie sets are equipped with the liquid detector, as it has been found that the liquid detector is the more sensitive and reliable. The circuits of the Massie set are shown in Fig. 67 and as all the parts are properly designated no further description will be given.

In Fig. 68 is shown a device termed the "Resonaphone," a complete receiving set. It consists of a liquid detector, potentiometer, and condenser, all mounted in one case. Handles are provided which work over a scale, the scale indicating the various degrees of regulation. Switches for operating the circuit are placed on each side of the case as shown in the figure. The Massie sets are also provided with means for cooling the spark gap while sending. This increases the radiation to an appreciable extent.

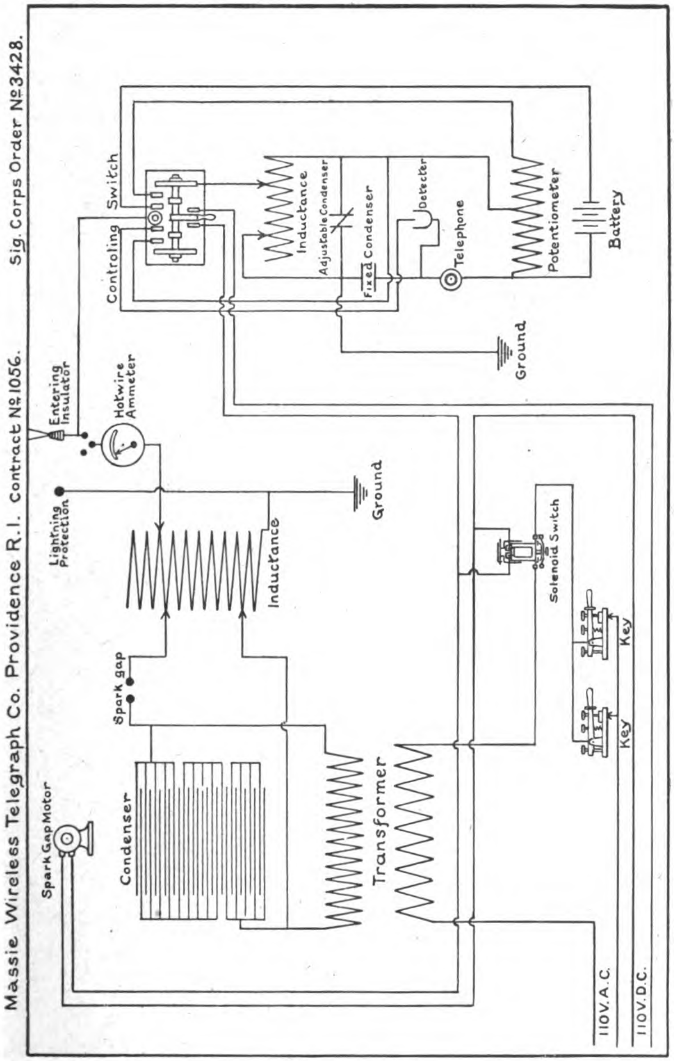


Fig. 67. Massie Wireless Telegraph Set.

THE FESSENDEN SYSTEM.

Prof. R. A. Fessenden has done quite a lot of creditable work in wireless telegraphy, and has perfected a number of instruments among which can be cited the

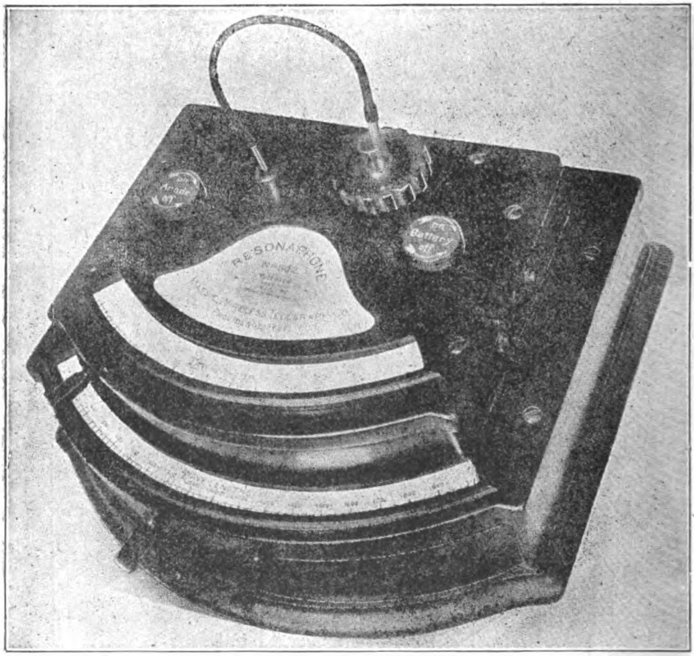


Fig. 68. The Resonaphone.

liquid detector, the most sensitive detecting device yet used. He has also devoted quite a lot of attention to tuning and has perfected this to what might be called the highest degree with the spark system.

A complete Fessenden set is shown in Fig. 69. On the

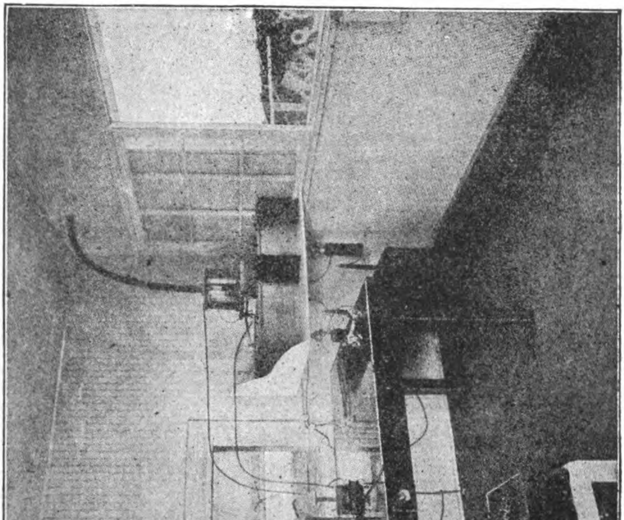


Fig. 69. Fessenden Wireless Set.

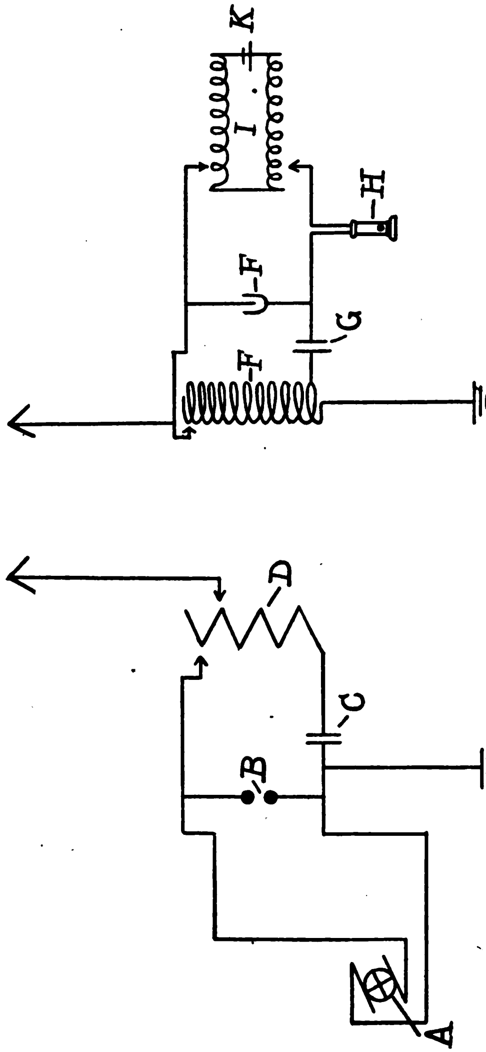


Fig. 70. Fessenden Sending and Receiving Circuit.

table is mounted the sending key, detector, etc., and in the extreme right corner the inductance and transformer.

A Fessenden sending and receiving circuit reduced to its simplest parts is shown in Fig. 70. The complete Fessenden circuit embodies a secrecy sender and interference preventer, which are used to a good advantage. However, when these two are used the range of transmission is reduced. The transmitting end is shown to the left of the figure and consists of the alternating current generator A, the spark gap B, condenser C, and inductance D. Note should be taken of the fact that the ground is made between the condenser and the spark gap.

The receiving end is shown to the right of the figure and consists of the tuning coil E, detector F, condenser G, receiver H, double roller potentiometer I, and battery K.

CHAPTER X.

WIRELESS TELEPHONY.

We now come to the limit of transmission without connecting wires, or the later art of wireless telephony, whereby articulate speech can be transmitted across indefinite space without a connecting medium. Wireless telephony cannot be called a new art, for we find that certain systems were in use some years ago, among which can be named the inductive and conductive methods, such as explained in Chapter II. However, the methods employed at the present day can be called new, as these methods embody an entirely different plan, and no limit has been found to the talking distance.

From such information as can be secured, the writer finds that one of the earliest systems of wireless telephony whereby an aerial and ground is utilized, was patented by Prof. Dolbear in 1886. This method was termed the electrostatic method. The plan used is shown in Fig. 71, of which A represents an induction coil, B a telephone transmitter, C a battery, D a condenser. For the receiving end was employed the telephone receiver F, condenser G, battery H, condenser I. It was the theory that by charging the earth around the sending end positively, and the receiving negatively, that a potential difference would exist, and when this strain was released the signs would change and indication be given.

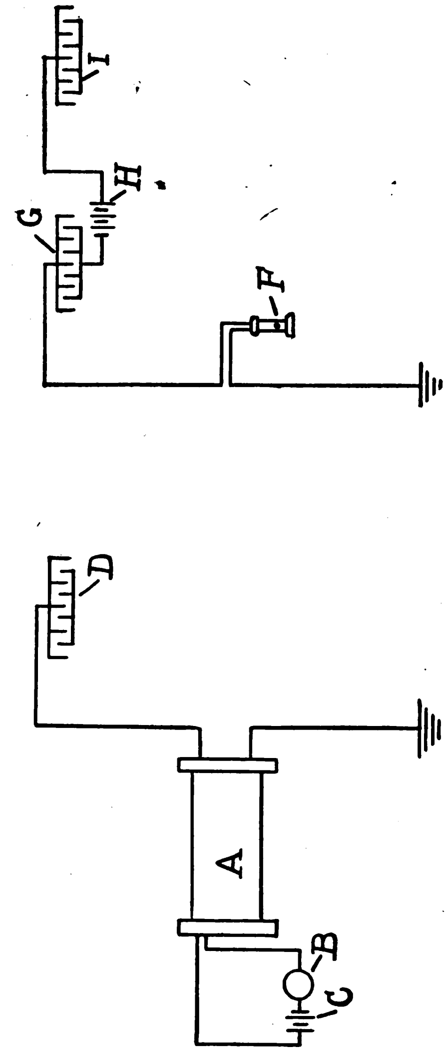


Fig. 71. Dolbear Wireless Telephone.

