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ELMER E. BUCHER

RY ...

Commercial Engineer, Radio Corporation of America, Instructing Engineer, National Wireless Association Member Institute of Radio Engineers

4th REVISED EDITION
Illustrated

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TABLE OF CONTENTS

Chapter I

Advice for the Amateur

Preliminary Education — Buzzer Practice System—Timely Advice—An Elementary Receiving Set—Receiving Aerials—Receiving Detectors—General Advice Concerning Government Licenses — Requirements for an Operator's License—Where to Take the Examination—Land Station License—A Beginner's Transmitting Set—A Transmitting Set of the More Advanced Type—Further Progress—Books on Wireless for Amateurs....

Chapter II

The Formation of a Radio Club
How to Get Together—Temporary
Organization — The Permanent
Organization—Constitution and
By-Laws for Radio Clubs—
Literature — The Workshop—
Quarters — Antenna — The Club
Drawing Materials—Radio Apparatus—Important Advice..... 16

Chapter III

Instruction in the Telegraphic Codes
Code Practice—How to Make the
Buzzer Squeal—A Small High
Frequency Generator............ 22

Chapter IV

A 200-Meter Amateur Set

General Data-The Transmitting Aerial - Aerial Insulation-The Earth Connection—The Closed Oscillatory or Sparking Circuit —The Condenser—Placing the Foil—The Oscillation former—A Spiral Oscillation Transformer-The Rotary Spark Gap—A Rotary Gap of Simple Construction — Transmitting Keys—Transformers (½ k.w.)— Reactance Regulators—1 Open Core Transformer—Condenser for Spark Coil—A Threeinch Spark Coil—The Lightning
Switch — Protective Devices—
High Frequency Choking Coils—
An Aerial Ammeter—Radiation
Indicator—Aerial Outgoing Insulator — Antenna Insulators—
Safety Gap for High Potential
Transformer — General Precautions—Adjustment of Transmitting Set—Notes on Coupling...

Chapter V

An Amateur's Wave-Meter and Its Uses

A Wave-Meter of Low Range—Determination of the Point of Resonance — The Manipulation of the Wave-Meter—Tuning the Amateur Set—Calibration of a Wave-Meter—A More Accurate Method of Calibration—Measurement of the Inductance and Capacity of an Aerial—Reduction of Wave-Length by a Series Condenser — Increasing the Wave-Length of an Aerial—Measurement of the Inductance of an Aerial—How to Plot a Resonance Curve—Approximate Calculation of the Capacity and Inductance of an Aerial......

Chapter VI

The Measurement of the Logarithmic Decrement

Chapter VII

Examples of 200-Meter Amateur Sets

A I k.w. Transmitter—A High Potential Condenser—The Oscillation Transformer — How to Start the Motor-Transmitting Key—The Earth Connection—A ½ k.w. Transmitter—A Simple Amateur Receiving Set......

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4

TABLE OF CONTENTS (Continued)

Chapter VIII

Chapter IX

The Receiving Tuner

Function of the Detector—Practical Adjustment of the Receiving Tuner—Receiving Tuners for Definite Range of Wave-Length—Duplex Switch for the Primary Winding—A Receiving Tuner for Arlington Time Signals—Determining the Wave-Length of the Receiving Apparatus—Tuned Buzzer Tester—Test Buzzers—Simple Calculation of Inductance—How to Design a Receiving Tuner.....

Chapter X

Receiving Detectors for Wireless Telegraphy

The Electrolytic Detector—Circuit for Electrolytic — Operation — Primary Cell Detector—Circuit for the Primary Cell—Mineral or Crystal Detectors—The Carborundum Detector—Circuit for the Carborundum Detector—Circuit for Operation—The Zincite Bornite Detector—Silicon Detector—Special Holder for Carborundum Crystals—The Filing Detector—The Marcon Magnetic

Detector — Operation — Adjustment—The Tikker Detector—
Adjustment—Circuit for Operation—The Goldschmitt Tone
Wheel—The Oscillation Valve—
Another Circuit for the Fleming
Valve — The Three Element
Valve—Circuit for Operation—
Action of Valve—Magnetic Field
About the Valve—The Use of
the Permanent Magnet.......100

Chapter XI

The Vacuum Valve Amplifier and Beat Receiver

The Single Step Amplifier—Double Step Amplifier—Regenerative Receivers—Beat Receivers—Vacuum Valve Generator—Regenerative Beat Receiver for Damped and Undamped Oscillations—The Special Regenerative Beat Receiver—A Unique Method for Detecting Undamped Oscillations—Measurement for the Dead Ends of a Receiving Tuner—Balancing Out Aerials.. 115

Chapter XII The Radio-Varlometer

The Actions Explained—General Design—Uses of the Variometer—The Variometer as an Element of a Wave-Meter—A Variometer of Increased Range—A Variometer of Simple Construction.. 138

Chapter XIII

An Experimental Wireless Telephone Dimensions—Adjustment 146

-Chapter I

Advice For the Amateur

It is generally conceded that amateur wireless telegraphy had its beginning in the United States. In fact the pursuit of the hobby has become so widespread that there is hardly a village or hamlet in which there are not one or more trailing aerial wires to show the popularity of the art. In all places where amateur wireless telegraphy has made a niche for itself the advantages of forming a radio club are sooner or later recognized and then arises the question, "How shall we go about it?"

A radio club should be educational, instructive and productive of advancement in wireless, for it is quite possible that some of its members will in time develop into radio engineers or become connected with allied branches of the art. In any event, the members of radio clubs will never regret the training they will receive by joining wireless organizations.

It was not found feasible in preparing this book to treat separately the requirements of the organization and individual members, and consequently the following pages will be devoted largely to instructions governing the amateur at his station at home as well at the club. The formation of a radio club generally follows the rise and stimulation of individual interest. Moreover, the knowledge gained at home is bound to benefit the members of the club organization as a whole.

It will first be in order then to offer advice to the prospective wireless club members. This will be followed by the procedure for the formation of an organization, after which a series of instructive experiments in radio telegraphy will be described in detail.

Preliminary Education.—It should be kept in mind that an interchange of signals between two amateur stations will not be allowed unless the owners possess operators United States license certificates as well as station license certificates. It is obvious that the prospective amateur is not yet qualified to enter into negotiations with the United States Government authorities; in fact he first must take a number of preliminary steps, particularly from a technical and operating standpoint.

The apparatus of the amateur who cannot interpret the signals of the international continental telegraph code becomes to its owner a useless toy and attempts at communication with his friends—even if allowed—will result in hopeless bungling. It is in order, therefore, for him to begin immediately the practice of the telegraph code. This he cannot do alone. He requires assistance from an amateur friend who has already passed this stage of development and will send to him from an artificial buzzer system for

hours at a time.

As far as sending is concerned, to learn the formation of the characters of the telegraphic code is not a difficult task and can be accomplished single handed in a very short time, but to recognize the characters of the code as sent by another is somewhat more difficult and requires considerable practice. While it is necessary that the beginner should attain a certain degree

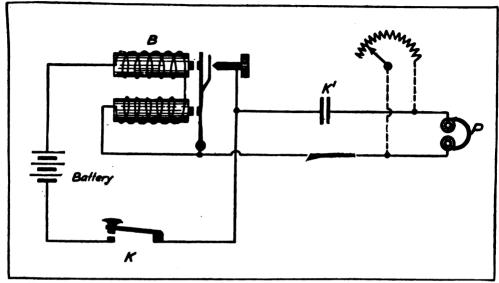


Fig. 1-Buxzer Key and Head Telephone Connected for making "Artificial" Radio Signals.

of proficiency in this respect, it is not essential for him to wait until he becomes a high speed telegrapher to enter the amateurs' ranks. In fact when he attains a speed of ten words a minute he is quite eligible to become a wireless amateur.

The Buzzer Practice System.—A simple buzzer system which can be used to advantage in practice of the telegraph code will now be described. In Fig. 1 a simple bell buzzer, B, is energized by a four-volt dry cell battery in series with which is connected the signalling key, K. Across the contacts of the vibrator is shunted the head telephone, P. (of seventy-five ohms resistance) in series with the condenser, K. The condenser, K, may be of almost any capacity desired but preferably is not less than of microfarad capacity. In order that the sound from the buzzer may not be of unbearable intensity, it may be necessary to shunt the head telephones with a variable resistance, as shown in the drawing. The foregoing connections having been made, the receivers, P, are donned by the learner, the sender transmitting on the key, K. If the buzzer is properly adjusted it will give a perfect reproduction of wireless telegraph signals.

Timely Advice.—The beginner should not attempt the more elaborate fields of experiment until he has become skilled in the simple methods. Having become proficient in the code, he should purchase or construct a receiving equipment of elementary design and simplicity. A license is not required for receiving purposes, and accordingly the receiving aerial may be within reasonable limit of any dimensions desired. Here again the experimenter must be guided by a sense of the fitness of things. He therefore requires an elementary knowledge of the fundamentals of wireless telegraphy, which he can obtain from books and periodicals on the subject.

It is also essential that the beginner should acquire an understanding of the elements of electricity and magnetism if he wishes to operate his instruments to good effect. Some naturally possess this knowledge, while to others it is a matter of attainment. However, by slight application such knowledge can be brought within the reach of all. The market is well supplied with books on elementary electricity and magnetism.

In studying the elements of electricity the author recommends that the beginner immediately learn the difference between alternating current and direct current. He should familiarize himself with the general conditions under which such currents are handled, getting such knowledge particularly as will enable him to know when a circuit is overloaded and also the size of fuses to be installed to carry a given amount of current. The prospective amateur should also learn the current-carrying capacity of various sizes of wire, thereby making sure that the power circuits at his station will not become overheated.

He should then make a thorough study of the underwriters' rules concerning the installation of power circuits, paying particular attention to the rules which relate to the erection of wireless telegraph apparatus. The underwriters' rules vary in different cities, but a copy of them can easily be obtained for reference.

Summing up the foregoing, it will be seen that the experimenter has prepared himself for amateur wireless work in two respects:

I He is able to telegraph at a fair speed and is therefore qualified to interpret wireless signals.

2 He understands the elementary princples of electricity and also the fundamentals of radio telegraphy

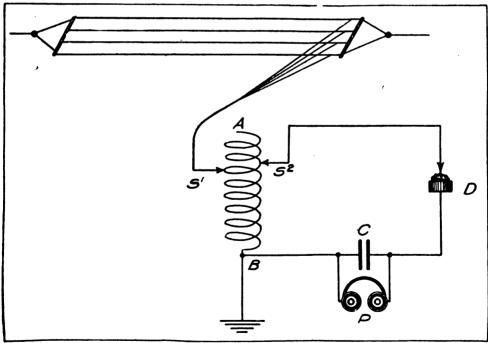


Fig. 2—Fundamental Diagram of Beginner's Receiving Set Including a Two Slide Tuning Coil, Detector, Fixed Condenser and Head Telephones.

He is now fully qualified to embark on his initial experiments and should begin with a simple receiving equipment. For this work the author recommends the simple two-slide tuner, connected up as shown in Fig. 2.

An Elementary Receiving Set.—A receiving set of elementary design comprises a single two-wire aerial, a two-slide tuning coil, A, B, having the

sliders, S-1 and S-2, a silicon detector, D, a small fixed condenser, C, and a high resistance telephone, P. The writer does not recommend receivers of less than 1,000 ohms resistance, because telephones of lower resistance are generally found unsatisfactory for use with a crystalline detector. If the experimenter desires to construct this tuning coil, the coil should be 8 inches in length by 3 inches in diameter, wound closely with a single layer of No. 28 S. S. C. wire. The slider, S-1, enables the wave-length of the antenna circuit to be altered while corresponding adjustments in the detector circuit are obtained at S-2.

With a receiving set of this type the learner has an opportunity to become a keen observer of the manner in which commercial and amateur wireless telegraph traffic is handled, thus obtaining an excellent preliminary education. Furthermore, a simple receiving set, as shown in Fig. 2, will give a very satisfactory degree of efficiency.



Fig. 2a-Station "2G.T." Which Has Made Notable Long Distance Records.

Receiving Aerials.—Returning to the subject of receiving aerials, the question is invariably asked: "How long should it be and what is its receiving range?" The actual length of a receiving aerial is probably gauged first by the space available, and second by the wave-length and power of the station from which it is desired to receive. It is best to begin experiments with a receiving aerial suited strictly to the reception of signals from amateur stations at a wave-length of 200 meters. Later, as the learner's knowledge of the subject increases, a more elaborate equipment and apparatus may be installed.

It is difficult to conjecture the receiving range of a station unless one is fully familiar with the local conditions surrounding the station. There are limitations to the length of an antenna for a given range of wave-lengths, and therefore it is preferable in all cases that the receiving aerial shall have smaller dimensions than the transmitting aerial of the distant station. The

necessity for this precaution will become apparent later on. The actual distance that can be received from at a given receiving station depends upon the general conditions at the transmitting station, such as the current flowing in the antenna, the decrement of damping, the local conditions surrounding the transmitting station and the type of apparatus employed for detec-

tion purposes at the receiving station.

The question as to the number of wires to be included in the aerial has been much discussed, but as it is understood today there seems to be little advantage in erecting a receiving aerial having more than two wires. An aerial comprising from two to four wires, 50 feet in height by 40 feet in length, with the wires spaced 2 feet apart, will have a natural wave-length of about 160 meters, which is of the correct dimensions to be loaded by the insertion of the auto-transformer (shown in Fig. 2) to a wave-length of 200 meters. Of course, this aerial can be employed for the reception of longer wave-lengths, say, up to 3,000 meters, but it will give better results from stations having wave-lengths between 200 and 700 meters.

It should be borne in mind that an aerial having a natural wave-length of 600 meters, however, is altogether too long for the reception of signals from amateur stations working on a wave-length of 200 meters. While the wave-length of such an aerial system can be reduced by a series condenser, it

never can be reduced in this manner to a period of 200 meters.

Having progressed so far in his wireless education, the student should devote himself diligently to the use of the receiving apparatus, familiarizing himself with the methods of communication employed by amateurs. He will find that many amateurs are accustomed to make use of the Phillips telegraph code and the beginner should learn some of these abbreviations commonly brought into practice.

Receiving Detectors.—Experimenters frequently ask which of the crystalline detectors are the most suitable for the beginner. For the person who is absolutely uninformed on the adjustment of receiving detectors, the cerusite or the "Perikon" detectors are recommended. Cerusite possesses a peculiar property—practically the entire surface of the crystal is of equal sensibility. The Perikon detector possesses somewhat similar characteristics but not to the same degree.

Galena and silicon crystals are difficult to adjust and to maintain in a sensitive condition. Carborundum crystals are nearly as sensitive as cerusite crystals and will hold their adjustments indefinitely. In fact such crystals are extremely rugged and highly desirable where considerable transmitting is done. The vacuum valve detectors are also very sensitive and stable in action, but require a little more skill than the detectors of the crystalline type.

There is no reason for the beginner who has only been able to cover from fifteen to forty miles with his receiving apparatus to feel discouraged when he hears other amateurs declare that they have received signals at a distance of 2,000 miles. He should keep in mind that the latter results are obtainable only at nighttime, during the more favorable months of the year. In the northern part of the United States the time favorable for long distance working seems to be from about September 25th to April 15th of the following year. The question as to what results can be obtained from the middle of April to the latter part of September is problematical.

When the amateur living in Minnesota informs us that he has heard signals from the Key West, Fla., naval station and commercial stations on the Atlantic coast he is undoubtedly voicing the truth; such accomplishments are possible, but only during the time previously mentioned And upon investigation invariably it will be found that a sensitive receiving set, thor-

oughly understood by the owner of the station, did the work.

In attempts at long distance receiving many amateurs do not take into account the effects of local conditions. For example: If the receiving aerial is located behind a steel building, in the tree tops, behind other structural steel work, or in valleys, signals from distant stations are not received as well as upon aerials which are in the open country, free from obstructions.

Government Licenses.—It is assumed that during these early experiments in receiving the beginner has practiced transmitting regularly on the buzzer set. When he is confident that he is capable of sending and receiving without causing undue interference, he should purchase a simple transmitting outfit. If his station is located so that the signals will carry beyond the borders of the state in which he resides, a license must be secured. If it is definitely known that the signals will not carry this distance a station license is not required. The experimenter should satisfy himself fully regarding this matter by communicating with the radio inspector in his district, giving a complete description of his station and requesting advice as to its probable wave-length and carrying range.

It is somewhat difficult to estimate the range of a transmitting set on account of the variable factors entering into the case. The range is dependent upon:

I. The height and dimensions of the transmitting aerial.

2. The nature of the earth connection.

3. The closeness of energy absorbing conductors, such as trees, smoke stacks, steel buildings, bridges, etc.

4. The character, efficiency and power of the transmitting apparatus.

5. The type of receiving apparatus employed at the receiving station and the skill with which it is handled.

With the average transmitting aerial, taking into account the receiving apparatus generally employed, a one-inch spark coil as a transmitting apparatus will give a range of not more than five or six miles. A two-inch spark coil will cover about ten miles, while a three-inch spark coil can be relied upon for fair communication at a distance of from fourteen to twenty miles. Stations fitted with a ½k.w. alternating current transformer can be expected to have a range of about twenty-five miles, while those with a 1 k.w. transformer should cover from forty to fifty miles under favorable conditions."* In some cases greater distances have been covered by amateurs, but these were accomplished under extremely favorable conditions (in a clear open country), with a receiving apparatus of the super-sensitive type.

The beginner should familiarize himself with the general restrictions imposed by United States legislation by studying a booklet entitled "Radio Communication Laws of the United States and the International Radio Telegraphic Convention," which can be purchased from the Government Printing Office, Washington, D. C. This booklet gives full information concerning the regulations governing wireless operators and the use of radio

telegraph apparatus at sea and ashore.

The experimenter first should refer to the pages which contain information regarding amateur station licenses, etc. From these he learns that when specially qualified and having had at least two years of experience the amateur can, in certain districts, secure a special license for an exceptional station. Such experimenters, of course, belong to the class of amateurs considerably advanced in the art. In paragraph 65 he finds that general amateur stations are restricted in transmission to a wave-length of 200 meters. In the same paragraph it also is stated that if a station is located within five miles of a naval station, the wave-length for transmitting purposes is limited

^{*}This statement requires some qualification because, during the night hours, many amateur stations in the United States communicate over distances of 1000 miles with ½ K. W. senders operated at the wave length of 200 meters.



to 200 meters and the consumption of the power transformer to 1/2 k.w. This station is said to be in the restricted class. A general or restricted amateur station must be in charge of an operator having an amateur's first grade or amateur's second grade operator's certificate, who shall be responsible for its operation in accordance with the United States regulations. In fact this station must always be under the supervision of a licensed man. For a receiving station, however, no license whatsoever is required.

Provisional licenses are issued to amateurs far remote from radio inspectors. If, after actual inspection, such stations are found to comply with the law fully, the term "provisional" is struck out and the station is indicated as having been inspected. Amateur station licenses and amateur operators' licenses hold good for a period of two years, when they can be renewed. No fees are required for either license.



Fig. 2b-A Typical United States Amateur Wireless Station.

Requirements for an Amateurs Operating License.—In order to secure an amateur's first grade license certificate, the applicant must be familiar with the adjustment and operation of wireless telegraph apparatus. He must be familiar with the rules of the International Radio Telegraphic Convention, particularly the regulations concerning the requirements in regard to interference. He must be able to transmit and receive at a speed sufficient to recognize distress or "keep out" signals. While a speed of five words a minute is generally considered sufficient for the requirements, the writer recommends that the amateur wait until he has attained a speed in transmission and reception of ten words a minute before taking the examination.

For an amateur second grade certificate, the requirements are similar to those for a first grade certificate, except that the former licenses are issued to an applicant who cannot be examined. If amateurs, for valid reasons, cannot appear in person and are able to convince and satisfy the government authorities as to their knowledge on the subject, a license of this kind may be issued. An appointment having been made with the officers at one of the United States Navy Yards or at other government examining posts, the examination is taken and, if a license is secured, the beginner should purchase or construct a simple transmitting apparatus.

Where to Take the Examinations.—Operators' examinations may be taken at the following United States Navy Yards: Boston, Mass.; New York, N. Y; Philadelphia, Pa.; Norfolk, Va.: Charleston, S C.; New Orleans, La.; Mare Island, Cal., and Puget Sound, Wash

Also at the following Naval radio stations: San Juan, Porto Rico; Colon, Panama; Honolulu, Hawaiian Islands, and Key West, Fla.

The following United States Army stations also hold examinations: Fort Offnaha, Neb.; Fort Wood, N. Y. Fortress Monroe, Va.; Fort St. Michael, Alaska, and Fort Valdez, Alaska

Amateurs residing in Washington and vicinity can take examinations at the Bureau of Navigation, Department of Commerce, Washington, D. C. Examinations

are also held at the radio inspectors' offices or elsewhere by special arrangement.

Applicants should write to the examining officer nearest to their station and secure a copy form 756, the application blank for an operator's license, and to the radio inspector for form 757 which is an application for a license for a land station. Amateurs at points remote from examining officers and radio inspectors can obtain second grade amateur licenses without personal examination. Examinations for first grade licenses will be conducted by the radio inspector when he is in the visinity of their stations, but special trips cannot be made for this purpose. Persons holding amateur second grade operating licenses should make every effort to take the examinations for an amateur first grade license or higher.

Land Station Licenses—To secure a land station license the applicant fills out a blank form on which he states the nature, type and character of his apparatus. The authorities use this information in making calculations and ascertaining the probable wave-length and range of the set. In their final decisions they are not guided wholly by the type of the set alone, but by the local conditions surrounding the station and the probable interference that it will set up. The license having been granted, the beginner may now communicate with other amateurs, happy in the feeling that he has moved up a round on the wireless ladder.

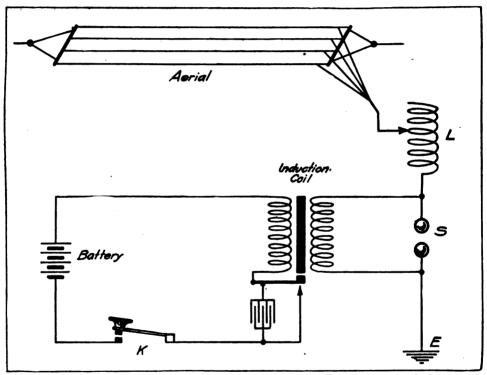


Fig. 3.—Beginner's Transmitting Set Consisting of Induction Coil, Key, Battery, Spark Gap, Aerial Tuning Coil and Aerial or Antenna.

A Beginner's Transmitting Set.—A transmitting equipment modeled after the fundamental diagram shown in Fig. 3 is well suited for the use of the beginner. The aerial, A B, having a natural wave-length of about 160 meters, has connected in series with it the tuning coil, L, and the spark gap, S. The spark gap, S, is connected to the secondary terminals of an induction coil having a normal spark discharge of from 1 inch to 3 inches. The primary winding of the coil is energized by from six to ten volts of storage battery, the cell preferably having a capacity of sixty ampere hours, although one of forty ampere hours will serve the purpose.

The spark discharge points at S should not be more than 3/16 of an inch in diameter and may be of zinc or brass. They should be carefully regulated

during the operation until the discharge is free and clear from flame. As turns of wire are added or subtracted at the coil, L, the wave-length of the aerial system is increased or decreased. Thus, if interference is experienced on one wave-length, another number of turns can be selected, giving a different wave-length. It shoul be understood that the United States authorities will not permit a transmitting set of this type to be operated within the zone of interference, because of the fact that the radiated wave is apt to be very "broad" (high decrement). This statement, however, only applies when the antenna circuit includes no localized inductance such as at the coil, L. The effect of this coil is to sharpen the radiated wave, thereby causing less interference. An amateur wireless telegraph station is considered within the zone of interference when it is located so closely to a commercial or naval station that the operation of these stations is apt to be interfered with.

In order that the transmitting set may emit a wave of greater purity, an oscillation transformer must be used and connected, as shown in Fig. 4.

A Transmitting Set of the More Advanced Type.—The progressive student soon passes the spark coil stage of development and becomes ambitious to acquire a more elaborate and effective equipment in order to place himself on a par with the more experienced amateurs in his vicinity. He therefore purchases a high potential transformer, a large high potential oil condenser, an oscillation transformer and a rotary spark gap. The author suggests in the case of the plain spark gap discharger, if the set is to be operated on sixty cycle current, that the capacity of the transformer be limited to ½ k.w.; with the rotary gap it may be of the ½ k.w. size. The secondary voltages of these transformers preferably are not less than 15,000 volts.

Returning to the matter of the oscillation transformer, in Fig. 4 the coil, L, is arranged so that it can be placed inside of L¹ or drawn away from it to any distance desired. L and L¹ are high potential coils consisting of a very few turns of heavy copper tubing or stranded insulated wire, the turns being well insulated from each other and of suitable current-carrying capacity.

When the coil, L, is drawn at a suitable distance from L¹ a pure wave will be radiated by the antenna, which will tune "sharp" at the distant receiving station. When the coil, L, is directly inside of L¹ a complex wave is radiated which tunes "broadly," causing considerable interference. The actual position of the two coils for a non-interfering wave is determined by means of a wave-meter and will be discussed later. It is plain that the oscillation transformer allows the character of the radiated wave to be definitely controlled in compliance with the restriction. The high potential condenser of the set shown in Fig. 4 preferably is excited by an alternating current transformer rather than a spark coil, although spark coils of the larger types can be employed.

The amateur now decides to inform himself on wireless telegraph matters more fully. He studies the intricacies of more complicated equipments; he attends lectures on the subject, becomes a member of a radio club and incidentally lends a helping hand to the beginner at the bottom of the ladder where he himself once started. He becomes interested in the general progress of wireless telegraphy and purchases important works on the subject.

Books on Wireless for Amateurs.—While there are a number of books published on wireless telegraphy, it is found that each publication is generally devoted to some particular phase of the subject. For general all around information the author recommends the "Year Book of Wireless Telegraphy," issued by the Wireless Press, Inc. Containing a wealth of data on the entire wireless situation, the information given in this book is indispensable to the amateur as a work of reference.

For a modern text book covering the elements of electricity and magnetism as well as the more up to date equipment employed in radio telegraph work the "Text. Book on Wireless Telegraphy," by Rupert Stanley is recommended. While the descriptions of some of the modern types of transmitting and receiving equipments are

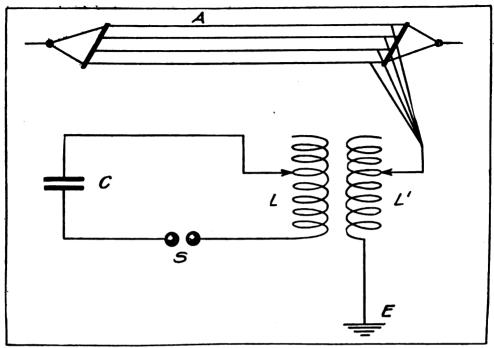


Fig. 4—Fundamental Diagram of the Inductively-Coupled Transmitting Set Showing What Are Termed the "Circuits of Radio Frequency."

somewhat brief, the explanations given are sufficient to afford the learner an insight into the general construction and operation of the apparatus.

If the student desires to study wireless telegraphy from the standpoint of the United States naval practice and incidentally desires a publication on the fundamentals of electricity, the "Naval Manual of Wireless Telegraphy for 1916," by Commander Robinson, is of incalculable value. However, should he desire a complete account of early experiments in wireless telegraphy, particularly those of Marconi, the "Elementary Manual of Radio Telegraphy and Radio Telephony," by J. A. Fleming, is most comprehensive.

For general knowledge of the fundamentals of wireless telegraphy, and particularly for the results of research work on receiving apparatus, the "Principles of Wireless Telegraphy," by George W. Pierce, is indispensable.

"Wireless Telegraphy and Telephony," by A. Kenelly, is recommended to the experimenters who require a simple explanation of the propagation of electro magnetic waves through ether. As the student progresses in his work he becomes desirous of owning a wave-meter but wishes a detailed treatise on its operation and general use. For him we recommend the "Wavemeters In Wireless Telegraphy," by Lieutenant Mauborgne.

When amateurs in a given locality have followed the rules laid down in this chapter and reached the stage of development indicated, the time is ripe for the formation of a local radio organization. We shall endeavor in the following chapter to give specific instructions for the formation of such an organization. If the general outline given is adhered to the ultimate success of a radio club is assured.

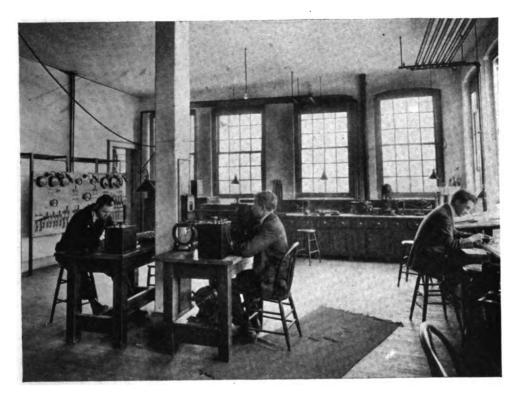


Fig. 4a—Research Unboratory of the Marconi Wireless Telegraph Co. at Aldene, New Jersey, Under the Guidance of the Company's Research Engineer, Where the Original Investigations are Made and New Wireless Apparatus Evolved.



Fig. 4b-Scudents at Marconi School Measuring Wave Length With Fleming's Cymometer.

Chapter II

The Formation of a Radio Club

I T is not difficult for amateurs to get in touch with one another, as a rule, for as soon as a new station has been erected and the owner begins to operate his set other wireless enthusiasts communicate with him. Names and addresses, which are among the chief requisites in the preliminary plans for the organization of a radio club, can be obtained easily.

How to Get Together.—In a community which is without a wireless organization the amateurs should meet and compose a letter inviting those in their neighborhood interested in the art who wish to join a radio club to correspond regarding the subject. This letter should be sent to the National Amateur Wireless Association, 42 Broad Street, New York City, with a request for its publication in THE WIRELESS AGE. After it has been published a letter should be sent to prospective members of the organization, giving the name of the place where the first meeting of the club will be held and the date.

It is the purpose of the National Amateur Wireless Association to create radio clubs in communities which lack them. Officers of the organizations will be admitted to the council of the National Amateur Wireless Association and arrangements will be made for the clubs to affiliate with military companies as accredited members and officers of signal corps which plan to hold summer military encampments.

The following brief outline of the parliamentary procedure in general practice will serve as a guide to amateurs. The outline for the constitution for a radio club has been made as brief as possible, but nothing essential has been omitted. No reference has been made to by-laws. In reality they are amendments to the constitution and may be adopted from time to time at the business meetings. Amendments generally refer to the duties of committees, enlarging or diminishing their powers.

Temporary Organization.—At the first meeting a temporary organization—a preliminary step to a permanent organization—should be formed. One of the amateurs present should rise and suggest that a chairman of the meeting be named. It is generally the custom to take a quick vote, and if the majority agree on some one individual he immediately may be considered elected and should take the presiding officer's chair immediately. This appointment should be given preferably to one of those who aided in composing the letters to prospective members.

The chairman should be supported by a recording officer, whom he may appoint directly. The recording officer, who is known as the secretary for the temporary organization, should make a complete record of the proceedings. of the meeting.

The chairman should then call the meeting to order. He should deliver a brief address, stating the object of the meeting and inviting discussion of

An amateur should rise, addressing the chairman (if he is not known he should give his name) and be permitted to have full opportunity to state his views—the possibilities and impossibilities of the enterprise under consideration and the advantage of taking active steps towards forming a club. All of those at the meeting may voice their opinion regarding the subject in this manner.

If the consensus of opinion shows that an organization is desired, it is in order for one person present to present a resolution which, for example, may be introduced

Amateur addresses the Chair "Mr. Chairman."

The Chairman acknowledges his right to the floor by calling his name: "Mr. Smith."

Mr. Smith, to the Chair: "It seems to be the general wish of those present to-night that a radio club be formed. I therefore propose that active steps be taken at once for the formation of such a club among the amateurs of this city.

The Chairman repeats the motion to the audience, and says: "The motion is

now open for discussion.

If no discussion takes place and no objection is offered, the Chairman says:

(1) "All those in favor of the resolution respond by saying aye."
(2) "All those of a contrary mind say nay."

If the ayes and nays seem about equal a vote by count should be taken.

Several committees may now be appointed. It is often customary to appoint a Resolutions Committee first. The members of this committee may be appointed directly by the Chairman or, if those present so desire, by a general vote.

It is the duty of the Resolutions Committee to draw up a definite statement, placing in the form of a series of resolutions the general desires of the founders of the organization. The committee may withdraw from the meeting in order to decide upon the form in which the resolutions are to be put to the chair and then ask'that they be acted upon by those present in the regular manner.

A second committee, to be known as the Nominations Committee, may be formed. The members of this committee may be appointed by the chair if those present at the meeting so desire. It is the duty of the members of the Nominations Committee to suggest or to place before the meeting, for nominations, the names of amateurs for election as officers of the permanent organization.

A third committee, to be known as the Rules and Regulations Committee, should be appointed. The duties of the members of this committee include drafting a constitution and by-laws for the permanent organization.

Before the permanent organization is founded, a fourth committee should be formed to determine the eligibility for membership of those at the temporary meeting. This committee may have full power to investigate and determine in whatever way it sees fit whether or not those who wish to join are eligible.

It is understood, of course, that the committee will carry out the ideas of the members of the club. It is suggested that no one should be allowed to join the club as a full member who has not been actively connected with amateur radio-telegraphy for at least one year. It should be further stipulated that in order to be eligible for membership the applicant must be thoroughly familiar with the United States laws pertaining to amateur radiotelegraphy. (Copies of these rules and regulations can be secured from the Department of Commerce, Washington, D. C., or the district radio inspectors. Send 15c for "Radio Communication Laws of the U. S.")

All committee reports must be presented to the chair for reading by the recording officer. It is then in order for some one at the meeting to present a motion for adoption or acceptance of the report of the committee. When a motion is offered it must be seconded by another person. After it has been seconded a vote should be taken to determine the general sentiment of those present.

As a rule, it is advisable that the meeting of the temporary organization be held first and the appointment of committees made as suggested.

The Permanent Organization.—The affairs of the permanent organization can be handled at a second meeting. This will give the various committees sufficient time to carry on their deliberations properly. It is, however, possible to effect the entire organization at one meeting, although better results will be obtained if the founding of the permanent organization is postponed to a later date.

When the permanent organization is to be effected, the various committees previously mentioned should report to the chairman. Usually the chairman of each committee reads his report before the entire assembly and the chairman of the temporary organization requests that action be taken.

The Membership Committee should offer its report first. It should name those eligible to membership in the club, and a general vote of all present should be taken. If there are any present who are not eligible to membership they should leave before further business is taken up.

The Rules and Regulations Committee should report next, stating clearly the constitution for the club. An outline of a constitution suited to general

needs follows:

Article I.—Sec. (1). The name of this association shall be The Radio Club of New York City, or The Cleveland Wireless Club, or The Allied Amateur Radio Clubs

(Sec. (2). The object of this club shall be the bringing together of the amateurs of this city who are interested in the advancement of radio-telegraphy and desire to become more familiar with the radio art. Progressiveness shall be the keynote of this organization, and a general diffusion of knowledge pertaining to radio telegraphy its endeavor.

Article II.—Sec. (1). The membership of this club shall be divided into two

classes-full members and students.

Sec. (2). Full members shall be those who have been actively connected with amateur radio-telegraphy for at least one year and are able to receive messages in the

Continental telegraph code at a speed of at least five words per minute.

Sec. (3). Students are those who have had no previous connection with amateur radio-telegraphy, but are interested in the art and who, in order to familiarize themselves more fully with radio apparatus, desire to join a radio club.

Sec. (4). A full member shall not be less than sixteen years of age, and a student not. less than twelve years of age.

Article III.—Sec. (1). The entrance fee (payable upon admission to the club) shall be \$1 for full members and fifty cents for students.

Sec. (2). The annual dues for full members shall be \$2, and for students \$1.

Article IV.—Sec. (1). The officers of the club shall be a President, Vice-Presi-

dent and Secretary-Treasurer. The latter office shall be filled by one member.

Sec. (2). The President and Secretary-Treasurer shall be elected for six months and the Vice-President for one year. The President and Secretary-Treasurer shall

not be eligible for immediate re-election to the same office.

Sec. (3). The terms of the officers elected at any annual meeting shall begin on

the second meeting of the club following the election.

Article V, Election of Officers.—(Sec. (1). Election of officers shall take place once every six months.

Article VI, Management of Radio Club.—Sec. (1). The management of the radio club shall be in the hands of the President, Vice-President and Secretary-Treasurer, who, in addition to their regular duties, shall be known as the Board of Directors.

Sec. (2). The Board of Directors shall direct the care and expenditure of the funds of the club, shall receive and pass on all bills before they are paid by the Secretary-Treasurer, and shall decide upon the expenditure of all moneys in various ways.

Sec. (3). The Board of Directors shall from time to time adopt a series of by-

laws which will govern the procedure of the various committees which are later to be

formed

The President shall have general supervision of the affairs of the club Sec. (4). under the direction of the Board of Directors. The President shall preside at the meetings

of the club and also at the meetings of the Board of Directors.

Sec. (5). The Secretary-Treasurer shall be the executive officer of the radio club, under the direction of the President and Board of Directors. The Secretary-Treasurer must attend all meetings of the radio club and of the Board of Directors, and record the proceedings thereof. He shall collect all membership fees due to the club, and shall give receipts for them. He shall have charge of the books and accounts of the club. He shall present, every three months, to the Board of Directors, a balance sheet showing the financial condition and affairs of the club.

Sec. (6). Three committees shall be formed:

(1). A Library Committee.

(2). A Meetings and Papers Committee.

(3). An Electrical Committee.

It shall be the duty of the Library Committee to keep the members of the club familiar with the latest articles pertaining to wireless telegraphy appearing in various publications with the latest articles pertaining to wireless telegraphy appearing in various publications. lications, and to see that the literature and books of the club are properly kept on file.

The Meetings and Papers Committee holds the most important position of all. shall be the duty of the members of this committee to make the meetings of the club of interest to all, particularly as regards intellectual development. It shall also be their duty to make the meetings of scientific and electrical interest to the members of the club, and they shall do all in their means to enhance the knowledge of the members of the club in matters pertaining to radio-telegraphy; they shall also see that once each month a paper is read by an amateur member, chronicling interesting experiments which he has performed or suggestions he has to make.

The Electrical Committee shall have direct charge of all the experimental apparatus in use by the club. The members of the committee shall see that the apparatus loaned by various members of the club is well taken care of. The Electrical Committee shall conduct

all experiments and shall see that these are performed in a scientific manner.

Article VII.—Sec. (1). The semi-annual business meeting of this radio club shall be held on the first Tuesday in November and on the first Tuesday in April of each year. At this meeting a report of the transactions of all meetings of the previous year shall be read and the semi-annual election of officers shall take place.

Article VIII.—Sec. (1). The regular meetings of this club shall be held on Tuesday night every week throughout the year. Every fourth meeting shall be devoted to

the reading of a paper on radio-telegraphy by one of the members present.

After the constitution and by-laws have been agreed upon and accepted by the members present, it will be in order for the Nominations Committee to present to the chairman a report on the nominees for the various offices to be filled. If the nominees are accepted, a general election by ballot shall take place. These officers should be elected in accordance with the constitution and by-laws adopted.