BELL RADIOPHONE.

The plan employed by Prof. Bell in his so-called Radiophone, is of little practical value, but from the view-point of a scientific novelty, it is wonderfully interesting and possesses many novel features.

The Radiophone gets its action from the fact (1) Selenium will vary in its conductivity with the degrees of light falling on it. (2) A beam of light can be varied in intensity by the inflections of the voice.

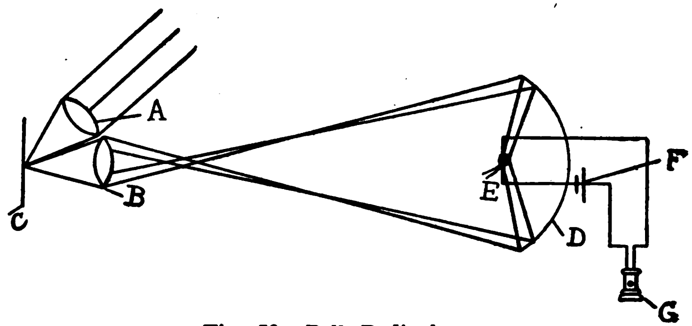


Fig. 72. Bell Radiophone.

These two facts are utilized in the plan shown in Fig. 72. A beam of light is focused by means of the lenses A on the thin, highly polished metal plate C. From C the light is reflected to the B, thence to the parbolic mirror D, which can be located some distance across the room. The parbolic mirror focuses the beam of light on the selenium cell E, which is placed in the center. The selenium cell is connected to the battery F and telephone receiver G.

When the metal plate C is spoken against, it vibrates in proportion to the spoken words, and in a like manner changes the intensity of the beam of light.

The beam of light is centered on the selenium cell E, and the light varying in its intensity to the spoken words, varies the conductivity of the selenium cell, thereby changing the battery current flowing through it to the same proportion, resulting in the spoken words in the telephone receiver.

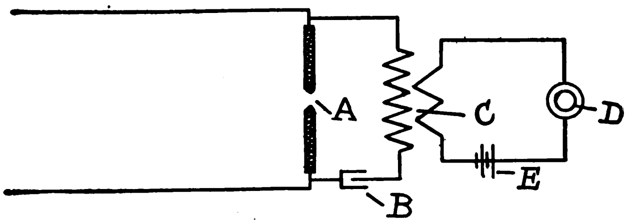


Fig. 73. View of Speaking Arc.

This plan was farther extended by Prof. Ernest Ruhmer, by using the speaking arc as the transmitting device, the beam of light coming from the arc itself. For the benefit of the readers who are not familiar with this arc a description will be given.

The peculiar action which takes place in the speaking arc was first discovered by Prof. A. T. Simon. The arc lamp consists of an ordinary hand feed arc lamp, employing cored carbons and burnt on a direct current circuit. The plan for connecting is shown in Fig. 73. A represents the cored carbons, B a low capacity condenser, C the induction coil, D the transmitter and E the battery.

The purpose of the condenser B is to prevent the heavy direct current from flowing through the secondary winding of C and burning it out, but will allow the alternating current as set up in the secondary winding of the induction coil to flow through it and affect the arc in a like manner. There is a number of other methods for producing the speaking arc, but this plan is very simple and easy to carry out.

The arc in this instance was placed in the center of a parabolic mirror, and focused to a second mirror, containing the selenium cell, some distance off. When the telephone transmitter is spoken into the battery current flowing through it to the primary of the coil is varied in the same manner, and a current of higher voltage induced in the secondary turns. The current flows from the secondary leads through the condenser to the arc, and it is supposed that this super-imposed current rapidly heats and cools the arc electrodes, thereby reproducing the spoken words. This varies the intensity of the arc. The beam of light from the arc is centered on the distant selenium cell, the same cycle of changes taking place as previously described, resulting in the words. With a set built up in this manner Prof. Ruhmer has been able to communicate up to seven kilometers. The above plans are of course limited, as it was necessary to focus a beam of light between the instruments.

HOW TO MAKE A WIRELESS TELEPHONE SET.

A very simple wireless telephone set can be constructed according to the inductive plan, as explained in Chapter II. This set will only work up to 20 or 40 feet but will prove very interesting, as communication can be had through solid walls, room to room and for other applications.

A complete set is shown in Fig. 74 and comprises a telephone transmitter A, set of batteries B, induction coil C, and transmitting coil D. The receiving coil is shown to the opposite side of the figure and consists of the receiving coil E and telephone receiver F.

The construction of the transmitting and receiving coils will be taken up first. The transmitting coil is made by winding 30 turns of No. 18 S. C. C. copper in a circle 5 feet in diameter. A very simple method for winding is to drive nails in the wall in a circle of the desired diameter, and lead the turns over the nails. When the

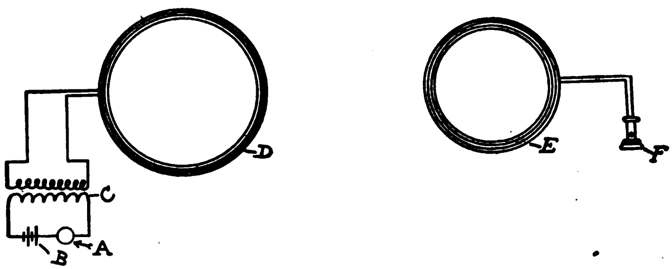


Fig. 74. A Simple Inductive Wireless Telephone.

required number of turns have been wound on, wrap with tape all the way around, leaving out several inches of the end terminal for connecting. This will form a circular cable, the tape holding the turns in place. The receiving coil is wound 3½ feet in diameter with 80 turns of No. 22 S. S. C. copper wire, and formed up in the same manner as the transmitting coil.

To complete the transmitting side an induction coil, a battery, and telephone transmitter are needed. The induction coil should be capable of delivering a high voltage current at the secondary terminals. The writer has used a $\frac{1}{4}$-inch coil with good results. If the coil is purchased complete a jumper should be placed across the vibrator contacts, which will allow a direct path for the current through the primary winding.

The secondary terminals of the induction coil are connected to the terminals of the transmitting coil. The batteries are four ordinary dry cells connected in series with the transmitter and primary of the induction coil.

To complete the receiving side an ordinary telephone receiver is connected to the respective terminals of the wound coil.

In use the coils are placed with their planes parallel to one another, and when words are spoken into the transmitter A, an alternating current will be set up in the secondary which flows through the turns D. This sets up magnetic lines of force which spread out, and are picked up by the coil E and conducted to the receiver and where the current is translated into speech.

The student can mount the parts in any desired manner, so long as the working features as explained above, are retained.

PRACTICAL WIRELESS TELEPHONY.

The methods previously named were of course limited, and to construct a set that would cover a great distance by some one of these plans, would involve an expense greater than by the ordinary wire methods. Realizing this fact, investigators have turned their time to the perfection of a system of wireless telephony, whereby it would be operated on the same principle as wireless telegraphy, i. e., the Hertzian Wave system, and which, broadly speaking, would not be limited in the range of communication.

That success has attained the efforts of the investigators is evident, for now we read of daily results and of new records, which proves that wireless telephony is already a competitor of the even new art of wireless telegraphy.

The wireless telephone in many respects resembles the ordinary wireless telegraph set, but the actual operation is vastly different, and to get a clear understanding of the wireless telephone, the point wherein this difference lies will be explained.

In the ordinary wireless telegraph set, the key is pressed and a cycle of transformation undergone, whereby a wave motion is set up in the ether through the aerial and ground wires. This wave motion, however, could not be employed for use in wireless telephony owing to the periodic character and damping proclivities. This is explained as follows: The condenser receives the charge from the secondary terminal until the break is made in the primary circuit. This break is made either by the action of the vibrator, or natural reversals of the alternating current. In either case the potential strain is released and the discharge across the spark gap from the condensers take place. As previously explained, the discharge of a condenser is not made in one sudden rush, but a continual backward and forward surging until a state of rest is reached. This sets up a wave which may be said to resemble the form shown in Fig. 75, and as will be noted the wave constantly decreases from the maximum to zero. The action of the vibrator is continuing and a number of such waves would constitute the one single dash of the code.

The variation of the voice ranges from 5,000 to 10,000 per second and if it were tried to impress on this wave the voice modulations, the breaks in the primary circuit which occasion the damping proclivities, would destroy all characteristics of speech, rendering the indication at the receiving end jumbled and confused.

Therefore, for wireless telephony it is necessary to produce a wave that remains constant and on which the voice can be impressed, the break being of sufficient rapidity not to destroy the parts of speech.

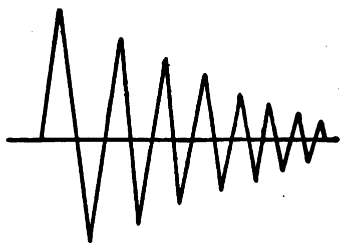


Fig. 75. Wave from Closed Circuit, Telegraph Sending Set.

At the present this is being accomplished by two different methods: the Elihu Thomson wave producer, and the Fessenden generator, or "wave mill."

The method for producing the continuous oscillations was patented by Prof. Elihu Thomson in 1892. The plan of his arrangement is shown in Fig. 76. The set consists of an arc lamp A burnt on a direct current circuit. The condenser B, and inductance coil C are shunted around the arc electrodes.