The Home of the Club.—A radio club should, if possible, maintain quarters of its own. It is possible in the majority of cities to secure a room at a low price in one of the less prominent buildings upon which may be erected an antenna of fair dimensions. If the finances of the organization will not permit this, it is best that the meetings be held at the station of the member having the best facilities for the accommodation of the members and an antenna well suited for their experiments.

The Antennae.—It is particularly important that the club room be located where it will be possible to erect a first-class antenna. There should be two separate and distinct antennae, one of the inverted L, flat-top type, having dimensions of about 50 feet in length by 40 feet in height. This will permit radiation at a wave-length of 200 meters to comply with the government law. The second antenna may be swung parallel to it and may be of any length up to 500 feet. The longer antenna should be used for the purpose of receiving the longer waves of the various high power stations located in the United States and abroad. The shorter antenna should be used only for the purpose of sending to and receiving from amateur stations.

Inside the Club Room.—In the club room there always should be on hand a file containing copies of THE WIRELESS AGE. The apparatus room should contain a black board to be used in the drawing of circuit

diagrams and explain the apparatus.

The members of the club should raise a fund to be devoted to the purchase of books dealing with the technical side of wireless telegraphy. These should be added to from time to time until the library is quite complete. The following books, which can be purchased from the Wireless Press, Inc., 42 Broad Street, New York City, will

serve to start the club library:

"The Year Book of Wireless Telegraphy and Telephony."

"Principles of Wireless Telegraphy," by George Pierce.

"Wireless Telegraphy and Telephony," by A. E. Kenelly.

"Practical Uses of the Wavemeter in Wireless Telegraphy," by Lieutenant J. O. Mauborgne.

"Text Book on Wireless Telegraphy," by Rupert Stanley.

"How to Pass the U. S. Government Wireless License Examination," by E. E.

Bucher.
"Handbook of Technical Instruction for Wireless Telegraphists," by J. S.

Hawkhead.

"Wireless Telegraph Construction for Amateurs," by A. P. Morgan.

"List of Radio Stations of the World," by S. A. Hart and H. M. Short.

"Lessons in Practical Electricity," by C. Walton Swoope.

A series of maps showing the location of wireless telegraph stations of the world can be purchased from the United States Department of Commerce. It is suggested, too, that one of the members of the club who has some skill as a draughtsman draw a map of the section in which the organization is located. The station of the various members and the distance from the quarters of the club to each station should be indicated on the map.

The Workshop.—The workshop of the club should adjoin a radio station. The tools and materials for the latter can be contributed by the members of the club or purchased by a fund collected specifically for this purpose. No apparatus should be constructed in the wireless station proper. All work of this nature should be done in the workshop and after the experiments have been completed the apparatus should be taken to the radio room to be tested. This room should contain a full set of electrician's tools, including an electric soldering iron and a first class work bench. Additional material necessary will suggest itself from time to time, and it may be supplied individually or purchased by a fund collected for the purpose.

The radio club, of course, should have a substantial drawing table with a full set of instruments necessary for the drawing of circuit diagrams, the plotting of resonance curves and the laying out of plans for the construction

of apparatus.

A Complete Equipment Desirable.—Interest at the club headquarters will be maintained if the radio station is fitted with a fairly complete equipment. It is somewhat difficult to give advice applicable to each organization as to how much apparatus to install. The question undoubtedly will be governed largely by the amount of funds available. However, every radio club should, if possible, possess the following:

An efficient 200-meter amateur transmitting set.

A transmitting aerial of the proper dimensions for the radiation of energy at this wave-length.

A 200-meter receiving set for communication with local enthusiasts.

An accurate wave-meter having a range of from 200 to 3,000 meters. If possible a second wave-meter having a range of from 3,000 to 10,000 meters should be provided.

An aerial hot wire ammeter.

A supersensitive long distance receiving set capable of giving response to damped and undamped oscillations.

A receiving aerial from 500 to 1,500 feet in length for use with the long distance set.

A complete buzzer test system.

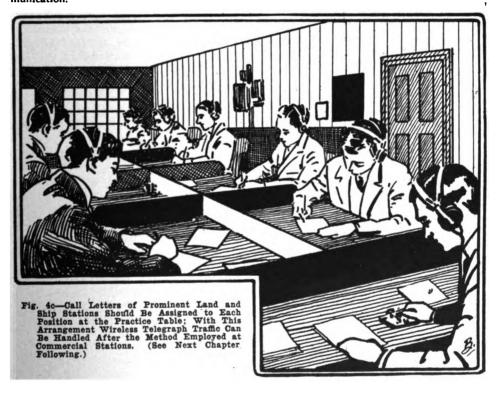
A complete buzzer practice system.

The foregoing will be described in the chapters following.

The readers of this book will be interested to learn that the Bureau of Navigation, United States Department of Commerce, has concerned itself with the plan outlined relating to the formation of a radio club and suggested that the following be published:

"Radio station licenses can only be issued in the name of the club if it is incorporated in some state of the United States; otherwise the license must be in the name of some individual of the club which will be held responsible for its operation.

"Radio clubs having a club station should apply to the radio inspector of their district for the assignment of an official call signal which must be used for all radio communication."



Chapter III

Instruction In The Telegraphic Codes

MEMBERS of a radio club should make every effort to acquire skill as telegraphers. There are several reasons for this, one being that the laws of the United States require that amateurs shall be able to receive a certain number of words a minute before they can obtain licenses. The significance of this statement will be apparent when it is understood that only licensed telegraphers are permitted to operate the equipment at a radio club.

Experimental tests cannot be conducted successfully unless the amateur in charge is a competent operator. A thorough knowledge of the code removes all doubt regarding the identity of the station which is sending, and a complete understanding of the regulations governing commercial message

traffic will be serviceable.

The members of a radio club should assist those in the organization who are not skilful operators to cultivate facility in manipulating the key. Proficiency cannot be arrived at quickly, however, from six to twelve months of practice being ordinarily required in order to be able to send at the rate of twenty words a minute.

A buzzer, telegraph keys and head phones, constituting a wireless telegraph system for the members of a radio club to practice upon, provide a practical means for cultivating skill as a telegrapher. It is of the utmost importance that the club should be supplied with such an equipment.

A plan for an arrangement of a table, with a circuit diagram of the connections to be used, is shown in Fig. 5. The actual dimensions are given, but these may be adjusted to suit the available room at the club. The arrangement has been planned for the accommodation of ten students, which is ample for the average amateur organization. Another table, known as the master table, is placed crosswise to the practice table. The apparatus for the production of artificial signals is mounted on the master table, where it is under the direct charge of the instructor in the code.

After the officers of the club have determined the arrangements suitable for their needs, they should make a thorough study of the circuit diagram as shown in Fig. 5, an explanation of which follows:

An ordinary buzzer, A, energized by either dry or storage cells, B (4 to 6 volts is sufficient), is used to operate the head phones, P, P¹, P². The circuit to the buzzer is so arranged that it may be closed by the master key, K, or any of the keys, K¹, K². The head phones, P¹, P², P³, etc., are connected in series with the condenser, C, which preferably has capacity of the order of two microfarads. The latter circuit is then shunted around the contacts of the interrupter of the buzzer, A.

The operation of the device is simple. The counter-electromotive force produced by the rapid make and break of the current passing through the coils of the buzzer charges the condenser, C, which in turn discharges through the head telephones,

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causing sounds, the tone of which will depend entirely upon the rapidity of the breaks made by the interrupter.

This arrangement gives an exact reproduction of the note of a wireless telegraph set and may be adjusted to imitate the 500-cycle quenched spark transmitter or the "grumble" of the induction coil with a magnetic interrupter. If properly adjusted these buzzers work with great regularity, remaining in adjustment for weeks at a time.

The note produced by each key on the practice table can be made to differ from the others if a small 10-ohm rheostat is included in series with each individual key. Each key then may have a different value of resistance in series with the buzzer, which causes a corresponding variation in the current flow through the buzzer, thereby changing the note. Thus the effect of several stations communicating with one another is created.

How to Make the Buzzer Squeal.—It is sometimes considered desirable to adjust the buzzer to a very high note. This is usually done to imitate the quenched spark transmitter. It may be accomplished in the following manner:

The soft iron armature of the average buzzer has the platinum contact mounted on a phosphor bronze spring. This spring should be removed and the platinum point fastened directly to the soft iron armature. When this is done the buzzer can be adjusted to a very high note and the operation

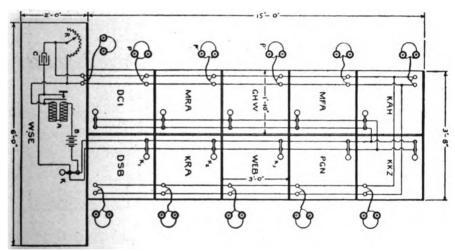


Fig. 5-Complete Wiring Diagram of Code Practice Table.

made practically noiseless. It should be added that for a time it may seem desirable to produce the high tones, but after a while the pitch becomes disagreeable and trying to the ears. Commercial operators declare that they prefer the lower pitch of the non-synchronous rotary spark discharger.

By reference to Fig. 5 it will be noted that a rheostat, R, is shunted across the head phone circuit at the master table. The rheostat is used to regulate the strength of sounds produced in the head phones. Ordinarily the sounds will be of unbearable intensity unless a shunt of less than a fraction of an ohm is used.

When the code practice tables are ready for use call letters of prominent ship and land stations should be assigned to each telegraph key. For the convenience of amateur organizations the call letters have been included in Fig 5.

With this arrangement wireless telegraph traffic can be handled after the method employed at commercial stations. The amateur who takes advantage of the opportunity to use the practice equipment will eventually reap the reward of his efforts, for the knowledge he thus obtains will enable him to avoid needless interference and employ better judgment when working the club's station.

As the circuit diagram indicates, only one student at a time can communicate with the land station (the master table). This is not a disadvantage, as it represents accurately the conditions in commercial practice.

A Small High-Frequency Generator.—Should the radio club desire a more positive method for producing imitation wireless signals it will be found that the apparatus shown in Fig. 6 is an easily constructed instruction device, demonstrating the principle of electro-magnetic induction. Referring to the dagram: A fan motor, A, has mounted on its shaft a soft iron spider, B, made from a casting having eight radial arms.

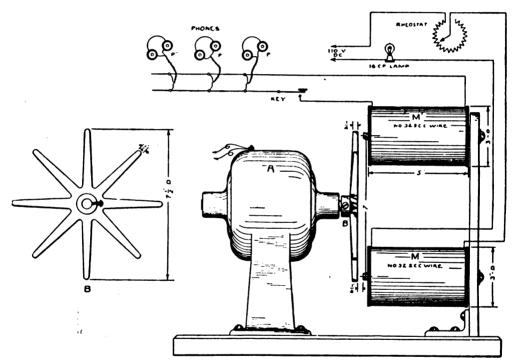


Fig. 6-A Small High Frequency Generator for "Artificial" Radio Signals.

The spider, B, revolves in front of the magnets, M and M', in such a manner that when two arms of the spider bridge the air gap between M and M' the magnetic circuit is closed, causing the lines of force to cut through the coil, M', and induce a current in it. This current, in turn, operates the head phones, P, P', P'. The motor should not rotate less than 2,400 R.P.M., preferably at a higher speed.

When the magnetic circuit is completed by the arms two distinct pulses are

When the magnetic circuit is completed by the arms two distinct pulses are produced in the head phones, one by the establishment of the magnetic circuit and the second by the breaking of the circuit which gives the stronger signal. What might be termed a mixed note is produced, usually somewhat higher than the rotation speed of the arm may indicate. The greater the speed of the arm the higher will be the pitch of the note. The speed of the motor is best controlled by a variable resistance in series with the field coils of the motor.

The intensity of signals in the head phones may be adjusted either by shunting the head phone circuit with a small battery rheostat, or a variable resistance may be

placed in the series with the magnet, M, thereby regulating the magnetic flux and consequently the intensity of signals in the head phone.

While a laminated iron core for the magnets is preferable, a solid soft iron core will serve the purpose.

The spider. N, is cast from a wooden pattern, which the members of the club can construct easily. The dimensions of the magnets, M and M', are clearly shown in the drawing. The magnet, M', is wound full with No. 34 wire; the magnet M, wound with one-quarter pound No. 32 wire, is connected to the electric light circuit in series with one or two incandescent lamps in addition to the rheostat. The device is in reality a miniature dynamo serving to illustrate the generation of alternating currents.

If a still more elaborate device is desired the shaft of the motor can be extended and two or three sets of magnets mounted, each with its own set of "spiders." Thus a variable tone transmitter is produced and variations of the note may be obtained as desired. Constructed in this manner, it may be used as an automatic "interfering" or jamming device. Signals of two or three tones can be supplied to the line, imitating the interference encountered at a commercial wireless station.

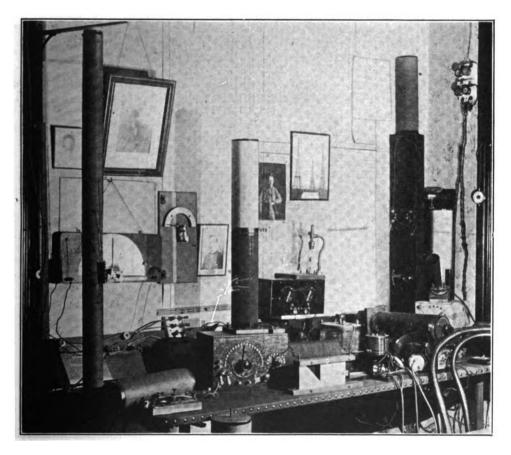


Fig. 6b-The Amateur Station of Charles Apgar Which Has Performed Notable Receiving Work.

At the Marconi School in New York City, we have found the following arrangement for the production of artificial radio signals to work very well indeed. A small No. 5 K. & D. motor is set into rotation by an 8-volt storage battery. A 3-microfarad condenser is connected in series with a dozen sets of head telephones and shunted across the brushes of the machine. The self-induced current of the armature flows through the condenser into the head telephones and produces a note having a pitch almost equal to a 500-cycle wireless telegraph transmitter. A small Western Union key is of course inserted in series with the circuit.

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Chapter IV

A 200-Meter Amateur Set

THE progressive amateur will, at the outset, make every effort to construct a transmitting set in full compliance with the-United States regulations governing amateur radio telegraphy. However, if he is not familiar with the formulae for the calculation of the capacity and inductance of a radio telegraph circuit, much less the operation of a wave-meter, it is likely that he will become confused in designing an equipment that will meet all requirements.

It is the purpose of this chapter to furnish data for the construction of a transmitting apparatus, the wave-length and character of the radiated wave of which will be in full compliance with the law. The information given should be of particular aid to the amateur who does not possess a wave-

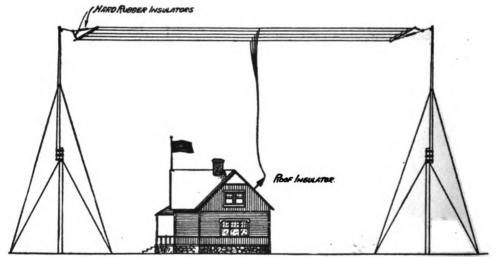


Fig. 7—The "T" Flat Top Aerial Consisting of Four Silicon Bronze Wires Supported by Two Weeden Hasts.

meter for calibration purposes. General instructions for the tuning and adjustment of a radio set also are included. The design is given for a spark gap circuit (closed oscillatory circuit) of predetermined wave-length which when constructed will not be more than five or ten meters off the government restrictions.

The United States regulations have allotted the amateurs for transmission purposes a wave-length of 200 meters. In some localities, particularly where it is assured that the stations will not interfere with the dispatch of government or commercial business, they may be allowed to operate their

equipments on longer wave-lengths. In this respect the experimenters living far inland seem to possess an advantage over the amateurs located on the seacoast or in the vicinity of prominent government or commercial stations. However, the construction of a radio set to meet the restrictions calls for more skill and inventive ability than the building of an apparatus to comply with the standard wave-length regulations, resulting in the production of a set having a high degree of efficiency.

A complete amateur's transmitting set consists of the following apparatus:

I.—A high voltage alternating current transformer which takes current at IIO volts in the primary winding and delivers current at the secondary winding at various voltages between 10,000 and 20,000 volts depending upon the design.

2.—A transmitting key that will make and break alternating current at 110 volts at various powers up to 1. K. W.

3.—A high voltage condenser the capacity of which can in no case exceed .or

microfarads and is preferably .008 microfarads.
4.—A spark discharge gap which is preferably of the rotary type giving about 240 sparks per second when the frequency of the source of current supply is 60

5.-A radio-frequency oscillation transformer, the primary and secondary windings of which may be made of copper tubing, or copper or brass strip

6.—An aerial or antenna which has a fundamental wave-length slightly less than 200 meters.

7.—A lightning switch having current carrying capacity of 100 amperes.

8.—An aerial ammeter range zero to 5 amperes.

g.—A short wave condenser having capacity varying between .00025 and .0005 microfarads. (This condenser is not required in cases where the natural wave-length of the aerial is less than 200 meters).

The Transmitting Aerial.—The aerial may take one of several designs. The vertical aerial is not often used by amateurs, but the flat top aerial is employed almost universally. Flat top aerials of two types are shown in Fig. 7 and Fig. 8, the only difference between the two being in the method of attaching the lead-in wires. In Fig. 7 the lead-ins are attached to the center of the flat top, but in Fig. 8 they are taken off one end. An aerial may consist of two to four wires; generally there is no advantage in using more than four wires, except in cases where a flat top no more than 40 or 50 feet in length can be erected. In an instance of this kind it may be of advantage to make the aerial of 8 or 10 wires. In commercial practice each of the wires composing an aerial is made of 7 strands of No. 21 silicon bronze wire, but fair results can be obtained with any kind of wire available.

In order that the wave length of the aerial may not exceed the government restrictions, its dimensions must be carefully chosen, hence the curves of Fig. 9 and Fig. 10 are shown. These were presented by Mr. A. S. Blatterman in the November issue of THE WIRELESS AGE. These curves indicate the natural wave-length of four-wire aerials from 30 to 120 feet in length and from 30 to 100 feet in height. The amateur should select from the curves an aerial most suited to the space at his disposal. The data of Fig. 10 are of particular interest because they show the wave-lengths of various dimensioned aerials with 10 microhenries of inductance in series at the base. This inductance may represent several turns of the secondary winding of an oscillation transformer which absorb a part of the energy of the oscillations flowing through the primary winding.

We see from these curves that a four-wire aerial having the wires spaced two feet part, consisting of a flat top with a length of 100 feet and a heighth of 40 feet, will have a wave-length of 200 meters when the secondary winding (of 10 microhenries inductance) is connected in series. We also see that the flat top may have linear dimensions of 80 feet and height of 60 feet; or the flat top length may be 100 feet and the height 30 feet. In every case, with a few turns of inductance in series, the radiated wave will be 200 meters in length,

It is clear also from the wave-length data that when the spark gap of a transmitting set is connected in series with the antenna system the aerial

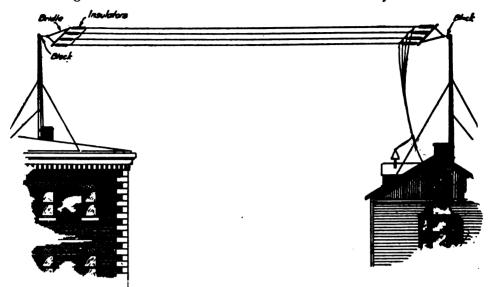


Fig. 8—The Inverted "L" Flat Top Aerial for Amateur Use.

may have increased dimensions. For example, the flat top length may be 80 feet and the height 80 feet, or the flat top length may be 100 feet and the

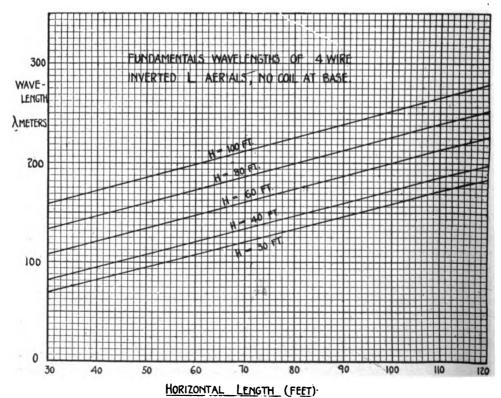


Fig. 9-Data for the Natural Wave Lengths of Four Wire Inverted "L" Aerials.

height 60 feet. If these dimensions are duplicated the radiated wave will have length of 200 meters.*

Aerial Insulation.—For purpose of transmission an aerial should be well insulated after the manner shown in Figs. 7 and 8. In Fig. 7 the bridle of the spreader (which may be of bamboo or light spruce) is made of 3/6-inch diameter Marlin rope which is covered for a distance of 21/2 feet with a hard rubber tube; the tube is then filled with hot sulphur, making it impervious to moisture. As an alternative, each wire may have its individual insulator, as shown in Fig. 8. There are various types of high potential insulators suitable for this purpose which can be purchased. Among these are the electrose insulator.

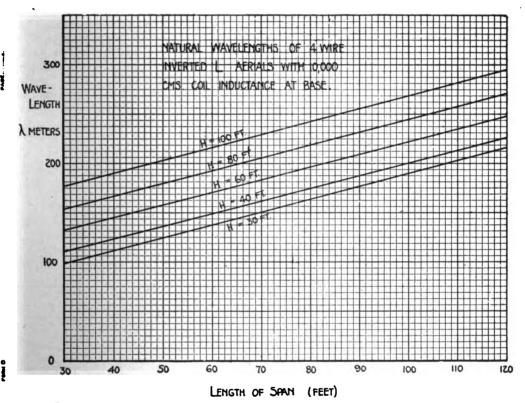


Fig. 10-Showing the Natural Wave Lengths of Four Wire Aerials With a Coil of 10,000 Centimeters Inductance Connected in Series at the Base.

For obvious reasons it is essential that the insulators for a transmitting aerial should have considerable linear dimensions as well as insulating qualities. This is, however, not so important with the receiving aerials, which may be effectively insulated by simply threading the aerial wire through the hole on one end of an ordinary porcelain cleat; the insulator in turn is fastened to the spreader by threading the wire through the other hole, which is then served about the spreader.

[•] It should be remembered, however, that acrials of these dimensions are not suitable for use with an oscillation transformer because when the secondary winding is connected in series the wave length will be raised so as to exceed the government restrictions.

An interpretation of the curves of Fig. 10 follows: Suppose the amateur has a four wire aerial 80 feet in length, 60 feet in height; following the vertical line corresponding to division 80 until the heavy line with notation "H = 60 feet" is reached, follow the horizontal line to the left to the marginal gotation which is seen to be approximately 197 meters,

The lead-in wires at the point where they enter the radio station require careful insulation. An insulator consisting of a hard rubber tube I inch in diameter and having a 1/4-inch hole through the center is quite suitable for the purpose. Glazed porcelain tubes occasionally are employed for this work, or often a window glass has a small hole bored in it of sufficient size to take the wires. Care should be taken to back-stay the wires at a point just above where they are fastened to the lead-in insulator so that there will no abnormal strain on the insulator itself. A point often overlooked by the amateur is that the lead-in wires should have the same current-carrying capacity as all the wires in the flat top.

The amateur should avoid transmitting aerials of irregular design. It is preferable that the aerial should be symmetrical; a long narrow aerial

gives the best results.

If the amateur desires to receive signals from high power stations he should erect a second aerial for receiving purposes, which may consist of a single wire several hundred feet in length. For wave-lengths up to 3,000 meters the single wire should be about 350 feet in length, but for wave-lengths beyond this it may be from 700 to 1,500 feet in length.

No advantage will be derived by putting more than two wires in the receiving aerial which gives sufficient conductivity for ordinary purposes.

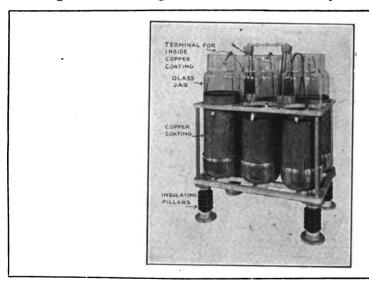


Fig. 9a-A Bank of Leyden Jar Condensers.

The Earth Connection.—The earth connection of a radio station is of more importance than many suppose. If the building in which the apparatus is placed has a steel frame, direct connection to it should be made. If possible to do so steam or water pipes should be avoided on account of the poor connection at the pipe joints. The writer is aware that many stations are so "earthed," but nevertheless this method does not make for efficiency.

If the radio transmitter is located at a considerable distance from the actual earth in a wooden building, a stout copper wire or copper strip should be run to the basement and direct connection made to the water mains on the street side of the water meter. This is, in fact, a requirement of the fire underwriters in many cities, and every effort should be made to comply with the regulation

If the amateur is situated in a country where the soil is dry, making it necessary to dig ten or fifteen feet in the earth to-reach moist ground, he can

obtain just as satisfactory results by spreading a number of wires radially over the surface of the earth, preferably directly underneath the aerial wires. Galvanized iron chicken wire netting has been found entirely satisfactory for this purpose. If it is desired to get it out of the way the wire may be buried five or six inches under the earth. This artificial earth or counterpoise, as it is often called, should have the same number of square feet of surface as the aerial itself, and, if possible, more. Amateurs in the country have found an earth connection made by dropping a galvanized iron plate connected to a stout copper wire in the ordinary drinking well to be entirely satisfactory.

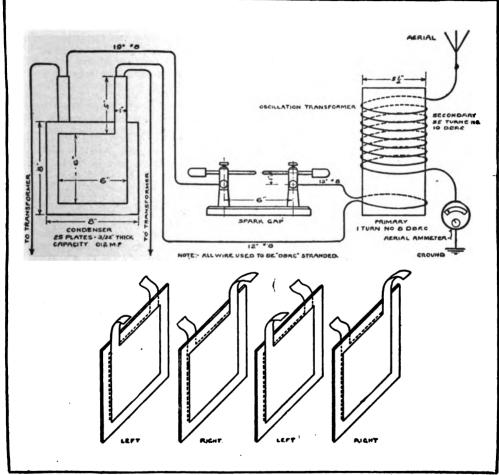


Fig. 11—Showing the Radio Frequency Circuits of a Small Amateur Set and the Assembly of the Oil Plate Condenser.

The Closed Oscillatory and Spark Gap Circuit.—Proper design of the spark gap circuit is a matter of no small importance because, unless it is accurately adjusted to the wave-length of the antenna circuit, the set will have little or no efficiency. For satisfactory operation on a wave-length of 200 meters the condenser in the spark gap circuit should have a capacity value not to exceed 0.01 microfarad. A condenser unit-having this capacity is shown in Fig. 11 which, with the length of leads indicated in that drawing, will give the closed oscillatory circuit a wave-length of 200 meters.

The assembly of the condenser in Fig. 11 should be carefully noted, the so-called alternate left and right plates being joined together by the connecting tabs shown. The complete unit consists of twenty-four plates of glass, 8 inches by 8 inches square, having an average thickness of about 1/8 of an inch. These plates are covered with foil, 6 inches by 6 inches, with extended connecting tabs as shown. The capacity of each plate is about 2005 microfarad.

A condenser having similar capacity, but employing larger plates, may have the following dimensions: The plates should have dimensions of 12 inches by 14 inches, covered with foil, 10 inches by 12 inches. Six of these plates connected in parallel will give a capacity value, provided the glass has thickness of about ½ of an inch, of .01 microfarad.

Placing the Foil.—The tin-foil is attached to the plates in the following manner: The surface of the glass is first covered with a good grade of thin fish glue. The

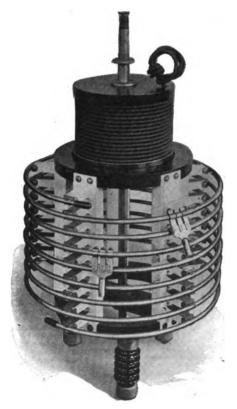


Fig. 11a—A Typical Transmitter Oscillation
Transformer for Sets from ½ K. W.
to 2 K. W.

sheets of tin-foil, which have been properly cut, are placed in position and rolled to smoothness by a "squeegee" roller. The plates are next placed in a rack and allowed to dry slowly, after which they are covered with one coat of orange shellac. They are then piled together, first a left plate and then a right plate and so on throughout the series, until the unit is complete. The entire unit is bound with insulating tape or a canvas strip and immersed in a tank of insulating oil. As a good grade of oil, Swan & Finch's Special Atlas AAA is recommended.

Another method for placing the tinfoil on the glass is as follows: The sheets of tin-foil having been properly cut, the glass plates are placed in an oven and heated for five minutes. They are then removed and rubbed with a good grade of beeswax. While the plates are still warm the sheets of tin-foil are rubbed into place by a "squeegee" and the edges painted with hot beeswax. Beeswax has in many instances been found superior to shellac because it does not blister.

Owing to variations in the dielectric constant of various grades of glass, and also because it is practically impossible to purchase glass of a constant thickness, the amateur may find after the construction of this condenser that the wave-length of the set is slightly more or less than 200 meters, and when the government inspector arrives to survey the station it will perhaps be discovered that the adjustments are

five or eight meters out of the way. Should this be the case it only will be necessary to lengthen or shorten the lead from the condenser to the spark gap (the nineteen-inch lead) to give the required wave-length.

Amateurs having the funds at their disposal are advised to purchase copper plated Leyden jars from some responsible manufacturing concern, as they are found to be less troublesome, less liable to breakdown, and more convenient to install.

Standard commercial jars have capacity of .002 microfarads and can be purchased at about \$5 per single jar.

The Oscillation Transformer.—A general outline of the construction of an oscillation transformer is shown in the upper right hand corner of Fig. II. The function of this apparatus is to transfer the oscillations generated in the condenser circuit to the antenna circuit, where they are radiated in the form of electric waves. The secondary winding comprises a number of turns of No. 6 or No. 8 S.B.R.C. wire, one terminal of the wire being connected through a hot wire aerial ammeter to the earth and the other terminal to the aerial. In this diagram the primary winding is given a single turn, which is about all that is permissible when the capacity of the condenser is .01 microfarads. If the capacity were reduced to .006 or .008 microfarads additional turns can be added at the primary, the exact number being determined by means of a wave-meter. In case the primary has a single turn the radiated wave will be pure and comply with the regulations, even if the turn is wound about the secondary winding. If the primary has several turns the oscillation transformer should be constructed so that the distance between the primary and secondary windings can be closely adjusted.

An Oscillation Transformer of the Spiral Type.—An oscillation transformer of the flat spiral type suitable for operation on wave-lengths of 200 to 600 meters can be constructed after the following dimensions: The primary winding has eight turns of flat copper ribbon placed on an insulating support edgewise, the copper being 3% of an inch in width by 1/16 of an inch in thickness. The outside diameter of the winding is 10 inches and the inside diameter about 43%, inches. The turns should be spaced 1/4, of an inch apart.

The secondary winding of this oscillation transformer may consist of nineteen or twenty turns of the same size ribbon, also spaced ½ of an inch apart, with a copper strip of the same dimensions. The outside diameter is about 14 inches and the inside diameter about 4½ inches. The secondary winding should be constructed so that it can be turned at right angles to the primary winding by means of a hinge, or may be drawn away from the primary winding on a sliding base.

In an oscillation transformer, it is essential that the turns of the primary winding should be well insulated and sufficiently spaced so that arcing between them will not take place. The winding should possess sufficient current-carrying capacity to avoid all possibility of heating. For the secondary winding it has been found possible to use very heavily insulated rubber covered wire, with the turns wound as closely together as possible.

An oscillation transformer of this type is shown on page 77.

The Rotary Spark Gap.—The design of a rotary spark gap is often a matter of some concern to the junior experimenter. For amateur sets ranging from ½ to 1 k.w. a rotary gap of the following construction is recommended: A disc of bakelite, micarta, or micanite, 8 inches in diameter by ¼ of an inch in thickness, should be mounted on the shaft of an ½ H.P.D.C. motor. The rim of this disc should be fitted with eight spark electrodes having a diameter of no more than 3/16 of an inch. The electrodes should possess uniform length and be accurately and equi-distantly spaced about the periphery. The stationary electrodes should have similar diameter and may be of any construction desired, but should be mounted so that the movable electrodes will move within 1/50 of an inch of the stationary electrodes.

The speed of the motor is preferably from 2,400 to 3,000 R.P.M. No advantage is derived in extremely high speeds or by fitting the rotary gap with an excessive number of spark points.

The disc just described will give a note of deep volume and musical characteristics similar to that produced by the Marconi station (WCC), Cape Cod. Mass.

A Rotary Gap of Simple Construction.—For cheapness and simplicity of construction the rotary spark gap design about to be described is recommended: A complete sketch of the assembly is shown in Fig. 10. A "Little Hustler" D.C. battery motor has mounted on the shaft an arm which carries the spark electrodes, 6. A "U" shaped piece of brass of the dimensions given has mounted upon it and spaced equidistantly a number of stationary electrodes as shown in the drawing. Contact is made to the movable arm which is insulated from the shaft of the motor through

the binding post, 7, and the corresponding brush.

Referring to Fig. 10, the "U" shaped piece of brass which holds the stationary spark electrodes is of 1/4-inch square brass rod, bent to the dimensions given. After bending, ten equally spaced holes are drilled and tapped as shown to receive ten No. 8-32 brass machine screws % of an inch in length. These screws are held from turning by a lock nut. Care should be taken that these holes are equally spaced and

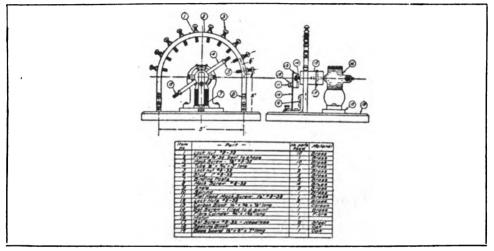


Fig. 12-A Rotary Spark Gap of Amateur Construction.

bored so that the inner ends of the screws will be in line and exactly the same distance apart. The "U" shaped piece of brass is mounted on the base with brass These should be heavy enough to prevent vibration of the stationary spark angles. electrodes.

A piece of fiber is turned up to 3/4 of an inch in diameter by 13/8 of an inch in ength, and a hole of 34 of an inch in depth drilled in the center of one end to receive he motor shaft. The fiber is held to the gap by two 8-32 headless set screws. At a listance of 3% of an inch from the other end a 3/16-inch hole is drilled at right angles to the line of the shaft. Through this hole is placed a piece of seamless brass tubing 3 inches in length by 1/8 of an inch and 3/16 of an inch inside and outside diameters respectively.

Each end is tapped to receive an 8-32 stud, I inch in length, which is held from turning by a lock-nut as indicated. This tubing is held central in the fiber by a set screw placed in the center of the end. This set screw is placed in a tight thread and then filed off to a point. This point runs in a piece of carbon held against it by a piece of spring brass. The carbon should be fastened loosely to the spring.

The motor should be fastened to the base at such a height that the shaft is at the center of the semi-circle. Then by adjustment of the screws in the tubing and in the semi-circle, the movable arm should rotate as closely as possible to the stationary electrodes and with exactly the same classroscial leaves are smooth points.

electrodes and with exactly the same clearance all the way around for each point.

One connection is made to the semi-circle of brass and the other to the spring brass brush which holds the carbon. Great care should be taken that the tubing is perfectly balanced in the fiber so that there will be no vibration while running.

An important feature of this gap is that it works very well with a low voltage transformer, since there is but one air gap to be bridged.

Transmitting Keys.—The market is well supplied with transmitting keys suitable for use in the primary circuit of a wireless telegraph transformer.

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These may be purchased at such a small price as to render construction on

the part of the amateur unnecessary.

Transmitting keys in wireless telegraph work were formerly fitted with platinum points, but later types are supplied with silver points of increased diameter, which serve the purpose at less expense. A transmitting key for amateurs' use should be capable of withstanding ten amperes of current. If equipped with silver points they should have a diameter of at least 5/16 of an inch.

Transformers.—The amateur market is well supplied with open and closed core transformers up to I k.w. capacity. The closed core transformer without a magnetic leakage gap is totally unsuitable for radio work on ac-

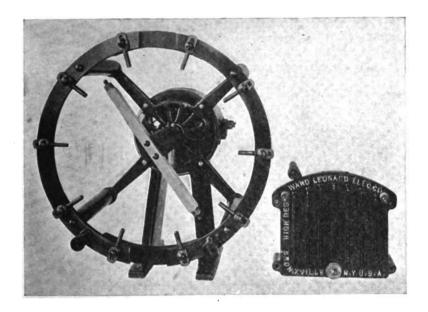


Fig. 18a-A Typical Non-Synchronous Rotary Spark Gap Driven by a Direct Current Motor.

count of its inherent characteristics. When the condenser of the spark gap circuit discharges across the gap the secondary winding of the transformer is practically short-circuited so that the transformer will experience an abnormal rise of current which may burn it out. The effects of this action may be offset to a certain degree by the insertion of a reactance coil in series with the primary winding. It is usually necessary, however, for the transformer to be operated at a smaller power consumption than for which it was originally rated.

The open core transformer is used in seventy-five per cent. of the commercial stations. It has an advantage, for the secondary winding may be short-circuited without injury, and, therefore, when the condenser discharges across the spark gap there will not be an abnormal rise of current in

either the primary or secondary windings.

For the amateur who desires to construct a transformer of the open core type having a capacity of ½ k.w. the following dimensions are suggested: The primary core should be 14 inches in length, 2½ inches in diameter, consisting of a bundle of very fine soft wires (No. 24 to No. 30), which should be taped in circular form. The core should then be covered with two or three layers of Empire cloth and afterwards wound with two layers of

No. 14 D.C.C. wire. The entire primary winding should then be inserted

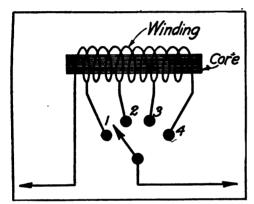
in a hard rubber tube of about 3/16 of an inch thickness.

The secondary winding is composed of ten separate sections, each about 7 inches in diameter by 1½ inches in thickness. Each of the pancakes, comprising a section, should be wound with No. 32 S.S.C. wire, which previously has been soaked in hot paraffin. The sections of the secondary winding may be separated from one another by micanite or paraffined paper washers.

A reactance coil may be inserted in series with the primary winding to

regulate the current consumption as desired.

Reactance Regulators.—A reactance regulator may take the designs indicated in Fig. 13 or Fig. 14. In the former a straight iron core has two or three layers of wire of suitable current capacity, the turns of which are equally divided between the contact points of a ten-point switch, or we may use the design in Fig. 14, where two coils of fixed inductance are connected in series and a "U" shaped iron core inserted. Then by drawing the core in and out of the windings, its self-induction can be varied over considerable range and the power input accordingly increased or decreased.



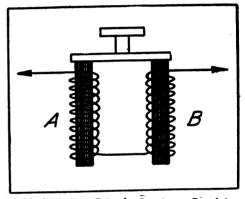


Fig. 13-Staight-Core Primary Reactance Regulator.

Fig. 14-"U" Core Primary Reactance Regulator.

For the average amateur transformer up to ½ k.w. the core for the design of Fig. 13 may be 14 inches in length, 2 inches in diameter, wound with three complete laters of No. 14 D.C.C. wire, with tappings brought out at certain intervals.