With this arrangement oscillations are produced ranging from 30,000 to 100,000 per second. Dr. DeForest and other scientists have explained the phenomena as follows: The completion of the current around the arc causes a rush of current into the shunt circuit in order to charge the condenser, thus drawing current away from the arc and increasing the resistance between the electrodes of the arc. This causes still more current to seek the condenser, charging it with a voltage higher than the normal capacity of the arc. This causes the condenser to discharge through arc, increasing the arc current and decreasing the resistance betwen the electrodes. As the condenser will discharge too much, the reverse process takes place, and thus the condenser is alternately overcharged and undercharged, and the circuit of which the

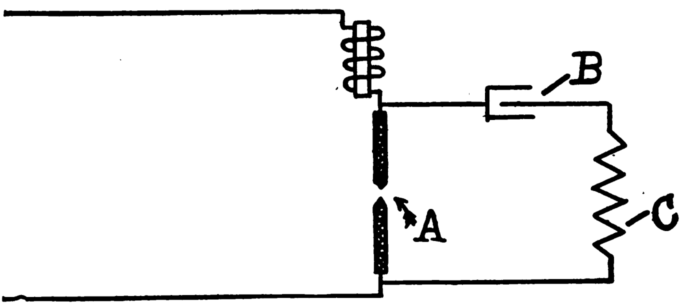


Fig. 76. Elihu Thomson Wave Generator.

condenser and inductance are parts, sustain an alternating current, whose frequency depends upon the resistance of the arc.

The above principles are utilized in a number of different wireless telephone systems.

Duddell experimented with the above arrangement but no records can be found where he improved in any way, on the original plan of Prof. Elihu Thomson. However, a number of foreign writers have erroneously given Duddell the credit.

Poulsen was the first to utilize the above plan for wireless communication. He also further improved on the original method by burning the arc in a gas field and using one copper water-cooled electrode, and one of carbon. With this plan he succeeded in getting alternations at a much greater frequency than with the original plan.

The alternations were farther increased by placing the arc under a magnetic stress. In some systems this is accomplished by winding turns of wire over an iron core, the D. C. current flowing through this winding, and the ends of the core being placed in near proximity to the arc.

Among the investigators who have done notable work with this type of oscillator may be mentioned Dr. DeForest, Poulsen, Ruhmer and others.

Prof. Fessenden has departed from the type given above and devoted his time to the perfection of a high frequency alternator, or generator, and has developed the machine to where it can be used for practical wireless telephony. Nikola Tesla was one of the earliest experimenters to begin words on high frequency alternators and his research work along this line has proven useful to the latter day investigators. Tesla designed a type which gave a frequency of 10,000 cycles per second. The construction of such generators is very difficult and expensive, and at the present time this is the greatest drawback to wireless telephony where this type of machine is used. However, with the constantly growing knowledge of the inner details, and the more systematized methods of manufacture, it may be possible at some early date to put the generators out at low cost. The alternator employed by Prof. Fessenden is described in his system of wireless telephony.

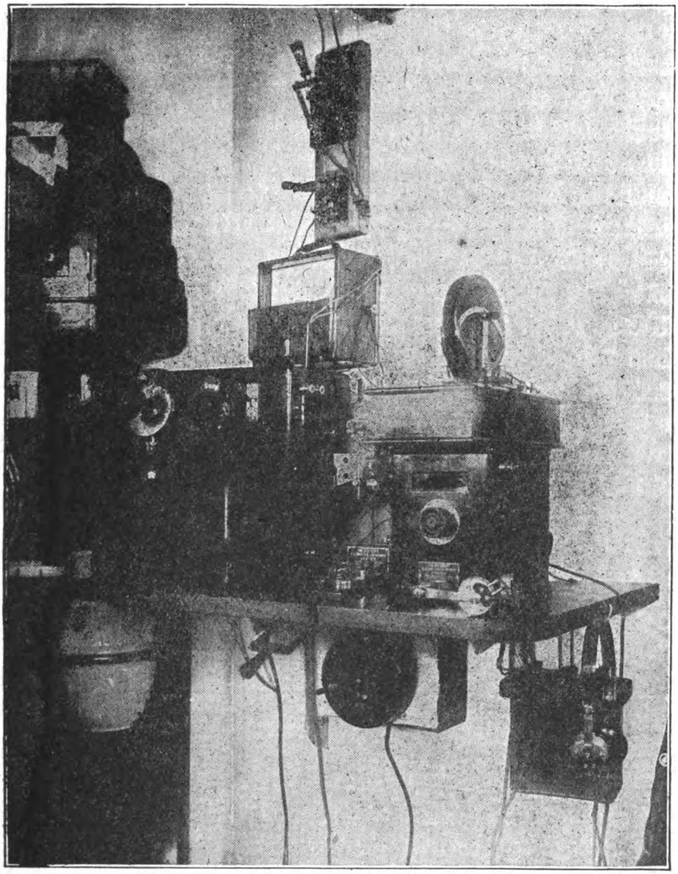


Fig. 77. View Showing Installation of De Forest Wireless Telephone Set on Shipboard.

DE FOREST SYSTEM OF WIRELESS TELEPHONY.

The DeForest system of wireless telephony which has been recently put in use on the United States war vessels is one of the most practical and efficient systems yet designed. Dr. DeForest employs the Elihu Thomson method of producing continuous oscillation, but has added many improvements and exclusive features. One of the main features of the DeForest system is the Audion detector which has proven to be especially adaptable for wireless telephony. The Audion was described in detail in Chapter VI. A view of the complete DeForest set as installed on the flagship Connecticut (United States Navy) is shown in Figure 77. To the right is shown the complete receiving set consisting of the Audion detector, storage battery for operating Audion, rheostat, etc., and on top of the case, the unique "pan cake" tuner which has been previously described.

To the left is shown the transmitting set consisting of the case containing the transformer, the transmitter, and overhead, the hot wire ammeter and necessary switches. The wiring diagram of the complete set is shown in Figure 78. The 250-volt generator supplies the current which burns the arc. The arc in this instance consists of one electrode of carbon and one of copper. The electrodes are burnt in the vapor from the flame of an alcohol lamp. As shown the inductance coil B is shunted around the two electrodes with the condenser in series. The upper terminal of the secondary of the inductance coil leads to the aerial wire, and the lower to the hot wire ammeter, switch and transmitter.

In operation the current from the dynamo flows through the choke coils, the choke coils being inserted in

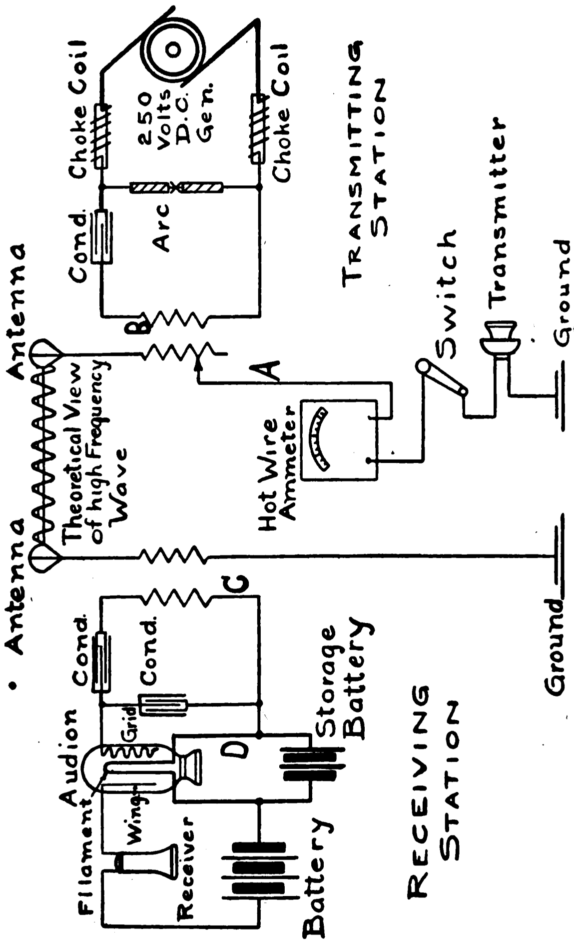


Fig. 78. De Forest Wireless Telephone Sending and Receiving Circuit.

order to prevent the alternations from flowing back on the line circuit. The arc due to the peculiar conditions under which it is burning, sets up alternations of about 100,000 per second. The alternations charge the condensers, which discharge through the turns of the inductance coil B. This induces a like current of enormous potential in the secondary turns of the coil, the current flowing through the aerial wire, and to the ground through the hot wire—ammeter and transmitter.

The current surging through the aerial and ground owing to the high number of alternations is noiseless, and no indication would be made on a distant receiver, but if some slight variation was made in the aerial circuit so that the wave would be changed in a like manner, the indication would be heard. It is the purpose of the transmitter to make such variations.

We can consider the current flowing from the secondary of the inductance coil B in one continuous stream. The current flows through the transmitter and if the transmitter be spoken into, the diaphragm will be set in vibration to the same proportion. This vibration is impressed on a mass of conducting granules, and changes in a like manner the conductivity and resistance of the mass, thereby changing the wave flowing through to the same proportion, and sending out a wave impressed with the modulations of the spoken words.

This wave motion spreads out and is picked up by the aerial wire of the receiving end and conducted down to the ground through the turns of the transformer C. A like current is induced in the opposite turns of the transformer connected to the audion. Within the audion is ionized gas which is a partial conductor. The incoming current increases and decreases the ionization of the gas

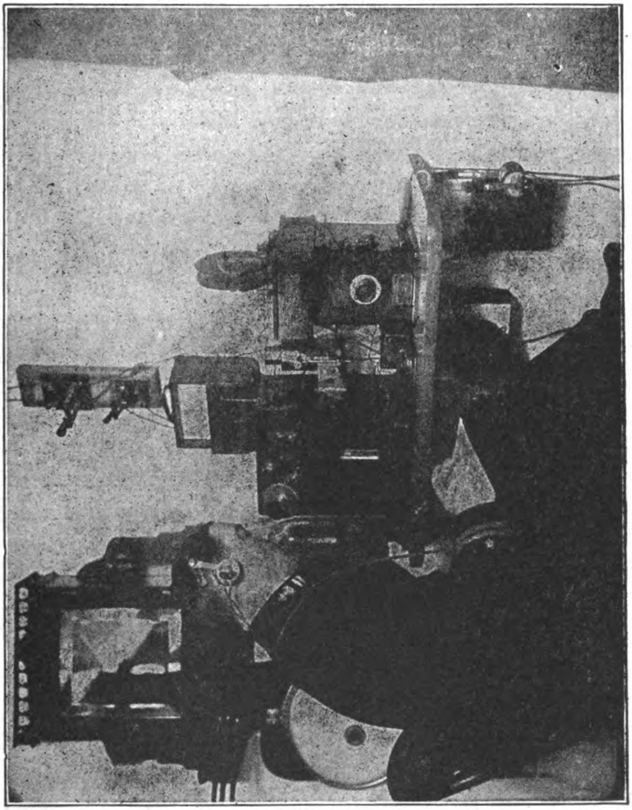


Fig. 79. De Forest Wireless Telephone Set in Use.

in proportion to the spoken words at the sending end. The receiver is included in the circuit as shown with a separate set of batteries. The ionization causes the current flowing through the receiver to vary and translates the current into articulate speech.