The core for the design (Fig. 14) should be laminated, i.e., constructed of thin sheets of iron, stacked up and assembled as the core of the usual type of transformer. The core for both windings A and B may be 1½ inches square, 8 inches in length, with a cross bar or yoke 7 inches in length. Two layers of No. 12 wire are wound on each leg. The precaution should be taken to wind the turns on each leg in the opposite direction.

It is, of course, understood in either type that the windings are insulated from the core by means of two or three layers of Empire cloth. The actual dimensions of these coils and the number of turns will probably not apply to all types of amateur transformers, but a few trial experiments with each

will reveal a winding of the correct proportion for a given radio set.

The windings for reactance (Fig. 14) must be wound on tubes or bobbins - not directly on the core.

A Transformer of Increased Capacity.—An open core transformer of I k.w. capacity has the following dimensions:

The core for the primary winding should consist of a bundle of iron wires (No. 24 to No. 30), 25 inches in length and 3 inches in diameter. The core should be

taped carefully and then wound with two or three layers of Empire cloth. Over this is placed two layers, each comprising 220 turns of No. 10 D.C.C. magnet wire. The primary

winding is then inserted in a tube, the walls of which have a thickness of ¼ of an inch.

The secondary winding comprises thirty-eight pancakes, each having a thickness of ¼ of an inch; there are 1,125 turns of No. 32 S.C.C. wire to each pancake. The transformer may be fitted with high frequency "choke" coils to prevent the condenser from discharging back and puncturing the insulation of the secondary winding. These coils may consist of twenty-four turns of No. 18 bell wire, wound in spiral form and baked in

an insulating compound, such as beeswax.

Many experimenters do not care to go to the expense of a power transformer and are content, in their preliminary work, to use a spark coil operated by a magnetic interrupter. The writer advises that spark coils having a capacity of less than three inches be operated without a condenser; that is to say, the spark gap should be connected directly in series with the antenna and the terminals in turn connected to the secondary winding of the spark coil. This has been found by experiment to be the most effective method of transmission, giving better results than those obtained by use of a condenser and an oscillation transformer.

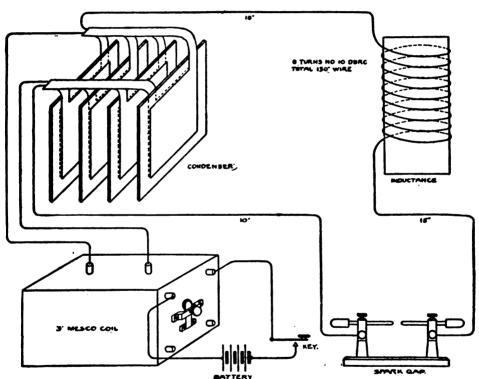


Fig. 15-Radio-frequency Circuits of Small Amateur Set Connected to a 3-inch Spark Coil.

This method of connection is known in wireless telegraph practice as the "plain aerial" connection. If the amateur's station is located within the zone of commercial or government stations the United States regulations will not permit his equipment to be connected in this manner. If, however, the government authorities are assured positively that the station is located outside the zone of possible interference, a license will be issued.

A Condenser for a Spark Coil.—A condenser suitable for use in connection with three-inch spark coil and to afford a wave-length adjustment in the cuit of 200 meters is shown in Fig. 15; a suitable primary winding for an oscillation transformer also is shown.

The condenser consists of four plates of glass 8 inches by 8 inches, covered with foil 6 inches by 6 inches, alternate left and right plates being used as shown in the drawing. The actual length of leads to connect the condenser to the oscillation transformer and spark gap also is given. A secondary winding for the oscillation transformer must be constructed at the discretion of the experimenter and will vary, depending upon the size of the aerial with which it is to be employed.

A Three-Inch Spark Coil.—The core of a three-inch spark coil should consist of a bundle of fine iron wires 3/4 of an inch in diameter by 8 inches in length, wound with a few layers of Empire cloth. Over this is wound 210 turns of No. 16 magnet wire, which is again covered with several layers of Empire cloth. The secondary winding should be made of 1½ pounds of No. 36 enameled wire, which is wound in two sections, each section having a diameter of about 3 inches.

The condenser connected across the vibrator should have about 2,500 square inches of tin-foil separated by thin paraffin paper.

The writer does not recommend the use of a spark coil having a capacity in excess of 3 inches. The experimenter should purchase a power transformer in preference.

The core of a one-inch spark coil should be five and three-quarter inches in length by one-half inch in diameter, covered with 175 turns of No. 18 magnet wire. The winding is then covered with several layers of Empire cloth. The secondary winding contains 34 pound of No. 38 B. & S. magnet wire and is wound in two sections. The approximate diameter of the secondary windings is two inches. The condenser across the vibrator should have 800 square inches of tin-foil.

The Lighting Switch.—The underwriters' rules in many cities require that the aerial, when the station is not in use, be connected to earth through a 100-ampere switch. Unless the experimenter is equipped with a good set of tools it is doubtful whether he will be able to construct a switch which will meet these requirements. Single pole, double throw switches of this capacity can be purchased at any electrical store. The switch should have a well insulated base and, if mounted outside the room, should be placed in a metal or asbestos lined box. It is important that the base of this switch possess the very finest insulating qualities.

Protective Devices.—The power circuits of the transmitting set are subjected to high potential currents, due to the electrostatic field set up about a

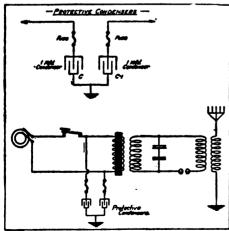
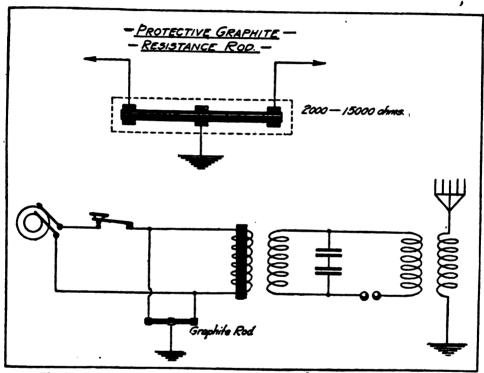


Fig. 16—Showing the Use of Protective Condensers on a Transmitting Set.

wireless telegraph transmitter, which in certain cases may puncture the insulation of the power meter, the motorgenerator (if used) or the primary windings of the power transformer. The device shown in Fig. 16 will neutralize such differences of potential and conduct the charges to earth. condensers having a capacity of one or two microfarads each, C and C-1, are connected in series and earthed at the center point. The remaining terminals are connected through fuses of ½ ampere capacity, to the alternating current leads from the source of The fuses are required in case of accidental short-circuit of one of the condensers.

Another device, which will serve the same purpose, is shown in Fig. 17, where a graphite resistance rod is connected across the circuit to be protected. The center of the rod is connected directly to the earth, as indicated. In some radio stations a condenser or protective rod is connected from the frame of the motor-generator to the windings, thus preventing a large difference of potential being set up between them. In amateur stations where the power leads enter the house through the basement and the radio apparatus is located on an upper floor, a set of these protective devices should be connected across the primary terminals of the transformer and a second set near to the basement meter.



Pig. 17-Showing the Use of Protective Resistance Hods on the Transmitting Set.

High-Frequency Choking Coils.—It is often desirable to protect the secondary windings of a high potential transformer from the high frequency oscillations released by the condenser during discharge. This is particularly important for a home-made transformer where the constructor lacks the facilities for properly insulating the windings. Should the spark gap be opened to abnormal length, the current of radio frequency may break down the insulation of the secondary pancakes and thus render the transformer inoperative.

Protective choke coils are represented at N, N, Fig. 18, and they may be constructed in a simple manner. A spiral winding of annunciator wire with outside diameter of 6 inches may be made on any convenient insulating base, or if preferred a single tube 4 inches in length, 4 inches in diameter, may be wound with a single layer in the usual manner. These coils may be constructed with or without an iron core, but they will be effective in either manner.

An Aerial Ammeter.—The experimenter preferring a hot wire aerial ammeter than can be calibrated by comparison with a meter of standard con-

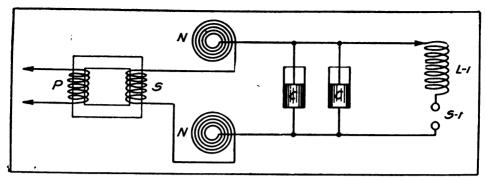


Fig. 18—Showing the Position of High Frequency Chokes Between the Condenser and Secondary
Winding of the High Voltage Transformer.

struction should note carefully the diagram in Fig. 19. The instrument shown therein will measure at the full scale position, 0.1 ampere, and by placing several additional wires in parallel to it, the range may be increased to any desired value. Between the copper bars, B-1 and B-2, is stretched a piece of Therlo resistance wire 4 inches in length and .003 inch in diameter, having approximately a resistance of 9.5 ohms. C, D is a piece of silk fibre about 3 inches in length, while G, H is another piece 2 inches in length. The latter thread is attached to C, D and wound around the shaft, F, which is preferably supported by jewelled bearings. Without the tension of the small hair spring, S, the pointer would fly to the full scale position, but the pull exerted by G, H holds it to the zero position. Then when the current is caused to flow through the W-1, W-2, the wire expands, releasing the back tension of the spring and the pointer accordingly moves across the scale.

To measure larger values of aerial current, four to six Therlo wires should be placed in parallel, from bar to bar, until the correct current carrying capacity is secured. The pointer may be made of a light piece of straw attached to the shaft by a bit of beeswax

A small counterweight, A, should be attached to the opposite end of the pointer to give the correct balance.

The ammeter is very useful for placing the primary and secondary circuits of a radio transmitter into electrical resonance. The closed and open oscillation circuits have the same natural frequency of oscillation at such adjustments that will give the highest possible reading of this meter. An accident to the aerial or electrical leakage of any kind will be at once detected, for the ammeter will either indicate a drop in the antenna current or give no reading at all.

Radiation Indicator.—An indicator for determining conditions of resonance between the condenser and aerial circuits of a radio station is an absolute necessity. The amateur market is not well supplied with a cheap and efficient aerial ammeter, and consequently many experimenters prefer as a substitute the indicator shown in Fig. 20.

The simplest device for this purpose is that indicated in Figure 20 wherein a two or four-volt battery lamp L, is connected in series with the aerial system through the binding posts, A and B. The lamp is shunted by the loop of wire, W, bent in a semi-circle over which slides the variable contact, C. The dimensions of the loop vary according to the current flowing in the aerial system; its diameter may have to be increased or decreased accordingly, but a few trial experiments will quickly reveal the correct position so that the lamp will not burn out when complete resonance is established.

The better method for obtaining resonance is to set the inductance of the closed circuit at some fixed point and follow it by altering the inductance in the aerial circuit until a brilliant glow is secured.

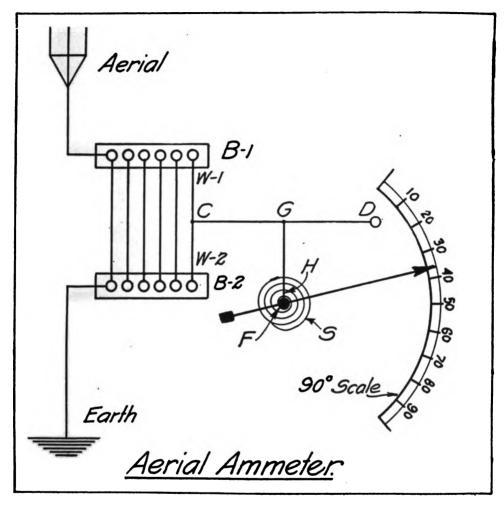


Fig. 19-Aerial Ammeter for Measuring the Antenna Current.

Aerial Outgoing Insulator.—An aerial insulator for bringing the aerial leads through the roof of a building or the side of the house must be carefully constructed to prevent leakage of water. An insulator of elaborate construction is beyond the means of many amateurs and therefore the type shown in the drawing, Fig. 21, may be substituted. A hard rubber tube at least 16 inches in length with a hole 3% of an inch to ½ inch in diameter is clamped to the roof by means of the wooden blocks, B, B, drawn together by the bolts, E, F. The fit of the tube should be snug when the bolts are tightly drawn. A second set of bolts is inserted at C, D and the blocks thereby drawn to the base board.

To make the joint watertight a strip of canvas slightly larger than the blocks has a hole the size of the tube cut in the center, after which it is thoroughly smeared with white lead. The bolts are then placed at C, D, and

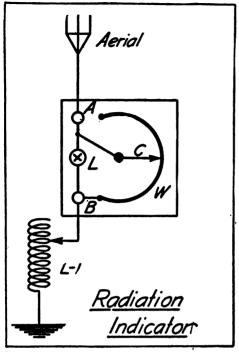


Fig. 20—Simple Resonance Indicator for Amateur Set. •

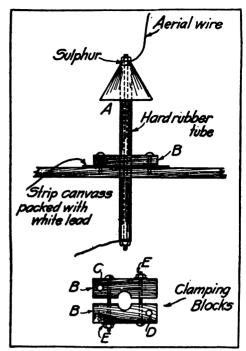


Fig. 31—Showing the Construction of a Roof
Antenna Insulator for Amateur Use,

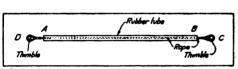


Fig. 22-Home Made High Voltage Insulater.

the blocks drawn to the roof. If allowed to dry a watertight joint will result, provided the strain of the lead-ins is removed by appropriate guys.

The wire extending through the insulator should be at least No. 6 D.B. R.C. stranded conductor, which may be made watertight by surrounding it with melted sulphur. A certain quan-

tity of sulphur should be heated in a pan until it runs freely; the bottom of the insulator is then stuffed up with waste and the sulphur poured from the top until the insulator is completely filled. When dry the sulphur hardens and possesses the requisite insulating qualities.

A cone shaped metal can may be attached to the top to prevent leakage of the high voltage current during a rain storm, but it is not absolutely essential.

Antenna Insulators.—In a somewhat similar manner we may construct insulators for aerial wires. A thin hard rubber tube about 12 inches in length, as in Fig. 22, may have extended through it a piece of 3%-inch diameter marlin rope which in turn is served about heart shaped thimbles, as at C and D. The tube should be large enough to permit a small air space between the rope and the walls, around which is poured a quantity of melted sulphur. When dry the sulphur usually soaks into the rope sufficiently to make a watertight joint, after which the insulators may be attached to the spreaders for support of the wires.

Safety Gap for High Potential Transformer.—During the adjustment of the rotary spark gap the secondary winding of the high potential transformer should be protected by a safety gap.

The design in Fig. 23 is applicable. Two brass rods ¼ inch in diameter have balls ½ inch in diameter mounted on the end. A third ball is placed in the enter and thoroughly connected to earth. The actual distance between A and B (Fig. 23) depends upon the potential of the transformer, but ordinarily the spacing is no more than ½ inch between the three electrodes. Then, if the spark gap proper of the closed circuit is widened to abnormal length, a discharge takes place from A to C, B to C, thereby protecting the windings.

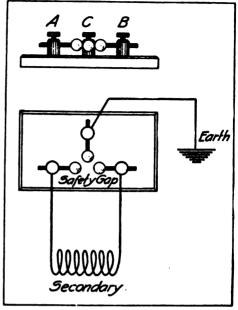


Fig. 23-Safety Spark Gap for Transformer.

General Precautions.—In the circuits of a radio transmitter, high resistance joints are to be avoided. Stranded copper wires or copper strip should be used for connecting together parts of the apparatus in the circuits of radio frequency—namely, the closed oscillatory circuit and the open oscillatory circuit.

It is of prime importance that the high frequency circuits be placed at some distance from the low frequency circuits or at least the wires from the two circuits

should be run at right angles to each other.

The transmitting apparatus should be well supported on insulating pillars, in order to prevent leakage through the table to anything metallic which may be in the vicinity.

The Adjustment of a Transmitting Set.—The design of a high potential transformer varies in the extreme. If the experimenter finds that, after he has constructed a condenser having a capacity value of .o. microfarad and upon trial when the transformer is connected to the condenser, the spark gap is "flamy" and the spark assumes the nature of an arc it may be due to two reasons. Either there is too much amount flowing in the primary circuit which may be reduced by the addition of a reactance coil, or the condenser capacity is insufficient to handle the current output of the secondary winding. A correction at either point should result in elimination of the difficulty.

Heavy arcing at the transmitting key is undoubtedly due to the flow of abnormal current which would not take place if the apparatus were properly designed. Flicking of the lights is a problem which practically every amateur encounters when he connects his transmitting apparatus to the lighting mains of the house. This is due to the sudden drop of potential when the primary circuit of the transformer is closed. A transformer having a high power factor will give the least trouble in this respect, as it will not draw abnormal current from the circuit. If, however, the latter condition seems to exist, a reactance coil should be connected in series with the primary winding and the current flow regulated accordingly. Very often a reactance coil is connected in shunt to the telegraph key, so that a portion of the current consumed by the transformer flows at all times, although it is not sufficient to cause a spark to discharge across the spark gap When the transmitting key is depressed, normal current flows through the primary winding whereupon a spark discharge takes place at the gap.

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The open core transformer and the closed core transformer with the magnetic leakage gap will give less trouble in this respect than the closed core transformer of

ordinary construction.

Notes on Coupling.—Many amateurs are under the impression that in order to have their sending sets radiate a pure wave, it is necessary to employ an oscillation transformer of the inductively-coupled type. The oscillation transformer of the "plain" helix" type is therefore apt to be discarded as valueless. An examination of Figs. 24 and 25, will show that this is untrue, for it is quite as possible to radiate a wave of single frequency and low decrement with the direct coupled oscillation transformer as with the inductively-coupled type. In Fig. 24 A, L-1, E is the antenna circuit at any station, L-1 being a helix of the type usually found in amateur stations. The condenser, C, of the closed oscillatory circuit, C, B, D, S, is of such value that in order to place this circuit in resonance with the antenna circuit, not more than ½ of a turn is required between the contact, B, and the end of the helix, D.

It is evident that the mutual induction between the closed and open circuit is

It is evident that the mutual induction between the closed and open circuit is

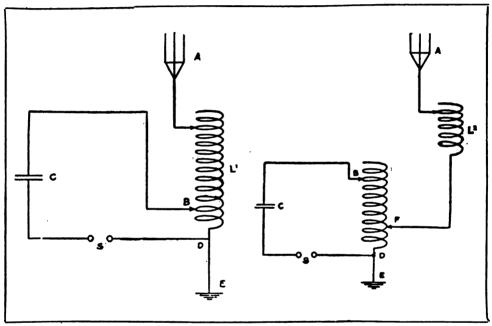


Fig. 24—Showing How Loose Coupling Can Be Obtained With Single-Coil Oscillation Trans-former. Fig. 25—Another Method for Obtaining Loose Coupling With Direct Coupled or Single-Coil Oscillation Transformer,

of small value; hence the reactions are unimportant and the radiated wave is practically of the single frequency, having a decrement value wholly within the United States regulations. It may be argued that the mutual inductance under such conditions is insufficient for the proper transference of energy; however, that has been wholly dis-

proven by experiment.

In Fig. 25 the closed oscillatory circuit has a greater number of turns of inductance and the value of the condenser, C, is correspondingly small as compared with the previous case. If the closed oscillatory circuit, D, S, C, B, has a period of, say, 200 meters, then the antenna circuit, L-1, F, D, E, can likewise be adjusted to the same wave length. If no more than one or one and a half turns are included between the contacts, F and D, the coupling between the open and closed circuits will be relatively "loose"; hence the emitted wave is pure and sharply defined. Amateurs should carefully study both diagrams in order to be able to proportion the circuits of the transmitter to comply with the law, using the equipment ordinarily at hand. A wave-meter is, of course, required for these adjustments and for examination of the purity of the wave.

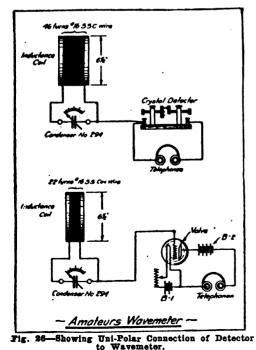
Chapter V

An Amateur's Wave-Meter and Its Uses

A N essential, but seldom found piece of apparatus at the average amateur station is a wave-meter for calibration of the transmitting and receiving circuits to resonance or to a definite value of wave-length. Many of the problems of the radio experimenter could be immediately solved if he would purchase or construct a wave-meter of suitable range and determine for himself whether or not his apparatus or aerial system complies with the United States restrictions. It is not a difficult matter to construct a wave-meter for amateur's use, but unless a calibrated instrument is available for comparison it will be of no value to the designer.

Experimental determinations were recently made with a home-made wave-meter comprising a Mesco condenser No. 294, designed to have a maximum value of capacity of 001 of a microfarad connected in series with an inductance coil having forty-six turns of No. 16 single silk covered wire,

wound on a hard rubber tube exactly 6½ inches in diameter. Two leads, 12 inches in length, were extended from the coil of inductance to the terminals



ble No. 1
Corresponding Value
of Wave-Length
185
225
325
380
465
530 580 630 670
<u>5</u> 80
630
670
710

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000, I

1,040

of the condenser. A crystalline detector, connected unilaterally, as shown in Fig. 26, was employed for determination of the point of resonance. At the zero position of the condenser scale the wave-length of the circuit was found to be 185 meters, and at the 180 degree position, 1,040 meters. It will then be observed that a meter of this range is quite suitable for calibration purposes between 200 and 800 meters. A complete table of wave-lengths for the entire scale of the condenser is tabulated on preceding page.

The foregoing data plotted in curve form appears in Fig. 27, from which the intermediate values corresponding to the intervening degrees of the condenser scale may readily be obtained.

For good signals in the head telephones, with the unilateral connection, a sensitive crystal, such as galena or cerusite, must be used, and if very loud signals are required one terminal of the condenser should be connected to the grid of a sensitive vacuum valve. (Fig. 26.)

A Wave-Meter of Low Range.—Another coil of wire comprising twenty-two turns of No. 16 single silk covered wire wound on an insulating tube of hard rubber 6½ inches in diameter with two extended leads each 12 inches in length, gave the following values of wave-length when connected in shunt

to the small Murdock variable condenser No. 368. This condenser has a maximum value of capacity of .0005 microfarads The data follows:

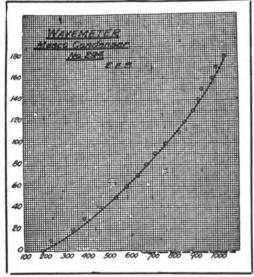


Fig. 27—Curve of Wave Length for Amateur's Wavemeter.

Table No. 2 Degrees of Con- Corresponding Value denser Scale of Wave-Length

denser Scale	of Wave-Len
Ο	140
10	160
20	195
30	235
30	2 60
40	300
60	300
8 0	340
.001	365
120	400
140	440
160	, 440 , 470 500
1 8 0	500

It cannot be expected that several of these condensers will check up identically, but if the coil of wire of the dimensions given is used a reasonable degree of accuracy can be expected, rendering it unnecessary for

the experimenter to work out elaborate formulae for the computation of the wave-length.

The data given in Table No. 2 is depicted in the curve Fig. 28.

The Mesco condenser No. 294 can be used for a wave-meter of increased range by connecting it in series with an inductance coil of increased dimensions. A hard rubber insulating tube 6½ inches in diameter and approximately 8½ inches in length was wound with 146 turns of No. 16 S. S. C. wire. At the tenth division of the condenser scale the wave-length of the circuit is 610 meters and at the 180th division 2,650 meters. The intermediate values are given in the following table:

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Table 1	No. 3
Degrees on the	Corresponding
Condenser	Wave-Lengths
. 10	610
20	845
30	1,040
40	1,230
50	1,400
60	1,570
70	1,660
8 0	1,780
90	1,875
100	2,000
110	2,100
120	2,170
130	2,285
140	2,350
150	,2,41 0
1 6 0	² ,495
170	2,565
180	2,650

The last described wave-meter fulfills the requirements of the average amateur radio station, and even though, owing to the unequal construction of condensers, a slight error of calibration exists, it will be a relief to the experimenters who heretofore have not had available facilities for measuring the wave-length of their apparatus, to have an approximation of the frequency of the circuits.

Determination of the Point of Resonance.—That the wave-meter is in resonance with the radio-telegraphic circuits under measurement can be ascertained by any of the following methods: In Fig. 29 a carborundum crystal or other rectifying detector, D, is connected in series with the head telephone, P; the remaining terminals are then connected in shunt to the vari-

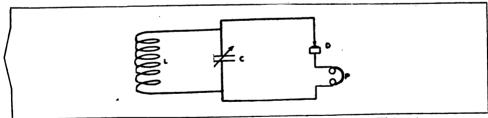
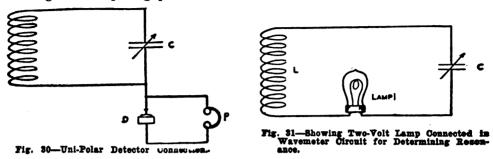


Fig. 29-Crystal Rectifier and Head Telephone Connected to Wavemeter.

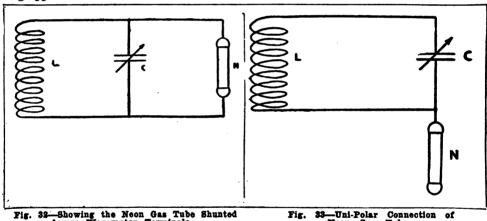
able condenser, C, of the wave-meter. When the wave-meter is so connected and placed near to a transmitting set in operation, the capacity of the variable condenser is altered until a maximum of sound is heard in the head telephone. If the wave radiated by a radio-telegraphic transmitter is sharp and well defined, very close adjustment of the condenser, C, must be made to obtain a reading. After the point of resonance is ascertained the wavelength of the circuit is obtained by reference to the chart which generally accompanies a wave-meter.

It is not necessary for the crystal and head telephones to be connected across the condenser, C; they may be connected unilaterally, as shown in

Fig. 30. Connected in this manner, the crystal and head telephones are not so apt to affect the constants of the wave-meter itself. If more visible indicating means are desired a two or four-volt straight filament battery lamp may be connected in series with the inductance coil and condenser as shown in Fig. 31. This method of connection is generally employed when taking readings of the spark gap circuit.



If a neon or carbon dioxide tube, N, is available, it may be connected in shunt to the variable condenser, as shown in Fig. 32, or may be attached to one binding post of the variable condenser, as shown in Fig. 33. The point of resonance is easily determined by the maximum glow of the tube, and particularly sharp readings are secured with the connections shown in Fig. 33.



Showing the Neon Gas Tube Shunted Across Wayemeter Terminals.

Meon Tube. Gas

A milliameter, which is frequently used as an indicating instrument for this purpose, is connected in series with the condenser and inductance coil of the wave-meter. A hot wire watt-meter may be employed in the same manner, being connected generally to the secondary winding of a small stepdown transformer, the primary winding of which is connected in series with the condenser and coil of the wave-meter.

The Manipulation of the Wave-Meter.-In operating a wave-meter the experimenter sometimes does not take into consideration the fact that if the meter is placed too near to the circuit to be measured, the crystal requires periodical readjustments owing to the strength of the oscillations from the transmitting circuit. This statement applies particularly to crystals of the sensitive type, such as galena or silicon. It also applies to the use of a small battery lamp as an indicator. If the wave-meter is placed too near to the spark gap circuit, the oscillations may be of such strength as to burn out the filament or puncture the insulation of the inductance coil. Several trial readings are required. Care should be taken that the coil is placed so that it is properly acted upon by the magnetic field of the radio frequency circuit.

Again, when a crystal, connected unilaterally to the circuit, is employed for determining the point of resonance, the wave-meter invariably must be placed nearer to the circuit than when connected in the regular manner (Fig. 29). The inductance coil of the wave-meter preferably is placed near to the earth lead of the open oscillatory circuit when measurements are being taken of the natural period of an antenna. Owing to the fact that greater radiation takes place from the open oscillatory circuit of a radio transmitter than from the closed circuit, the wave-meter may be placed at a greater distance than when making the measurements of the closed circuit alone.

How to Tune the Amateur Set.—After either wave-meter has been constructed in accordance with the foregoing instructions, it is important to understand thoroughly the manner in which the instrument is to be used. Suppose, for example, it is desired to measure the fundamental or natural wave-length of a transmitting aerial to find out whether it complies with the restrictions: The complete procedure is shown diagramatically in Fig. 34. The aerial wires are represented at A, the earth connection at E, a small spark gap connected in series at S-2 and the secondary terminals of a small induction coil at S-1. The inductance coil of the wave-meter is indicated at L, the small variable condenser at C, the crystalline detector at D and the head telephones at P.

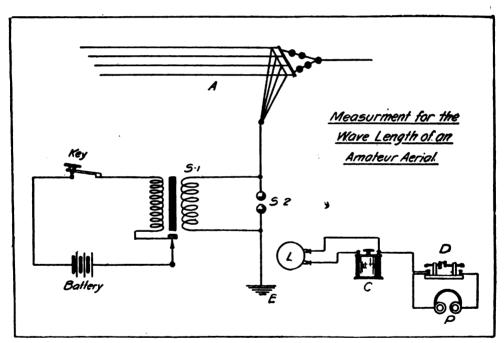


Fig. 34.—Showing How the Natural Wave Length of an Aerial Is Measured With a Wavemeter.

The circuit to the primary winding of the induction coil is closed and the length of the spark gap carefully adjusted until a clear spark note, free from arcing, is obtained. The inductance coil, L, is placed in proximity to the earth lead from the spark gap, S-2, and careful adjustment made of the detector, D. The small condenser, C, is then altered in capacity, and if the natural wave-length of the antenna is within range of the scale of wave-lengths on the wave-meter, a point will be located where loud signals are obtained in the head telephones. This indicates that the circuits of the wave-meter are in resonance with the antenna system and by reference to the table of wave-lengths corresponding to the degrees on the variable condenser the required reading is quickly obtained.

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If the point of resonance is not well defined and the signals can be heard over a considerable number of degrees on the scale, the coil, L, should be moved to a distance from the earth lead until the signals are barely audible. In this manner sharper readings on the scale of the condenser are obtained. If a humming sound is heard in the head telephones over the entire scale of the variable condenser, it indicates that the wave-meter is not of suitable range for the antenna system and therefore one of greater (or possibly lesser) range will have to be constructed.

Should the measurement made as in Fig. 34 indicate that the fundamental wave-length of the aerial system is in excess of 200 meters, the value may be reduced either by decreasing the length of the flat top portion of the antenna or by connecting three or four small condenser plates (connected in series with each other) in series with the aerial system. By proper selection of capacity the natural wave-length of the aerial may readily be reduced to 200 meters.

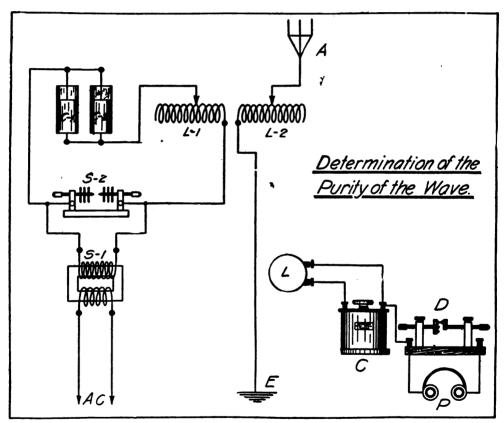


Fig. 35-Showing How the Characteristic (Sharpness or Broadness) of the Radiated Wave Is Determined.

If an oscillation transformer is used to transfer the energy from the spark gap circuit to the aerial wires, as indicated in Fig. 35, and a close degree of coupling is employed between the primary and secondary windings, the wave radiated by the aerial wires is apt to be broad, i.e., the aerial wires may radiate two waves, one of which is far in excess of 200 meters. In this case if the wave-meter is placed in close inductive relation to the earth lead and the spark caused to discharge across the gap, two positions will be found on the condenser scale where the signals are audible.

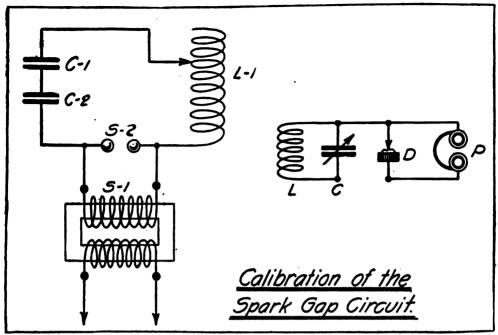
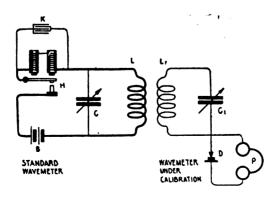


Fig. 36-Showing How the Closed Circuit Can Be Calibrated in Wave Lengths.

But if the primary and secondary windings, L-1 and L-2, respectively, (Fig. 35) are drawn apart, the two positions of resonance will come nearer on the condenser scale until finally but one sharp point of resonance is obtained. The emitted wave from the aerial wires is now said to be "pure" and if the decrement of damping is less than 0.2 the requirements of the government regulation are fully met.

In a similar manner the amateur may measure the wave-length of the spark gap circuit as shown in Fig. 36, and then subtract or add turns at the coil, L-1, or increase or decrease the size of the condenser bank until the closed circuit is in complete resonance with the aerial circuit.

Calibration of a Wave-Meter.—If a calibrated wave-meter can be procured the wave-meter described at the beginning of this chapter can be calibrated by it in simple manner, as shown in Fig. 37.



ig. 37-Calibration of a Wavemeter from a Standard.

Here L and C respectively are the inductance coil and condenser of a standard wave-meter, which is set into excitation by the buzzer, H, and the batteries, B. The winding of the magnets of the buzzer are shunted by a condenser, K, of about 1 microfarad capacity, for which may be substituted, if desired, a non-inductive resistance of about 100 ohms. These are intended to absorb the counter electro-motive force of the buzzer winding.

When the buzzer is set into operation, the wave-meter, L C, becomes a miniature transmitting set, emitting waves of a definite frequency which will be recorded on the wave-meter, L-I, C-I, when it is in resonance with L C. The standard wave-meter, L C, is then set at various wave-lengths and the buzzer set into operation, being carefully adjusted for a clear tone. The capacity of the condenser, C-I, is then altered until a maximum of sound is heard in the head telephones. Obviously L-I, C-I, has the same wave-length as L, C, and a record of the setting is made accordingly. Thus if six or eight readings are taken, covering the entire scale of C-I, points may be located on cross section paper and a curve drawn. Intermediate values of wave-lengths are readily determined from the curve.

For accuracy during calibration, the degree of coupling between L and L-1 must be kept as low as is consistent with the strength of signals. If response is not secured readily at the wave-meter, L-1, C-1, it may be that the values of inductance and capacity are such as not to permit resonance with the standard wave-meter, L C. If so, different values of inductance or capacity must be selected until a resonant response is secured. It is not necessary for the crystal rectifier, shown in Fig. 37, to be connected unilaterally to the wave-meter It may be employed as indicated in Fig. 29

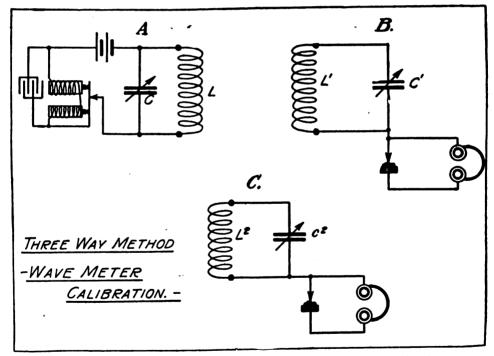


Fig 38-A Very Accurate Method for Calibrating a Wavemeter from a Standard.

A More Accurate Method of Calibration.—To eliminate all possibility of error in calibration due to the added capacity effect of the shunt excitation circuit as in the foregoing procedure, a three-way method may be employed as shown in Fig. 38. Herein B is an accurately calibrated standard wave-meter with a crystal detector and head telephones connected unilaterally. The wave-meter under calibration is represented at C and also has a detector connected unilaterally. At A are the circuits comprising the fixed inductance. L, the condenser, C the buzzer, B, the battery, Bat, and the shunt condenser. By means of the calibration chart furnished with the wave-meter, B, the condenser, C-1, is set at the values giving the wave-length adjustment desired.

The buzzer having been put into operation, the variable condenser of the oscillation circuit, A, is altered in capacity until maximum response is secured at the

head telephones of the wave-meter, B. During this operation the coupling between the coils, L and L-1, should be as loose as is consistent with the strength of signals in the head telephones. The point of resonance having thus been obtained, the coil, L-2, of the wave-meter, C, is placed in inductive relation to L. The capacity of the condenser, C-2, is then altered until a resonant response is secured in the head telephones. Obviously, the wave-length of the wave-meter, C, is now identical with that of the wave-meter, B.

In this manner a number of settings can be taken at the standard wave-meter and resonant adjustments made at the condenser, C-2, until a complete set of calibrations are obtained. If desired, the crystalline detector connected to the wave-meters, B and C, may be connected in series with the head telephones and then in shunt to the condensers. The connection shown, however, affords greater accuracy because the constants of the wave-meters are not so seriously interfered with.

Measurement of the Inductance and Capacity of an Aerial.—Members of amateur organizations having a limited equipment frequently find themselves in need of a simple method for the measurement of the effective inductance and capacity value of an aerial. Such a measurement may be made easily, but it calls for the use of a wave-meter and a standard of inductance or capacity.

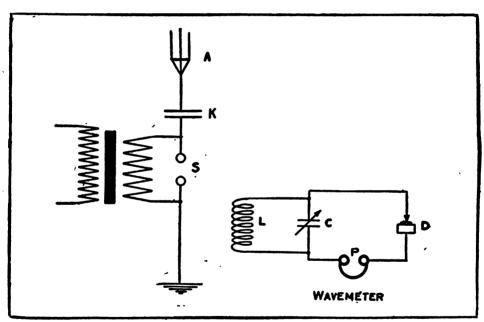


Fig. 39-Measurement of the Capacity of an Aerial.

Therefore in measuring the capacity of an aerial, a high voltage Leyden jar of a known capacity, in addition to the wave-meter, must be secured. If a standard Leyden jar can be obtained it will serve the purpose admirably, as all are coated for that height, which will give a capacity of .002 microfarad. The capacity of the jar, however, is preferably .001 microfarad, and, therefore, two of the jars referred to should be placed in series.

With the known condenser at hand the capacity of the aerial is obtained by two simple measurements, as shown in the drawings (Figs. 34 and 39). First, the spark gap, S-2, connected to the secondary terminals of the induction coil is placed directly in series with the antenna circuit. With the spark discharging across the gap the wave-meter (with crystal and head telephone) is brought in inductive relation to the aerial and preferably placed near to the earth lead. The capacity of the condenser is then altered until a point of maximum intensity of signals is found by turning the handle of the variable condenser. The wave-length reading so obtained is known as the natural wave-length of the aerial which we shall designate by \(\lambda_{\text{int}} \).

The known condenser, K, is then placed in series with the aerial as indicated in Fig. 39. The spark gap is energized and a second wave-length reading taken, which may be called λ_1 . Obviously λ_2 will be less than λ_1 .