This is the operation of not only the DeForest wireless telephone but all other systems as well.

A complete set in actual use on shipboard is shown in Fig. 79. The tower as erected on the Terminal building, New York, is shown in Fig. 80. The tower is 110 feet high and rests 310 feet above the street level. The cross arm is supported by means of a rope run through a pulley and will allow the whole to be lowered for inspection of the aerial wires. The aerial consists of eight, stranded phosphor bronze wires which drop from the cross arm to the roof of the building and here are connected to the lead-in that runs down to the room in which the instruments are located. The distance covered from this station has an average range of 75 miles, but this will soon be increased indefinitely as the new and more powerful instruments are installed.

The DeForest patents pertaining to wireless telephony are controlled by the Radio Telephone Co., and important installations are being made along coast line and on the steamers of the Great Lakes. Dr. DeForest is at the present perfecting a device, which will indicate the distance between ships at sea, ships to land, or for other available uses. Contrary to the general opinion, such instruments are very simple. The device operates according to the following: A whistle is sounded and a wireless wave sent out, the operator at the receiving end notes the time between the reception of the wireless wave and the sound wave and as each of these have a certain rate of

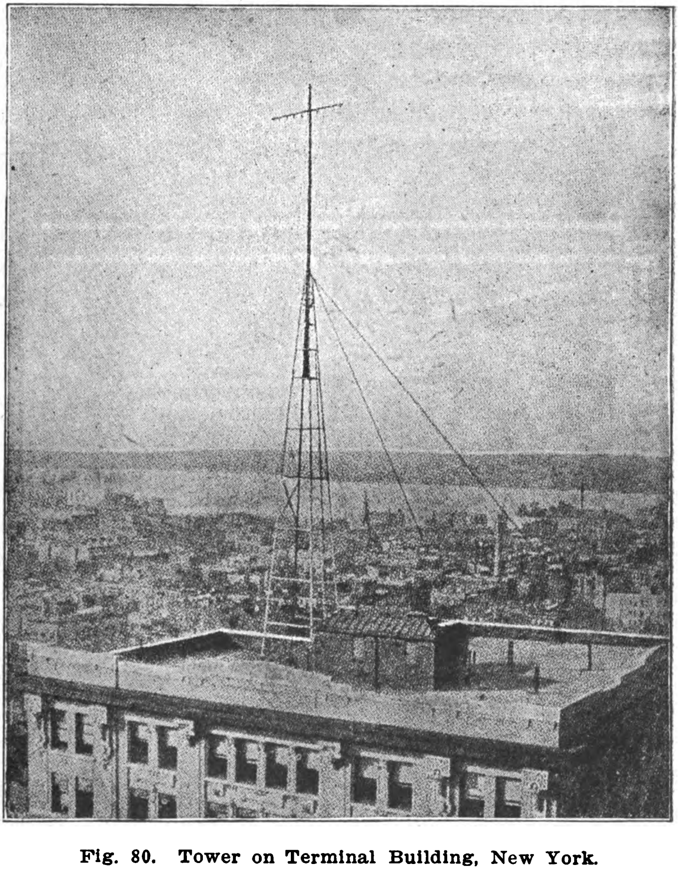


Fig. 80. Tower on Terminal Building, New York.

speed he can calculate the distance by the time between the two.

While this device is limited to the range of the sound wave, yet in case of storm, or fog, the ships could calculate the distance from one another and avoid collisions. It is expected that this device will soon come in universal use.

THE FESSENDEN SYSTEM.

No other investigator has devoted more time to the study of wireless communication than Prof. Fessenden, and the various instruments and improvements which he has brought out in the last few years speak for themselves.

His experiments in wireless telephony cover a broad range as he has used the majority of methods but has finally adopted the high frequency alternator as producer of the continuous oscillation and has, with it, been able to hold communication over a distance of 100 miles.

Prof. Fessenden's first experiments were with a very simple set. The circuit consisted of an induction coil, with the primary terminal connected to a battery source and mechanical "make and break" that gave 10,000 sparks per second. The secondary terminal was connected to the aerial and ground with transmitter included. With this arrangement communication was held over a distance of 1 mile, although the articulation, it is understood, was by no means good owing to the irregularity of the spark.

Experiments were conducted with other types of generators which gave up to 20,000 sparks per second, but results were poor with all these types, as the received

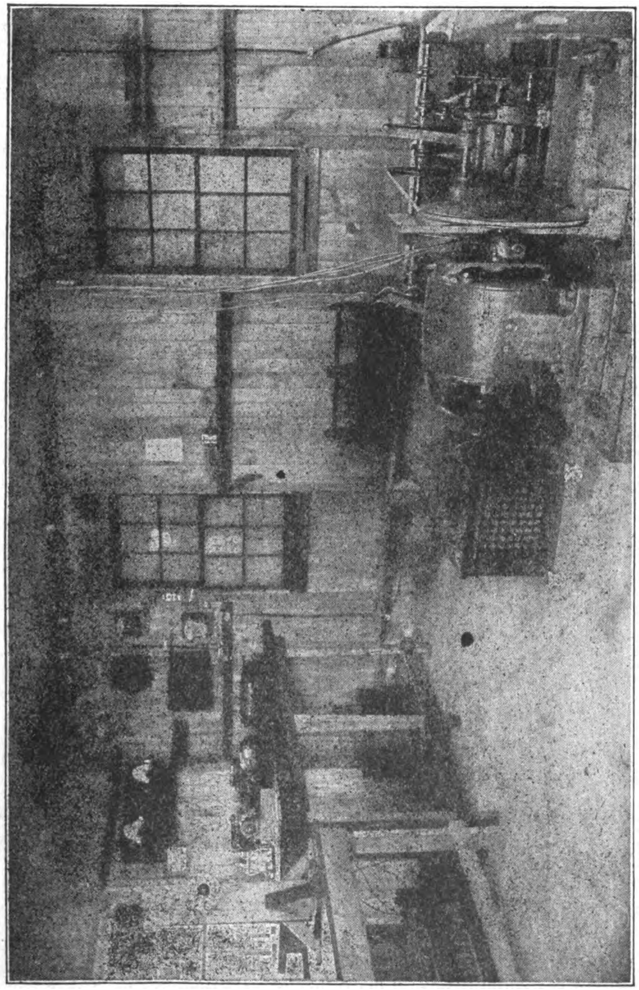


Fig. 81. Interior View of a Fessenden Wireless Telephone Station.

speech was accompanied with a harsh, grating noise, due to the slow speed of alternation.

The alternator which is used at the present day runs at a frequency of 80,000 to 100,000 per second, and the disagreeable noise at the receiving end has been entirely eliminated. Such an alternator when run at a frequency of 81,700 per second, gives a voltage of 150 volts open circuit and a field current of 5 amperes.

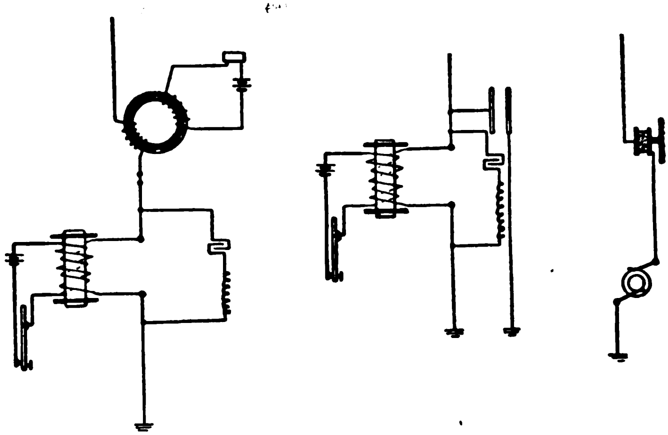


Fig. 82. Transmitting Circuits Employed by Prof. Fessenden.

The interior view of a station is shown in Fig. 81. The high frequency alternator is shown to the right; the receiving equipment, telephone transmitter, and measuring instruments to the left.

A number of different plans can be utilized for modifying the emitted wave to the voice inflections. Three different plans are shown in Fig. 82. The plan to the left consists of a primary and secondary winding wound on an iron core. The primary terminals are connected to the aerial lead and the secondary terminal to a transmitter and set of batteries. If the transmitter be spoken against the resistance of the secondary will be changed and in a like manner the iron field, varying the inductance of the primary winding to the same proportion, and the wave flowing through. No receiving circuits are shown as the same cycle of transformation, as explained in this DeForest system above, take place in all receiving circuits, whether the audion detector is employed or not.

In the middle plan what is known as the condenser transmitter is employed. This transmitter is very simple and unique in operation. It consists of a fixed metal plate with a thin plate, free to vibrate in front of it.

If the thin plate is spoken against it will vibrate and increase and decrease the air dielectric separating the plates, to the same proportion as the spoken words, impressing on the wave current flowing through the variations of the voice. Prof. Fessenden regarding this transmitter says the following: "As a practical illustration with a diaphragm, 2 centimeters in diameter, a movement of 1-100 of an inch inwards with the arrangement used for telephoning to Plymouth reduced the current from 3′1 amperes to 2′5 amperes. This is without a resonant circuit 'between the movable terminals of the condenser transmitter and ground. With this and other modifications, which I cannot publish at the present, much greater effects are obtained." The writer in experiments has found that this transmitter gives wonderfully clear and articulate tones, but seemingly the current is reduced to such an extent that it would not be adaptable for long distance use.

To the right hand side is shown the carbon transmitter. This type was fully described in the preceding DeForest

System. Numerous plans can be used and it has not yet been determined which method is the best. From the methods which have been shown, the reader can understand that the question of providing a suitable transmitter is a very important one. The objection to the ordinary transmitter is that it will not carry over one half ampere, and the current to be utilized ranges up to five amperes. A transmitter that has been utilized to a certain extent is made by arranging several transmitters in a circle, so that the voice will actuate the whole, the current dividing up among the various transmitters. This type, however, has never proven practical.