After these two readings have been taken their values may be substituted in

the following formula:

$$K_{1} = \frac{\lambda_{1}^{2} - \lambda_{2}^{2}}{\lambda_{1}^{2}} \times K.$$
 (No. 1)

Where $K_1 =$ the capacity of the aerial in microfarads, $\lambda_2^1 =$ the square of the natural wave-length of the aerial, $\lambda_3^3 =$ the square of the wave-length of the aerial with K series, K = the condenser of known capacity,

When the value of capacity is thus obtained, the inductance of the aerial can be calculated by the following formula:

$$L = \frac{\lambda_1^2}{3552 \text{ K}}$$
 (No. 2)

Where L = the inductance of the aerial system in centimeters.

 λ_1^2 = the square of the natural wave-length of the aerial, K = the capacity of the aerial in microfarads as determined in the first reading.

The value of L may be converted from centimeters to microhenries by dividing by 1,000.

The values of inductance and capacity after determination can be checked up by the following formula: -

$$\lambda_1 = 59.6 \ \lor \ L \ K \tag{No. 3}$$

Where λ_i = the natural wave-length as previously measured,

L = the inductance of the aerial system, K = the capacity value of the aerial system.

Reducation of Wave-Length by a Series Condenser.—Often it is desired to determine what value of capacity a series condenser should have to reduce the wavelength of the aerial to a definite value. Having already determined the capacity and inductance value of the present aerial in microfarads the following formula can be used:

$$K_{i} = \frac{\lambda_{i}^{3} K}{3552 L K - \lambda_{i}^{3}}$$
 (No. 4)

Where K_s = the capacity of the series condenser required to reduce the antenna to a certain wave-length

 L = the inductance of the present aerial in centimeters,
 K = the capacity of the present aerial in microfarads,
 λ_s² = the square of the new wave-length desired.
 Increasing the Wave-Length of an Aerial.—It is desirable often to determine the value of an inductance required to raise an aerial of given wave-length to a higher wave length; then letting

L = the value of inductance of the present aerial determined as in No. 2 in centimeters,

 $\lambda_1 =$ the wave-length corresponding to this value of inductance,

 λ_1 = the new wave-length desired,

i = the value of inductance to be inserted to obtain
$$\lambda_i$$
; then
$$1 = \frac{\lambda_i^2 - \lambda_i^2}{\lambda_i^2} \times L \qquad (No. 5)$$

A, is obtained from the wave-meter by excitation of the aerial with the spark gap in

Measurement of the Inductance of an Aerial.—The effective inductance of an aerial also can be determined by the insertion of an inductance coil of known value in series with the aerial. The method is similar to that employed when obtaining the value of capacity by the insertion of a known condenser.

The natural wave-length having been obtained, as shown in Fig. 34, an inductance coil of known value is inserted in series with the aerial, as in Fig. 40, and a new

reading of wave-length is obtained which may be called h.

These values can then be substituted in the following formula:

$$L = \frac{\lambda_1^2}{\lambda_2^2 - \lambda_1^2} \times 1$$
 (No. 6)

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Where L = the inductance of the aerial system in centimeters,

 $\lambda_i = \text{the natural wave-length of the aerial.}$

 λ_3 = the wave-length of the aerial with the known inductance 1 in series.

1 = the inductance coil of known value.

For amateurs' use a standard of inductance can be made by closely winding a mandrel of glass or wood 5 inches in diameter with twelve turns of No. 10 D.B.R.C. standard wire. At a wave-length of 400 meters, corresponding to a frequency of 750,000 cycles, the inductance is approximately 15,000 centimeters, or fifteen microhenries. This standard can be employed effectively in measuring the inductance of an aerial by the method described.

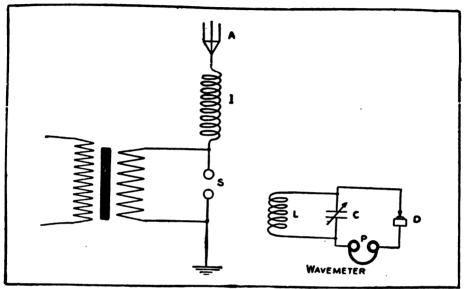


Fig. 40-Measurement of the Inductance of an Aerial.

How to Plot a Resonance Curve.—The resonance curve of a radio transmitter is a graphic equation showing the relation between current amplitude and frequencies or wave-lengths at points on and off the fundamental frequency. The value of the plotting lies in the fact that it enables the experimenter to obtain, in a general way, the over-all distribution of energy in the emitted wave, the decrement of damping and the relative power of the two waves, if present.

To plot the resonance curve of a radio transmitter, a wave-meter is required in series with which is connected either a hot wire milliammeter or a hot wire milliwattmeter. The milliammeter should have a range of, say, forty to 240 milliamperes, while the watt-meter may have a scale reading of .01 to .1 watt. The latter instrument is preferably connected to the secondary winding of a step-down transformer, the primary winding of which is connected in series with the circuit to the wave-meter. This transformer, as a rule, is made up of Litzendraht wire, the primary consisting of ten turns wound on a wooden spool, about 1½ inches in length by 1 inch in diameter. The secondary winding consists of five turns of the same wire wound directly over it with a single layer of Empire cloth between.

The wattmeter having been connected accordingly, a few preliminary determinations are made in order that the proper inductive relation between the coil of the wavemeter and the antenna circuit may be found. Care must be taken that the wattmeter is not burned out at the point of resonance. The proper inductive relation having been obtained by trial, the coil of the wave-meter is placed in such position as to give a near maximum scale deflection of the wattmeter at the peak of resonance for the longer wave. If the maximum deflection of the wattmeter is obtained at resonance, it is evident that there will be a decrease of current at wave-lengths off resonance, the reduction being dependent upon the decrement of the circuit.

Readings of the indicating instrument having been observed at resonance, corresponding readings are begun off resonance at a point where the indicating instrument shows a small scale deflection, say, .o. watt. Similar observations are made at other wave-lengths approaching resonance and beyond resonance until a full set of calibra-

tions are obtained; that is to say, the readings are continued to a point beyond resonance where a nearly zero deflection of the wattmeter is obtained.

A diagram of connections and the relative positions of the apparatus for this determination are shown in Fig. 41, where the closed oscillatory circuit of an amateur radio transmitter is represented by the primary winding, L, the high potential condenser, C, and the spark gap, S. The antenna system includes the secondary winding, L-1, the aerial tuning inductance, L-2, and the earth wire, L-3, which preferably has a single turn inserted scries. The coil of the wave-meter, L-4, is placed in inductive relation to L-3 and is in series with the primary winding of the step-down transformer, T, and the variable condenser, C-4. The wattmeter is indicated at I.

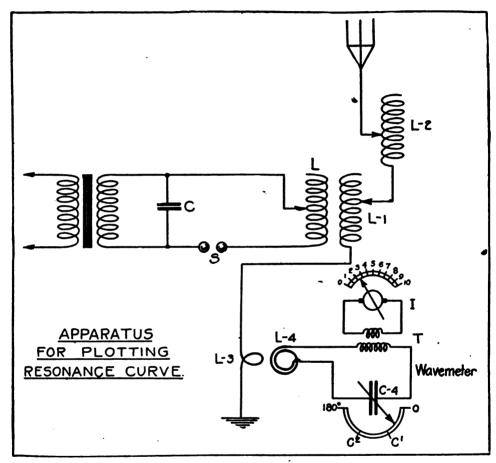


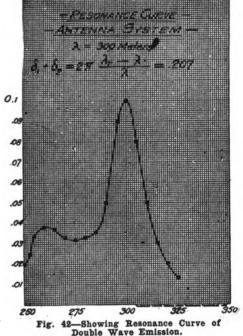
Fig. 41-Complete Circuits for Plotting a Resonance Curve of the Antenna Oscillations.

Assume, for example, that the spark gap, S, is discharging and that the closed and open oscillatory circuits are in exact resonance; furthermore, that the points, C-1 and C-2, on the variable condenser, C-4, are the peaks of resonance in the double wave. Then, as the pointer of the variable condenser is moved from zero position toward C-1, the reading of the wattmeter increases, until the point, C-1, is passed, when a decrease takes place. An increase of current again takes place as C-2 is approached followed by a decrease when the peak of resonance is passed. If the setting of wave-length for the wave-meter is noted and the corresponding deflection of the hot wire wattmeter observed, the data thus obtained may be plotted in the form of a resonance curve in the following manner (see Fig. 42).

Placing in one column the wave-lengths corresponding to the condenser scale of the wave-meter, and in the second column the corresponding deflection

of the hot wire wattmeter, co-ordinate points are laid off on cross-section paper through which a common line or curve is drawn. A typical set of readings follows:

Wave-length of the wave-meter	Corresponding deflection of the hot wire wattmeter
250	.02
255*	.034
260	.038
265	.037
270	.034
	.032
275 280	.033
285	.035
290°	:05
295	.09
300	.I
305	.08
310	.05
315	.03
320	.02
325	.013



With the cross section proper before us, the wave-length readings are laid off horizontally as indicated in Fig. 42 and are known as the abscissas of the points on the curve, while the hot wire wattmeter readings are laid out vertically and are known as the ordinates of the points in the curve Take, for example, the wave-length of

290 meters; the corresponding hot wire wattmeter deflection is .05. Then follow the vertical line corresponding to 290 to that point where the horizontal line is met corresponding to .05 and place a dot or a cross, as indicated. Proceed in a similar manner throughout the entire set of readings until a complete set of points for the curve are located. Then draw a line joining them.

Now, if the coil, L-4, of the wave-meter is allowed to remain in the same position to the coil, L-3, and various degrees of coupling are employed between the primary and secondary winding of the oscillation transformer, L and L-1, the curve in Fig. 42 will become sharper or broader, accordingly, as the coupling is decreased or increased. In this manner a comparison may be made of the relative sharpness of the radiated waves allowing to some extent a predetermination of the amount of interference to be expected. If the coupling between L and L-1 is sufficiently decreased, the lower peak of resonance, which in the curve exists at about 260 meters, may completely disappear and a single sharp maximum peak result. The resonance curve shown in Fig. 42, is not that of a "pure" wave in compliance with the United States restrictions. To be considered as such the energy in the lesser wave must not exceed ten per cent. of that in the greater.

Should the wave-meter indicate no sharp or defined peak of resonance, it may be that an excessive coupling is in use between L and L-I, or that high resistance joints or poor connections exist in the antenna circuit. Again, this may be due to leakage of the insulators; the remedy, of course, is obvious.

Using the same apparatus as that employed for plotting a resonance curve, the amateur experimenter may obtain other curves indicating the wave-length of the open and closed oscillatory circuits with various turns of inductance in use at the primary and secondary windings. For example, if it is desired to determine the increase in wave-length by the addition of turns in the closed circuit, the apparatus is set up as shown in Fig. 43. The coil of the wave-meter, L-4, is placed in close inductive relation to L, but not too close to burn out the wattmeter, I. Starting with one turn in the closed circuit, the corresponding wave-length is read on the wave-meter at the point where the maximum deflection of the wattmeter is obtained

(with spark, of course, discharging). Turns are then added progressively at L throughout the series until a full set of readings is obtained. A typical case follows:

Turns	Corresponding Wave-Lengths
I	100
2	145
3	200
4	242
5	242 295
6	34 5
7	395

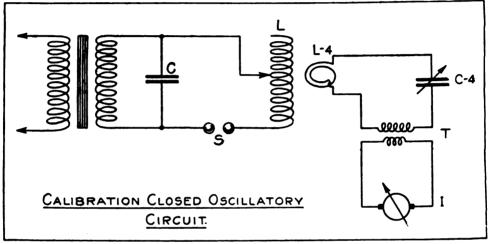


Fig. 43-Showing Calibration of the Closed Oscillation Circuit.

Plotted in curve form these data appear in Curve A, Fig. 44. Here the wave-lengths in meters are the abscissas of the points on the curve and the helix turns the ordinates of the points on the curve. The corresponding wave-lengths between complete turns on the helix can be calculated readily by following the abscissas to the base line or the horizontal axis.

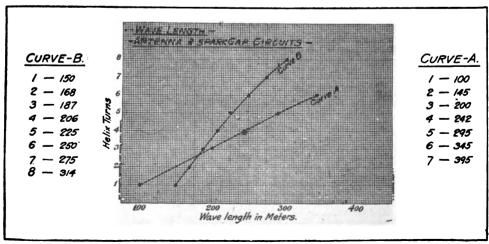


Fig. 44-A Typical Set of Curves of Closed and Open Circuits.

We can plot the readings for the open circuit of a transmitting system in a similar way, but in this case a spark gap must be connected in series with the antenna system and in turn connected to the secondary winding of an induction coil. Generally the current flowing in the antenna circuit is not powerful enough with this connection to operate the wattmeter, or, in any event, the spark discharge is too irregular to permit a reading of the wattmeter to be observed. It is therefore preferable to shunt the wave-meter by a crystalline detector and head telephone, the point of resonance being located by the maximum sound in the receiver. A diagram of connections for obtaining this reading is given in Fig. 45. Here the secondary winding of

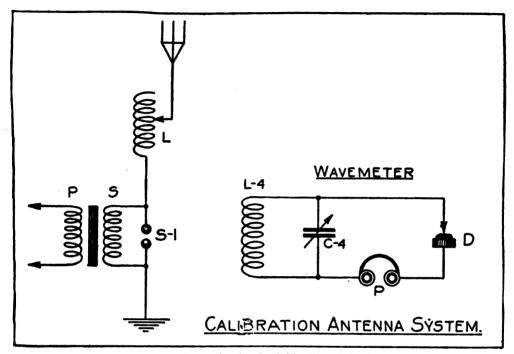


Fig. 45-Showing the Connection for the Calibration of the Antenna System

the oscillation transformer is represented at L and has a variable tap-off. The spark gap in series is indicated at S-1, the primary and secondary windings of the induction coil at P and S. The wave-meter, L-4, C-4, is shunted by the crystalline detector, D, connected in series with the head telephone, P. Various turns are added in the circuit at L and corresponding wave-lengths readings made on the wave-meter. A typical set of readings follows:

Turns I 2 3 4 5 6	Corresponding Wave-Lengths in Meters 150 168 187 206 225 250 275
7 8	275 314

These data appear in the curve, B, on Fig. 44 and intermediate values lying between the complete turns may be taken as in the previous case.

It is recommended that curves of the latter type be prepared at each amateur station and posted in the apparatus room for quick reference. In this manner the wave-length of the open and closed oscillatory circuits may be quickly changed, with the assurance that the two circuits are in exact resonance. Of course, the radiated wave is somewhat altered in length as the coupling between the primary and secondary, windings is changed. Therefore at each standard wave-length various degrees of

coupling should be tried out, until the one most suitable for local conditions of interference and effectiveness is determined.

Approximate Calculation of the Capacity and Inductance of an Aerial.—An approximate estimation of the capacity of an aerial in micro-farads may be made from the dimensions. For example: The capacity of a single wire aerial approximates .0000018 micro-farads for each foot in length; hence a single wire aerial with a flat top portion 100 feet in length and a lead-in-wire of 50 feet has a capacitance of .0000018 x 150 or .00027 micro-farads. For an aerial of the same dimensions having two wires spaced about 6 feet apart, the value obtained previously (.00027) is multiplied by 1.6, thus giving a resultant value of .000432 micro-farads which may be taken as fairly

The capacity of a four-wire aerial spaced 2 feet apart averages .0000025 micro-farads for each foot in length; therefore, a flat top aerial 60 feet in length, 40 feet in

height, represents a capacitance of 100 × .0000025, or .00025 + micro-farads.

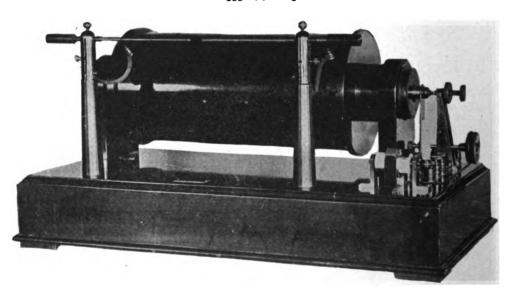
For an eight-wire aerial, the wires spaced 2 feet apart, the capacitance per foot is slightly increased. It approximates .000003 micro-farads; hence an eight-wire aerial 60 feet in length, 40 feet in height has a capacity of approximately .0003 micro-farads. Although not strictly accurate, the foregoing method enables the junior experimenter to obtain a fair idea of the values of capacity with which he deals in wireless telegraph aerials.

After the natural period of the aerial is known and the capacity calculated, the approximate value of the antenna inductance is obtained from the following formula:

$$L = \frac{\lambda^2}{355^2 \times C}$$

An aerial with a natural period of 200 meters and a capacity of .0003 microfarad has inductance capacity as follows:

$$L = \frac{200^{\circ}}{355^{\circ} \times .0003} = 37,500 + centimeters.$$



Chapter VI

The Measurement of the Logarithmic **Decrement**

ONTRARY to the opinion often expressed, the practical measurement of the logarithmic decrement of a wireless transmitter is a simple proceeding entirely within the scope of the amateur's capabilities. of the measurement lies in the fact that it enables the experimenter to determine in advance the general distribution of energy in the radiated wave and the amount of interference to be expected from a given transmitter. With the aid of the following formula he can calculate the number of complete oscillations in a wave train before the last oscillation has attained a value of .o. of the amplitude of the initial oscillation:

$$M = \frac{4.605 + \delta}{\delta}$$

Where

M = complete number of oscillations per wave train.

 δ = decrement of the antenna circuit of the transmitter.

The quantity & is the Naperian logarithm of the ratio of two successive oscillations in the same direction (as per Fleming).

It has been shown by V. Bjerknes that when two radio-frequency circuits are magnetically coupled the combined decrement of damping is given by the following formula:

$$\delta_1 + \delta_2 = 2 \pi \left(I \frac{\lambda_1}{\lambda_r} \right) \sqrt{\frac{I^2}{I_r^2 - I^2}}$$
 (No. I)

Where (in the case where a wave meter is coupled to the antenna system of a wireless telegraph transmitter)

 δ_1 = decrement of the circuit under measurement

 $\delta_2 =$ decrement of the decremeter

 λ_r = wave-length at resonance

 λ_1 = wave-length not more than 3 per cent. to 5 per cent. off resonance t^2 = current indicated in a measuring instrument connected in series with the wave-meter when the wave-meter is adjusted to λ_1

 I_{r}^{2} = current indicated as in the foregoing when the wave-meter is adjusted

For accuracy δ_2 must be small as compared with δ_1 .

In terms of the condenser capacity of the wave-meter the foregoing formula can be written as follows:

 $\delta_1 + \delta_2 = \pi \frac{C_r - C_1}{C_r} / \frac{I^2}{I_r^2 - I^2}$ (No. 2)

where.

 C_r = capacity of the wave-meter condenser at resonance,

C₁ = capacity of the wave-meter condenser of a certain point off resonance. It has been found for practical purposes that if the value of I² is selected to have one-half the value of I², the formula is sufficiently accurate; hence the integers underneath the radical may be cancelled and the combined and total decrement of the two circuits obtained from the following simple

formula:

$$\delta_1 + \delta_2 = \frac{C_r - C_1}{C_r} \pi \quad \text{(No. 3)}$$

Now, it is found by experiment that the resonance curve of a radio transmitter is not symmetrical and, therefore, different values for the decrement will be found accordingly, as the measurement is made on either side of the maximum ordinate. Consequently the results will be more accurate if values

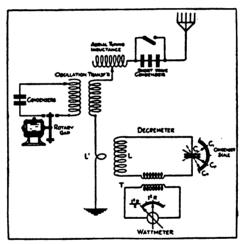


Fig. 46-Apparatus for Determining the Logarithmic Decrement.

for the capacity of the condenser are taken above and below resonance, the corresponding values of current in the wattmeter being one-half that value obtained at resonance; therefore the mean value for the decrement is as follows:

$$\delta_1 + \delta_2 = \frac{C_2 - C_1}{C_2} \frac{\pi}{2}$$
 (No. 4)

Where.

C₂ = the capacity of the condenser at a point above resonance where the reading of the wattmeter falls to one-half that obtained at C_r and

 C_1 = the capacity of the condenser at a similar current value below C_r .

Although it is possible to make this measurement with a hot wire ammeter connected in series with the wave-meter, it is recommended that the high frequency wattmeter be employed.

The Apparatus.—The principal pieces of apparatus required to make the foregoing measurements are a wave-meter (one of amateur construction will do) and a high frequency wattmeter having a range from .01 to .1 watt. The latter instrument can be purchased for about \$30. The condenser of the wave-meter should have a calibration chart showing the capacity in microfarads corresponding to the scale reading.

When measuring the decrement the wartmeter is generally connected to the wave-meter, as shown in Fig. 46, where L is the inductance coil of the wave-meter, C the variable condenser, and T a small step-down transformer which generally has about five turns in the secondary winding and, say, ten turns in the primary winding. These turns are wound on a mandrel about 1¾ inches in diameter.

The secondary winding is connected in series with the low range wattmeter while the primary winding is placed in series with the inductance coil and the condenser of the wave-meter.

As the wattmeter is a consisting instrument are a charillater.

denser of the wave-meter. As the wattmeter is a sensitive instrument, care should be taken not to place the coil of the wave-meter too near to the antenna circuit to be

measured or the wattmeter may be burned out.

The coil, L, of the wave-meter is now placed in inductive relation to the antenna system at the single turn of wire, L-I. The key of the transmitting apparatus is then held down continuously and the spark gap adjusted for clearness and smoothness of the note. This is followed by a variation of capacity of the wave-meter condenser until a maximum reading is obtained on the wattmeter which, of course, is the resonant adjustment of the two circuits under measurement. The inductance coil, L, is then waved about that is to say, the coupling between it and the antenna coil. adjustment of the two circuits under measurement. The inductance coil, L, is then moved about—that is to say, the coupling between it and the antenna coil, L-1, is changed until the maximum reading of the watt-meter falls (as a matter of convenience) on some even number, say 0.08 watt. The capacity of the condenser corresponding to this reading is, of course C_r . The pointer of the condenser is then set at a lower value of capacity, C_1 , where the reading of the wattmeter is 0.04 watt. A value of capacity above C_r is then observed (C_2) where the reading of the wattmeter again falls to 0.04 watt. Substituting these values of capacity in formula No. 4 the combined decrement of the two circuits is obtained at once. The relative positions of the pointer on the variable condenser and also on the wattmeter corresponding to the values of on the variable condenser and also on the wattmeter corresponding to the values of

C₃, C₁, and C_r, are shown in Fig. 46.

Now, the decrement of the wave-meter must be subtracted from the total value obtained in equation No. 4 to give the decrement of the antenna itself. The value for the instrument can be obtained by direct calculation or by actual measurement.

If the variable condenser of the wave-meter is well constructed so that the capacity varies directly with the scale reading, the condenser degrees can be substituted in the formula for the actual values of capacity. If it is definitely known that the condenser possesses the "straight line law of calibration" it is not necessary that the value of either the inductance or the capacity be known or that the combination be calibrated directly in wavelengths in order to measure the decrement, provided they are of such value as to allow resonance with the circuit under measurement. If the members of an amateur club have on hand a variable condenser of good construction they can fit to it inductance coils of such value as to allow resonance with the transmitting circuits they desire to measure. This apparatus, with the high frequency wattmeter, is all that is required for measurement of the decrement of damping.

Calculation of the Decrement of the Wave-Meter.-Having been initiated thus far in the measurement of the logarithmic decrement, it is in order to present a method for obtaining the decrement of the wave-meter itself. After the value of $\delta_1 + \delta_2$ is obtained, the wave-meter coil is allowed to remain in the same position in reference to

tained, the wave-meter coil is allowed to remain in the same position in reterence to the antenna system. A piece of resistance wire, R (Fig. 47), is stretched tightly between two binding posts and connected in series with the circuits of the wattmeter. The amount of wire in use is gauged by the sliding contact, T-1. A piece of No. 28 German silver wire about 15 inches in length will be found satisfactory.

With the pointer of the condenser set at C_r, or resonance, the spark gap is energized and sufficient resistance added at R until the reading of the wattmeter falls to exactly one-half that obtained in the original resonance adjustment, 0.04 watt. The condenser of the wave-meter is then shifted to either side of resonance to such a value of conseive that will give one-half the wattmeter reading obtained at C_r viz. 0.02 watt of capacity that will give one-half the wattmeter reading obtained at C_r, viz., 0.02 watt. Let the reading below resonance be represented by C_s and the reading above resonance by C_s. Then the following formula is applicable:

$$\delta_1 + \delta_2 + \delta_3 = \frac{C_4 - C_3}{C_r} \times 1.57 \qquad (No. 5)$$

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Now, & is the decrement due to the addition of the resistance. R. and it is evident that if the value of $\delta_1 + \delta_2$ is subtracted from $\delta_1 + \delta_2 + \delta_3$, the value of δ_3 is at once obtained.

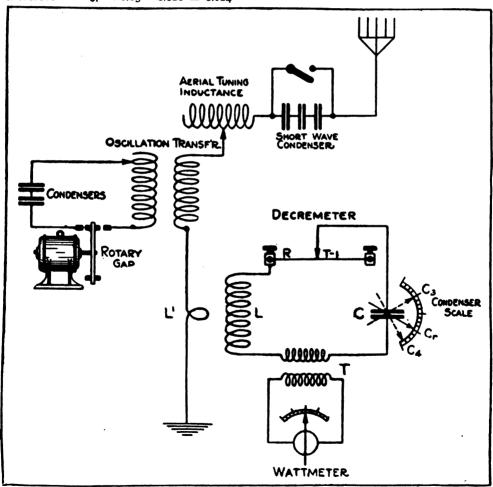
It has been shown by Fleming and others that if the value of & is thus known we may evaluate the decrement of the wave-meter δ_2 by the following formula:

Letting V stand for the value obtained in equation No. 4 and V' for the value

in No. 5 then

$$\delta_z = \frac{V^i \ \delta_s}{^2 \ V - V^i}$$

Hence by subtracting the value of δ_2 from $\delta_1 + \delta_2$ we have δ_1 , the decrement of the aerial circuit under test. Suppose for exampe



Determining Decrement of the Antenna Oscillations and Decrement of the Wavemeter. Fig. 47-Compete Apparatus for

Throughout the entire series of measurements described in this chapter extreme care must be taken not to change the coupling between the wavemeter and the circuit under measurement. The power input to the transformer also must be kept as constant as possible and the spark discharge should remain uniform.

If oscillations of two frequencies are present in the antenna circuit the decrement measurement can be applied to each separately. If means are at hand for obtaining the following values the decrement of the wave-meter can be calculated by the formula:

$$\delta = \frac{\pi}{2} \quad R^1 / \frac{C}{L}$$

Where R1 = high frequency resistance

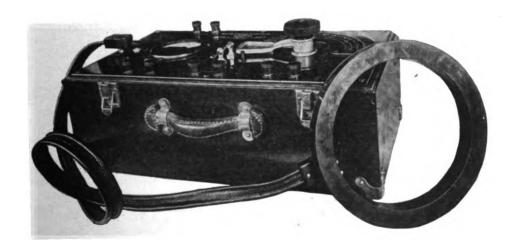
C = capacity,

L = inductance.

R1 C and L must be expressed in corresponding units.

Definition of a Pure and Sharp Wave.—It may be of interest to amateurs to define here the difference between a pure and a sharp wave, according to the United States regulations. A transmitting set is said to radiate a pure wave when if current flows a two frequencies in the antenna circuit, the energy in the lesser wave is not more than ten per cent. of that in the greater wave. Thus, if the wattmeter, as used in Fig. 46, should indicate 0.00 watt at the peak of the longer wave-length and slightly less than 0.01 watt at the second wave-length, the regulations are fully complied with.

A sharp wave is one the logarithmic decrement of which is less than 0.2 per complete oscillation. This value is obtained by the method just described.



Chapter VII

Examples of 200 Meter Amateur Sets

MANY amateurs follow the practice of commercial companies by mounting their apparatus compactly on an insulating panel, but others prefer to have the various parts of the equipment placed so that they are easily accessible for repair or adjustment. For those who follow the latter plan a suggested lay-out for the apparatus of a station is shown in the drawing Fig. 48, wherein particular care has been taken to place the oscillation transformer, spark gap and condenser near to one another, thus allowing short connecting leads—a self-evident requirement for a 200-meter set. In addition, simplicity of installation was kept in view to avoid the usual bungling and criss-crossing of circuits often observed in amateur equipments.

The operating table is placed about 32 inches from the floor and is approximately 30 inches in width. It may be from 6 to 8 feet in length, according to the space available, and is, of course supported at intervals by 2-inch by 4-

inch uprights.

Under the table and to the left in the drawing is placed the high potential transformer, which, for the requirements of the amateur station, must not exceed the primary input of I k.w. with a secondary potential varying between 12,000 and 20,000 volts. The transformer shown in the drawing is of the open core type, and is of more suitable design for amateur installations than one of the closed core type, unless the latter is constructed so that it has a certain amount of magnetic leakage. The secondary terminals of the transformer are insulated by corrugated hard rubber bushings, B-I, capable of withstanding an applied potential of 20,000 volts without leakage. A safety gap is provided to protect the windings of the transformer and the condenser in the event that the spark gap proper is abnormally lengthened. It merely consists of 2 discharge electrodes connected to the secondary terminals of the transformer and separated sufficiently to prevent discharge when the regular spark gap is in use.

The High Potential Condenser.—The condenser rack mounted on the top of the operating table is insulated from it by the corrugated porcelain or electrose legs, B-3. For operation at the wave-length of 200 meters, the unit may consist of about sixteen plates of glass, with an average thickness of one-eighth of an inch, the other dimensions being 14 inches by 14 inches, covered with tinfoil 12 inches by 12 inches. The plates are divided into two 8-plate banks, connected in parallel, and two banks are finally connected in series. The leads from the secondary winding of the transformer are led up through the table through the insulating bushings, B-2, and are attached to the binding posts, B-4, which are mounted on hard rubber slabs on the edge of the condenser rack. No. 14 insulated D B R C. wire will easily

handle the output of the secondary winding, but a neater job will be effected if 3/16-inch copper tubing is employed, as it may be bent at right angles, wherever necessary, and is self-supporting when properly attached to the binding posts, B-1.

The connecting tabs of tinfoil from the plates of the condenser are attached to the binding posts, B-4. To afford better protection for the plates, the entire unit comprising the wooden rack and the plates may be immersed in a metal or porcelain tank filled with a good grade of insulating oil. However, this design often is not found suitable, as it is difficult, even with the best compound, to keep the tinfoil on the plates when they are thus immersed, unless they are stacked up and closely bound together with insulating tape

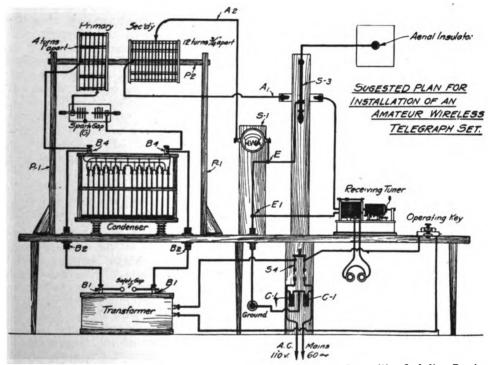


Fig. 48—A Suggested Plan for Installation of an Amateur ½ K. W Transmitter Including Receiving Apparatus.

The Oscillation Transformer.—To keep the connecting leads from the condenser and spark gap to the primary winding of the oscillation transformer at a minimum length, the oscillation transformer is mounted on a wooden rack supported by the pillars, P-1, with the cross rod, P-2. The primary winding is permanently fixed to this rod, but the secondary winding may be slid backward and forward thus allowing a variation of the coupling

The primary winding has about four turns of 3/16-inch copper tubing, with the turns spaced 1 inch apart. The winding may be from 8 to 10 inches in diameter. The secondary coil contains from eight to ten turns, spaced 34 of an inch apart, and may have the same size of tubing. To keep the radiated wave pure and within the limits of the law, it generally is not necessary to have the secondary winding inside of the primary winding; usually there is an air space intervening of from 2 to 3 inches at the most effective degree of coupling. It is quite essential that both the primary and secondary turns be

well insulated and, in consequence, the supports of either must be made up of some good insulating material, such as a high grade of hard rubber, procelain, bakelite or micarta.

A spark gap, G, is placed between the condenser and oscillation transformer and may take one of several designs. It is the custom at the more advanced amateur station to use a gap of the non-synchronous type, which usually consists of an insulating disc, 6 to 8 inches in diameter, with eight discharge electrodes, mounted on the shaft of a motor having a speed of 2,400 revolutions a minute. At stations lacking a source of direct current the terminals of the motor must be connected to the A C power mains, and since the majority of such motors have a synchronous speed of 1,800 revolutions a minute, the diameter of the disc may be slightly increased and fitted with from ten to fourteen electrodes.

The terminals of the motor are connected to the top terminals of a 50ampere power switch by means of which it can be started and stopped. Of course various methods can be devised for starting the motor, one being to fit the antenna switch with an extra set of contacts, so that when it is thrown into transmitting position, the circuit to the motor is closed For the sake of simplicity, however, the beginner is advised to employ the method shown in the drawing. Owing to the noise from the gap, it is desirable to enclose it in a suitable muffling box, which may be constructed after various designs, but whatever the construction, particular care should be taken to have short connecting leads to the condenser and oscillation transformer. It is obvious that the terminals of the spark gap must be well insulated from the containing box and also from the wall upon which the box is mounted. The gap can be effectively cooled by drilling two holes in the side of the box and fitting the rotor with a cooling fan. The burned gases are thus removed and a fresh supply of air constantly fed. This will tend to maintain the insulating qualities of the gap supports inside the box and prevent leakage

The Antenna Switch.—The antenna switch, S-3, is of the simplest possible design, merely consisting of a single blade, double-throw switch, which, when thrown to the left, connects the secondary winding of the oscillation transformer to the antenna and to the right makes contact with the connection to the receiving tuner. In the center position the blade of this switch connects the antenna to the earth lead of the transmitting apparatus at the point, E, making an efficient lightning switch. To comply with the underwriters' regulations, this switch must be capable of carrying a current of 100 amperes and from the standpoint of wireless apparatus requirements, all contact studs should be separated at least 6 inches to prevent the direct discharge of antenna potentials over the insulating base. It is, of course, evident that the lever and studs of the switch must be mounted on a good insulating material, which in no case should be of slate. A good grade of hard rubber, bakelite or micarta will in this case fulfil the requirements

A connection is extended from the aerial wires to the lever of the changover switch through the insulator, I, which is a hard rubber tube with walls % of an inch in thickness, with a ¼-inch hole. A brass rod is threaded at both ends and fitted with nuts and connecting lugs, passed through the hole and firmly fastened in place. As an alternative a hole can be drilled through a window pane and a brass rod passed through it, but the incoming leads of the aerial must then be well backstayed to remove the strain from the glass

The right hand stud of the antenna change-over switch is connected to the antenna post of the receiving tuner and the earth connection from the latter makes contact at the point, E-1, to the wire to which the transmitting apparatus ground lead is attached. With this type of switch in use it is intended

that the receiving tuner be fitted with a shunt switch to protect the detector from the local oscillations of the transmitter during the period of transmission.

The Transmitting Key.—The transmitting key is mounted immediately to the right of the tuner, being placed far enough from the edge of the table to allow the sending operator's elbow to rest on the ledge. It should be capable of carrying a current of 10 amperes without arcing. These keys are generally fitted with platinum or silver contacts.

The hot wire ammeter may be connected either in the aerial lead, A-1, or in the earth lead, A-2. If connected in the former, it should be mounted on an insulating stand made of a sheet of hard rubber or other suitable material of the correct dimensions to support the meter. The base should be insulated from the wall by hard rubber legs. It is not entirely necessary that this meter be mounted on an insulating support when connected in series with the earth lead, but it is a requirement of the underwriters in many cities that this bedone, regardless of the point at which it is connected. It should be noted in the diagram that the meter is mounted on an upright piece of 1-inch wood, which is fastened to the table by means of iron brackets in the rear.

The Earth Connection.—For amateur stations located in isolated districts where there are no water mains or steam pipes for connection to the earth, a satisfactory earth connection can be made from 250 square feet of galvanized sheet iron or copper, laid in moist earth, let us say, to a depth of from 5 to 8 feet. A connection of copper strip 2 inches in width should be firmly attached and soldered to the plates and led directly to the oscillation transformer of the transmitting apparatus. Additional contact can be made with the moist earth by driving several lengths of gavanized iron pipe with a sledge hammer to a depth of 8 or 10 feet under the copper plates previously mentioned. Surface grounds have also been effectively employed at amateur stations. These consist of several copper wires laid directly under the antenna system, or galvanized wire netting. This is of the kind used in country places for fencing.

Connection should not be made to the gas mains of any house, as in many cities the gas mains are fitted with an insulating bushing near to the meter, which effectively disconnects the pipes from the earth. At every station, where it is possible to do so, a piece of copper ribbon, let us say 2 inches in width, or a piece of heavily insulated No. 2 or No. 4 D. B. R. C. wire, should be attached to the water main on the street side of the house meter. In many homes and apartment houses it is not possible to do this, and, therefore, connection must be made to the steam pipes, to the water mains inside the house, or to the steel frame of the building, if such exists.

The underwriters require in some localities that the earth lead from the apparatus be thoroughly insulated up to the point where actual connection to the earth capacity is made; hence in many installations it is necessary to construct special insulators to hold the copper ribbon away from the structure to which it is attached.

The switch, S-4, breaks the main A. C. line and is of 50 amperes capacity. It is fitted with fuses of the enclosed type and connection from the main should be attached to the bottom side of the fuses. The connections from the switch to the transformer and key are of No. 12 lead covered cable, securely strapped in place by means of small brass pipe straps.

A ½-k.w. amateur transmitting set of different-design is shown in the diagram of Fig. 49 which includes a ½-k.w. open core transformer, four standard copper plated Leyden jars of the type furnished by the Marconi Company (capacity .002 microfarad each), an oscillation transformer mounted directly above the condenser, a non-synchronous rotary spark gap, an aerial changeover switch and a hot wire aerial ammeter. The majority of experimenters are aware that the connections in the closed oscillation circuit of an amateur wireless telegraph transmitter must be exceedingly short to permit the use of a condenser of large capacity for a given wave-length and since the experimenter is restricted to a condenser of .008 microfarad capacity, this value is used in the set described.

It is to be noted that the condenser jars are mounted in a wooden rack, the base of which is covered with a sheet of copper. Small upright posts, having 4 holes 4¾ inches in diameter (cut out by a jig saw) to take the jars, support the top piece shown in Fig. 2.

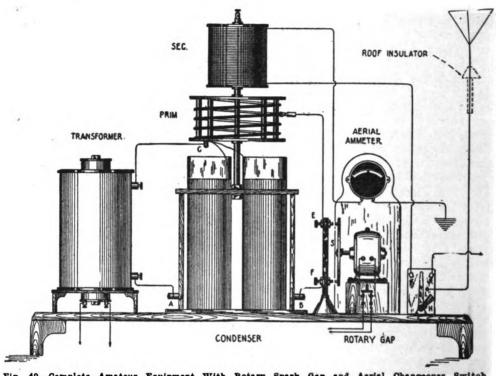


Fig. 49-Complete Amateur Equipment With Rotary Spark Gap and Aerial Changeover Switch.