Prof. Fessenden employs a certain type of receiver, known as the Heterodyne receiver, which he says is far more sensitive than the ordinary telephone receiver, and is employed direct in the aerial circuit. Prof. Fessenden gives a description of the receiver as follows in the Electrical Review.

"All forms of voltage operated receivers, and most forms of current operated receivers, with the exception of two or three of the writer's invention, are very inefficient. Even the liquid barreter, which is as sensitive as any of those in common use, has an efficiency of only about one tenth of one per cent for weak signals. This might of course, be expected from the fact that the liquid barreter forms a thermo-dynamic Engine."

"In the writer's experiments the magnetic receiver is rather less efficient; in any case, the efficiency, or rather the unefficiency, is of the same order of magnitude.

"A liquid barreter or a magnetic receiver will give an audible indication between 1-100th and 1-1000th of an erg. An ordinary telephone receiver requires to produce an indication less than a millionth of an erg.

"It is evident if any method could be devised for using the telephone receiver direct the efficiency would be increased about a thousand times."

"This the writer has succeeded in doing with his Heterodyne receiver. This is a combination of "beats" method of United States patent 706,740 and the method of operating by continuously generated waves of United States patent 706,737."

A telephone is constructed having a fixed magnetic core formed of iron wires 1-1000th of an inch thick, and excited from a source of high frequency such as a frequency or condenser dynamo.

A small coil with or without a core is cemented to a thin mica diaphragm, and this coil is arranged to be excited by the oscillations produced by the received magnetic waves.

It is, of course, impossible to make the frequency of the wave generated at the sending station exactly equal to the high frequency oscillations, generated at the receiving station. In fact this is not desirable for most work. Advantage is, however, taken of the fact that if the frequencies are slightly different, beats will be produced and the telephone will emit a musical note. This is undoubtedly the most efficient form of receiver in existence, and it is doubtful if the method will be improved upon so far as most classes of work are concerned. No difficulty is found in practice in maintaining the frequency of wave generators, or wave mills as they are called, to within one-quarter of one per cent by automatic means.

One advantage of the Heterodyne receiver is, that it is obviously unaffected by atmospheric disturbances or by disturbances from nearby stations, and that it lends itself very nicely to multiplex working, it being unnecessary to point out that there is no difficulty with this receiver in receiving a message on the same aerial which is being used to transmit a message to another station. This places for the first time wireless telegraphy on an absolutely commercial basis and renders it capable of entering into competition with both landlines and cables.

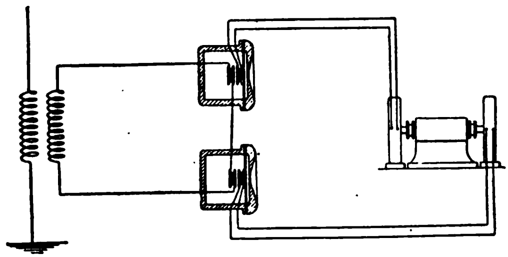


Fig. 83. Heterodyne Receiver.

With the Heterodyne system, practically any number of messages can be simultaneously transmitted and received on the same aerial without interference from each other, or from neighboring stations.

The diagram of the Heterodyne receiver circuits is shown in Fig. 83. A second interior view of the Fessenden station is shown in Fig. 84.

THE POULSEN SYSTEM.

Mr. Poulsen, the Danish "Edison," is deserving of special mention as his system was the first to utilize the Elihu Thomson method of producing continuous oscillations. Soon after his original experiments investigators in all parts of the world realized the broad advantages

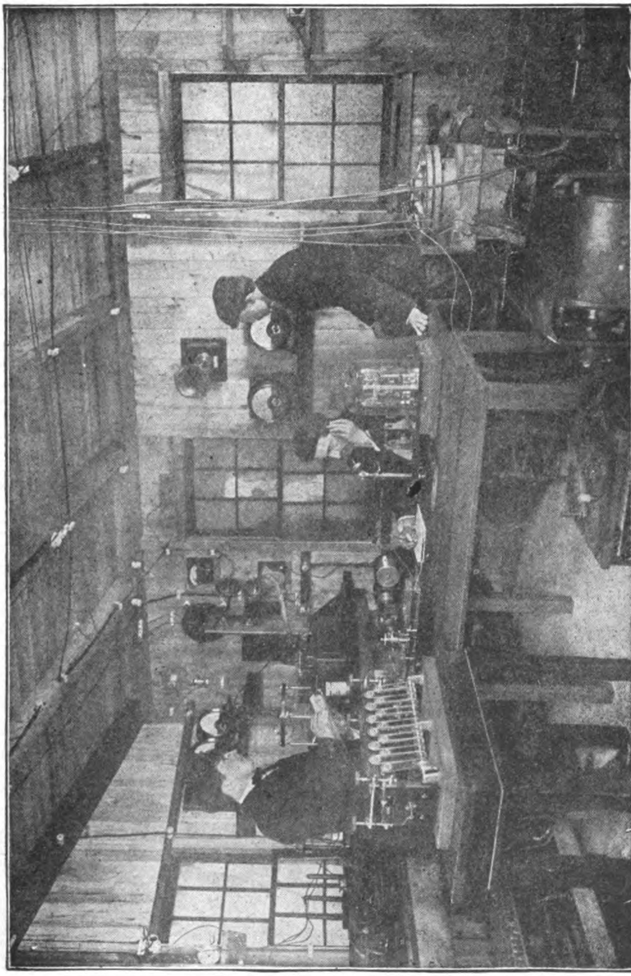


Fig. 84. Interior View of Fessenden Station.

to be derived from sparkless system of wireless communication, and many improvements have been added since that date by both American and foreign inventors.

Mr. H. Gernsback of the Modern Electrics Publication describes the station at Lyngby, near Copenhagen as follows: The aerial is elevated to an approximate height of 280 feet. Two masts about 90 meters apart support the aerial elevation.

A 20 H. P. Gasoline Engine drives a 10 K. W. 500 volt dynamo, which supplies the current to the arc lamp. The arc is placed in a strong magnetic field.

The positive electrode of the arc is of copper, the negative of carbon. If more than 6 K. W. are used the copper anode is constantly cooled by means of water circulation to the interior of the electrode.

Instead of burning the arc in the flame of an alcoholic lamp or supplying the hydrogen by means of a generator, alcohol is dropped in slowly to the chamber. It is said that one or two drops per second are sufficient for a load of K. W.

From the above description the reader will see that the Poulsen system is nearly identical with the DeForest system.

RUHMER SYSTEM.

Prof. Ruhmer, it will be remembered, has conducted quite an extensive series of experiments with the Radiophone or Photophone as previously described. He is now devoting his time to a system of wireless telephony utilizing the continuous oscillation producer and is doing creditable work.

The circuit of the Ruhmer set is shown in Fig. 85. The sending end is shown to the left hand side and the

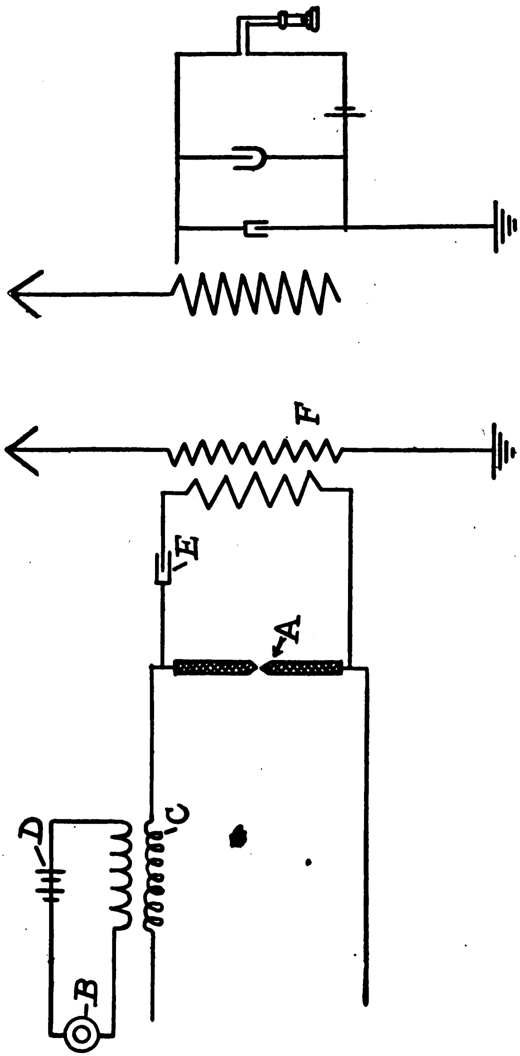


Fig. 85. Ruhmer Wireless Telephone System.

receiving to the right. The arc A is burnt in a hydrogen field and shunted by the Leyden jar condensers E, through the primary of a Tesla coil F.

In this case the transmitter is not placed in the aerial radiating circuit. C represents an induction coil with primary and secondary windings. The 220 V. D. C. which supplies the arc lamp flows through the primary of this coil. To the secondary is connected the battery D and transmitter B. When the transmitter is spoken against the inductance of the turns C is changed to the same extent, and likewise the current flowing through which supplies the arc. This sets up a series of oscillations affected with the voice tones which surges through the primary of the coil F and induces a like current in the aerial.

The receiving circuit employs the liquid detector in shunt with a condenser, and in series with a battery and telephone receiver.

No record is given of the distance covered with this equipment.

LAUGHTER WIRELESS TELEPHONE SYSTEM.

A system that has been designed and put in use by the writer is shown in Fig. 86. As this plan embodies several novel features a description will be given.

Two arcs A-A are burnt in series on a 440 volt direct circuit. Solid triangular shaped carbons are used as this style has been found to give better alternations. Blow out magnets are located behind each arc flame. The current flowing through the winding energizes the blow out magnets and places the arcs in a state of magnetic stress. The alternations are sent surging from one arc to the other with the result that the alternations increased to an indefinite amount over the arrangement where only one arc is used. The arcs are burnt in the usual hydrogen field.