Fastened to the top of the rack is an upright rod of metal, hard rubber or wood, which supports the primary and secondary windings of the oscillation transformer. It will be seen that with this arrangement of apparatus the connections in the closed circuit are exceedingly short and the complete closed oscillation circuit can be traced out in the following manner:

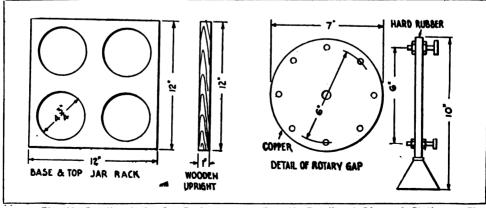


Fig. 50-Details of the Jar Rack.

Fig. 51—Details of Disc and Stationary Electrodes for Rotary Gap.

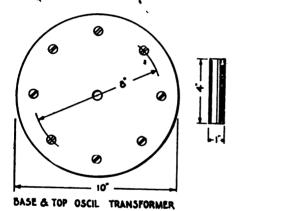
The four connections from the inside coating of the four Leyden jars are connected to the binding post, C, which is mounted on the base of the primary winding of the oscillation transformer. The circuit continues through the

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turns of the primary winding through the flexible contact, D, to the binding post, E, of the rotary spark gap. The circuit then continues through the disc of the gap, out the binding post, F, and finally makes connections to the binding post, B, which in turn is connected to the copper strip at the base of the jar rack. With this connection no more than two or three turns of the primary winding are required to obtain the wave-length of 200 meters.

The primary winding is made of copper tubing $\frac{3}{6}$ inch in diameter, spaced I inch from center to center of the turns. This tubing is fastened to the hard rubber post by means of brass machine screws, the copper tubing and the hard rubber post being drilled accordingly.

The secondary winding of the oscillation transformer comprises from six to twelve turns of No. 6 D. B. R. C. wire which are closely wound and the top terminal connected to one binding post of the aerial meter while the opposite terminal of the latter is connected to earth. The other terminal of the secondary winding leads to point K of the aerial change-over switch, then extends to the contact blade, L, and thus on to the aerial. When the switch is thrown to the contact point, R, the aerial is connected to the receiving equipment.



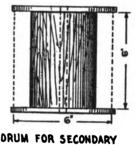


Fig. 52—Detail of Base and Top of Oscillation Transformer.

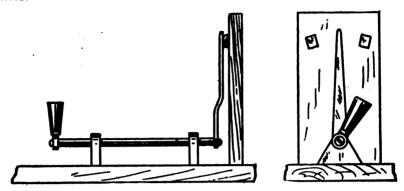
Fig. 58-The Drum for Secondary Turns.

Drilling and over-all dimensions for the top of the jar rack appear in Fig. 50, similarly for the rotary gap disc in Fig. 51; while the top and base for the primary winding of the oscillation transformer are constructed as shown in Fig. 52. Fig. 53 gives the dimensions of the drum support for the secondary winding which may be of wood.

Specific dimensions for the wooden block upon which the rotary gap motor is mounted cannot be given, owing to the difference in the dimensions of motors, but whatever the make the motor should be designed to revolve at a speed of 1,800 revolutions per minute. The disc, S, mounted on the shaft of the motor, should be about 7 inches in diameter and should have eight sparking points equally spaced about the circumference. These may be made of machine screws. The sparking points should be placed on a radius of 3 inches from the center and the stationary electrodes, B and F, should accordingly be separated about 6 inches. With this design 240 breaks or interruptions of the condenser circuit per second are obtained, being about the equivalent of 120-cycle alternating synchronous sparks.

As will be observed, the transformer is of the open core type and is mounted in a vertical position, being supported by three wooden legs equidistantly spaced on the wooden base. The dimensions for the transformer are as follows. The primary core should be 14 inches in length, 2½ inches in diameter, consisting of a bundle of very fine soft iron wires which are taped in circular form.

The core is then covered with two or three layers of empire cloth and afterwards wound with two layers of No. 14 double cotton covered wire. The entire primary winding is then inserted in a hard rubber tube of about 3/16 inch in thickness.



DETAIL OF AERIAL SWITCH

Fig. 54-Simple Changeover Switch.

The secondary winding is composed of ten separate sections, each about 7 inches outside diameter 1½ inches in thickness. The inside diameter is approximately 3½ inches. Each of the pancakes comprising a section should be wound with No. 32 S. S. C. wire which has previously been soaked in hot paraffin. The secondary sections may be separated from one another by micanite or paraffin paper washers.

The aerial ammeter is mounted on a board immediately behind the rotary spark and at such a height that the reading of the scale is directly visible

The aerial change-over switch appears in Fig. 54. A metal rod is mounted on bearings and has a hard rubber band. On the opposite end is mounted

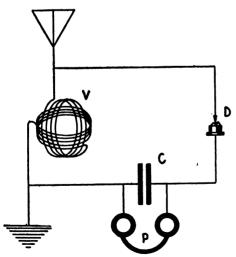


Fig. 55—Elementary Diagram of Simple Amateur's Receiving Set,

the switch blade which is 8 inches in length. The antenna connects to this rod by means of a stranded flexible conductor, but the opposite end makes contact with the stationary points, K and R, as in Fig. 49. The upright supports for the contacts should be of hard rubber and they should be separated by at least 6 inches.

Simple Amateur Receiving.—The receiving apparatus for this set is of extreme simplicity and is shown assembled in Fig. 56. It must be remembered that it is designed for the reception of signals at the wave-length of 200 meters and the construction is simplified accordingly.

Diagammatically the circuit appears in Fig. 55, wherein a variometer, V, is connected in series with the antenna system and in series with it is placed a crys-

tal detector, D, and the fixed condenser, C. The latter is shunted by the head telephone, P. A suitable variometer will be described in Chapter XII. The placing of the apparatus is as follows: Alongside the variometer (See Figure 56) is placed a fixed condenser of .005 microfarad, and immediately to the

right a suitable crystal detector. Two binding posts are furnished, one for the aerial and earth connection, the other for the head telephones.

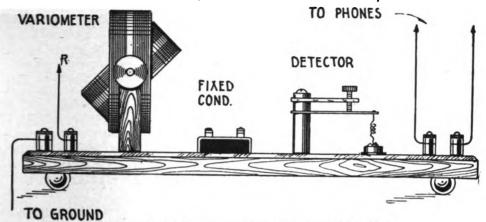


Fig. 56-Simple Amateur Receiving Set Mounted for Use.

Dimensions for the variometer are as follows:

Two cardboard tubes one, 6 inches in diameter the other 5 inches in diameter each being 2 inches in width, are wound with a single layer of No. 24 S. wire. A space should be left in the winding in the middle of the tube for about 4 inch. Care should be taken to get the same amount of wire on each tube. The tubes are then connected in series. A hole is drilled in both sides of each tube and through these holes is placed a piece of 1/4-inch round brass rod 8 inches in length. When mounting the variometer a small tube should be fastened to the brass rod so that it will revolve with the knob. A pointer may be fastened with will work over a scale.

In tuning to an amateur station it is only necessary to vary the relative positions of the outer and inner coils of the variometer until maximum response is obtained.

To adjust the transmitting apparatus, the builder of this set should purchase a wave-meter (or if he desires, construct one) and then accurately adjust the closed circuit to 200 meters. Then turns may be added or taken out at the secondary winding until the hot wire ammeter gives the maximum deflection.

An ammeter having a maximum range of three amperes is satisfactory.

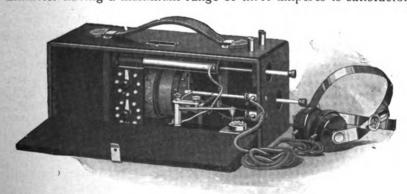


Fig. 56a-Type B Portable Receiving Set for Reception at 200 Meters.

A small fused switch may be mounted on the wooden block supporting the motor for turning the current on and off. By more elaborate design extra contacts can be added on the shaft of the aerial switch to start and stop the motor.

Chapter VIII

The Quenched Spark Discharger

B ECAUSE there is little or no retransfer of energy from the antenna to the spark gap circuit, the quenched spark discharger is considered the most efficient of modern gaps for the handling of small powers. Some amateurs, ambitious to obtain the maximum degree of efficiency from their transmitters, fit their stations with gaps of this type, but the results obtained are frequently somewhat disappointing. Considerable misapprehension seems to exist regarding the adjustment and use of the quenched spark discharger, and this chapter was written with the object of bringing about a better under-

standing regarding the subject.

To be efficient the quenched spark type of transmitter must be uniformly designed throughout; that is to say, the generator, the transformer, condenser and gap must be constructed along certain definite lines before the apparatus can be expected to produce results. It is not within the scope of this article to discuss the design of a complete commercial quenched spark type of transmitting apparatus, but directions will be given which will enable the gap to be employed in connection with any type of existing amateur apparatus with increased flow of antenna current. The adjustment of the quenched spark transmitter, even when properly designed, is somewhat difficult and it is due to the absence of the necessary controlling devices for obtaining closeness of regulation of the various circuits that the amateur meets with discouragement.

* The Spark Plates.—As is well known, the plates of the quenched gap are made of copper, carefully ground and perfectly milled, with sufficient heat dissipation surface to take care of the required energy. In addition, the individual plates of the gap are separated by insulating washers of the correct thickness, so that when compressed the sparking surfaces will be separated by no more than 1/100th of an inch. It is particularly important that the space between the sparking surfaces be air-tight. To this end the insulating discs or washers are treated with a special insulating compound, such as varnish, paraffin, etc. Under the heat of the gap this compound will soften and when the plates are tightly pressed an air-tight joint results.

It is customary to allow 1,200 volts per gap; hence the number of gaps to be employed in a given set can be readily calculated from the applied voltage. It should be kept in mind, however, that it is not the voltage of the transformer alone that is taken for computation; it is the available potential when the condenser is connected in shunt to the secondary winding that is taken into consideration. This value of potential can be determined by the sphere gap method, the tables for which are usually given in the appendix

of electrical hand books. Briefly, this method involves the use of two spheres or balls of a certain diameter, which are separated by a micrometer adjustment with a corresponding scale. These discharge balls are connected in shunt to the source of high potential and gradually separated until the spark ceases to discharge. The length of the gap is noted and reference made to the table for the corresponding value of voltage. It should be kept'in mind that these tables generally give the maximum voltage per cycle and not the R.M.S. value.

The writer conducted a number of experiments with quenched gaps on sixty-cycle amateur apparatus and found that with the proper precautions increased flow of current in the antenna circuit could be obtained. As a result of these tests it was immediately observed that the capacity of the condenser in the closed oscillatory circuit must be reduced below that value employed with the plain type of spark gap.

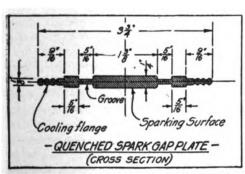


Fig. 57-Details of a Quenched Spark Gap Complete.

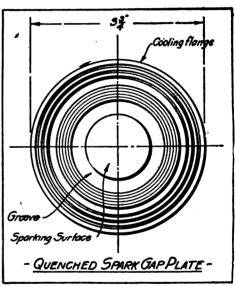


Fig. 58—Details of a Quenched Spark Gap Complete.

The Spark Note.—An additionally important factor in connection with these dischargers is the pitch of the note. To secure a clear tone it is necessary that the voltage applied to the high potential condenser should be very carefully regulated. When the source of current supply is a motor-generator the voltage of the transformer may be readily controlled by means of the generator field rheostat. However, when current is taken from the city mains it may become necessary to construct a transformer fitted with variable tapoffs in the secondary winding in order that the correct value of voltage may be obtained. With certain transformers the proper reduction of voltage may be secured by the insertion of a reactance coil in series with the primary winding, but this method is not found to be as efficient as the one where tap-offs are taken from the secondary winding.

Some experimenters believe that the mere fitting of a quenched gap to a radio transmitter will give a high spark note. This is not true. But if properly adjusted this gap will tend to smooth out the pitch of the note, regardless of the applied frequency. High pitched notes are only obtained

by the use of current at frequencies in excess of 120 cycles.

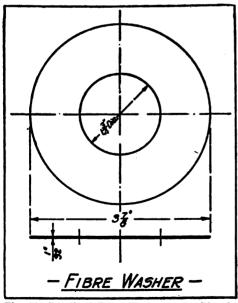
It is essential in connection with the quenched spark transmitter that the inductance of either the primary or secondary circuits of the oscil-

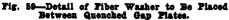
lation transformer be continuously variable, i. e., fitted with a sliding contact in order that turns may be added or subtracted by fractions of an inch. It is preferable then to employ an oscillation transformer of the pancake or flat spiral type in order that sliding contacts may be fitted for variation of the inductance. Again, the coupling between the primary and secondary, windings must be very closely adjustable, and if possible the oscillation transformer should be constructed so that the inductance of either the primary or secondary winding and the coupling between these windings can be varied simultaneously.

At this point it should be kept in mind that the quenched spark discharger permits a closer degree of coupling between the primary and secondary windings than is possible with the rotary disc discharger or plain gap. Because of this increased flow of antenna current takes place and in addition the energy is radiated at a single fundamental frequency.

The high potential transformer for a quenched gap system should possess a certain amount of magnetic leakage. The open core transformer naturally possesses this characteristic, but if a transformer of the closed core type is employed it should be fitted with a magnetic leakage gap.

Quenched Gap for Low Powers.—The average amateur transmitting set supplied with a 1/4 or 1/2 k.w. transformer, requires from 8 to 14 copper plates for the quenched gap, which may be designed from the sketch shown in Fig. 57, a plan view of which is shown in Fig. 58. As indicated, the actual sparking surface of the plates is 13/8 inches in diameter, surrounded by a groove 5-16ths of an inch in width by about 3-32 of an inch in depth. It will also be observed that the outer rim, upon which the insulating fibre rests, is 5/8 of an inch in width by 15/8 inches outside diameter. The complete plate, including the cooling flange, is 33/4 inches in diameter.





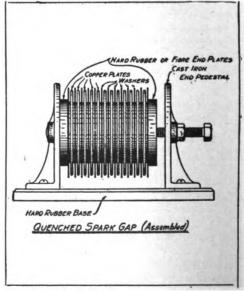


Fig. 60—Complete Assembly of Quenched Spark
Gap.

The plates of a quenched spark gap cannot be constructed in a slipshod manner. They must be cast in a solid piece and very carefully molded. In fact, it is not sufficient that these plates be smoothly cast. They must be

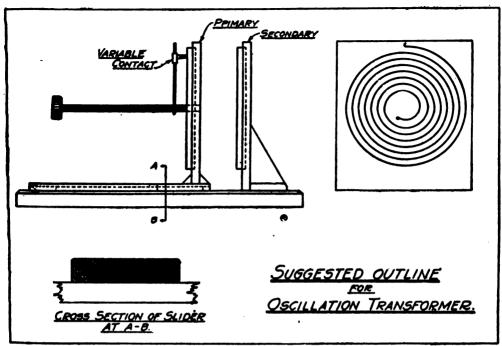


Fig. 61-Suggested Design for Pancake Oscillation Transformer.

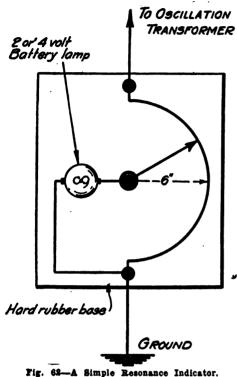
placed in a lathe or milling machine and ground to a smooth surface with extreme accuracy. If the sparking surface is uneven the spark discharge will take place at the highest point and finally short-circuit the gap.

After completion these plates must be carefully mounted in a containing rack and placed under great pressure. The junior experimenter is accustomed to stack these plates between two insulating slabs and draw them together by means of iron bolts. It is impossible to compress the plates evenly in this manner. As a matter of fact, efficient results cannot be expected unless the plates are mounted in a cast iron frame, properly insulated from it and pressed together by means of a large set screw on the end which acts directly upon the center of the plates. In this manner a great pressure can be exerted, making the intervening spaces airtight.

The dimensions for the insulating washers are given in Fig. 59, the suggested outline for the design of a gap container in Fig. 60, and a simple sketch of a suitable oscillation transformer in Fig. 61. Complete constructional details of the oscillation transformer are not given, but for amateurs' information it can be stated that they are generally constructed of strip copper, placed in slots cut in spiral form on a slab of hard rubber, bakelite or other insulating material.

The Spiral Oscillation Transformer.—For operation at a wave-length of from 200 to 600 meters the oscillation transformer for a ½ k.w. set may have the following dimensions: The primary winding has eight turns of flat copper ribbon placed on an insulating support edgewise, the copper being ¾ of an inch in width by 1/16 of an inch in thickness. The outside diameter of the winding is 10 inches and the inside diameter about 4¾ inches. The turns should be placed ¼ of an inch apart. The secondary winding of this oscillation transformer may consist of nineteen or twenty turns of ribbon of the same size, also spaced ¼ of an inch apart, with a copper strip of the same dimensions. The outside diameter is about 14 inches and the inside

diameter about 4¼ inches. It will be observed from Fig. 61 that the inductance of the primary winding of the oscillation transformer is altered by a sliding contact operated by the control handle. In addition, the primary winding is mounted on the base so that it can be drawn away from the secondary winding for variation of the coupling.



Resonance Meter.—A radiation indicator suitable for determining conditions of resonance between the spark gap and antenna circuits is shown in Fig. 62. It is, of course, preferable that a hot wire ammeter be employed, but in the event that it is found too expensive, the indicator will fulfill the requirements. It consists merely of a two or four volt battery lamp, shunted by a semi-circle of copper wire with a sliding contact, so that the inductance and resistance of the shunt can be regulated by fractions of an inch. When this indicator is connected in the antenna system, experimental trials must be made and the shunt set at the correct value to prevent the lamp from burning out. A diagram of connections for the complete quenched spark gap system is shown in Fig. 63.

Adjustment.— Assuming that the experimenter has constructed a quenched gap along the lines described and that the plates are properly mounted in the containing rack and made airtight, if the following procedure is carried out efficient results will be obtained.

As remarked previously, the capacity of the transmitting condenser should be reduced and corresponding careful regulation made of the number of gaps in use as well as the applied potential. Here it should be remarked that when first assembled the quenched gap is not in condition for immediate use. The spark should be allowed to discharge for at least two hours to remove the accumulated gases. After being treated for this period the primary winding of the oscillation transformer is placed in close inductive relation to the secondary winding and extremely careful regulation made of the inductance of either winding; at the same time the antenna current indicator should be noted to determine when the maximum flow of current is obtained. When this point of adjustment is reached, the coupling between the primary and secondary winding is reduced with simultaneous small changes in the inductance values of the primary winding with the idea of ascertaining whether increased antenna current can be obtained. During this adjustment the pitch of the spark note can be observed by listening in on the telephones of a wavemeter adjusted to resonance with the set, or by connecting into the circuit the secondary winding of the receiving tuner. Careful adjustment of the transformer voltage is made and the corresponding note observed in the telephones.

It is important that the plates of the quenched spark gap be properly cooled. It is customary in commercial apparatus to effect this by a small motor blower mounted directly on the same base with the quenched gap which supplies a constant pressure of air to the outside surface of the plates. Similiar results can be obtained by using a small electric fan arranged to direct a blast of air upon the cooling flanges. A slight rise in temperature has the effect of increasing the efficiency of the gap, but if excessive the plates will be ruined. After a few hours' use it is found necessary to gradually take up the adjusting screw in order that the plates may be kept airtight.

It will readily be understood from the foregoing explanation that the oscillation transformer of the conductive or inductive type employed at the amateur station is unfitted for use in connection with the quenched gap system. While it is possible by a tedious series of experiments to locate the proper values of inductance, it is far more preferable to build an oscillation transformer after the type suggested.

more preferable to build an oscillation transformer after the type suggested.

The writer feels assured that if the experimenter will adopt the foregoing suggestions he will not discard the quenched spark discharger as useless, but will

be loud in praising its efficiency.

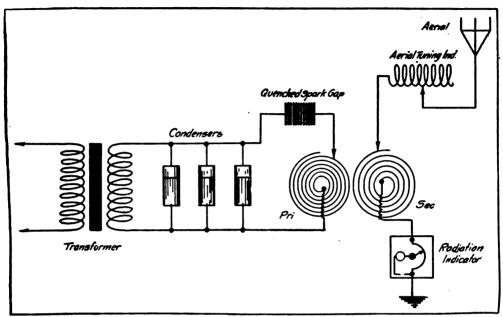


Fig. 63-Complete Wiring Diagram for a Quenched Spark Transmitter.

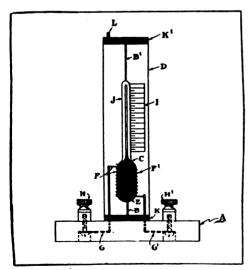


Fig. 63a—Hot Fire Ammeter Suggested by a Reader of the Wireless Age. A Few Turns of Resistance Wire Are Wound About the Bulb of a Thermometer, the Current Flowing in the Antenna Circuit Heating the Wire and Causing the Mercury to Expand,

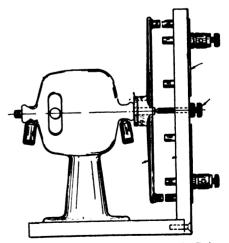


Fig. 63b—Non-Synchronous Type of Rotary
Spark Discharger Suggested by a Contributor
to the Wireless Age. Stationary Electrodes
Are Mounted on a Vertical Sheet of Hard
Rubber and Two Rotating Electrodes Are
Mounted on an Aluminum Arm Attached to
Shaft of D. C. or A. C. Motor.

Chapter IX.

The Receiving Tuner

A N understanding of the fundamental principles upon which the functioning and manipulation of the receiving tuner are based is essential to the members of all radio organizations. While the amateurs in the United States have made considerable progress in wireless telegraphy many of them do not handle their apparatus with basic understanding and there is need in the field for knowledge regarding the operation of a receiving tuner Therefore the following instructions are offered:

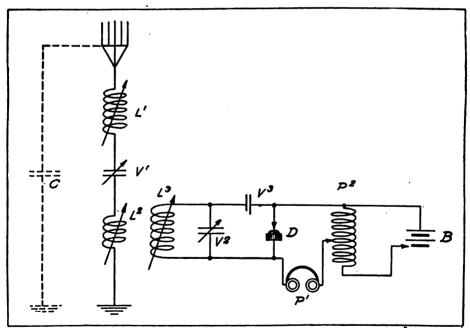


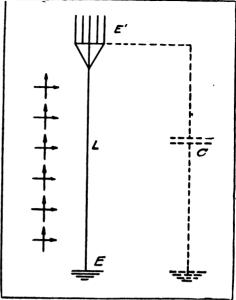
Fig. 64-Fundamental Diagram of Carborundum Rectifier Tuning Circuit Complete.

The inductively-coupled receiving tuner depends primarily for its operation on the principles of electrical resonance. It comprises fundamentally two main circuits. (1) the open oscillatory circuit with its appliances for tuning; (2) the closed oscillatory circuit in which radio signals are made audible.

The open oscillatory circuit generally contains three elements as indiated in Fig. 64: (1) the aerial tuning inductance, L-1; (2) a short wave variable condenser, V-1; (3) the primary winding of the oscillation transformer, L-2.

The closed oscillatory circuit comprises (1) the secondary winding, L-3; (2) the variable condenser in shunt, V-2; (3) the fixed or stopping condenser, V-3; (4) the detector, D: (5) the potentiometer, P-2; (6) the head telephones, P-1, and (7) the battery, B. The circuit diagram shown in Fig. 64 contains the potential requirements of an efficient receiving set and no deviation from the method of connection given will afford increased results.

The functioning of the receiving ap-



paratus of Fig. 64 will perhaps be better understood from the following explanation: A wireless transmitting or receiving aerial of any type whatsoever has a certain amount of distributed inductance and distributed capacity which combine to give it a natural frequency of oscillation varying inversely as the square root of the product of these two values or

*Frequency of oscillation
$$\Rightarrow \frac{5,033,000}{\sqrt{L \times C}}$$

Where L = the total inductance of the aerial in centimeters.
C = the effective capacity in microfarads.

Hence if an aerial, for instance, had capacity of .0005 microfarads and inductance of 5,033,000 50,000 centimeters, the frequency of oscillation = -= 1,000,000 cycles per second approximately.

Now if the frequency of the oscillations flowing in the transmitting aerial is known, the length of the radiated wave can be obtained from the formula:

Since electric waves are propagated through space at the rate of 300,000,000 meters per second, then, a frequency of 1,000,000 would correspond to a wave motion the length of which from crest to crest or hollow to hollow would be 300 meters.

Thus if an amateur's transmitting aerial radiates electric waves of 200 meters length, the frequency of oscillation must be:

Frequency
$$=\frac{300,000,000}{=1,500,000}$$
 cycles.

[•] This formula applies strictly to closed circuit oscillators and is only approximate for open circuit oscillators. In case the antenna has a large amount of concentrated inductance inserted at the base, this formula is nearly as accurate for the open circuit oscillator as for the closed circuit oscillator

aerial.

The electric waves radiated from a transmitting aerial are composed of magnetic and static lines of force which are propagated through space. These may be represented by the crossed arrows of Fig. 65, which roughly indicate the direction of the magnetic field which in the perfect case is at right angles to the receiving aerial and the static field, which lies parallel to the aerial. These two forces act simultaneously upon the wire E,E-1 inducing in it oscillations of the frequency of the transmitting

The arrival of these trains of flux at a given receiving station must be in exact agreement with the natural time period of oscillation of the circuit E,E-1; otherwise the oscillations induced in the receiving aerial will have but little strength. To be more explicit, a half cycle of the oscillation must complete itself in the circuit E,E-1 before the flux corresponding to the other half cycle acts; otherwise the current set up by the first half will be opposed resulting in reduced current flow. All this may be summed up by saying that the receiving aerial must be so adjusted that if it were transmitting electrical waves they would have the same length as those radiated by the transmitting station. More clearly the product obtained in multiplying the inductance by the capacity of the transmitting aerial circuit must equal the product obtained by multiplying the inductance by the capacity of the receiving aerial. This is the only condition under which the maximum strength of signals will be obtained in the receiver.

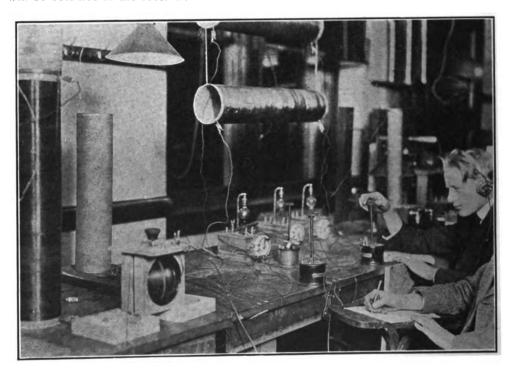
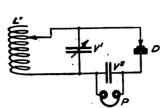


Fig. 65b-Long Distance Beat Receiver. Amateurs Taking Down Signals Over Long Distances.

The function of the elements in Fig. 64 will now be explained: The coils L-1 and L-2 of the antenna circuit are variable inductances. L-1 will probably be made of a few hundred turns of No. 22 or No. 24 S. S. C. wire wound on an insulating form from 3 to 5 inches in diameter. Winding L-2 may have from 10 to 300 turns of No. 24 S. S. C. wire wound on a form 3 or 4 inches in diameter. Similarly winding L, the secondary winding, may have several hundred turns of No. 32 S. S. C. wire wound on a form several inches in diameter.

Now if the variable condenser V-1 connected in series with the antenna circuit is short-circuited, the natural frequency of oscillation of the receiving aerial may be increased or decreased by variation of L-1 and L-2. Increase of inductance at L-1

or L-2 will give the receiving aerial a lower frequency of oscillation, and as will be apparent from the formula establishing the connection between wave-length and frequency in cycles per second, it will respond to electric waves of great length; conversely if the inductance of L-1 and L-2 be decreased, the natural frequency of oscillation will increase and the receiving aerial will respond to waves of shorter length.





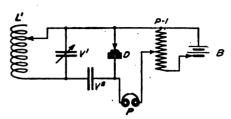


Fig. 67-Diagram of Local Circuit of Carborundum Rectifier.

The minimum wave length to which any receiving aerial will respond will be the same as its natural wave length; but it will be seen from the diagram of Fig. 64 that a certain amount of inductance must be inserted at the base of the antenna to transfer the oscillations from the primary winding L-2 to L-3.

When the oscillation frequency of the transmitting aerial exceeds that of the receiving aerial, the natural oscillation frequency of the latter can be increased by connecting a variable condenser in series at V-I. With this condenser in the circuit, the receiving aerial responds to waves of greatest lengths when large values of capacity are employed and to waves of shorter length at values of capacity near to zero.

All this may be summed up by saying that the inductance elements permit the receiving aerial to be adjusted to waves in excess of the natural wave length, while the variable condenser permits response to waves shorter than the natural wave length of the receiving aerial.

When the oscillations are built up to maximum amplitude in the receiving aerial, the closed oscillation circuit L-3, V-2, is tuned to resonance by variation of the capacity of V-2 or the inductance of L-3. When the condenser V-2 has received the maximum charge for a group of oscillations the charge leaks off through condenser V-3 through the crystal detector D and creates a sound in the telephone P.

Function of the Detector.—There is some difference of opinion as to the actions taking place in crystalline detectors during the reception of signals. It is beyond the scope of this paper to enter into a complete discussion of the subject, but we may consider briefly the supposed actions of the crystalline detector as used in certain circuits.

In Fig. 66, L-1 is the secondary winding of a receiving tuner. V-1 the condenser in shunt, V-2 the fixed condenser, D the crystalline detector, and P the head telephone. The energy stored up in the condenser, V-1 is released in the form of high frequency electrical oscillations which flow readily through D in one direction, but are opposed in the opposite direction because of the rectifying properties of the crystal. Thus in a single series of incoming oscillations, the condenser, V-2, is charged over the duration of a wave train and, owing to the preponderance of current in one direction (on account of the rectifying action of the crystal), the coatings of the condenser, V-2, are charged to a definite polarity. On the completion of the charge (which has accumulated during a wave train), V-2 discharges through the inductance, L-1, and the head telephone, P, causing a single sound.

When the receiving detector is supplied with an auxiliary battery circuit, as

When the receiving detector is supplied with an auxiliary battery circuit, as shown in Fig. 67, the actions are as follows: In this case the current from the local battery, B, flows through the crystal, D, and the head telephones, P. The current flowing through the crystal and head-phones is regulated by the potentiometer, P-1. When connected in this manner during the reception of signals there is super-imposed upon the direct current already flowing through the crystal an alternating current of high frequency. If the flow of battery current is adjusted to a certain definite value, the alternation of current flowing in one direction will increase the current flowing through the head telephones from the local battery and the impulse in the opposite direction will cause a slight weakening of the current from the local battery. Owing to the fact that the added voltage through the head telephone circuit is agreater than the subtracted voltage, the result is an increase of current through the head telephones from the battery. In other words, the head telephones are traversed by a current of increased strength at a rate corresponding to the spark frequency of the

distant transmitting spark. Thus it is evident that the head telephones are not operated directly by the current induced in the aerial circuit, but the effect is to increase the current from a local battery circuit.

The sudden increase of current from the local battery circuit is not entirely due to the fact that voltage is added in one direction and subtracted in the opposite direction, but is also accounted for by the peculiar characteristics which all crystalline detectors possess—in respect to conduction they do not obey Ohm's law. That is to say, the current flowing through the crystal at first does not increase directly with an increase of electromotive force, but after a certain critical potential is reached the rise in current is considerably greater than the value to be expected from Ohm's law. In actual operation sufficient battery current is allowed to flow through the crystal, D, to reach the critical point referred to. For fuller investigation, the reader should be familiar with the plotting of the volt-ampere characteristics of non-uniform conductors.

The Practical Adjustment of a Receiving Tuner.—The wireless operator often observes that it is possible to separate two stations at his receiving tuner having identical wave-lengths. In some cases this is due to the fact that the signals from one of these stations is stronger than from the other, but in other instances these results can be obtained because of the fact that two transmitting stations may have identical wave-lengths but different degrees of damping.

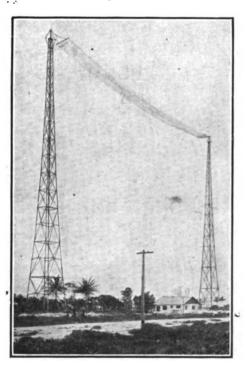


Fig. 67a—High Power Wireless Station at Swan Island, Carribean Sea.

When a receiving set is calibrated it becomes apparent at once that the receiving apparatus may be adjusted to a given wave-length with several adjustments of inductance and capacity in either the open or closed circuit. The one, therefore, to be selected is that which will give the receiving tuner the same values of coupling and decrement as the sending station. When the apparatus is adjusted to the wave-length of a given station, interference may be experienced simultaneously from another station of different wave-length owing to the two degrees of freedom of oscillation (under conditions of tight coupling) Should this occur, the open and closed oscillation circuits of the receiver must be individually adjusted to the wave-length desired and the degree of coupling between the primary and secondary windings be at a minimum value consistent with the strength of received signals

To avoid a "broad" adjustment in the secondary circuit of a receiving tuner the conditions necessary in the primary circuit hold, namely, inductance should predominate and the capacity should be of small value.

Three methods for the practical adjustment of a receiving tuner will now be considered.

- (1) Where the primary and secondary circuits are not calibrated in advance.
- (2) Where the secondary circuit is properly precalibrated;
- (3) Where the primary and secondary circuits are individually precalibrated,



and a chart of wave-length adjustments supplied.

With the conditions of (1), adjustments to stations of various wave-lengths can only be obtained by experience and experiment.

The method of procedure is as follows:

(a) Very close coupling should be employed between the primary and secondary windings.

(b) The condenser in shunt to the secondary windings is set at zero.

(c) About one-half the secondary turns should be connected in the circuit.
(d) The inductance in the antenna circuit should be increased or decreased until the signals from the desired station are heard.

When the signals are thus heard:

(a) The inductance in the secondary winding is altered to ascertain if in-

creased strength of signals can be obtained.

(b) The coupling between the primary and secondary windings is slightly decreased and a smaller value of secondary inductance included, followed by a slight increase of capacity of the condenser in shunt.

(c) The antenna circuit is "stiffened" by the method previously described.

In this manner stations, the wave-lengths of which are definitely known, can be brought to the maximum strength of signals and the corresponding positions on the inductance and capacity scales tabulated for future reference.

The adjustment of the receiving tuner to a station, the wave-length of which is definitely known, under the conditions outlined in (2), is a simple matter. In this case the secondary winding of the receiving tuner has been precalibrated and a chart showing the values of inductance and capacity necessary for a given wave-length is furnished. The method of procedure is as follows:

(a) For the wave-length desired, large values of inductance and small values of

capacity are selected at the secondary circuit.

(b) A fair degree of coupling between the primary and secondary windings is

employed.

(c) The inductance in the antenna circuit is altered until the station desired is heard.

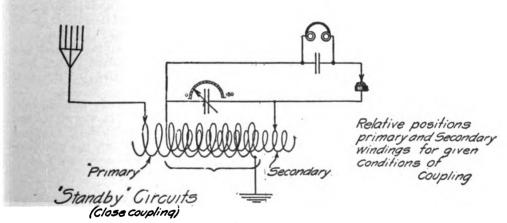


Fig. 68-Stand-by Circuit of an Inductively Coupled Receiving Tuner.

Under the conditions set forth in (3) the receiving operator may adjust both circuits in advance to the wave-length desired, with the assurance that a calling station will be heard without variation of the variable elements of either circuit.

By reference to the chart furnished with the set:

(a) Correct values of inductance and capacity are selected in the antenna circuit for the required wave length.

(b) Selections for the same wave-length are made in the secondary circuit. Digitized by 🗘 🔾

(c) A medium degree of coupling is employed between the primary and secondary winding.

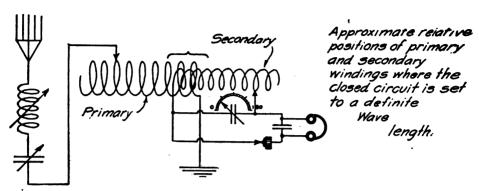


Fig. 69-"Fairly Loose" Coupling Between Primary and Secondary Windings.

When the condenser in shunt to the secondary winding of the receiving tuner is set at the zero position and tight or close coupling is employed between the primary and secondary windings, it is often observed that the secondary circuit will respond strongly to a definite wave-length and that the response to other wave-lengths will be much weaker. In certain cases this is due to the distributed capacity of the coil. Every coil of wire has distributed capacity, that is, it possesses the property of storing up energy in the form of electrostatic lines of force between adjacent turns. With coils of a certain length, this capacity may attain such value as to give the coil a distinct time period of vibration. Hence, when wave-lengths similar to the natural period of the coil are received and the entire coil is in use the maximum intensity of signals is obtained; but if only a portion of the coil is employed, and the required wave-length is obtained by placing a condenser in shunt to the used portion considerable losses of energy may result.

To afford the student a clearer idea of the conditions under the three methods of adjustments described Figs. 68, 69 and 70 are published. Fig. 68 shows the circuits of a receiving tuner for "stand-by" work. In this case about one-half the value of the secondary inductance is employed and the condenser in shunt is set at the zero position. The used turns of the secondary winding are placed directly underneath the used turns of the primary winding; hence a close coupling is effected.

In Fig. 69 the wave-length of the closed circuit is definitely known, and a small amount of the capacity of the variable condenser in shunt to the secondary winding is employed. The used turns of the secondary winding are placed partly inside the used turns of the primary winding, the coupling being fairly "loose." In Fig. 70 the wave-length of both the open and closed circuits is known, hence a small value of coupling is employed.

Receiving Tuners for a Definite Range of Wave-Length.—The wireless experimenter frequently wishes to construct a receiving tuner that has a definite upper range of wave-length adjustment for use with an aerial of given dimensions. It is not possible to give the actual dimensions for a primary winding suitable to all types of aerials as two antenna systems seldom possess identical dimensions or similar values of inductance and capacity. We may, however, take aerials of given dimensions, calculate approximately their inductance and capacity and fit to them a primary and secondary coil properly designed for a distinct value of wave-length.

It is generally assumed and experiment seems to prove that a secondary winding possessing a rather high value of inductance and a correspondingly low value of capacity is the one best suited for the crystalline and vacuum valve detectors. This, together with the fact that the capacity of the usual

variable condenser supplied to the amateur market has a maximum value of either .0005 or .001 microfarad—rarely more—will be taken into consideration in the examples to follow. For either crystalline or valve detectors, the condenser in shunt to the secondary winding should not exceed .0005 microfarad. A special example, however, is cited where the capacity of the condenser totals .001 microfarad

It is found by experiment that No. 32 S. S. C. wire is best suited for the secondary winding of a receiving tuner; No. 24 or No. 26 S. S. C. for the primary winding and No. 22 S. S. C. for the antenna loading coil.