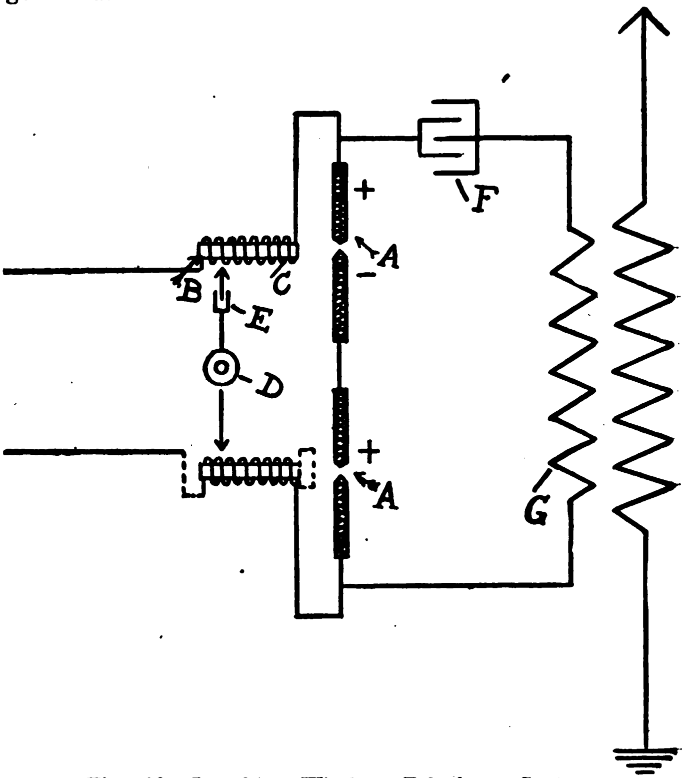


Fig. 86. Laughter Wireless Telephone System.

A special type of transmitter D is connected across the windings over the blow out magnets, with a small condenser E in series. It is the purpose of the condenser to prevent the direct current from flowing through the transmitter. However a certain amount of current will leak through the condenser. By varying the conductivity of D, the leakage will vary in a like manner. If variations on D are caused by the voice, the leakage will be of like proportion, and cause a corresponding change in the amount of current energizing the blow out magnets, and change the alternations as set up, to the same frequency as the spoken words. The alternations now flow through the primary of the transformer G and induce a like current in the secondary which flows out the aerial to the ground and produce a wave motion impressed with the voice tones.

The turns on the blow out magnet B-B are so made that a different number turns can be thrown in the circuit as desired, until the most sensitive point has been reached. A special type of transformer is employed at G, but a more complete description can not, for obvious reasons, be given at the present.

The receiving set is the ordinary tuned circuit, with liquid detector, as employed in general use.

No attempts have ever been made to talk over great distances with this set, but the writer believes that this arrangement is more efficient than several of the methods employed today. Over the distance which it has been used the tones were clear and articulate.

WIRELESS TELEPHONY IN GENERAL.

From the systems which have been described the readers will see that the majority are based on the same plans and no positive statement could be made as to which type is the more efficient. However, considering the development in a general way, we can not fail to realize the wonderful future in store for the new sparkless system of wireless communication. The most important feature lies in the tuning. Heretofore, with the spark gap a wave was sent out which consisted of many irregularities and tuning was only possible where a broad difference existed in the tune of the respective stations. With the new system, the outgoing wave current may be compared to water flowing continuously through a pipe. The tuning instruments at the sending end vary the quantity of this flow, and the tuning instruments at the receiving end are set to the point where response will be made only to the amount of flow from this respective sending end. In this manner a number of messages can be received on one aerial at the same time. In fact, the tuning can be extended to almost any possible degree.

By use of proper relays, it is now possible to hold conversation with a steamer at sea, from any point to where the ordinary wire lines extend. In operation the party talks into the telephone, which sets up a current that flows out over the ordinary wire line to the wireless station. Here, the current actuates a relay which in turn controls the wave radiated from the wireless station, setting up in the ether a wave impressed with the modulations of the voice as spoken into at the wire telephone. This wave is picked up by the aerial at the receiving end and translated into speech.

When the party on the steamer speaks into the transmitter, the same cycle of transformation is gone through and waves radiated into the ether. The above wireless station picks the wave up, conducts on the telephone line to the receiver, and is again here translated into speech.

Among the other important features of the wireless telephone, is the fact that conversation is many times more audible over the wireless than over the wire telephone. This is due to the distorting effects which the wire line has to the electric current. If it were not for this distorting effect conversation could be held over wire lines to an indefinite distance. The best known investigators predict that it will only be a matter of a short while before the wireless telephone will supplant the wire telephone for long distance use.

It has been suggested that wireless telephone sets can be placed on moving trains and communication held with other points. The value of such a service is evident for the danger of collisions would be reduced to a minimum, and an unknown convenience provided to all travelers.

However, as previously stated, it would be impossible to predict the ultimate ending of wireless development, for each month brings some new improvements, that opens up a new utility hitherto undreamed of.

CHAPTER XI.

WIRELESS GLOSSARY

WORDS, TERMS AND PHRASES USED IN WIRELESS PRACTICE.

The invention of the wireless telegraph and telephone and the marvelous progress that has been made in the field of radio engineering during recent years has resulted in the creation of certain terms and phrases in connection therewith, the meaning of which is apt to be confusing to the mind of the average student.

The list is arranged in alphabetical order, and the terms are arranged according to the noun referred to.

The definitions of terms and the illustrations of Standard Graphical Symbols presented in the following pages are reprinted by permission of the Institute of Radio Engineers, New York City.

1. **Absorption, Atmospheric:** That portion of the total loss of radiated energy due to atmospheric conductivity.
2. **Ammeter** { **Hot Band:** / **Hot Wire:** An ammeter dependent for its indications upon the change in dimensions of an element which is heated by a current thru it.
3. **Ammeter, Thermo:** An instrument for measuring current, depending for its indications on the voltage generated at the terminals of a thermo junction heated either directly or indirectly by the current to be measured.
4. **Amplifier** or **Amplifying Relay:** An instrument which modifies the effect of a local source of energy in accordance with the variations of received energy; and, in general, produces a larger indication than could be had from the incoming energy alone.
5. **Amplification, Coefficient of:** The ratio of the useful effect obtained by the employment of the amplifier to the useful effect obtained without that instrument.
6. **Antenna:** A system of conductors designed for radiating or absorbing the energy of electromagnetic waves.

7. **Antenna, Directive:** An antenna having the property of radiating a maximum of energy in one (or more) directions.

8. **Antenna, Flat Top:** An antenna having horizontal wires at the top covering a large area.

9. **Antenna, Harp:** An antenna having an approximately vertical section of large area and considerable width.

10. **Antenna, Inverted L:** A flat top antenna in which the leading down wires are taken from one end of the long narrow horizontal section.

11. **Antenna, Loop:** An antenna in which the wires form a closed circuit, part of which may be the ground.

12. **Antenna, Plain:** An approximately vertical single wire.

13. **Antenna, T:** A flat top antenna in which the horizontal section is long and narrow, the leading down wires being taken from the center.

14. **Antenna, Umbrella:** One whose conductors form the elements of a cone from the elevated apex of which the leading down wires are brought.

15. **Antenna Resistance:** An effective resistance which is numerically equal to the ratio of the power in the entire antenna circuit to the square of the R. M. S. current at a potential node (generally the ground).

Note: Antenna Resistance includes

Radiation resistance

Ground resistance

Radio frequency ohmic resistance of antenna and loading coil and shortening condensers.

Equivalent resistance due to corona, eddy currents, and insulator leakage.

16. **Arc:** The passage of an electric current of relatively high density thru a gas or vapor the conductivity of which is mainly due to the electron emission from the self-heated cathode. Under present practical conditions, the phenomena take place near atmospheric pressure.

17. **Arc Oscillator:** An arc used with an oscillating circuit for the conversion of direct to alternating or pulsating current. The oscillations generated are classified as follows:

Class (1). Those in which the amplitude of the oscillation circuit current produced is less than the direct current thru the arc.

Class (2). Those in which the amplitude of the oscillation circuit current is at least equal to the direct current, but in which the direction of the current thru the arc is never reversed.

Class (3). Those in which the amplitude of the initial portion of the oscillation circuit current is greater than the direct current passing thru the arc, and in which the direction of the current thru the arc is periodically reversed.

18. **Attenuation (Radio).** This is the decrease, with distance from the radiating source, of the amplitude of the electric and magnetic forces accompanying (and constituting) an electro-magnetic wave.

19. **Attenuation, Coefficient of (Radio).** The coefficient, which, when multiplied by the distance of transmission thru a uniform medium, gives the natural logarithm of the ratio of the amplitude of the electric or magnetic forces at that distance to the initial value of the corresponding quantities.

20. **Audibility:** The ratio of the telephone current variation producing the received signal, to that producing an audible signal. (An audible signal is one which permits the mere differentiation of dots and dashes.)

The measurement of audibility is an arbitrary method for determining the relative loudness of telephone response in radio receivers, in which it is stated that a signal has an audibility of given value. The determination of the above ratio may be made by the non-inductive shunt-to-telephone method, except that a series resistance should be inserted to keep the main current constant, and that the shunt resistance should therefore be connected as a potentiometer.

21. **Brush or Coronal Losses:** Those due to leakage convection electric currents thru a gaseous medium.

22. **Cage Conductor:** A group of parallel wires arranged as the elements of a long cylinder.

Note: Any conducting element of an antenna may be a cage conductor.

23. Capacity, Effective, of an Antenna: The effective capacity and effective inductance of an antenna at any oscillation frequency are the equivalent capacity and inductance values determined from the following fundamental equations:

$$\omega = \sqrt{\frac{1}{LC}} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (1)$$

where $L =$ the total antenna inductance,
$C =$ the total antenna capacity,
$\omega =$ the angular velocity of the free alternating currents in the antenna.

$$d = \pi R \sqrt{\frac{C}{L}} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (2)$$

or

$$d' = \pi R' \sqrt{\frac{C}{L}} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (2a)$$

where $R' =$ series resistance inserted at the base of the antenna and
$d' =$ increased decrement resulting therefrom.

Solving (1) and (2a) for L and C, we have

$$L = \frac{\pi R'}{\omega d'} = \frac{R'}{6 \times 10^8 \times d'} \cdot \lambda \qquad (\lambda \text{ in meters})$$

$$C = \frac{d'}{R'} = \frac{d'}{6\,\pi^2 \times 10^8 \times R'} \cdot \lambda \qquad (\lambda \text{ in meters})$$

Having the antenna inductance and capacity, the resistance R of the antenna can be determined from equation (2). This value of R satisfies the fundamental equation:

$RI^2 =$ power absorbed by the antenna,
where $I =$ current measured at the base of the antenna.