Dimensions for the coils of a receiving tuner to be used with aerials of definite lengths follow:

Example No. 1: Assume that a four-wire flat top aerial of the inverted L type, 50 feet in length, 40 feet in height, the wires spaced 2 feet apart, is being discussed. This aerial is of the correct dimensions for transmission at the amateur wave-length of 200 meters and of course is used for receiving purposes for the shorter range of wave-lengths. The inductance of the aerial is approximately 32,000 centimeters, the capacitance .00022 microfarad, and the natural wave-length about 163 meters. A receiving tuner connected to this aerial and designed to work at the restricted wave-length of 200 meters should have the following dimensions:

The secondary winding is made on a cardboard tube, hard rubber tube or other insulating material, 2½ inches in diameter and wound for a length of 1 inch with 100 turns of No. 32 S. S. C. wire. When shunted by a capacity of but 0001 microfarad, the winding responds to a wave-length of about 500 meters and has sufficient proportions to allow the secondary winding to be placed in resonance with the primary winding (adjusted to 200 meters) with practically a zero value of capacity at the shunt variable condenser. It is recommended that the turns of the secondary winding be equally divided between the points of a four-point switch.

A suitable primary winding for this tuner may be 3 inches in diameter, wound for ½ inch with twenty-eight turns of No. 26 S. S. C. wire. This winding, connected in series with the aerial previously cited, raises the wave-length of the antenna system to a value above 200 meters. The primary winding should be fitted with a sliding contact or a multiple point-switch for variation of the inductance values.

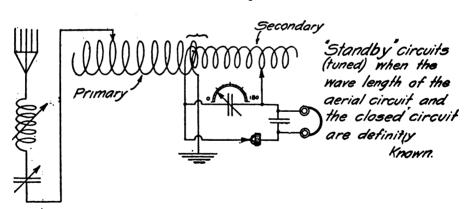


Fig. 70-Position of Primary and Secondary Windings for Sharp Tuning.

Example No. 2: Assume that it is desired to construct a tuner that will raise the wave-length of the aerial described in example No. 1 to an upper wave-length adjustment of 1,000 meters. In this case the secondary winding is 2½ inches in diameter, wound for 2 inches with 200 turns of No. 32 S. S. C. wire. Shunted by a capacitance of .0002 microfarad, which corresponds to the first ten or fifteen degrees of the average small variable condenser, the wave-length of the circuit is 1,150 meters.

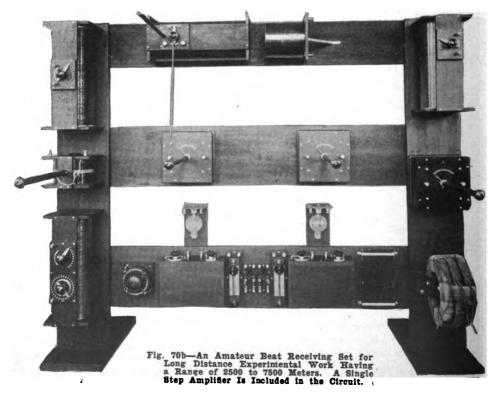
Owing to the increased wave-length the dimensions of the primary winding must be increased; it is now 3 inches in diameter, 4 inches in length, wound with 222 turns of No. 26 S. S. C. wire. This winding will, at its maximum value of inductance, raise the wave-length of the antenna system to about 1,150 meters.



The secondary winding should have its turns equally divided between the taps of a 6-point switch, and the primary winding should be fitted with two switches to be described further on.

Example No. 3: A station is fitted with a four-wire receiving aerial, 100 feet in length, 60 feet in height, and a receiving tuner is required for adjustment to a wavelength of 1,000 meters. We may safely assume the capacity of the aerial to be .0004 microfarad; the inductance 62,000 centimeters, and the natural wave-length 300 meters.

Fig. 70a—Miss Cecil Powell and Her Wireless Set. Miss Powell Who Is a Well Known Amateur Has Recently Been Awarded a Government License Certificate. Not Only Can She Operate This Equipment, but She Is Able to Construct Radio Apparatus,



The antenna system will respond to wave-lengths slightly in excess of 1,000 meters with a primary winding 3½ inches in diameter, wound for 2 inches with ninety turns of No. 24 S. S. C. wire. A suitable secondary winding has 200 turns of No. 32 S. S. C. wire wound for a distance of 2 inches on a form 3 inches in diameter. Shunted by a capacitance of .00015 microfarad, the winding responds to wave lengths slightly above 1,000 meters. A 6-point switch is sufficient for variation of the inductance value.

Example No. 4: In this case the aerial denoted in example No. 3 is to be raised to a wave-length of 3,000 meters in both the primary and secondary windings. The primary winding is 4 inches in diameter, wound for 6 inches with 275 turns of No. 24 S. S. C. wire. The wave-length of the antenna system is raised to the wavelength of 3,000 meters by the addition of a loading coil which is 4 inches in length, wound for 4 inches with 222 turns of No. 22 S. S. C. wire. The antenna, the loading coil and the primary winding of the oscillation transformer connected in series will cause the aerial to respond to waves slightly above 3,000 meters.

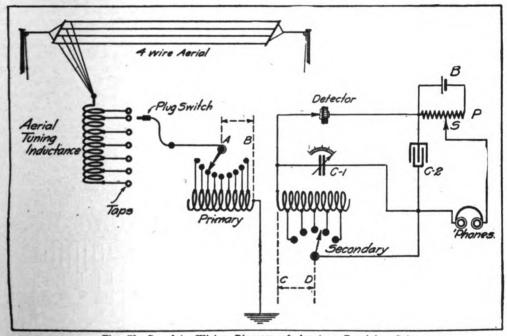


Fig. 71-Complete Wiring Diagram of Amateur Receiving Set.

The corresponding secondary winding is 3½ inches in diameter, wound for 6 inches with 600 turns of No. 32 S. S. C. wire. A capacitance in shunt of .0002 microfarad will cause this circuit to respond to a wave-length of 3,000 meters.

Example No. 5: The dimensions of a primary and secondary winding for use at the wave-length of 10,000 meters are often required. The secondary winding, let us say, must possess a particularly high value of inductance in order that it may work with efficiency in connection with the vacuum valve detector. A hard rubber tube or one of other insulating material 6 inches in diameter, wound for 12 inches with 1,000 turns of No. 30 S. S. C. wire, fulfills the requirements. Shunted by a capacitance of .0001 microfarads, the circuit is responsive to the wave-length of 4,950 meters, but with a value of .0005 microfarads connected in at that point, the wave-length of the circuit is slightly in excess of 10,000 meters. This winding is well adapted for the longer range of wave-lengths and may be fitted with a multiple-point switch for variation of the inductance but, as will be observed, the wave-length can be varied

over a considerable range by means of a small variable condenser alone.

With an aerial of four wires, 400 feet in length and 100 feet in height, the primary winding may be 7 inches in diameter, wound for 12 inches with 540 turns of No. 24 S. S. C. wire. The antenna system with the maximum value of inductance will respond to a wave-length of about 11,000 meters. The capacitance of this aerial is about .00127 microfarads, the inductance 192,640 centimeters, and the natural wave-length 970

meters.

Example No. 6: Often for purposes of minimizing space and material, we desire a at the secondary condenser and small values of inductance. A tube 3 inches in diameter, wound for 2 inches with 200 turns of No. 32 S. S. C. wire, responds with a capacitance of .001 microfarad in shunt, to the wave-length of 3,000 meters.

A suitable primary winding for the aerial cited in example No. 3 may be 3½ inches in diameter, wound for 4½ inches with No. 30 S. S. C. wire. The antenna system is then responsive to wave-lengths slightly in excess of 2000 meters.

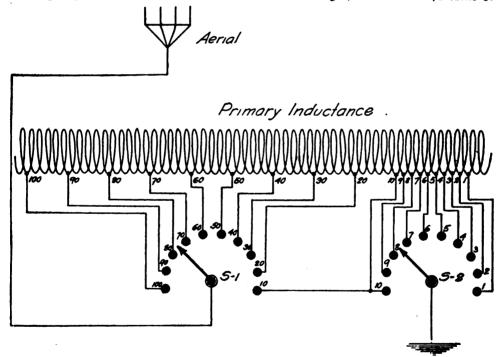
system is then responsive to wave-lengths slightly in excess of 3,000 meters.

Example No. 7 In connection with the vacuum valve detector, many amateur experimenters obtain satisfactory results with a secondary winding of No. 36 S. S. C. wire. If the reduction in the cost of material and space is a consideration, a winding of this nature is recommended.

The dimensions for a 10,000-meter winding with a capacity of .0005 microfarad in

shunt follow:

The secondary tube is 6 inches in diameter, wound for a length of 6 inches with 820 turns of No. 36 S. S. C. wire. For adjustment to the shorter waves it may be fitted with a fifteen-point switch the taps of which are equally divided between the entire winding. The following dimensions for the primary winding and loading coil are correct for a four-wire aerial of the inverted L type, 200 feet in length and 60 feet in height. The approximate inductance of this aerial is 94,800 centimeters, the capacitance .00071 microfarad, and the fundamental wave-length about 450 meters. The primary winding may be 7 inches in diameter and 6 inches in length, wound with 272 turns of



(*Fig. 72-Showing the Method of Varying the Inductance of the Primary Winding of a Receiving Transformer by Means of Two Multi-Point Switches.

No. 24 S. S. C. wire. The loading coil is 30 inches in length and 6 inches in diameter, wound with 1,100 turns of No. 22 S. S. C. wire. The loading coil may be tapped every inch and the primary winding fitted with two switches for variation of the inductance. The condenser in shunt to the secondary winding may be one of the small Murdock type.

The dimensions given for the secondary windings in the foregoing examples are applicable to aerials of all lengths, but the primary windings must, of course, be altered with aerials of other dimensions. To obtain the correct value of inductance for the primary winding with other aerials a few trial experiments should be made, because if the wave-length of the secondary circuit is already known, it is then only

on the diagram of Fig. 72, notations on the switch, S-2, should be reversed, that is to say, the point now marked "10" should be point "1," and the point marked "10" on S-1 should be 0; point "20" should be "10," and so on.

necessary to place the latter in inductive relation with the primary winding and alter the value of inductance at this winding or in the antenna loading coil, until response to a distant station (which is known to be in operation), is obtained.

In the design of a receiving tuner, the precaution to connect the multi-point switch of either winding so that the used turns of the primary and secondary are in direct inductive relation should be taken. They should bear the position shown in Fig. 72 where the turns, A to B, are those in use in the primary winding, C to D, the turns in use at the secondary winding. The zero value of inductance for the primary is obtained at the B end; the zero value for the secondary winding at the C end. And after this essential point is taken into consideration, it becomes self-evident that if the secondary turns are placed too far inside the primary turns, the turns, C to D, are moved beyond the turns, A to B, resulting again in a decrease of the coupling between the windings; hence it may be of value to leave the turns of the primary and secondary exposed in order that the relative position of the two windings may at all times be observed. This is particularly important at the lower values of inductance, but of course is not so essential at the maximum values.

Duplex Switch for the primary winding: To prevent the wires being worn through by excessive friction of a sliding contact, the primary winding of modern receiving tuners is fitted with two multi-point switches, as per Fig. 72. The switch, S-2 is connected to the first ten single turns of the primary winding and the taps of the switch, S-1, are connected to groups of ten turns. It is at once evident that any number of turns from 1 to the maximum may thus be included in the circuit. For larger windings, S-2, may be a fifteen-point switch, while the remaining turns may be connected in groups of fifteen to the points of the switch, S-1.

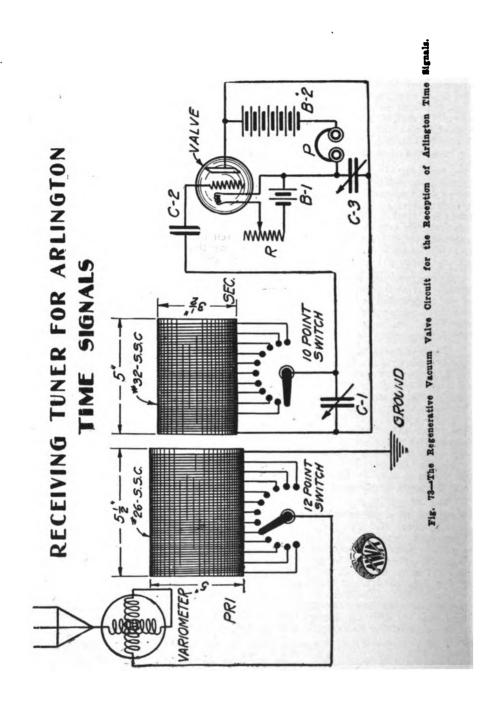
For receiving tuners like those described in examples 5 and 7 it is not entirely essential that switches of this type be fitted to the primary winding. These windings may be tapped every half inch and connected to the points of a single multi-point switch A variometer similar to that described in the book, "How to Conduct a Radio Club," is connected in series with the loading coil and primary winding to obtain the necessary fineness of adjustment in that circuit.

The fixed or stopping condenser: The condenser of fixed capacity, C-2, indicated in the drawing (Fig. 72), may have capacity varying from .003 to .04 microfarad, depending to some extent upon the type of telephone in use. This condenser may consist of several sheets of tin-foil, interleaved with thin paraffine paper, and the surface on one side of the condenser must have from 300 square inches to 1,200 square inches of tin-foil. Inasmuch as the dielectric constant of various grades of paper varies and also the fact that the capacity of the unit depends upon the pressure placed upon the sheets of foil and paper, it is not quite possible to give specific dimensions, but for general all around work a condenser should be constructed to have a surface on one side of 600 square inches, the sheets of foil being separated by thin paraffine paper. It is not required that this condenser be constructed of a single large sheet; it may be made of several small sheets with dimensions of, say, 4 by 6 inches, the only requirement being that the necessary surface on each side is obtained.

The potentiometer: The sensitiveness of crystalline detectors is enhanced by the addition of a potentiometer of suitable proportions and a small battery, as indicated in Fig. 71. The crystalline detector and potentiometer P may be one of the ordinary type of 400 ohms resistance, but there must be connected in series therewith a fixed resistance of about 1,800 ohms. If, however, a closer variation of the current is desired, the potentiometer, P, may have a resistance of about 2,500 ohms. It may then consist of a hard rubber tube properly threaded and wound with 650 feet of No. 32 "advance" wire, as made by the Driver-Harris Company, New York City. The battery, B, should be one of about 1½ volts. Particular care must be taken to have the polarity of this cell correct. The proper direction of current flow for different types of crystal is best determined by experiment. Hence, it is of value to fit the battery, B, with a reversing switch, which may be of any design desired.

A Receiving Tuner for Arlington Time Signals.—A receiving tuner for response to the time signal from Arlington (Radio, Va.) can be constructed along very simple lines. If cheapness of construction is a consideration it is recommended that the primary and secondary windings be made on cardboard tubes or other cheap insulating supports. Suitable dimensions are supplied for a coupler adjustable to wave-lengths between 2,500 and 3,000 meters, and which is particularly adapted for use with either the vacuum





valve or crystalline detectors. In place of the elaborate primary switch generally fitted for the variation of inductance the necessary fineness of adjustment in the antenna circuit in this case is obtained by means of a variometer, the details of construction for which are clearly presented in Chapter XII.

The inner and outer winding are made on cardboard tubes and then connected in series. The position of the variometer in the antenna circuit is shown in Fig. 73. The inside and outside windings should be covered with No. 26 S. S. C. wire. The primary winding is fitted with a simple twelve-point switch, the taps of which are equally divided throughout the entire winding. The secondary winding is connected to the points of a tenpoint switch.

Dimensions for the windings follow:

Primary—Four inches outside diameter by 5½ inches in length, wound closely with No. 26 S. S. C. wire.

Secondary—Three and one-half inches outside diameter by 5 inches in

length, wound closely with No. 32 S. S. C. wire.

The condenser, C-1, in shunt to the secondary winding is one of very small capacity; hence that value represented by the first ten or fifteen degrees of the average small variable condenser supplied to the amateur market will be quite sufficient.

If the vacuum valve detector is employed then the fixed condenser, C-2, may consist of two sheets of tin-foil, 3 inches by 3 inches, separated by a thin piece of paraffine paper and clamped between two boards. If a crystalline detector is substituted, the condenser, C-2, should have increased value of capacity. It may consist then of two sheets of tin-foil, 30 inches by 2½ inches, separated by a thin piece of paraffine paper. The entire unit may be wound up in a circular form and sealed in a small case with paraffine wax, the necessary connections being brought out to two small binding posts.

For use with the vacuum valve the rheostat R has a resistance of ten ohms, the battery, B-1, a maximum value of four volts, and B-2 from thirty to sixty volts. The head telephones, P, may vary from seventy-five to 2,000 ohms resistance. The condenser, C-3, has .003 microfarad capacity.

The foregoing described windings are suitable for an aerial system comprising two or more wires from 100 to 250 feet in length. In actual practice the secondary winding generally is placed about half way inside the primary winding.

With the exception of the vacuum valve detector and the head telephones the entire equipment can be constructed at a small expense.

Determining the Wave-Length of the Receiving Apparatus.—The wavelength of a distant transmitting station can be determined at the receiving station by means of the apparatus shown in Fig. 74. Here the primary winding of a receiving tuner is represented at L, the aerial tuning inductance at L-2 and the secondary winding at L-1. To the right of the drawing is shown a standard wave-meter consisting of the condenser, VC, and the inductance coil, L-3, in series with which is placed the spark cap, S. The spark gap, S, in turn is connected to the terminals of the high potential induction coil.

The signals from a distant transmitting station are tuned to the maximum strength by alteration of the variable elements in the antenna circuit and the local detector circuit; the coupling between L and L-1 is then decreased to the smallest value consistent with the strength of signals in the head telephones. The secondary circuit, L-1, is then drawn away from the primary circuit, L, and the coil, L-3, of the wave-meter placed in inductive relation to coil, L-1. The spark gap of the induction coil is energized in the

regular manner, whereupon the wave-meter, L-3, V C, becomes a miniature

transmitting set in which oscillations of a definite frequency flow.

The capacity of the variable condenser, V C, is then altered until the loudest sound in the head telephones is produced. The local detector circuit of the receiving tuner is then in resonance with the wave-meter and by reference to the chart accompanying the wave-meter the wave-length of the detector circuit is obtained. When taking this reading the smaller the degree of coupling between the primary and secondary windings the more accurate will be the determination of the distant transmitting station's wave-length.

The presence of the spark gap in series with the wave-meter introduces damping in the circuit and does not allow the accuracy of reading which otherwise might be obtained. More accurate readings are secured by the methods shown in Fig. 75, where it will be noted that the wave-meter is excited by a buzzer and battery cell rather than by an induction coil.

It should be observed that the circuit from the battery to the buzzer is made through the wave-meter coil, L-3, and when the buzzer is in operation

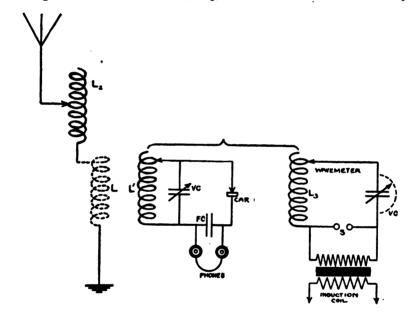


Fig. 74—Showing the Calibration of the Secondary Winding of a Receiving Tuner.

a change of lines of force takes place about the wave-meter coil, causing the condenser of the wave-meter to be charged and then discharged through the circuit. Thus high frequency oscillations are set up in the wave-meter and recorded on the receiving tuner detector. Very accurate readings can be taken by this method provided all apparatus is in proper adjustment.

In determining the wave-length of a distant transmitting station at the receiving station the method just described may be reversed, the circuits being shown in Fig. 76. Again the receiving tuner is adjusted to the greatest intensity of signals and then the buzzer circuit is used to excite the receiving tuner circuit. The local circuit of the receiving tuner now becomes the transmitter and the corresponding wave-length radiated can be read directly upon the wave-meter. In this class the wave-meter condenser is shunted by the carborundum crystal in series with a pair of head telephones.

The wave-lengths of the antenna or open oscillatory circuit of the receiving tuner can be read in a similar manner, as shown in Fig. 77. The buzzer testing circuit is connected through the primary inductance of the

receiving tuner, so that the circuit from the battery must pass through it. When the buzzer is in operation a change of lines of force takes place through the coil, L, which charges the antenna system and which in turn discharges at its natural period of oscillation. The inductance coil of the wavemeter, L-3, is then placed in inductive relation to the earth lead of the antenna and the capacity of the condenser, V C, altered until the loudest

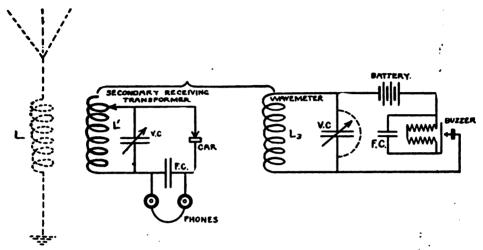


Fig. 75-Showing Wavemeter Set into Excitation by Busser.

response is received in the head telephones. The wave-meter is now in resonance with the antenna system and of course the wave-length reading is obtained directly from the chart accompanying the wave-meter.

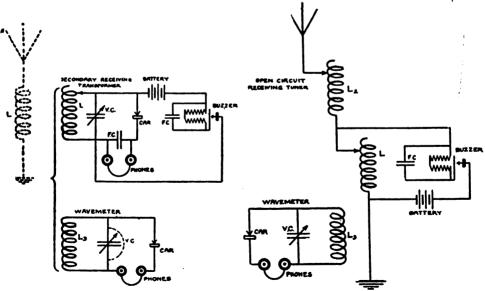


Fig. 76—Excitation of Receiving Circuits by Busser, Signals Being Recorded on the Wavemeter.

Fig. 77-Measurement of the Wave Length of the Antonna Circuit.

Tuned Buzzer Tester.—As an all-round method for calibrating a receiving set for the maximu mstrength of signals from a given station and for adjusting the receiving detector to sensitiveness the circuits given in Fig.

78 are particularly recommended. The open oscillatory circuit of a receiving set is represented by the single turn of wire, L-1, the primary winding of the receiving transformer, L-2, and the aerial tuning inductance, L-3.

The secondary circuits of the receiving tuner are represented by the inductance coil, L-4, the variable condenser, C-2, the crystalline detector, D, the head telephones and the fixed condenser, C-3. To the left of the drawing a wave-meter is represented by the fixed inductance, L, the variable condenser, C, the high frequency buzzer and the batteries.

If it is desired to adjust the antenna system to a denite wave-length the variable element of the wave-meter, C, is set to the required wave. The buzzer is then set into operation, whereupon high frquency oscillations cor-

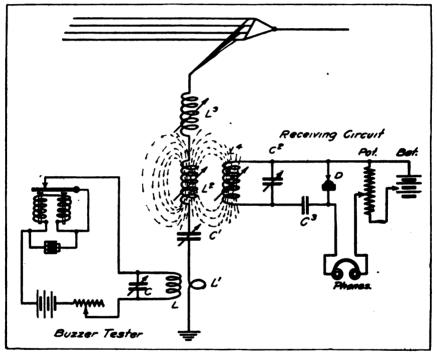


Fig. 78-Complete Apparatus for Pre-Calibrating a Wireless Set.

responding to a definite wave-length flow through the coil, L. The coil, L, is placed in inductive relation to the single turn of wire, L-1, to transfer part of the energy of the high frequency oscillations to the antenna system.

The loudest response will be received in the head telephones when the antenna circuit and the local detector circuit are adjusted to exact resonance by the variable elements, and to resonance with the wave-meter, L-C.

In practice, the local detector circuit, L-4, C-3, is tightly coupled to L-2 and the inductance values at L-2, L-4, altered until a maximum response from the wave-meter is received in the head telephone. The secondary circuit, L-4, C-2, is then drawn at a distance from L-2 and either the inductance of L-4 or the capacity value of C-2 altered until a still louder response is obtained in the telephone. The experimenter is then assured that the receiving set is adjusted throughout to the wave-lengths dsired and that the receiving decrector is adjusted to the maximum degree of sensitiveness.

Test Buzzers.—The test buzzer is often used simply to adjust the crystalline detector to the maximum degree of sensitiveness. The complete circuits are shown in Fig. 79. A small inductance coil, generally consisting of a single turn, L-4, is connected in series with the fixed condenser, F C. having capacity of about .02 microfarad. Both are then shunted across the vibrator of the buzzer, as shown in the drawing. When the buzzer is in operation the oscillatory circuit, L-4, F C, becomes a miniature tranmitting

set sending out highly damped waves which in turn induce currents in the receiving tuner circuits, enabling the operator to secure the most senstive

point on the crystal.

Amateurs who do not possess a wave-meter can calibrate their receiving apparatus by noting that point on the tuner where certain transmitting stations the wave-lengths of which are definitely known, are received. In this manner intermediate values of wavelengths can be approximated.

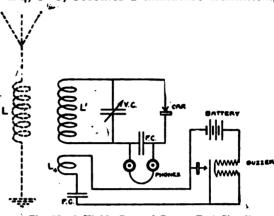


Fig. 79-A Highly Damped Busser Test Circuit.

Simple Calculation of Inductance.—To enable the radio experimenter to calculate the inductance of the coils of a receiving tuner from the dimensions, the following wire table is appended, giving the diameter in mils of wires ranging from No. 20 to 40 (B. and S. gauge):

TABLE NO. 1 Silk and Cotton-Covered Annealed Copper Wire

Diameter in Mils						
B. & S. Gauge.	Bare,	Single Cotton	Double Cotton	Single Silk.	Double Silk.	
20	31.961	37.861	42.161	34.261	36.161	
21	28.462	34.362	38.662	30.762	32.662	
22	25.347	31.247	35.547	27.647	29.547	
23	22.571	28.471	32.771	24.871	26.771	
24	20.100	26.000	30.300	22.401	24.300	
25 26	17.900	23 800	28.100	20 200	22.100	
	15.940	21.840	26.140	18.240	20.140	
27 28	14.195	20,095	24.395	16.495	18.395	
	12.641	18.541	22.841	14.941	16.841	
29	11.257	17.157	21.457	13.557	15.457	
30	10.025	15.925	20.225	12.325	14.225	
31	8.928	14.828	19.128	11.228	13.128	
32	7,950	13.850	18.150	10.250	12.150	
33	7.080	12.980	17.280	9.380	11.280	
34	6.304	12.204	16.504	8.504	10.504	
35	5.614	11.514	15.841	7.914	9.814	
36	5.000	10.900	15.200	7.300	9.200	
37	4.453	10.353	14.653	6.753	8.653	
38	3.965	9.865	14.165	6.265	8.165	
39	3.531	9.431	13.731	5.831	7.731	
40	3.144	9.044	13.344	5.344	7.344	

With this data before us it is comparatively easy to calculate the number

Table No. 2

2 a	_
<u> </u>	Q
.2	3.63240
.3	5.23368
.4	6.71017
.5	8.07470
.6	9.33892
.7	10.51349
.8	11.60790
<i>*</i> .9	12.63059
1.0	13.58892
1.2	15.33799
1.6	18.30354
1.8	
2.0	• • •
2.2	• • • • • • • • • • • • • • • • • • • •
2.4	
2.6	0,
2.8	
3.0	
3.2	
3.4	
3.6	
3.8	
4.0	28.85335

of turns in a given coil and also the pounds or fraction of pounds of wire necessary.

Knowing the over-all length of the coil, we divide it by the diameter in mils (thousandths of an inch) and thus determine the number of turns. Knowing the diameter of the coil, we multiply the value by 3.1416 and obtain the number of inches of wire required for each turn. Multiplying this value by the number of turns and dividing by twelve, we obtain the total number of feet for the winding. Having determined the number of turns in a given winding, together with the diameter and length of the coil, we may use the following simple formula for the calculation of inductance:

 $L = a n^2 Q$.

Where, A = the mean radius of the winding in centimeters.

n = the number of turns in winding.

b = the length of the winding in centimeters (to edge of insulation).

(To convert inches to centimeters multiply by 2.54.)

The corresponding values of Q for the ratio ——is given in the following table:

b

Assume, for example, it is desired to calculate the inductance of a tuning coil 4 inches mean diameter, 10 inches in length wound closely with No. 24 S. S. C. wire. From the table we find the diameter of No. 24 wire to be .0224 inches. Hence dividing 10 by .0224 we obtain 446, the total number of turns in the coil. Also the mean radius of the coil is 5.08 centimeters and the ratio

Hence, L = $5.08 \times 446^2 \times 6.71 = 6,780,408$ centimeters or 6780 + microhenries.

How to Design a Receiving Tuner.—When the foregoing simple formula for the calculation of inductance is understood, receiving tuners of definite range of wavelength adjustment can be readily designed. It is preferable to begin with the secondary winding, but before we can calculate the correct dimensions for a given secondary we must assume a certain capacity for the variable condenser in shunt. It is generally not advisable to exceed .0003 microfarads at this condenser, hence if this is to be the maximum value of capacity and the upper range of wave-

length adjustment is decided upon, the required inductance for the secondary winding can be determined by the formula:

Inductance in centimeters = wave length (squared)

3552 × capacity

Therefore if a tuner is to have an upper range of adjustment of about 3,000 meters,
3000

then the inductance in centimeters $=\frac{3660}{3552 \times .003}$ = 8,490,556 centimeters or 8,490

microhenries. Rather than transpose the formula given for the calculation of inductance, it would perhaps be easier for the experimenter to assume a secondary coil 3 or 4 inches in diameter of a certain length wound with No. 32 S. S. C. wire and find by calculation how near it approaches to the desired value. The length of the winding can either be increased or decreased until the desired value of inductance is obtained

The same formula could be applied to the open circuit and a primary winding of the correct dimensions for a given wave length constructed. This formula is not strictly true for the open circuit oscillator but is sufficiently accurate for ordinary

calculation.

(The inductance and capacity of an antenna can be measured by the method

shown in Chapter V.)

If the inductance of the secondary winding of a receiving tuner for instance is known, and also the capacity of the variable condenser at any particular position, the possible wave-length adjustment can be obtained by the following formula:

Wave length = 59.6 × V inductance in centimeters × capacity in microfarads. This formula is not accurate for the open circuit oscillator except in cases where-large amounts of inductance are inserted at the base of the receiving aerial, but it suffices for ordinary amateur calculations.

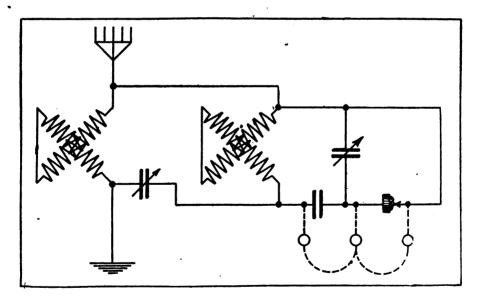


Fig. 79a-Receiving Set Tuned by Variometers.

CHAPTER X

Receiving Detectors for Wireless Telegraphy

THE members of a newly formed radio club frequently do not fully understand the properties, functioning, relative sensibility or the general instructions for the working of the various types of receiving detectors in use to-day. Hence they are not able to easily decide on the type of receiving detector best suited for their requirements. For beginners in this class there follows a description of the more important types of receiving detectors, together with additional advice for adjustment and operation.

Electrolytic Detector.—A receiving detector that has rapidly fallen into disuse since the discovery of the sensitive crystals is the "whisker point" electrolytic responder, although in the early days of wireless telegraphy in the United States it played an important part. The essential elements of this detector are indicated in Fig. 80 and the correct circuit for its operation in connection with an inductively coupled receiving tuner, in Fig. 81.

Referring to Fig. 80: The upright binding post, M, has the extended arm, R, through which is screwed rod A. The latter has soldered to the lower end a piece of platinum wire, W, having a diameter varying between .0001 and .000038 of an inch. This wire is known as "Wollaston wire" and was formerly used for another purpose. It is coated with silver to permit

easy handling.

The fine platinum point dips into the glass cup, C, which need only be large enough to hold eight or ten drops of a 20 per cent. solution of nitric acid—the electrolyte. In the base of the glass cup is placed a small sheet of platinum, E, about 3-16 of an inch square, which is connected to the binding post, C, by means of a connecting wire placed under the hard rubber base.

Circuit for the Electrolytic Detector.—The preferred circuit for this detector is indicated in Fig. 81, the important part of the diagram being the connection of the potentiometer and the local battery. The battery, B, should be one of five or six volts shunted by a wire wound potentiometer, P-2, of 300 to 400 ohms resistance. The telephones, P-1, may vary from seventy-five ohms to 2,000 ohms, the point of importance here being that they are well constructed and sensitive. The positive pole of the battery, B, should be connected to the fine wire point of the detector. The variable condenser, C-2, should have at least a maximum value of .0025 microfarad.

Operation.—To adjust this detector to a sensitive condition two rules must be observed. First, the fine wire platinum electrode must touch the

acid, in fact barely make contact with it; second, the silver must be removed

from the platinum wire.

The silver coating may be removed by three methods: First, an abnormal value of battery current from the local battery, B, may be sent through the electrolyte with the platinum point slightly submerged. A hissing, grumbling sound is heard which, after a period of two or three minutes, tends to cease. The current from the local battery, B, is then reduced until a buzzer tester indicates a loud response. The second method is to remove the fine wire electrode from the holder and place it for a moment in a very strong solution of chemically pure hydrochloric acid, the point being removed at intervals and examined by the aid of a magnifying glass to determine the degree to which it has been "trimmed." If an extremely fine "whisker" is observed, the point is ready for use, and to prevent further action of the hydrochloric acid it should be dipped in fresh water. The third method is to heat a small amount of mercury over a Bunsen burner. If the platinum point is dipped into the hot mercury, the silver is immediately removed.

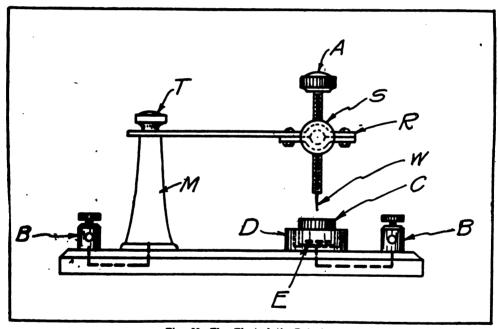


Fig. 80—The Electrolytic Detector.

The support for the holder of the fine point, W, is preferably of another design, in fact the holding rod, A, had better be a square one entering the arm, R, through a square hole. The rod, A, is then moved in a vertical position by means of a rack and pinion. Since this design demands rather elaborate construction, the holder, shown in Fig. 80, is considered sufficient for amateur requirements, but it is of advantage to have a holder that prevents the platinum point from turning during adjustment.

The amount of acid in the containing cup and the area of the surface of the lower electrode of the cell are unimportant, with the exception that the upper point and the lower electrode should be separated no more than 1/4 of

an inch.

It was the custom at commercial stations for a number of years to employ glass coated electrodes. The small platinum wire was sealed in a glass

jacket with only the extreme tip exposed, and since the remainder of the wire was covered with glass, the depth to which the platinum electrode was lowered in the solution had no effect on the degree of sensibility obtained. The process of scaling the fine platinum wire in the glass is a little difficult

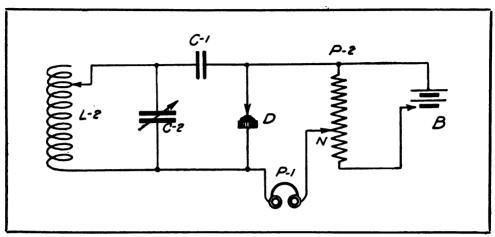


Fig. 81-The Circuit for the Electrolytic Detector.

for the experimenter inexperienced in glass-blowing, but one familiar with work of this nature should meet with no difficulty in constructing an electrolytic point of this type.

Good results have been secured with the electrolytic detector by the use

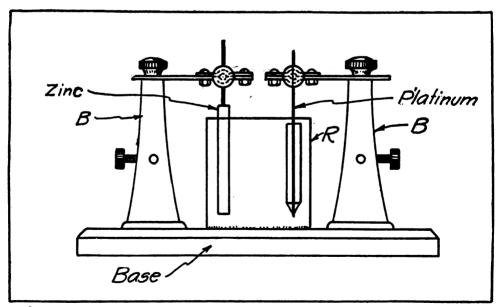


Fig. 82-Shoemaker Primary Cell Detector.

of a super-saturated solution of caustic potash, but the acid solution is more generally favored.

Several theories have been advanced regarding the action of the electrolytic detector; the subject is still a matter of argument, but it seems to be

the general opinion that the current induced in the antenna wires, which is transferred to the local circuit, causes a variation of the current from the local battery in accordance with the spark frequency of the transmitter. For further discussion of the operation of this detector the reader is referred to some of the morst important text books on wireless telegraphy

It may be of interest to some experimenters to know that signals from the electrolytic detector can be amplified by means of a single vacuum valve.

Primary Cell Detector.—Another form of electrolytic detector, sensitive and reliable in operation, is known as the primary cell detector or the "Shoemaker Electrolytic." In addition to performing the function of a detector, it has the added property of generating its own battery current; in fact, it is nothing more than a small chemical battery constructed so it can be adopted for use as a wireless telegraph receiving detector.

The details of the device appear in Fig. 82. To a hard rubber base are fitted two upright binding posts, B, and the hard rubber or glass cup, R, having a capacity of about four or six ounces of electrolyte. The left hand element of the cell is a small piece of amalgamated zinc about one-third the size of that usually employed in wet cells. The right hand element is a small platinum electrode having a diameter of .001 or .0001 of an inch, sealed in glass, with the tip of the wire only exposed to the acid. The electrolyte is a 20 per cent. solution of sulphuric acid in which the two elements are immersed. If a telephone is joined across the two terminals of the primary cell a decided click is heard, indicating that an electric current is being generated. In fact, such cells have often shown an electro-motive force of 0.5 volt.

Circuit for the Primary Cell.—The circuit for the primary cell detector as the same as that shown in Fig. 81, with the exception that local battery B and the potentiometer P-2 are eliminated and the head telephones connected to the platinum and zinc poles of the cell respectively. The condenser, C-3, should be variable in capacity and possess a maximum value of .005 microfarad. Good results can frequently be obtained by connecting the head telephones in shunt to the condenser, C-3. Owing to the simplicity of this detector, preliminary instructions are not required. It is only necessary to insert the elements in the acid and carefully adjust the tuning elements of the receiving tuner until response from a given station is obtained. The only difficulty experienced with the detector is the fact that the platinum point will polarize rather rapidly, which has the effect of reducing the sensitiveness. The gas accumulated upon this electrode can, however, be destroyed by shaking the point, or the action is automatically performed by a severe discharge of atmospheric electricity at any given station. Occasionally it is necessary to remove the zinc electrode from the solution for a thorough cleaning, after which it should be coated with amalgam of mercury.

A bare electrode of the type used in the "whisker point" electrolytic may also be employed for the primary cell, but, of course, the depth to which the electrode is immersed in the solution must be very carefully gauged. Experiment seems to prove that both of these receiving detectors require a secondary winding of rather low resistance, hence a receiving tuner secondary wound with No. 24 or N. 26 S. S. C. wire, may give the best results.

Both types of detectors are sensitive, particularly the "whisker point" electrolytic, which, when properly adjusted, compares very well with the sensitive types of mineral detectors. It is, however, not so rugged as crys-

tals of carborundum and possesses the added disadvantage that severe discharges of atmospheric electricity burn off the fine wire point, putting the detector completely out of operation until a new point is prepared.

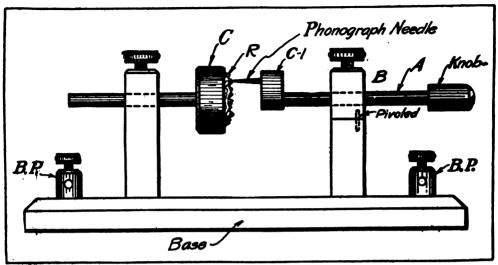


Fig. 88-The Carborundum Detector Holder.

Mineral Detectors.—Certain minerals found in Mother Earth, or crystals compounded by various processes, possess the property of rectification and will accordingly convert an alternating current of radio frequency to a unidirectional or pulsating current, thereby changing the signals of a distant transmitting station to a form suitable for attracting the diaphragm of a telephone receiver. One of the most rugged and practical of all crystalline detectors is the crystal of carborundum, which is much used at commercial radio stations.

It should be known at the start that the crystal of carborundum is not a native mineral, but a production of the electric furnace, a combination of sand, salt, sawdust and coke. The finished crystal is known to chemists as carbide of silicon.

The Carborundum Detector.—Although various holders have been de vised for crystals of this type, and all are to some extent satisfactory, the one shown in Fig. 83 is recommended, since it allows a sensitive point to be located at any point on the crystal. The crystal of carborundum, R, is imbedded in Woods metal or other soft metal in containing cup, C. The movable arm, A, has a double movement sidewise, at the point B, and "round and round" at the offset cup, C-1. A steel phonograph needle is soldered in this cup with a slight portion of the point projecting.

Adjustment.—Sensitive carborundum crystals cannot be told at sight, nor can specific instructions be given for locating the sensitive point. It is sufficient to say, however, that the steel needle is oriented about the crystal and "jabbed in" at different spots until a buzzer tester indicates a sensitive condition. As compared with certain other crystal detectors, this one demands a rather heavy pressure on the contact, C-1.

The adjustment of this detector cannot be considered complete until the voltage of the local battery, B, is carefully regulated

Circuit for the Carborundum Detector.—The preferred diagram of connections for the carborundum crystal appears in Fig 84. The head tele-

phones, P, are of 2,000 to 3,000 ohms resistance, the potentiometer, P-1, has resistance of 400 ohms and the battery, B, an electromotive force of 3 volts. The condenser, C-2, may have a capacity between .01 and .04 microfarad. As it is extremely important that the current from the battery, B, flow in a certain direction, the connections to it should be reversed during the test; the same effect is obtained by turning the crystal about in the holder, the former being left in the position where the loudest signals are obtained.

With the usual crystals of carborundum the use of the local battery is absolutely essential; therefore the potentiometer should be one giving fine

gradations of the applied voltage.

Some experimenters prefer for the carborundum detector the circuit indicated in Fig. 85, stating that it gives added response from a given station. It will be noted in this diagram that the telephones are shunted about the fixed condenser of the local circuit, the potentiometer being connected in series. With a circuit of this type it is often of value to have the condenser, C-2, variable in capacity.

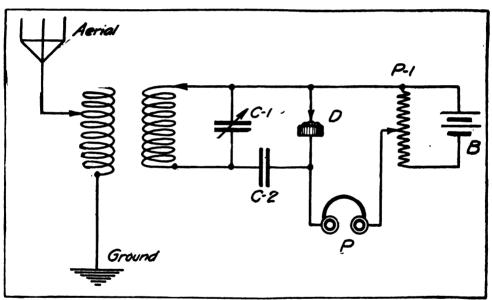


Fig. 84-The Preferred Circuit for the Carborundum Detector.

The Galena Detector.—This mineral is a natural sulphite of lead, generally found in the formation of cubical crystals. It has a blue gray color with a noticeable metallic lustre. One of the peculiar characteristics of this crystal when used as a wireless telegraph detector is that no local battery is required and that the opposing contact must be extremely light. The crystal holder indicated in Fig. 83 is applicable to galena, but the phonograph needle must be removed and a very light piece of clastic wire wound in the form of a spring substituted.

Adjustment.—Specific directions for the adjustment of galena crystals cannot be given, but the fine point should be placed in light contact with the crystal at various points until by means of a buzzer tester the most sensitive spot is located.

If a more positive contact than that afforded by a cat "whisker" is desired, a piece of graphite from a lead pencil may be employed. Increased pressure can then be applied.

Circuit for Operation.—The best circuit for the galena detector is that shown in Fig. 85, provided the potentiometer and battery are eliminated from the telephone circuit. With certain crystals of galena, the author has obtained increased sensitiveness by the application of a very small potential from the local battery, but to obtain similar results there must be connected in series with the main potetiometer a fixed resistance of about 2,500 ohms.

The Zincite-Bornite Combination.—Because of the ease with which a sensitive spot is located, many amateurs favor this combination of minerals, but owing to the fact that adjustment of the detector cannot be continuously maintained under the rugged conditions of commercial or amateur service it is not as well adapted to practical use as some other crystals, notably carborundum.

Zincite is a native oxide of zinc. It is a rather brittle substance of blood

red color, due to the presence of manganese.

Bornite is a copper ore consisting of about sixty parts of copper, fourteen of iron and twenty-six of matrix crystals. It possesses a rather odd bronze color.

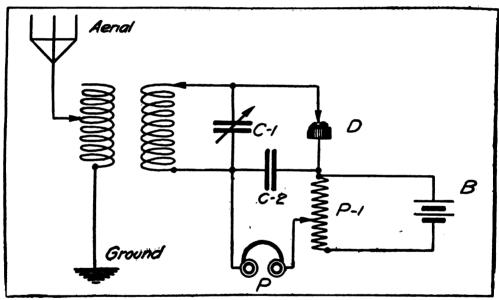


Fig. 85-The Preferred Circuit for the Perikon Detector.

The crystal holder in Fig. 83 is suitable for this combination of minerals. It is the custom to place several crystals of zincite in the large cup, C, and a single crystal of bornite in the revolving cup, C-1. During adjustment the crystal of bornite is touched at various spots on each of the crystals of zincite until a sensitive spot is located. The application of a slight electromotive force from the local battery is of some value to this detector; hence the circuit shown in Fig. 85 is correct, provided a fixed resistance of about 2,000 ohms is connected in series with the usual potentiometer at 400 ohms.

With a fresh set of crystals this detector is found to be more sensitive than crystals of carborundum and hence will give the stronger signals from

a given station.

In the earlier forms of this detector copper pyrites or chalcopyrite was used in place of the bornite crystal and it was frequently observed that a sensitive spot could be located more easily with the latter combination than with the one previously described. A copper pyrites crystal is easily dis-

tinguishable. It is a copper sulphate containing considerable iron, possess-

ing a brilliant brass yellow color and a rather bright metallic lustre.

With either combination of crystal it is necessary from time to time to clean the zincite crystals because the filings from the bornite or chalcopyrite crystal caused by rubbing the two crystals together may deposit themselves upon the crystals of zincite, thus destroying the sensitiveness. The crystals of zincite may be cleansed with ordinary soap and water, with gasoline or with a solution of carbon bi-sulphide. After the crystals are thoroughly dry they will be found, to some extent, to possess their original state of sensibility.

The Silicon Detector.—Silicon is non-metallic and one of the most abundant elements in nature. It is not, however, found in an uncombined state. The crystals used in wireless telegraphy have a gray metallic looking substance. This element possesses properties somewhat similar to that of galena, and, like galena, generally requires a rather light opposing contact. Hence it is customary to use a small whisker point of steel wire or other elastic wire for making contact with various points on the crystal. The holder described in Fig. 83 is applicable to this crystal, but the cup, C-I, is fitted with a light piece of wire in place of the rigid steel phonographic needle. The silicon detector functions with or without a local battery, but with certain types of crystals the best results are obtained by the application of a weak local current.

In one form of silicon detector the crystal is ground down on an emery wheel to a smooth polished surface, but amateur experimenters frequently report that they obtain the best results from the rough crystals in their natural state.

As in the case of the galena crystal, we can, in this instance, apply the diagram of connections in Fig. 85, provided a fixed resistance of 2,500 ohms

is connected in series with the standard potentiometer...

It is needless to say that a number of other elements have been found to possess the property of rectification. For example, the crystal of molybdenite in conjunction with a contact of copper has been found to act as a detector of electrical oscillatins. Likewise, a crystal of iron pyrites in combination with a steel contact will act efficiently as a receiving detector. Occasionally a crystal of tellurium with a contact of aluminum is used. In fact any single element of the foregoing combinations may be combined with an element of another combination. For example: zincite and galena are good rectifiers and are fairly sensitive. Likewise iron pyrites and zincite are often used in combination. A crystal of zincite in contact with a piece of light steel will act as a detector of radio signals. A crystal of copper pyrites in contact with an extremely light wire "whisker" often responds with marked intensity to the signals of a distant station; but it is found extremely difficult to keep this combination in adjustment.

A Special Holder for Carborundum Crystals.—A sensitive spot on a carborundum crystal may often be more quickly obtained by means of the holder and the method indicated in Fig. 86.

The overhanging arm, A, carries the vertical post, B, cut with gear teeth to take the gear wheel, G. At the lower extremity of the rod is placed the cup, E, in which is mounted the carborundum crystal, D, by means of Woods' metal.

The lower cup, H, may be of glass, brass, rubber or copper, and is filled with mercury to about one-half its depth. It should be I inch in diameter and about one inch in depth. It is, of course, connected to the binding post, B, by means of a wire running underneath the base.

During the adjustment the crystal, D, is gradually lowered into the mer-

cury in the cup, H, until a sensitive spot is located. If care is taken to place this detector in a spot free from vibration the adjustment will be maintained indefinitely. It has been found that a more sensitive adjustment

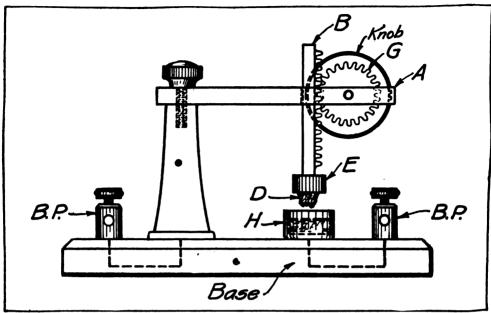


Fig. 86-A Novel Detector for Carborundum. Crystal Dips in Cup of Mercary.

is obtained with this device than by means of the ordinary sharp-point contact. It is probable that similar results might be obtained with other crystals by means of the mercury contact.

The Filings Detector.—There has recently appeared on the amateur market in the United States a new form of crystalline detector modeled somewhat after the original Marconi coherer, consisting essentially of a

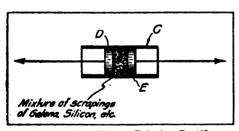


Fig. 87-The Filings Detector Rectifier.

cartridge, C, Fig. 87, in which are placed two brass lugs, D and E, which fit snugly into the inside of the cartridge. The space between the two brass lugs is filled with a mixture of scrapings from some of the well known crystals. The manufacturers of the device are reluctant to give the constituents, but good results have been obtained with mixtures of galena and silicon filings, to

which has been added a slight amount of brass and nickel filings. In fact, the scrapings of any of the crystalline detectors known to-day may be used. It is only necessary to separate the brass lugs by a distance of about 1/4 of an inch and half fill the intervening space with a mixture of scrapings. The filings are then scaled up tightly in a cartridge and in some cases exhausted by means of a vacuum pump. The detector is then connected in the circuit of an ordinary receiving tuner in the standard manner and the tube revolved by hand until a sensitive spot is located.

In order to facilitate the adjustment to a sensitive condition, a buzzer tester, one side of which is directly connected to a terminal of the detector, is employed. When the buzzer is turned on certain of the filings will co-

here, and thus automatically select a sensitive point of rectification. It is rather difficult to state offhand just how these detectors operate, but it is probable that the action is no different from that in an ordinary rectifying mineral; however, it may be that with so many filings in contact a sensitive point of rectification is more readily located than by the ordinary means. Some experimenters advance the theory that a certain form of coherence takes place between the crystals. If this is a fact it is difficult to understand how the de-coherence of the filings takes place, which, as is well known, is essential for telephonic reception. Some detectors of this construction are found to have a rather low value of resistance and consequently are used in series with the condenser and the coil of the secondary circuit of the usual receiving tuner. It then becomes necessary to change the usual type of stopping condenser to one of variable capacity because it is now an active element of the oscillation circuit.

It has been found that some types of the filings detector require a rather high value of local battery current, much in excess of that passed through the usual crystals of zincite, bornite, etc. Hence good results are obtained by the use of a vacuum valve amplifier for increasing the strength of signals obtained.

It is asserted by the manufacturers that the filings detector will stand considerable jarring and will remain in adjustment under conditions that would not be possible with the ordinary types of crystals.'

Marconi Magnetic Detector.—One of the most reliable and fool-proof of all detectors in commercial use today is the Marconi magnetic, widely in use aboard ships. It consists essentially (Fig. 88) of the iron wire band, B (several strands of No. 36 iron wire twisted in the form of a cable), having a total length of from 18 to 24 inches, which is slowly drawn through the glass tube, P, by the ebonite or wooden pulleys, W-1 and W-2, which, in turn, are set in rotation by clock work or by a small direct or alternating current motor. The glass tube, P, is wound with from 6 to 10 feet of No. 36 single silk covered wire and directly around it is placed another winding, S, of No. 36 single silk covered wire having a resistance of about 180 ohms. The head telephones, joined across are terminals of S, should have a resistance of close to 150 ohms. Immediately above the two bobbins of wire are placed two horseshoe magnets with like poles adjacent. These magnets generally have a separation between the poles of about 1½ inches and are placed at a distance of approximately ¾ of an inch to 1 inch from the band, B.

The glass tube, P, is usually about 2 inches in length and 3-16 of an inch in diameter. The bobbin of wire for the head telephone circuit has a diameter of 1½ inches and an overall width of ½ inch.

Operation.—When the band, B, is set into movement by the clock-work some parts of it are magnetized as they approach the south pole of the magnet, and accordingly are demagnetized when approaching the north pole of the magnet; however, owing to the well-known effect of hysteresis, the change of flux does not take place immediately any part of the band is directly under a magnetic pole, but is effected at a point beyond, the final result being that the iron band is in a magnetic state which is extremely susceptible to outside changes of magnetic flux which may be caused to act upon it. When high frequency electrical oscillations radiated by a transmitting radio station flow through the winding, P, for each group of oscillations, a momentary change in the position of the magnetic lines of force of the band takes place, which, in turn, causes a variation of movement of the flux threading through the coil, S, creating a single sound for the entire group. Thus impulses of current in accordance with the note of the distant transmitting station will be induced in the circuit of the head telephones.

Adjustment.—No preliminary instructions for the adjustment of the magnetic detector are required, since it is only necessary that the band, B, move at a very low rate per second, usually making a complete turn in about two seconds. The circuit, however, in which this detector is connected is

important, as the device is one of low resistance, and therefore may be, if so desired, connected directly in series with the aerial circuit. satisfactory circuit for the detector is indicated in Fig. 89, in which an aerial tuning inductance, L-1, is joined in series with the primary winding of the detector, P, and thence extended to the earth connection. E. As indicated by the dotted lines, a variable condenser, C-1, is sometimes connected in shunt to the antenna winding. is then only necessary to tune the antenna to the distant transmitting whereupon audible station. sponse is secured.

In order to obtain the full benefit of the phenomenon of resonance, the magnetic detector is sometimes connected in the circuit indicated in Fig. 90, which is a duplicate of the well-known Marconi multiple tuner. The intermediate circuit of this tuner comprises the winding, S, in

Fig. 88—Marconi's Magnetic Detector.

y winding, P, the variable condenser in

inductive relation to the primary winding, P, the variable condenser in shunt, C-2, and the second inductance coil, P-1, which is in inductive relation to S-1. The secondary winding then continues through the variable

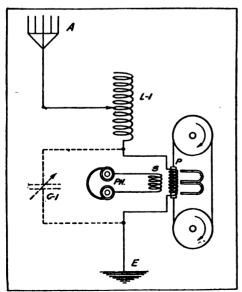


Fig. 89—"Stand-By Circuit" for Marconi's Magnetic Detector.

condenser, C-1, to the demagnetizing winding, P, of the magnetic detector. Since, as mentioned before, this detector is considered to be a current-operated device, the secondary winding, S-1, must have rather low values of inductance and be made up of coarse wire. For example, No. 18 or 20 single silk covered, or Litzendraht wire, is preferred. It should be remembered in this circuit that the variable condenser, C-1, is an active part of the oscillatory circuit and changes of wave-length can be effected by very close variation of it. \ Usually a condenser of about .005 or .01 microfarad is employed at this point; consequently, even for wavelengths inclusive of 3,000 or 4,000 meters, the winding, S-1, may have a very few turns of coarse wire.

It has been found by experiment

that the signals from 500-cycle spark transmitters are better received when the iron band, B, is set into rotation at a greater speed than that ordinarily employed for spark transmitters of lower frequency. Increased results frequently can be obtained by shifting the position of the horseshoe magnet, but for general commercial working they need not be moved.

An interesting point in connection with these detectors is the fact that they are more responsive to the lower oscillation frequencies, in fact, the best results are obtained at wave-lengths between 2,000 and 3,500 meters.

In commercial practice the revolving band is fitted with two sets of wire bobbins placed on opposite sides of the band so that in case one set of windings is by any means injured, the second set of windings may be immediately brought into use.

The Tikker Detector.—By reason of the fact that there are no discontinuities in the wave train radiated by an undamped oscillation radio-transmitter, it is necessary to provide means at either the tranmitting or receiving apparatus to break these oscillations up into groups suitable for response in the head telephone receiver. When an ordinary crystalline detector is used in receiving system which is in resonance with a continuous wave transmitter, no sounds are produced in the head telephones except at the opening and closing of the telegraph key, due to the fact that the continuous alternating current flowing in the transmitting antenna circuit is converted into a pulsating direct current at the receiving station. The latter merely displaces the diaphragm of the receiver magnets and does not release it until the key of the transmitting station is raised.

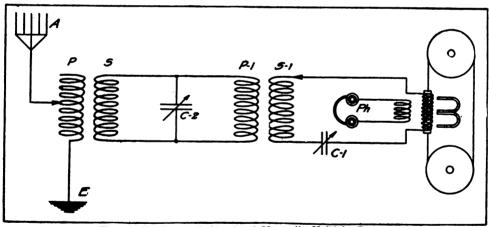


Fig. 90-Fundamental Circuit of Marconi's Multiple Tuner.

The original tikker detector is nothing more than a circuit interrupter mounted on a common bell buzzer. Referring to Fig. 91, the magnets of the buzzer are energized by the battery, B-1, the armature being set into vibration. By careful design of the weight of the armature and the rigidity of the spring a very high rate of interruption per second of time can be obtained. At the end of the armature, G, is mounted the contact, D, which makes contact with the stationary point, E. As will be further observed, the last two contacts are connected in series with the secondary winding of the receiving tuner and thus they periodically open and close the circuit to the telephone condenser, C-2.

When undamped oscillations traverse the receiving antenna the secondary circuits are interrupted at a rate of from 300 to 800 times per second, producing

a semi-musical tone in the telephone receivers, Ph. The result is that the charge accumulated in the secondary condenser, C-1, discharges at regular intervals into the condenser, C-2, which in turn discharges into the head telehones, creating an audible sound. Owin gto the fact that the circuit interrupter does not break the circuit immediately at the peak of each alternation of current in the closed oscillatory circuit, a uniform note is not produced; consequently the resultant note is apt to be more or less "hissy" and not of the pure tone that could be expected from modern heterodyne circuits. A detector of this type, however, is effectual and by careful adjustment will give good results at any receiving station. In the original form, instead of having platinum contacts at the points, D and E, two light gold wires were placed in contact and the circuit is thus interrupted.

A modified form of the tikker is indicated in Fig. 92, wherein a toothed wheel is driven at a certain rate per second. One terminal of the secondary system is connected to the brush, B, which makes contact with the wheel,

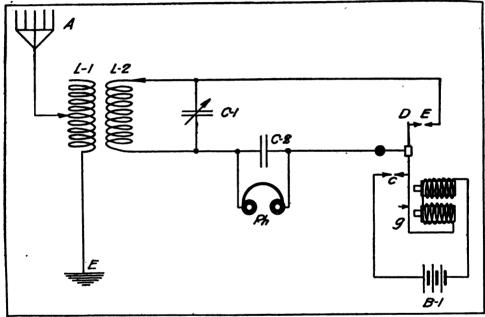


Fig. 91-Simple Laboratory Tikker,

W-1. The second terminal of the secondary system is connected to the brush, S, which is placed in light contact with the teeth of the wheel by means of the set screw, R. If the wheel is revolved to interrupt the circuit at a rate of, say, 600 per second, a fairly uniform note will result. A more satisfactory arrangement is to construct a commutator interrupter of the well-known type, one side of the circuit being connected to all the bars of the commutator and the other side of the secondary circuit being connected to a brush which is in electrical contact with the bars.

At a later date another form of detector, known as the slipping contact detector, was devised, the essentials of which are shown in Fig. 93. In this case a small motor, M, has mounted on its shaft the wheel, S, which is about I inch in diameter. This wheel has a small groove in which is placed the light elastic contact, C. The other terminal of the secondary receiving tuner is connected to the brush, B, which is in contact with the shaft of the motor. Owing to the constant slipping and gripping of the contact, C, a contact of variable resistance

is obtained, which has the effect of varying the energy which accumulates in the telephone condenser. Usually with this type of detector a more uniform note is secured than with either of the foregoing described tikkers, but still a musical note is not obtained, the resultant note being somewhat similar to that of steam escaping from a radiator.

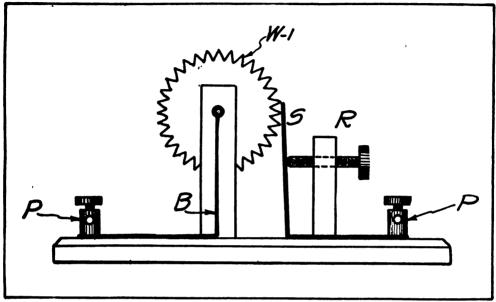


Fig. 92-Showing the Principle of the Tikker Interrupter.

If the transmitting station radiates damped oscillations at a rather high spark frequency, any of the tikkers or a slipping contact detector may be used for receiving purposes, but of course the normal note of the spark station will

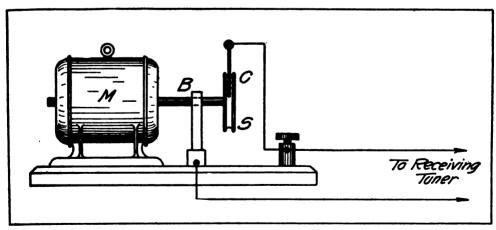


Fig. 93-The "Slipping Contact" Detector.

be distorted, the resultant note being lower in pitch and of unstable and irregular characteristics. Certain tests made by the United States, Naval Radio Telegraphic Laboratory indicate that this detector is from three to ten times as sensitive as the ordinary minerals.

Adjustment.—Perhaps the most difficult to adjust of all the tikkers just described is the one indicated in Fig. 91, which requires close adjustment of the contacts, D and E, in order that a fairly uniform note may be obtained. The detectors in Figs. 92 and 93 are perhaps the most easy to adjust, the only requirement being in the slipping detector that the contact, C, be given a light pressure.

Circuit for Operation.—The diagram of connections indicated in Fig. 91 is suitable for any of the tikker detectors. Any receiving tuner designed for crystalline detectors will respond with the tikker. It is, however, the usual practice with these detectors to supply a secondary winding of relatively low resistance made up of Litzendraht wire or of coarse copper wire. Good results have been obtained with wires ranging in gauge from No. 20 to 24 and by means of the data given in Chapter 9, it is easy to calculate the dimensions of a coil for a given value of inductance.

It is sometimes the practice to connect a rectifying detector in series with the tikker. It is found by experiment that it has the effect of smoothing out the

note, but it decreases the sensibility of the system as a whole.

The Goldschmitt Tone Wheel.—It was mentioned in connection with the previous types of circuit interruptors that the note was irregular, due to the fact that successive alternations of current were not broken or interrupted at the same point on the cycle. Hence means were devised by which a pure musical note can be obtained by a mechanical circuit interruptor which adds considerably to the efficiency of the device of th

ciency of the device:

To understand the operation of a Goldschmitt tone wheel we must begin by assuming the following problem: Suppose, for example, that a distant transmitting station employed an alternating current to charge the antenna circuit, having a frequency of 50,000 cycles per second, corresponding to a wave-length of 6,000 meters, and assume, further, that a circuit interrupter (tikker) is devised which gives 50,000 breaks per second and is driven at such speed that the peak of every other alternation in the wave train is interrupted; then it is plainly evident that only one-half of each cycle of alternating current will flow in the head telephones. That is, the radio-frequent current will be converted to a direct current which will merely displace the diaphragm. Suppose, however, that the disc is run at a slightly lesser or greater speed than that necessary to obtain synchrony, the circuit being interrupted at the rate of 49,000 times per second; then every thousandth alternation of current in the aerial system is interrupted directly at the peak (in the case of a 50,000 cycle alternator at the transmitting station), and all intervening alternations are interrupted at different points on the complete cycle. The final result of this action is to produced in the telephones a beat note, or, in other words, a nearly sinusoidal alternating current of a frequency of 1,000 cycles per second. Keeping these facts in ffind in order to obtain similar results with an ordinary tikker, it is necessary to construct a tikker interruptor with a great number of points of contact in order that from 30,000 to 55,000 interruptions of the circuit can be obtained per second of time. Of course the number of interruptions necessary depends upon the wave-length of the distant transmitting station and on the shorter wave-lengths, say 3,000 meters, an interruptor giving 100,000 breaks per second is required. It is found difficult to obtain the required rate of interruption with a mechanical device, however, and consequently the tone wheel is more p

Contrary to expectations, it is not difficult to find a satisfactory adjustment of the tone wheel, but it is highly important that the motor revolve at a constant speed, and that it be fitted with a regulating rheostat which will allow the speed of the motor to be accurately adjusted over considerable range. Then, by listening in on the head telephones when the distant transmitting station is in operation, variation is made in the speed of the motor until a musical note of desired pitch is

secured.

Chapter XI

The Vacuum Valve Amplifier and Beat Receiver

PERHAPS the most interesting types of receiving detectors in use at present are the variously constructed vacuum valves, the forerunner being the Fleining Valve, which is shown diagrammatically in Fig. 94. A tungsten or carbon filament F is sealed in a glass

carbon filament F is sealed in a glass bulb with a copper or nickel plate P, the bulb being exhausted to a high degree. The filament is brought to incandescence by the battery B, which may be of 4 volts or 12 volts. The incandescence of the filament is controlled by the rheostat R, which usually represents a resistance of about 10 ohms.

2. It is generally asserted that the vacuous space between the plate P and the filament F is conductive only to oscillations in one direction, hence when the condenser C-2 discharges into the valve

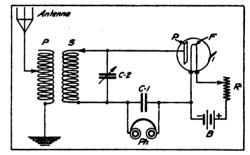


Fig. 94—Elementary Connections for the Fleming Oscillation Valve

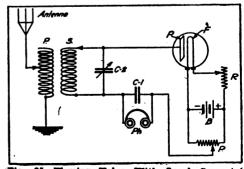
elements, the alternating current of radio-frequency is converted into a pulsating direct current which charges the condenser, C-1, and thus actuates the head telephones.

The complete circuit for this detector, as shown in Fig. 94, includes the primary and secondary winding of the receiving couplers P and S, the secondary winding being shunted by the variable condenser of low capacity, C-2.

The telephones are shunted by the condenser C-1, which usually represents a value of .003 microfarad.

It is not difficult to bring this detector into a state of sensitive adjustment; it is only necessary to regulate the incandescence of the filament F by means of the rheostat R, until the best response is secured from the distant station.

The best results are obtained when the secondary winding, S, possesses a high value of inductance and the condenser, C-2, a rather low



ig. 95—Fleming Valve With Local Current Flowing Through Head Telephone Circuit.

value of capacity. Generally C-2 does not exceed .0002 microfarad. The Fleming valve detector is sensitive and possesses the great advantage for commercial service of exceptional stability and uniformity of action, being continuously operative as long as the filament burns. It is not easily influenced by the local transmitter, a highly desirable feature at a busy commercial station.

Another Circuit for the Fleming Valve.—The circuit for this detector is sometimes altered as in the diagram, Fig. 95, wherein a potentiometer, P, is employed and a small local current passed through the vacuous space in the bulb between the plate and the filament. In this case the potentiometer has resistance of about 400 ohms, the rheostat, R, about 10 ohms, but the remainder of the circuit is identical with that given in the diagram, Fig. 94.

To adjust the detector in this circuit the rheostat, R, and the sliding contact of the potentiometer, P, are adjusted until the loudest signals are obtained from the distant transmitting station. If desired a second set of

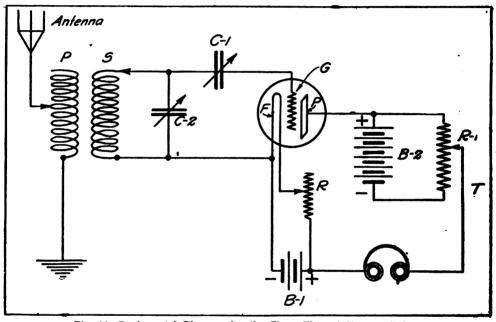


Fig. 96-Fundamental Diagram for the Three Element Vacuum Valve.

batteries may be employed for the potentiometer circuit, but the same results are obtained with the connection given in the diagram, Fig. 95.

The Three Element Valve.—A modification of the Fleming valve is the three element vacuum valve, which, in addition to the elements indicated in Fig. 95, has a platinum grid, G, placed between the tantalum filament and the plate, as in Fig. 96. In this circuit, in addition to the lighting-battery, B-1, we have the second battery, B-2, connected in series with the head telephones, the circuit continuing from the plate, P, to the filament, F, through the space in the bulb. The voltage of the battery, B-2, is adjustable between 25 and 60 volts for ordinary work. Sometimes it is shunted by the potentiometer, R-1, of 2,000 ohms resistance and then, by movement of the contact, T, the current flow in that circuit can be very closely regulated.

Circuit for Operation.—The usual primary and secondary windings are represented at P and S and the shunt condenser at C-2. The condenser, C-1, may be of fixed or variable capacity, but in any event it must not exceed .0003 microfarad for ordinary usage. The condenser, C-2, also has low values of in-

ductance at all wave-lengths, for it is preferable in a circuit of this type to have inductance predominate.

When two bulbs are employed as an amplifier this condenser may be eliminated, but for certain classes of work the diagram, Fig. 96, is preferred.

It is important that the plus pole of the B-2 battery is connected to the plate, P, and that the negative terminal of B-2 be connected to the positive terminal of the lighting battery, B-1.

If the vacuum valve is not highly exhausted and one of the type in which considerable gas is present, the filament, F, is brought to a certain degree of incandescence by the rheostat, R, and the voltage of the B-2 battery adjusted until the best response is secured. If too much voltage is applied at the battery, B-2, a characteristic blue glow appears which may or may not destroy the sensibility of the valve. Generally, however, the bulb is worked just below the blue glow adjustment and will then give the best response. When the bulb is highly exhausted the blue glow is not evident, even when very high voltages are applied to the local telephone circuit. The operator in adjusting a vacuum valve to sensibility should try various degrees of incandescence and various values of voltage at the battery, B-2, until good response is secured, and to prolong the life of the filament he should hold to that adjustment which allows the lowest degree of incandescence.

Action of Valve.—It has long been known that when this filament is brought to a certain degree of incandescence a current applied from an external source will readily flow in one direction from the plate to the filament, but will be opposed in the opposite direction. This is due to the fact that the filament, when heated, throws off electrons (in the case of a highly exhausted bulb) which constanly bombard the cold plate, P. In the case of the three-element valve used, as shown in Fig. 96, when an incoming wave train induces radio-frequent electrical oscillations in the secondary windings of the receiving tuner, they are rectified by the valve action of the filament and the grid into a series of direct current impulses which charge the condenser, C-3. A negative charge is therefore sustained on the grid which cuts down the flow of electrons from the filament to the cold plate, resulting in a decrease of the current through the local head telephone circuit. When the charge has leaked off the grid the local current returns to normal strength.

This, it will be seen, occurs at audi-frequent rates and makes the diaphragm of the telephone vibrate according to the spark frequency of a distant transmitting station.

On account of the amplifying action just described, the vacuum valve often is referred to as a "trigger device," for the reason that the high frequency oscillations produced in the receiving antenna do not energize the head telephones direct, but are used to pull the "trigger," so to speak, of the local circuit containing the heavier battery current; hence the sensitiveness of the device. It is not unlike the operation of a telegraph relay where the feeble current of the line operates a local circuit carrying heavier current which gives increased strength of sound.

The battery cells for use with the vacuum valve are divided into two classes—the low voltage cells for the filament and the high voltage cells for the head telephone circuit. After ten cells are included in the high voltage battery a multiple-point switch should be used to connect three cells in the circuit at a time from ten to maximum, for it is very important that the voltage in the head telephone circuit be exact. As a matter of fact, no one can tell in advance the values of voltage to be used at either the high voltage battery or the filament battery, but after a little experimenting it will be found that a certain proportion between the two will give the best results. It is well to bear in mind the necessity for having sixty volts in the head tele-

phone circuit because there are certain grades of valves which require that amount of potential and even more.

The Magnetic Field About the Valve.*—That an external magnetic field applied to the vacuum valve at a certain angle will in some cases increase its sensitiveness has been well understood for a number of years. Recent tests have revealed that a tubular magnetic field supplied by a battery current flowing through a coil of wire, when held in a certain position above the bulb may be effective in renewing its sensitiveness.

A cardboard or other insulating tube, 3½ inches in diameter by 2½ inches in length, is wound closely with No. 30 S.C.C. magnet wire in the same manner as the coils of a receiving tuner. The winding is then connected to an eight or ten-volt dry cell battery in series with which is connected a ten or fifteen-ohm battery rheostat. A tubular magnetic field is produced, the intensity of which can be regulated by means of the rheostat. The complete circuits for this arrangement are shown in Fig. 97.

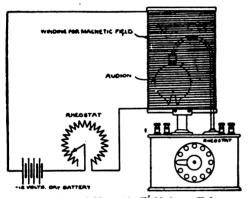


Fig. 97-External Magnetic Field for a Valve.

If the tube is then placed directly above the valve bulb in such a manner as to cause the magnetic flux to act directly upon the vacuous space, a considerable increase in strength of radio signals can be expected. though it has not been proven, the explanation offered is that the magnetic field so produced materially assists the assage of the ions or electrons from the filament; hence the increased sensitiveness. Again it is believed that the magnetic field steepens the volt-ampere characteristic of the bulb and therefore gives increased strength of signals in the telephone. The complete

for the tubes are shown in Fig. 97. The polarity of the magnetic flux issuing from the tube is important and should not be overlooked. Of course, it may be reversed by changing the direction of the flow of the battery current. During recent experiments it was found that for the best results with a certain valve the tube should be placed twelve inches above it. The test also indicated the necessity for very careful regulation of the magnetic field. It was observed further that with some bulbs the tube did not give increased strength of signals, but a decided decrease. When the triple valve amplifier is used the magnetic tube seems to be of no assistance to the first valve, but if applied to the second or third bulb an increase of signals to five times the original strength is obtained.

If an abnormal value of current is supplied to the coil the valve suddenly becomes inoperative. After a wait of a minute or two (without any change of voltage adjustment) normal conditions seem to be restored automatically. The complete circuits for the tube are shown in Fig. 97.

The Use of Permanent Magnet.*—Should the experimenter desire to employ a permanent magnet for the purpose just described the method which was described in the May, 1914, issue of The Wireless Age is recommended.

Referring to Fig. 98, the apparatus consists of a permanent horseshoe magnet, the poles of which are far enough apart to allow the bulb to be introduced between them and so arranged that it can be oriented about the bulb until the point of maximum sensitiveness is found and clamped there. In

^{*}The statements made in these paragraphs concerning the effect of an external magnet field were intended to apply strictly to the type of bulb not highly exhausted.



Fig. 98 A is the valve bulb, M the magnet, S a standard to support the magnet, and R a pair of concentric brass rings, machined to the shape shown, between which the standard, S, moves, and is clamped at any point by the nut.

This allows the magnetic field of M to be rotated with respect to the valve, A, and held at the most sensitive position.

The effect with some valves is surprising. Signals formerly inaudible come in clearly and others, formerly quite faint, may be read with the phones lying on the table.

A side view of the device just described is shown in Fig. 99. Careful observation of both drawings will reveal that the electrons of the bulb may be deflected at any angle desired.

The Single Step Amplifier.—If the members of a radio club have on hand a carborundum, Perikon or

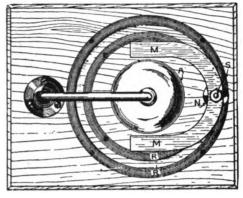


Fig. 98—External Field Supplied by Horseshoe Magnet

other crystalline detector employing a local battery current the three-element valve can be used to amplify its signals to a marked degree. The complete diagram of connections for this method is shown in Fig. 100 and should be studied carefully.

The primary winding of the receiving tuner is represented at L-1, the aerial tuning inductance at L-2 and the short wave condenser at C-1. The secondary winding is represented by the coil, L-3, the condenser is shunt, C-2, the fixed stopping condenser, C-3, and the crystalline detector, D. A potentiometer having resistance of 300 ohms is represented at R. A fixed

resistance, R-1, of 1,800 ohms is conected in series with the battery, B. A variable tap-off, T, allows regulation of the current flowing through the auto-transformer, P, which has a I to I ratio between the primary and secondary turns. One terminal of the auto-transformer is connected to the grid of the valve, G, the other terminal to the filament, F. The high voltage battery is represented at B-2 with the head telephone connected in series, and the low voltage battery at B-1. A rheostat, R-2, is connected in series with the filament. A variable condenser, C-3, connected in shunt to the head telephone, PH, is used to amplify the signals.

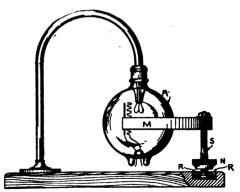


Fig. 99—Side Elevation Showing Position of

The auto-transformer having a one to one ratio of turns is constructed in the following manner: A core 14 inches in length by 2 inches in diameter, consisting of a bundle of No. 30 very soft iron wires, is wound with several layers of No. 34 S.S.C. wire; it is, in fact, covered with about four pounds of this wire. When complete it will have resistance from 7,000 to 10,000 ohms. This transformer acts as a temporary storage for the change of current in the local circuit of the first valve from which it is impressed upon the grid

and filament of the second valve where the incoming signal is amplified. If desired an inductively coupled transformer may be substituted for the auto-

transformer just described.