Note: The equation

$$I = \omega C E$$

$$\left(\text{and also } E = \frac{\pi R'}{d'} \cdot I\right)$$

defines an effective voltage E, which is the voltage approximately given by the equation,

$$\text{Energy per spark} = C E^2.$$

24. **Center of Capacity of an Antenna:** See Form Factor, Note 2.

25. **Changer, Frequency:** A device delivering alternating currents at a frequency which is some multiple of frequency of the supply current.

26. **Changer, Wave:** A transmitting device for rapidly and positively changing the wave length.

27. **Characteristic, Dynamic, of a Conductor:** (For a given frequency and between given extremes of impressed E. M. F. and resultant current thru the conductor): This is the relation given by the curve obtained when the impressed E. M. F.'s are plotted as ordinates against the resultant currents as abscissas, both E. M. F.'s and currents varying at the given frequency and between the given extremes.

28. **Characteristic, Static, of a Conductor:** This is the relation given by the curve plotted between the impressed electromotive force as ordinates and the resultant current thru the conductor as abscissas, for substantially stationary conditions.

29. **Coefficient, Attenuation, Radio:** See Attenuation.

30. **Coefficient of Amplification.** See Amplification.

31. **Coefficient of Coupling, Inductive:** The ratio of the effective mutual inductance of two circuits to the square root of the product of the effective self inductance of each of these circuits.

32. **Coherer:** A device sensitive to radio frequency energy, and characterized by (1) a normally high resistance to currents at low voltages, (2) a reduction in resistance on the application of an increasing electromotive force, this reduction persisting until eliminated by the application of a restoring or disturbing mechanical force, and (3) the substantial absence of thermo-electric or rectifying action.

33. **Communication, Radio:** The transmission of signals by means of electromagnetic waves originating in a constructed circuit.

34. **Compass, Radio:** A radio receiving device for determining the direction (or the direction and its opposite) in which maximum energy is received; or

A radio transmitting device for determining the direction (or the direction and its opposite) of maximum radiation.

35. **Condenser, Air:** A condenser having air as its dielectric.

36. **Condenser, Compressed Gas:** A condenser having compressed gas as its dielectric.

37. **Conductor, Cage:** See Cage Conductor.

38. **Corona:** See Brush or Corona Losses.

39. **Counterpoise:** A system of electrical conductors forming one portion of a radiating oscillator the other portion of which is the antenna. In land stations, a counterpoise forms a capacitive connection to ground.

40. **Coupler:** An apparatus which is used to transfer radio frequency energy from one circuit to another by associating portions of these circuits.

41. **Coupler, Capacitive:** An apparatus which, by electric fields, joins portions of two radio frequency circuits; and which is used to transfer electrical energy between these circuits thru the action of electric forces.

42. **Coupler, Direct:** A coupler which magnetically joins two circuits having a common conductive portion.

43. **Coupler, Inductive:** An apparatus which by magnetic forces joins portions of two radio frequency circuits and is used to transfer electrical energy between these circuits thru the action of these magnetic forces.

44. **Coupling:** See Coefficient of Coupling (Inductive).

45. **Current, Damped Alternating:** An alternating current whose amplitude progressively diminishes. (Also called oscillating current.)

46. **Current, Forced Alternating:** A current, the frequency and damping of which are equal to the frequency and damping of the exciting electromotive force. See further Current, Free Alternating.

Note 1: During the initial stages of excitation, both free and forced currents co-exist.

47. **Current, Free Alternating:** The current following any transient electromagnetic disturbance in a circuit having capacity, inductance, and *less* than the critical resistance. See further, Resistance, Critical.

48. **Curve, Distribution, of a Radio Transmitting Station for a given distance:** This is a polar curve the radii vectors of which are proportional to the field intensity of the radiation at that distance in corresponding directions. See also Compass, Radio.

Note 1: The distribution curve depends, in general, not only on the form of the antenna, but also on the nature of the ground surrounding the station.

Note 2: The distribution curve generally varies with the distance from the station.

49. **Curve, Resonance, Standard:** A curve the ordinates of which are the ratios of the square of the current at any frequency to the square of the resonant current, and the abscissas are the ratios of the corresponding wave length to the resonant wave length; the abscissas and ordinates having the same scale.

50. **Cyclogram:** See Characteristic, Dynamic.

51. **Cyclograph:** An instrument for the production of cyclograms.

52. **Decrement:** See Decrement, Linear, and Logarithmic.

53. **Decrement, Linear, of a Linearly Damped Alternating Current:** This is the difference of successive current amplitudes in the same direction divided by the larger of these amplitudes.

Note: Let I_n and $I_n + _1$ be successive current amplitudes in the same direction of a linearly damped alternating current.

Then, the linear decrement

$$b = \frac{I_n - I_n + _1}{I_n}$$

Also: $I_t = I_o\ (1 - bft)$,

where I_o = initial current amplitude,

I_t = current amplitude at time t,

f = frequency of alternating current.

54. **Decrement, Logarithmic, of an exponentially damped alternating current:** This is the logarithm of the ratio of successive current amplitudes in the same direction.

Note: **Logarithmic decrements are standard for a complete period or cycle.**

Let I_n and I_{n+1} be successive current amplitudes in the same direction,

d = logarithmic decrement,

Then, $d = \log_{\epsilon} \frac{I_n}{I_{n+1}}$, where $\epsilon = 2.718 +$.

55. **Decremeter:** An instrument for measuring the logarithmic decrement of a circuit or of a train of electromagnetic waves.

56. **Detector:** That portion of the receiving apparatus which, connected to a circuit carrying currents of radio frequency, and in conjunction with a self-contained or separate indicator, translates the radio frequency energy into a form suitable for operation of the indicator. This translation may be effected either by the conversion of the radio frequency energy, or by means of the control of local energy by the energy received.

57. **Device, Acoustic Resonance:** A device which utilizes in its operation resonance to the audio frequency of the received signals.

58. **Diplex Reception:** The simultaneous reception of two signals by a single operating station.

59. **Diplex Transmission:** The simultaneous transmission of two signals by a single operating station.

60. **Duplex Signaling:** The simultaneous reception and transmission of signals.

61. **Excitation, Impulse:** A method of producing free alternating currents in an excited circuit in which the duration of the exciting current is short compared with the duration of the excited current.

Note: The condition of short duration implies that there can be no appreciable reaction between the circuits.

62. **Factor, Damping:** The product of the logarithmic decrement and the frequency of an exponentially damped alternating current.

Let I_o = initial amplitude,

I_t = amplitude at the time t,

ϵ = base of Napierian logarithms (2.718 +),

a = damping factor,

Then, $I_t = I_o \epsilon^{-at}$

63. **Factor, Form:** The form factor of a symmetrical antenna for a given wave length is the ratio of the algebraic average value of the R. M. S. currents measured at all heights to the greatest of these R. M. S. currents.

Note 1: For a given R. M. S. current at the base of the antenna, the field intensity at distant points is proportional to the form factor times the height of the antenna.

Note 2: The effective height (height of center of capacity) is equal to the form factor times the actual height of the antenna.

Note 3: The limiting values of the form factor for various types of antennas are as follows:

	Linear or Vertical Antenna	Flat Top Umbrella Antenna
Long Waves	Lower Limit, 1/2	Upper Limit, 1
Fundamental	Lower Limit, $2/\pi$	———

Note 4: The form factor varies in a given antenna at various wave lengths due to variation of the current distribution.

64. **Frequencies, Audio (abbreviated a. f.):** The frequencies corresponding to the normally audible vibrations. These are assumed to lie below 10,000 cycles per second.

65. **Frequencies, Radio (abbreviated r. f.):** The frequencies higher than those corresponding to the normally audible vibrations, which are generally taken as 10,000 cycles per second. See also Frequencies, Audio.

Note: It is not implied that radiation cannot be secured at lower frequencies, and the distinction from audio frequencies is merely one of definition based on convenience.

66. **Frequency, Changer:** See Changer, Frequency.

67. **Frequency, Group:** The number per second of periodic changes of amplitude or frequency of an alternating current.

Note 1: Where there is more than one periodically recurrent change of amplitude, or frequency, there is more than one group frequency present.

Note 2: The term "group frequency" replaces the term "spark frequency."

68. **Frequency Transformer:** See Changer, Frequency.
69. **Fundamental of an Antenna:** This is the lowest frequency of free oscillations of the unloaded antenna. (No series inductance or capacity.)
70. **Fundamental Wave Length:** The wave length corresponding to the lowest free period of any oscillator.
71. **Gap, Micrometer:** A device for protecting any apparatus from excessive potentials, and consisting of a short gap designed for fine adjustment.
72. **Ground:** A conductive connection to the earth.
73. **Height, Effective, of an Antenna:** See Factor, Form; Note 2.
74. **Inductance, Effective of an Antenna:** See Capacity, Effective of an Antenna.
75. **Impulse Excitation:** See Excitation, Impulse.
76. **Interference, Wave (In Radio Communication):** The reinforcement or neutralization of waves arriving at a receiving point along different paths from a given sending station; (to be distinguished from ordinary or station interference, which is the simultaneous reception of signals from two or more stations).
77. **Key:** A switch arranged for rapidity of manual operation and normally used to form the code signals of a radiogram.
78. **Key, Relay:** See Relay Key.
79. **Length, Wave:** See Wave Length.
80. **Losses, Brush** or **Corona:** See Brush or Corona Losses.
81. **Meter, Wave:** See Wave Meter.
82. **Oscillations (In radio work):** See Current, Damped Alternating.
83. **Oscillator, Arc:** See Arc Oscillator.
84. **Potentiometer:** As commonly used for radio receiving apparatus, a device for securing a variable potential by utilizing the voltage drop across the variable portion of a current carrying resistance.
85. **Radiation, Sustained:** See Waves, Sustained.
86. **Radiogram:** A telegram sent by radio.
87. **To Radiograph (verb):** To send a radiogram.

88. **Radio Telephone:** An apparatus for the transmission of speech by radio.

89. **Radiophone (noun):** A telephone message sent by radio.

90. **To Radiophone (verb):** To send a radiophone.

91. **Rectifier, Electron:** A device for rectifying an alternating current by utilizing the approximately unilateral conductivity between the hot cathode and a relatively cold anode in so high a vacuum that a pure electron current flows between the electrodes.

92. **Rectifier, Gas:** An electron rectifier containing gas which modifies the internal action by the retardation of the electrons or the ionization of the gas atoms.

93. **Relay, Electron:** A device provided with means for modifying the pure electron current flowing between a hot cathode and a relatively cold anode placed in as nearly as possible a perfect vacuum.

These means may be, for example, an electric control of the pure electron current by variation of the potential of a grid interposed between the cathode and the anode.

94. **Relay, Gas:** An electron relay containing gas which modifies the internal action by the retardation of the electrons or the ionization of the gas atoms.

95. **Relay Key:** An electrically operated key. See further, Key.

96. **Resistance, Antenna:** See Antenna Resistance.

97. **Resistance, Critical, of a Circuit:** That resistance which determines the limiting condition at which the oscillatory discharge of a circuit passes into an aperiodic discharge.

98. **Resistance, Effective, of a Spark:** The ratio of the power dissipated by the spark to the mean square current.

99. **Resistance, Radiation:** This is the ratio of the total energy radiated (per second) by the antenna to the square of the R. M. S. current at a potential node (generally the ground connection). See further, Antenna Resistance.

100. **Resistance, Radio Frequency:** This is the ratio of the heat produced per second in watts to the square of the R. M. S. current (r. f.) in amperes in a conductor.

101. **Resonance:** Resonance of a circuit to a given exciting alternating E. M. F. is that condition due to variation

of the inductance or capacity in which the resulting effective current (or voltage) in that circuit is a maximum.

Note 1: Instead of varying the inductance and capacity of a circuit the frequency of the exciting field may be varied. The condition of resonance is determined by the frequency at which the current (or voltage) is a maximum.

Note 2: The resonance frequency corresponds the more accurately to the frequency of the free oscillations of a circuit, the lower the damping of the exciting alternating field and of the excited circuit.

102. **Resonance, Acoustic Device:** See Device, Acoustic Resonance.

103. **Resonance, Sharpness of:** See Tuning, Sharpness of.

104. **Signaling, Duplex:** See Duplex Signaling.

105. **Sharpness of Tuning:** The measure of the rate of diminution of current in transmitters and receivers with detuning of the circuit which is varied.

If d_2 is the decrement of the free alternating current in the circuit and d_1 the decrement of the exciting E. M. F., then the sharpness of tuning is arbitrarily defined as $\frac{2\pi}{d_1 + d_2}$

106. **Spark:** An arc of short duration.

107. **Static:** Disturbances caused by atmospheric charging of the antenna.

Note: When it is definitely known that disturbances are due to atmospheric charging of the antenna, the word "Static" shall be used. In general, disturbances shall be called "Strays."

108. **Strays:** Electromagnetic disturbances set up by distant discharges.

109. **Telegraphy, Radio:** The art of sending and receiving radiograms.

110. **Telephony, Radio:** The art of sending and receiving radiophones.

111. **Train, Wave:** The waves emitted which correspond to a group of oscillations in the transmitter. See also, Frequency, Group.

112. **Transformer:** In present radio practice the term should be restricted to audio frequency transformers. See Frequency, Audio.

113. **Transmission, Diplex:** See Diplex Transmission.

114. **Tuning:** The process of securing the maximum indication by adjusting the time period of a driven element. See Resonance.

115. **Tuning, Sharpness of:** See Sharpness of Tuning.

116. **Vacuum Tube, Three Electrode:** As examples see Relays, Electron and Gas.

117. **Vacuum Tube, Two Electrode:** As examples see Rectifiers, Electron and Gas.

118. **Waves, Electromagnetic:** A periodic electromagnetic disturbance progressive thru space.

119. **Wave Length (of an Electromagnetic Wave):** The distance in meters between two consecutive maxima, of the same sign, of the electric and magnetic forces.

120. **Wave Length, Fundamental:** See Fundamental Wave Length.

121. **Wave Length, Natural:** In a loaded antenna (that is, with series inductance or capacity) the natural wave length corresponds to the lowest free oscillation.

122. **Wave Changer:** See Changer, Wave.

123. **Wave Meter:** A radio frequency measuring instrument calibrated to read wave lengths.

124. **Waves, Sustained:** Waves radiated from a conductor in which an alternating current flows.

125. **Wave Train:** See Train, Wave.

TESTS AND RATING

1001. **Radio frequency generators should be rated** according to their capacity at continuous load. The method of measuring output in operation is given in Sections 1011 and 1012 below. Unless otherwise specified, a continuous load shall correspond to a locked key test.

1002. **Radio transmitting sets should be rated** on the basis of their actual antenna input, not including in antenna input the losses in the antenna switch, and in antenna loading inductances or series capacities. The radio transmitting set starts therefore at the first piece of electrical equipment definitely a part thereof, comprises all further equipment, and includes the antenna switch and antenna loading inductances and series capacities (or any other apparatus placed in the antenna circuit which forms part of the transmitting equipment; e. g., an antenna relay for break system).

1003. The **over-all efficiency** of a radio transmitting set shall be the quotient of the actual power output measured in a standard antenna (either real or artificial) to the power input supplied to the first piece of electrical equipment which is definitely a part of the radio transmitter.

Examples of the application of this rule are the following:

1004. (a) **A ship station.** Direct current is supplied from the ship's mains to a motor generator set, which furnishes alternating current to the high tension transformer of the radio set. The ratio of power in the antenna to power supplied to the motor of the motor generator set and to the auxiliary radio equipment (e. g., blower motors, rotary gap motors) is the over-all efficiency.

1005. (b) **An auxiliary ship station.** Storage batteries are charged from the ship's mains, and operate a motor generator set or an induction coil. The over-all efficiency is the ratio of the kilowatt-hours supplied to the storage battery for a full charge to the kilowatt-hours delivered by the antenna circuit during the complete time of discharge. The energy ratio, rather than the power ratio, is here required, because of the method of storing energy in such batteries. It may be conveniently measured by the ratio of (kilowatt-hours on discharge of the storage battery to kilowatt-hours on charge) multiplied by the ratio of (power delivered in the antenna to power supplied by the storage battery to the radio equipment). This method is closely approximate.

1006. (c) **A land station.** High voltage alternating current (2,200 volts, for example) is supplied to the station from local power mains. This is stepped down to operate a motor generator set which supplies current of the definite type desired for the station. The over-all efficiency is the ratio of the power output of the antenna to the power supplied to the motor generator. If the step-down transformer feeds other electrical machinery or apparatus not a part of the radio equipment (e. g., lamps), the power supplied to such apparatus shall be subtracted from the total power supplied by the step-down transformer when calculating the over-all efficiency. If the motor generator in question is used to charge storage batteries which operate the station, an energy ratio, somewhat as in case (b) above, must be taken instead of the power ratio.

1007. (d) **A land station.** A large steam engine operates directly or indirectly an audio or radio frequency alternator which supplies current to the radio station exclusively. The over-all efficiency is the ratio of the power output in the antenna to the brake kilowatts of the engine driving the alternator.

1008. (e) **A land station.** A steam or gasoline engine drives a high voltage direct current generator which feeds directly or indirectly arcs or special gap dischargers in the station. The ratio of the antenna power to the brake kilowatts of the engine is the over-all efficiency (under similar conditions to those of (c) above).

1009. The **power output** shall be taken as the product of the total effective resistance of the antenna (not including the resistance of inductance coils, series antenna capacity, or switches and other equipment in the antenna), into the square of the current measured at a potential node.

1010. **Standard Antennas.** Two standard antennas are proposed; one for ships carrying sets of 2.5 kilowatts or under, and one for ships carrying sets of 2.5 kilowatts but not greater than 5 kilowatts.

1011. (a) **SMALL ANTENNAS**

Capacity=0.001 microfarad. Inductance=50 microhenrys

Standard Test Wave Length = 600 meters

Test Wave Lengths	**Antenna Resistance**
*300 meters	8 ohms
600 meters	4 ohms
1200 meters	3 ohms
1800 meters	4 ohms

1012. (b) **LARGE ANTENNAS**

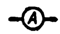
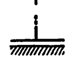
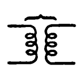
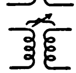
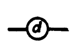
Capacity=0.002 microfarad Inductance=30 microhenrys
Standard Test Wave Length=600 meters

Test Wave Length	Antenna Resistance
†600 meters	4 ohms
1200 meters	3 ohms
1800 meters	3 ohms
2400 meters	4 ohms
3000 meters	5 ohms

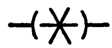
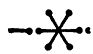
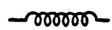
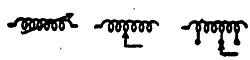
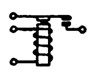
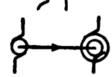
*At 300 meters a suitable series condenser will be inserted in the antenna circuit. The resistance of this condenser will not be included in the antenna resistance, since this condenser should be supplied with, and forms part of, the transmitting set.

†See note referring to 300 meters, above.

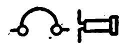
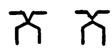
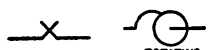
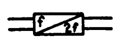
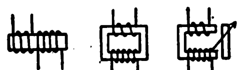
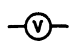
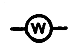
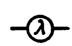
STANDARD GRAPHICAL SYMBOLS

Alternator	
Ammeter	
Antenna	
Arc	
"Audion"	*See Vacuum Tube, Three Electrode.*
Buzzer, Exciting	
Coherer	
Condenser, Audio Frequency	
Condenser, Compressed Gas	
Condenser, Radio Frequency	
Condenser, Variable	
Counterpoise	
Coupler, Inductive	
Coupler, Variable Inductive	
Decremeter	
Detector	

STANDARD GRAPHICAL SYMBOLS
(CONTINUED)

Detector, Magnetic	
Frequency Meter	
Gap, Non Synchronous	
Gap, Quenching	
Gap, Spark	
Gap, Synchronous	
Ground	
Inductance	
Inductance, Iron Core	
Inductance, Variable	
Insulator	
Key	
Key, Relay	
Microphone	
Motor Generator, D.C. to A.C.	
Mover, Prime	

STANDARD GRAPHICAL SYMBOLS
(CONTINUED)

Receivers, Telephone	
Relay	*See Key, Relay*
Resistance, Non-Inductive	
Resistance, Variable	
Telephone	*See Receiver*
Thermo Junction	
Tikker	 ROTATING
(Transformer,) Frequency Changer	
Transformer, Iron Core	 VARIABLE LEAKAGE
Transmitter, Telephone	
Vacuum Tube, Three Electrode "Audion"	
Vacuum Tube, Two Electrode "Valve"	
Voltmeter	
Wattmeter	
Wavemeter	

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