The entire apparatus is adjusted to sensitiveness in the following manner: The auto-transformer is disconnected and the detector connected up to the head telephone in the ordinary manner. The potentiometer, B, is then regulated and the sharp point of the receiving detector placed at different points upon the crystal until the loudest signals are obtained. After the perikon detector has been adjusted to the highest degree of sensitiveness, the head telephone should be disconnected from the fixed condenser and the auto-transformer connected to the valve in the manner shown in Fig. 100. The rheostat, R, in the low voltage battery circuit of the valve is now adjusted to give a certain degree of heat to the filament and the pressure of the high voltage battery is varied in intensity, while a distant station is working. A point of adjustment will be found at which very loud signals are secured—much louder, in fact, than can be obtained with either the perikon or the valve alone. Like all devices of this nature, it demands skill on the part of the amateur and

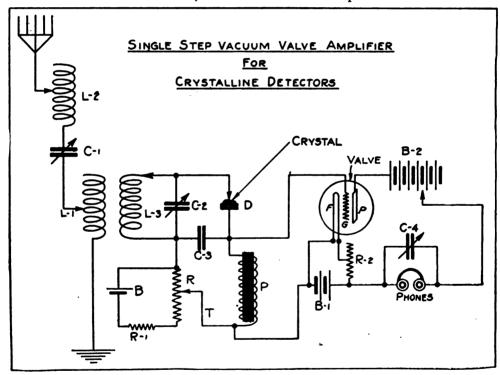


Fig. 100—Single Step Vacuum Valve Amplifier for All Types of Rectifying Detectors.

an intimate knowledge of radio telegraph receiving circuits. He should not be discouraged if the first tests are unsuccessful.

As a matter of experiment, the two leads from the one to one transformer connected to the filament and grid respectively may be reversed and then left to remain at the connection which gives the best results. It is important that the positive pole of the high voltage battery be connected to the cold plate as shown in the drawing.

If the apparatus is connected up as shown, surprising results are in store for the amateur, but he must take particular care to keep the perikon and the valve in the most sensitive adjustment. During tests of this device amplifications of Arlington time signals of twenty times the strength produced in

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the head telephone with either the perikon or valve alone were obtained. A single valve has been employed to amplify the signals from any of the detectors such as silicon, perikon, carborundum, galena and electrolytic as ordinarily used in wireless telegraphy. Particularly good results can be obtained

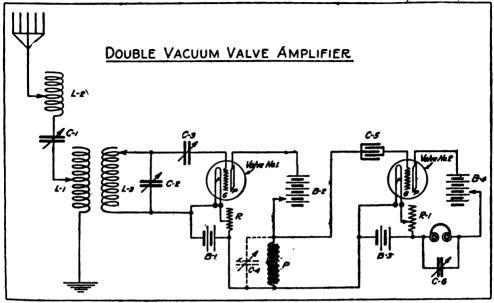


Fig. 101-Two Valve Amplifier for the Amplification of Audio-frequency Currents.

by using carborundum which, on account of its ruggedness, is of value during heavy atmospheric electricity.

Double Step Amplifier.—The diagram of connections for two valves as an amplifier is shown in Fig. 101. Observe that valve No. 1 is connected up in the regular manner with the exception of the head telephone. In place of the head telephone is connected a one to one auto-transformer, P, having resistance value of 9,000 or 10,000 ohms. The core for this transformer is of the same dimensions as the one previously described. However, it is wound with about four to five pounds of No. 34 wire. The two leads are then tapped off from the auto-transformer and led to the grid and filament of the second valve. The latter valve has its individual high voltage battery and the telephones are connected to it in the regular manner. A variable condenser, C-5, may be connected in series with the grid of the second valve if desired. Very often good results can be obtained by inserting in that part of the circuit a condenser of, say, ½ microfarad capacity. It is of value to connect a condenser (C-4) of .001 microfarads capacity in shunt to the transformer, P. C-6 should have a value of .005 microfarads.

Like all similar devices, familiarity with the apparatus is necessary, and it is impossible to advise in advance concerning the adjustment of battery current or voltage to be used in either valve. This can be determined best by experiment. It is not difficult if the experimenter understands the adjustment of valves as used individually, but in all cases there is a proportionment of the high voltage battery to the degree of heat in the filament which gives the best results. When two valves are used as an amplifier, however, these adjustments may not be the same as when either valve is used singly and in the ordinary manner. This must be determined by experiment.

A series of experiments seem to indicate that when the double amplifier is in the most sensitive condition the following proportion holds good:* The filament of the first valve generally burns at very low incandescence, i. e., cherry red, but the filament of the second valve must be burned at a degree of

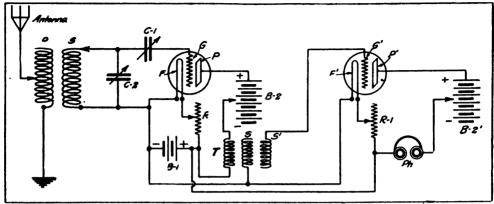


Fig. 102—Showing How the Filaments of Two Amplifying Valves Can Be Lighted by One Battery.

high incandescence. That proper adjustments are secured is also made plain, when, if the filament voltage of the first valve is not adjusted properly, the telephone produces a singing noise. The local head telephone circuit of the first valve generally requires a rather high voltage, while the second valve requires somewhat less.

The market is supplied with various types of ampliphones and loudspeaking telephones, but they will only increase the strength of signals which are already loud enough to be heard in the ordinary magneto telephone. The vacuum valve amplifier, however, will pick up and intensify signals when others types of crystal or electrolytic detectors fail to do so. When two valves are connected in cascade the signals are so loud that those from stations which ordinarily have fair intensity can be read at least fifteen or twenty feet away from the head telephones. Using this amplifier surprisingly clear messages have been copied from 2 k.w. sets at sea in broad daylight at a distance of 1,200 miles.

Members of radio clubs can give an interesting demonstration of radio telegraphy by purchasing a loud-speaking telephone for use in connection with the double With this additional equipment it will not be necessary for them to wear head telephones in order to receive radio signals. Loud-speaking telephones can be purchased from the large commercial telephone companies at reasonable prices. After the vacuum valve has been connected up the loud-speaking telephone should be substituted for the regular telephone and placed in the center of the room. Then the receiving tuner should be adjusted to the Arlington time signals. The ticks of the clock from the Arlington plant can be read easily at a distance of from twenty to thirty feet away from the head telephone, and those present will be able to set their watches by government station time. If the amplifier is used there is no reason why members of radio clubs within 600 miles of Arlington should not be able to read the signals from ten to twenty-five feet away from the loud-speaking telephone,

provided from the organizations are equipped with efficient antennae.

If any difficulty is experienced in securing results with the amplifier, it is undoubtedly due to the fact that the batteries (low and high voltage) are opposing one another in each individual valve, or that the connections from the second valve to

the one to one transformer are incorrect and need to be reversed.

If amateurs desire more elaborate equipment they should place a third valve in the circuit, using another one to one transformer between the second and third valves. The third valve should have its individual lighting and high voltage bat-If all connections are properly made with the triple arrangement and the

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^{*} These remarks apply to the partially exhausted valves.

voltage, is properly adjusted, amplification of 150 times the strength of signals to be

obtained from the perikon or electrolytic detectors can be secured.

Amateur stations equipped with more elaborate recording antennæ should be able to receive signals from ships at a distance of 2,800 miles during the winter months. It has often been noted that fair results in tuning can be secured by the adjustment of either the battery voltage or the filament voltage of the second or third valve. As a matter of fact, a slight adjustment of valtage will enable the experimenter to eliminate signals having different spark frequencies, although the various stations

sending these signals can be operating on the same wave-length.

The circuit indicated in Fig. 101 may be altered as in Fig. 102, and in this case the transformer, T, has two secondaries, S and S1, which are left open at the ends and connected exactly as shown. This transformer may or may not have an iron core, provided the inductance values are the same in either case. Usually good results can be obtained by a primary winding having a resistance of about 5,000 ohms, while the secondary windings, S and S'; may have 2,500 ohms, respectively. By means of this connection a single storage battery unit may be used for lighting all filaments without interfering with the sensibility of the apparatus.

Regenerative Receivers.—While remarkable results can be obtained by

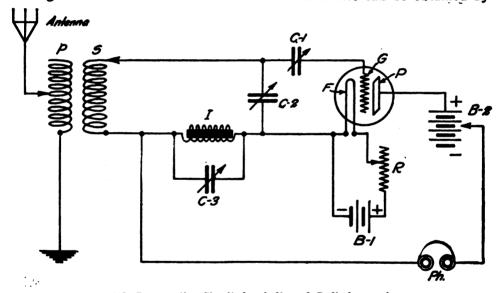


Fig. 103-Regenerative Circuit for Audio and Radio-frequencies.

the two cascade systems of amplification on spark signals described in Figs. 101, 102 and 103, very good amplification can be obtained on a single threeelement bulb by the use of diagram indicated in Fig. 103. Here the circuit from the local battery, B-2, makes connection with B-1 and the vacuum valve filament through the impedance coil, I, of 3,000 to 5,000 ohms resistance. This coil is in turn shunted by the condenser, C-3, of .001 to .005 microfarad capacity, in order that the oscillations of radio frequency in the secondary curcuit may be permitted to pass to the detector. Any variation of current flow in the telephone circuit is repeated back to the grid circuit and reinforced by the relay action of the valve,

A modification of this circuit is shown in Fig. 104, where the grid circuit of the valve and the local telephone circuit are coupled together by the condenser, C-3, which is connected in shunt to the telephone and the battery, B-2. By very careful adjustment of the condenser, C-3, and of the telephone circuit voltage at the battery, B-2, and corresponding adjustment of the incandescence of the filament, a point will be found where considerable amplification is obtained from either damped or undamped stations, but the best response with this circuit is secured at wave-lengths in excess of I,000 meters?

It should be understood that the three-element vacuum valve will repeat the current of radio frequency flowing in the grid circuit into the local battery circuit. By properly coupling these oscillations can be repeated back to the grid and thus reinforced or amplified. A current of audio frequency can be reinforced through the grid circuit as well as one of radio frequency

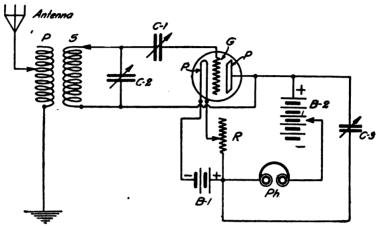


Fig. 104-Simple Regenerative Circuit.

In the diagram of Fig. 103 the valve is arranged to repeat audio and radio frequencies, that is to say, the variation of current in the local telephone circuit caused by a group of semi-oscillations being stored up in the condenser, C-I, are repeated back to the grid circuit and reinforced by the trigger action of the valve. The coil, l, with an iron core, passes the audio-frequent current, while coil C-3 permits the passage of the radio-frequent current. In the diagram, Fig. 104, oscillations of radio-frequency are reproduced in the local circuit of the valve and repeated back into the grid circuit through the condenser, C-3, which gives a certain amount of electrostatic coupling between the two circuits.

"Beat" Receivers.—As mentioned previously, ordinary crystalline detectors cannot be used for the reception of undamped oscillations nor can the vacuum valve detector, unless the circuits of either are interrupted by a ticker or a buzzer at a certain uniform rate ranging between 500 and 1,000 times persecond. We can, however, in such systems make undamped oscillations audible by what is known as the "local interference" method, sometimes termed the "heterodyne effect" or the "beat" phenomenon.

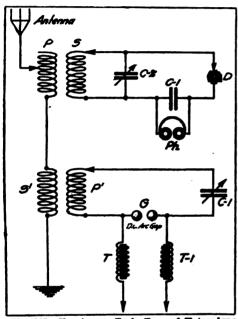
It is a well known fact that if sound notes of slightly different pitch or frequency are made to impinge upon a given receiving medium, a "beat" note of increased intensity is produced at regular recurring periods—this note generally having a frequency equal to the numerical difference between the two applied frequencies.

A similar action takes place when two alternating current of radio frequency but of slightly different periods flow in the aerial circuit of a given receiving system. A "beat" note having a pitch equal to the difference be-

tween the frequencies of the two applied currents is produced.

Now, in a wireless receiving system one of these frequencies may be that set up by a distant transmitting station, and the other may be supplied by a local source such as an arc generator. The requirements of this system are indicated in the diagram, Fig. 105, where the aerial of the receiving station is represented at A, with the radio frequency coils P and S.

connected in series. A standard receiving detector circuit is represented by the secondary winding, S, the secondary condenser, C-2, the fixed condenser, C-1, the crystalline detector, D, and the head telephones, PH. An arc generator for the production of sustained oscillations is represented by the arc gap G, the variable condenser C', and the inductance coil P', which is in inductive relation to the coil S'. The arc gap is fed with from 110 to 500 volts D. C. through impedance coils T and T'. When the arc gap is properly adjusted, the frequency of the oscillation generator may be regulated by means of the variable condenser C', and consequently any frequency within given limits supplied to the antenna system through the oscillation transformer P'. S.



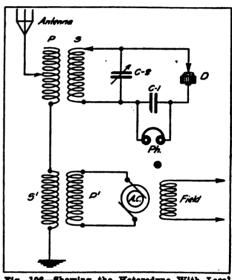


Fig. 105—Showing an Early Type of Heterodyne Receiver.

Fig. 106—Showing the Heterodyne With Local Radio-frequency Alternator.

Assume, for example, that the wave-length of the distant transmitting station using undamped oscillations is 6,000 meters corresponding to a frequency of 50,000 cycles per second. Then if the antenna system with the 'elements P and S is placed in resonance with the distant transmitting station, alternating currents of this frequency flow. Then if the arc generator is set at such values of inductance and capacity as to give a frequency of 40,000 cycles per second, forced oscillations will be induced in the antenna circuit through the coupling coil P1 S', and the interaction of these two frequencies will produce a pitch or "beat" note of 1,000 cycles. This current of audible frequency is afterward rectified by the crystalline detector D, which in turn charges the condenser, C-1, the discharge of the latter causing a single sound in the head telephones. By slight variation of the frequency of the local arc generator the pitch of the note may be altered over given limits; in fact, it can be varied from the equivalent note of a 200 cycle alternator up to and beyond the limits of audibility. In this system it is important that a certain critical degree of coupling be used at the transformer, P1 S', and that the crystalline detector D be one of rugged adjustment and not easily influenced, by the oscillations from the local generator. If the generator G, C¹, P¹ can supply 4 or 5 watts of energy, it will be sufficient for the functioning of this system,

A small high frequency alternator may be employed in place of the local arc generator, as indicated in the diagram, Fig. 106, where an alternator of radio frequency (20,000 to 100,000 cycles per second) is connected to the radio frequency coil P¹, which is placed in inductive relation to S'. Then by variation of the speed of the alternator the local frequency can be varied in such a way as to produce "beats" at audio-frequent rates. A generator having an output of 2 to 10 watts is all that is required for this system.

Vacuum Valve Generator.—Instead of the arc generator or radio frequency alternator just described, we may use the vacuum valve to generate undamped oscillations of any frequency desired. The circuits for this system (Fig. 107) are more complicated than in the foregoing methods, but good results have been obtained by various experimenters, signals having been received in the United States from stations located in foreign countries, with marked intensity. Referring to Fig. 107: The standard crystal detector cir-

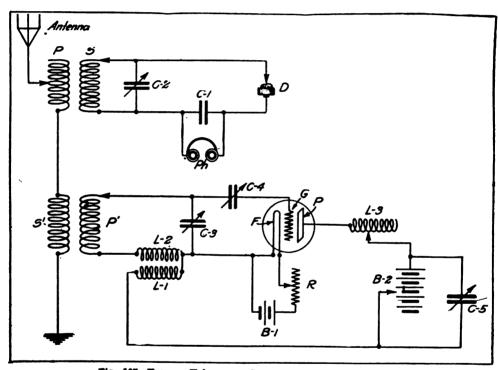


Fig. 107-Vacuum Valve as a Generator of Local Oscillations,

cuit is identical with that of Fig. 106, and contains the necessary elements for obtaining conditions of resonance, but the vacuum valve circuits are arranged so that the bulb becomes a fairly steady generator of sustained oscillations, the frequency of which may be varied over a considerable range. It will be noted from the diagram that the B-2 battery of the vacuum valve is shunted by the variable condenser, C-3, in series with which is placed the inductance, L-3. When the correct degree of incandescence is obtained at the filament and proper variation of the voltage of the B-2 battery made, sustained oscillations flow from the condenser through the inductance, L-3, across the vacuous space in the bulb at a frequency determined by the capacity of the condensers and the inductance of the coils. The amplitude of the oscillations generated in this manner may, however, be reinforced and the device perhaps made a more steady generator by coupling the local telephone circuit to the grid circuit of the vacuum valve through the radio frequency

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transformers, L-1 and L-2. Then by placing these two circuits in resonance, or near resonance, steady oscillations are produced which in turn can be transferred to the antenna circuit through the radio frequency transformer, P¹, S¹, that is to say, the best results are obtained when P-1, L-2, C-3 is in resonance or near to resonance with L-1, L-3, C-3.

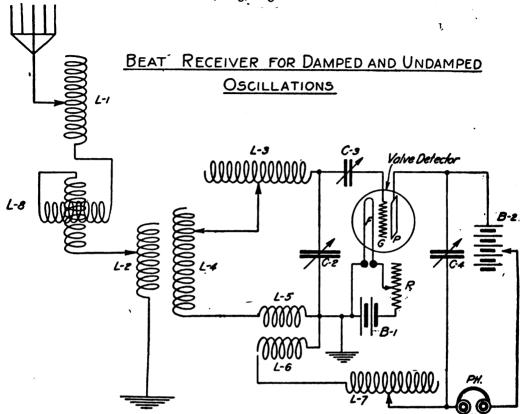


Fig. 108-Long Distance Beat Receiver for Damped and Undamped Oscillations.

It may be difficult for the beginner to obtain the correct adjustment for securing a steady state of oscillation in the vacuum valve bulb, but one accustomed to work of this type will have no difficulty in determining the condition. Usually the state of oscillation may be more quickly determined by connecting a head telephone in series with the battery, B-2, and then when the circuits are in state of oscillation there will be found near to that point a peculiar thumping sound when the frequency of either the grid circuit or the local battery circuit is altered.

The vacuum valve bulb having thus been set into a state of oscillation, the current of radio frequency may be forced into the antenna through the secondary winding of the coupling transformer, S-1. If its frequency be made to differ by a certain amount from the incoming frequency, the result will be a "beat" note of any desired pitch from a low grumbling note to an extremely high tone. To obtain the best signals the coupling between P-1 and S-1 is critical and careful adjustment must be made.

Regenerative Beat Receiver for Damped and Undamped Oscillations.— The vacuum valve can be employed as a combined oscillator, beat receiver and amplifier, as per the diagram of Fig. 108. While the apparatus therein is suitable to the reception of either damped or undamped oscillations, more marked results are obtained with the former. With proper construction and

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subsequent adjustment the equipment shown in Fig. 108 will permit the rereception of signals over a distance of 5,000 miles from stations within the range of wave-length for which it is designed (see United States Patent No. 1,113,149). The dimensions of the coils are intended to cover a receiving tuner for adjustment to wave-lengths between 6,000 and 11,500 meters. It will be observed that the telephone battery circuit includes the inductance L-7 and the condenser C-4 which upon certain adjustments of the filament to incandenscence with corresponding adjustments of the voltage of the battery, B-2, circuit, will cause the complete apparatus to become a generator of undamped oscillations, the frequency of which is largely determined by the values of C-4 and L-7. The oscillations of radio frequency thus generated can be amplified by coupling this circuit to the secondary circuit of the receiving tuner through the radio-frequency transformer L-5 and L-6. For effectiveness it is quite essential to tune the secondary circuit of the receiving tuner to resonance with the elements of the local battery circuit. If the antenna system is then tuned to the incoming wave and the valve circuit caused to oscillate at a slight different frequency, beats are produced which are in turn amplified by the well known trigger action of the vacuum valve.

Referring to the diagram, the high voltage battery, B-2, consists of from 50 to 100 miniature flashlight cells adjustable in steps of three at a time or preferably finer. The filament battery, B-1, generally has no more than four volts pressure. The rheostat, R, has a resistance of ten ohms which should

be closely adjustable.

The inductance coil of the local telephone circuit, L-7, is twenty-six inches in length and five and a half inches in diameter, wound closely with No. 28 S.S.C. wire. The coil, L-6, is six inches in diameter by six inches in length, wound closely with No. 26 S.S.C wire. The coil, L-5, is also six inches in length by five and a half inches in diameter and so mounted that it can be telescoped inside of L-6. It is rarely necessary to place L-5 completely inside of L-6, but it should be arranged so that the coupling between the two coils is closely variable. The coil L-5, is also wounded. the coupling between the two coils is closely variable. The coil, L-5, is also woundwith No. 26 S.S.C. wire.

The secondary winding of the receiving tuner, L-4, is five inches in diameter by fourteen inches in length, covered with No. 28 S.S.C. wire. The secondary loading coil, L-3, has similar dimensions to the coil, L-7, each of which may be wound

on a cardboard form.

The secondary condenser, C-2, has a maximum value of capacity of 0005 micro-farad and preferably is constructed so that the zero position on the condenser scale represents a practically zero value of capacity. The grid condenser, C-3, is identical with the condenser, C-2. Both should be fitted with handles at least twelve inches in length, in order that the constants of the circuit are not interfered with by the body of the manipulator. The condenser, C-4, should have a maximum capacity of .002 microfarad.

The primary winding, L-2, is five and a half inches in diameter by twelve inches in length, covered with No. 24 S.S.C. wire. The dimensions of a suitable variometer, L-8, are given in detail in chapter XI of this volume.

It is somewhat difficult to give complete dimensions for the aerial tuning inductance, L-1, unless the constants of the antenna with which it is to be employed are known, but for receiving work with an aerial having a natural period of 450 meters, it may be twenty-eight inches in length by five and a half inches in diameter, wound closely with No. 20 S.S.C. wire. A tap-off should be taken every inch and led to the contacts of a multiple point switch. The leads to the switch from the tap-off should

not be bunched but separated as far as possible.

It will facilitate the preliminary adjustment of this tuner if access can be obtained to an accurate wave-meter. This wave-meter, shunted by a buzzer excitation circuit is placed in inductive relation to the earth lead of the antenna system and the signals at any particular wave-length of the wave-meter are recorded on the receiving apparatus. In this manner a pre-calibration is effected, eliminating all guess work. It is not, however, difficult to tune the apparatus to an undamped station, if certain precautions are observed. To begin with, the coil, L-5, is placed in slight inductive relation to L-6. L-4 is placed about half way inside L-2. The coil, L-7, generally is used at the maximum value and the condenser, C-3, at an exceedingly small value of capacity (near to zero). The condensers, C-2 and C-4, are varied simultaneously in capacity until a peculiar thumping sound is heard in the head telephones. At about this point the secondary circuit and the local circuit are in oscillation and in resonance. It is, of course understood that during this operation the filament of the valve has been brought to a certain degree of incandescence and critical adjustment

of the high potential battery, B-2, made.

A description of the complete tuning of the set follows: The antenna system is tuned to resonance with the incoming wave, but the secondary circuit and the local telephone circuit are set into oscillation at a slightly different frequency. In this manner beats within the limits of audibility are produced and accordingly the note in the head telephones may be varied over a considerable range. In manipulating this apparatus it is shown (during the reception of undamped oscillations), that proper adjustment has been attained when, if the variable elements of either of the associated circuits of the complete tuner are altered in value, a corresponding change in the telephone note takes place. During the initial adjustment and afterward the body of the manipulator must be kept at a considerable distance from the high potential ends of the coil; otherwise the circuits will be thrown out of resonance and signals will disappear.

With apparatus of the foregoing type and a three-wire aerial, 60 feet in length) signals from Honolulu have been copied in New York City at night time.

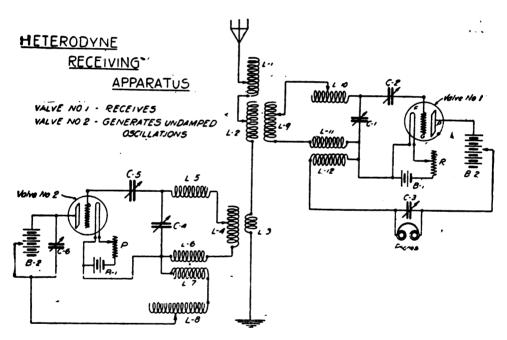


Fig. 109—Supersansitive Long Distance Receiving Apparatus Employing a Vacuum Valve Detector for "Reterodyning" and a Second Vacuum Valve as a Detector.

Regenerative Amplifier and Beat Receiver.—An extremely sensitive apparatus for long distance reception, one which will give remarkable signals from Nauen and Hanover, Germany, during the daylight hours, is indicated diagramatically in Fig. 109. Somewhat similar circuits are described in the Proceedings of the Institute of Radio Engineers for September, 1915, but the dimensions of the coils and instructions for operation are not given. In justice to certain experimenters, it should be stated that similar apparatus and circuits were experimentally in use previous to the presentation of the beforementioned paper and the amplifications resulting therefrom were fully known.

In the system in Fig. 109, vacuum valve No. 2 is used for the sole purpose of generating undamped oscillations of variable frequency for the production of the so-called "heterodyne" effect. More clearly, valve No. 2 supplies the aerial system with undamped oscillations of a definite frequency differing slightly from the frequency of the incoming signals thereby producing beats in the circuits of valve No. 1 which are amplified by what is known as a regenerative circuit.

Regardless of the apparent complications of the circuit, the manipulation and adjustment of the apparatus are quite simple and practicable, a point of importance being that the amplitude of the oscillations supplied by the local generator to the antenna system may be controlled by the coupling coils L-3 and L-4. Like all circuits of this type, the adjustment to a given wave-length will be considerably facilitated if a wavemeter set into excitation by a buzzer is placed in inductive relation to the earth lead of the receiving aerial and corresponding adjustments made of the elements of the receiving apparatus until the maximum response is secured. This indicates that the receiving apparatus is in resonance with the wavemeter and the experimenter is assured that the circuits are adjusted for immediate operation.

Suitable dimensions for the various colls and condensers follow:

- L-1-20 inches in length by 51/4 inches in diameter wound full of No. 20 S.S.C. wire (for the average amateur aerial).
- L-2-12 inches in length by 51/2 inches in diameter wound full with No. 24 S.S.C. wire.
- L-3-6 inches in length by 6 inches in diameter wound full with No. 24 wire.
- L-4-6 inches in length by 5 inches in diameter wound full with No. 24 S.S.C.
- L-5-26 inches in length by 51/2 inches in diameter wound closely with No. 28 S.S.C. wire.
- L-6-6 inches in length by 6 inches in diameter wound closely with No. 28 S.S.C. wire.
- L-7-6 inches in length by 5 inches in diameter wound closely with No. 28 S.S.C. wire.
- L-8—22 inches in length by 5½ inches in diameter wound closely with No. 28 S.S.C. wire.
- L-9-12 inches in length by 5 inches in diameter wound full with No. 28 S.S.C. wire.
- L-10-22 inches in length by 51/2 inches in diameter wound full with No. 28 S.S.C. wire.
- L-11-6 inches in length by 5 inches in diameter wound closely with No. 28 S.S.C. wire.
- L-12-6 inches in length by 6 inches in diameter wound full with No. 28 S.S.C. wire.

And for the condensers:

C-1-Maximum value .0005 microfarads.

C-2— C-3— C-4— C-5— C-6— 1000. " " .. .003 " " .0005

" " .0001 to .0005 microfarads.

.003 microfarads

As usual, the voltage of the local battery of either valve varies from 40 to 100 volts according to the degree to which the bulb has been ehausted. Likewise the filament battery is usually of 4 volts and the filament rheostat has maximum resistance of 10 ohms.

In the circuits of valve No. 2, L-4, L-5, C-4 and L-6 are tuned to resonance with L-7, L-8 and C-6. For frequencies corresponding to wave lengths between 7000 and 9000 meters the principal adjustments are made at the condensers C-4 and C-6 with corresponding careful adjustment of C-5. Generally C-5 is used at very low values of capacity. It should be taken seriously into account, that if considerable amplitude of oscillation is to be secured in the circuits of valve No. 2, the elements in the wing

circuit and those in the grid circuit must remain in resonance at all frequencies. Generally the coil L-6 is placed about half way inside of L-7 or perhaps at a lesser degree of coupling.

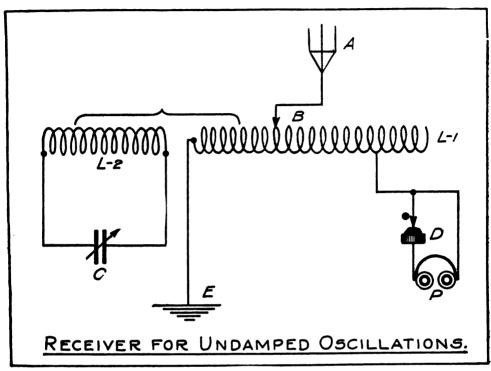


Fig. 110-Crystal Rectifier for the Reception of Undamped Oscillations from Arc Senders.

For the reception of undamped oscillations from a given station the circuits of vacuum valve No. I must be adjusted to resonance with the antenna system. This may be accomplished by the wavemeter as previously mentioned. Such adjustments may be made in the secondary circuit at either the coil L-9 or L-10 which should be fitted with variable tap-offs. Extremely careful adjustment must be made of the condensers C-1 and C-2 and a fairly close adjustment of the condenser C-3. A close degree of coupling is employed between the coils L-11 and L-12. It should be understood that the circuits of vacuum valve No. I do not oscillate, it being simply a regenerative circuit for amplifying the oscillations flowing in the secondary circuit of the receiving tuner. Suppose, for example, that the antenna system is adjusted to a wave length of 6,000 meters corresponding to a frequency of 50,000 cycles per second. Then the circuits of vacuum valve No. 2 are adjusted, let us say, to an oscillation frequency of 49,000 cycles. The inter-action of the two frequencies in the antenna system will produce 1,000 beat currents which are considerably amplified by vacuum valve No. I. After the experimenter has once obtained the necessary adjustments in all circuits, it is advisable to carefully adjust the coupling between L-3 and L-4 because in this manner the strength of the incoming signals may be enormously amplified.

The apparatus described is applicable for the amplification of either damped or undamped oscillations but the most marked results are obtained from the latter. With an aerial consisting of two wires from 400 to 700 feet in length, raised at least 100 feet above the surface of the earth, signals of considerable strength should be received from abroad, in broad daylight by amateurs situated on the Atlantic coast, and loud night signals should be obtained by experimenters throughout the entire United States. As usual, sensitive apparatus of this type amplifies static signals to a considerable degree and it may be necessary to adjust the apparatus to a less sensitive condition, to receive radio signals.

The coils of the dimensions given are suitable for the reception of signals at wave lengths between 5,800 and 10,000 meters.

When the coil L-4 is placed in close inductive relation to coil L-3 and the circuits of valve No. 2 carefully adjusted to resonance with the antenna system, sufficient current should flow in the antenna wires to allow the apparatus to be used as a transmitter for distance of about one-half a mile. A telegraph key may be inserted in series with the earth connection of the antenna system. Of course the receiving apparatus at the distant station should be similar to that at the sending station.

The apparatus described will give stronger signals from undamped stations than that shown on page 127. The equipment obviously is more expensive, however, and the adjustment to sensitive condition slightly more difficult. Still, it should be borne in mind with this system only one of the vacuum valves is required to be in a state of

oscillation.

A Unique Method for Detecting Undamped Oscillations.—The United States patent office has issued copies of an application containing details of a novel method for the reception of undamped oscillations through the medium of a crystalline detector. During experiments on a similar circuit signals were received from a distance of several hundred miles. A limiting condition of this system lies in the fact that the wave-length of the transmitting station must be between 7,000 and 12,000 meters.

Details of the apparatus are shown in Fig. 110. The coil, L-1, varies in length according to the frequency of the received wave; that is to say, it must have, as an open circuit oscillator, a natural time period of oscillation suitable to that of the incoming oscillations. A variable tap-off, B, on the coil, L-1, allows the antenna circuit to

be placed in resonance with the coil and the received wave. The crystal detector, D, preferably of the cerusite or silicon type, is shunted by the head telephone, P, and connected unilaterally to L-1.

The circuit comprising the coil of inductance, L-2 and the condenser, C, has such value that it may be placed in resonance with the coil, L-1. With a slight degree of coupling between L-1 and L-2, the reaction of L-2 upon L-1 (during the reception of signals) will set up oscillations of two frequencies in the complete circuits. If these frequencies differ by a slight amount, "beats" suitable to the maximum response in the telephones will be produced. With this apparatus difficulty is experienced in producing notes in the head telephones which have the musical characteristics obtainable from the vacuum valve detector. The tone usually resembles the sound of escaping steam from a radiator, but is of sufficient clearness and intensity to permit the reception of undamped oscillations from a considerable distance.

To be adjustable to wave-lengths in the vicinity of 8,000 meters, the coil, L-1, may be thirty-two inches in length by five and a half inches in diameter, wound closely with No. 30 S. S. C. wire. The coil, L-2, may be thirty-two inches in length by five

inches in diameter, wound closely with No. 30 S.S.C. wire. The condenser, C, may have a value of 0.0005 microfarad.

To insure exact resonance between the coil, L-1, and the antenna system, it is preferable to employ a wave-meter set into excitation by a small battery and huzzer. The inductance coil of the wave-meter is placed in inductive relation to the earth lead of the coil, L-1, and the crystal detector tapped off at various points of L-1 until the maximum response is secured. It is, of course, preferable for the coil, L-1, to have a different length for each change of wave-length; dead-ends are to be avoided.

Measurement for the Dead-Ends of a Receiving Tuner.—Dead-ends in receiver tuning coils cause considerable concern among amateurs, although the losses from them are not so great as many believe. For the benefit of readers

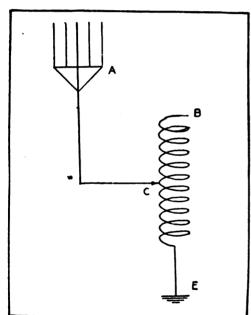


Fig. 111—Showing the "End-turns" of a Receiver Tuner Winding.

who are not clear on the subject an explanation may not be amiss. Referring

to Fig. 111: Let the coil, B to E, represent the primary winding of a receiving tuner and the circuit A C E, represent the path of the oscillations in the antenna circuit through the coil to earth. The portion of the coil, C to B, is known as the dead-end or "end turn" portion, and is therefore useless if only the amount of inductance shown is necessary for a given wave-length.

It is possible with certain windings that the coil, B to E, may have a natural wave-length of the same order as that of the antenna circuit. For example, A C E may be adjusted to 600 meters, while the coil, B to E, may have the same, or nearly the same, wave-length. If this is the case, considerable energy will be absorbed by the coil itself, which is equivalent to the extraction of a certain amount of energy from the detector circuit, resulting in a reduction of the strength of signals.

If the wave-length of the coil, B to E, is decidedly different from that of the antenna circuit, the losses due to the end turns are not so objectionable. Suppose, for example, that during the greater part of his receiving work the amateur receives from 600-meter stations and is interested to know whether

the end turns of his receiving tuner are of sufficient proportions to produce energy losses. If so it easily can be determined whether the wavelength of the coil approximates that of the antenna circuit. It should be understood that if this factor is evaluated the amateur may reconstruct his receiving tuner accordingly.

Referring to Fig. 112, the antenna conection, C, is removed from the coil, B, a sensitive crystal detector is connected, as at D, and shunted by the head telephones, P. The wave-meter, C, is set into excitation by the buzzer, B, and the battery cells as shown. A single turn of wire, L_zI, is inserted in series with the earth lead for the purpose-of coupling with the inductance, L.

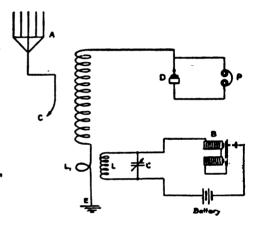


Fig. 113-Measurement of the Natural Wave-Length of the Primary Winding.

The crystal, D, is then adjusted to sensitiveness. The capacity of the condenser is altered until a maximum of response is secured in the head telephones, P. Referring to the wave-length chart, the reading obtained may be taken as the natural wave-length of the coil, B to E. If this value is found to be in the neighborhood of the wave-length at which the receiving is generally done, it is at once evident that a change in the design of the primary primary winding will be necessary if it is desired to receive signals with the maximum degree of efficiency.

The natural wave-length of the secondary winding may be obtained in much the same manner. In Fig. 113 the detector circuit is broken at C and the head telephones are shunted around the crystal detector, D. The coil is excited by the wavemeter, as in the previous experiment, the capacity of the condenser being altered until a maximum of response is securd. This reading is the natural wave-length of the coil, S. If only a part of the coil, S, in connection with the variable condenser, C, is required (Fig. 114) for the wave-length of, say, 600 meters, and the period of the coil itself is 600 meters, some energy losses may be expected for that particular wave-length and it is of 21-vantage to rearrange the design.

It is not intended to convey the idea that the energy losses are present only when the coil has the wave-length of the received oscillations. Such

effects in the average amateur tuner are not violent, however, unless conditions of resonance are approximated.

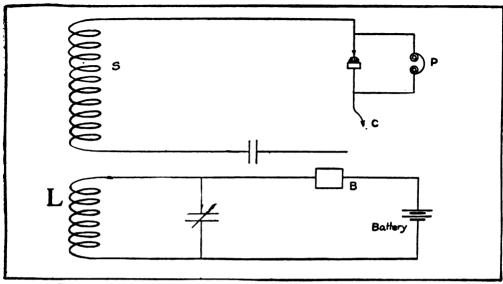


Fig. 113-Reasurement of the Natural Wave Length of the Secondary Winding.

"Balancing Out" Aerials.—It is believed that few amateurs are aware of the results that can be obtained in the prevention of interference through the proper use of "balancing out" aerials. Interesting experiments along this line can be made in a simple manner. As far as the writer is aware, the method to be described was first used by the Marconi Company.

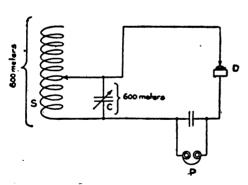


Fig. 114—Showing the "End-turns" of the Secondary Winding.

Referring to Fig. 115, A represents the aerial at any amateur station, while B indicates a second aerial which is preferably placed at right angles to the aerial, A, or at least at some distance from it. S is secondary winding of the receiving tuner, and is preferably a winding of a fixed value of inductance, but should be so designed in connection with the condensers, C, as to afford a range of wave-lengths over which it is desired to work. The coil, P, is the primary winding connected to the aerial, A. The coil, P-1, is connected to the "balancing out" aerial, B, and is placed in magnetic op

position to P. If the circuits of either aerial contain variable elements, such as a loading coil or a series condenser, allowing a wide range of adjustment, the aerials, A and B, may be decidedly dissimilar in construction—that is to say, while the aerial A may be of standard four-wire construction, the aerial B may consist of a single wire of fair dimensions.

The operation of the apparatus is simple and quite self-evident. Suppose, for example, the aerial A is adjusted to a wave-length of 600 meters and, due to the nearness of certain high-power stations, interference is experienced simultaneously on a wave-length of 2,800 meters; then the antenna, B, is adjusted to a wave-length of 2,800 meters and the winding, P-1, is coupled to

the winding, S, just sufficiently to destroy the oscillations induced by this wave in the winding, S, through the winding, P. While the strength of signals may be somewhat decreased by this arrangement, it will be found that the 600-meter signals can be heard and the oscillations set up by the 2,800-meter interfering signal wholly eliminated. Experiments have proven that this arrangement of circuits, in many cases, allows communication which otherwise could not be accomplished.

Experiments have been made with more elaborate arrangement where two "balancing out" aerials were used for eliminating the signals from the second interfering station. The coil of the second balancing out aerial was constructed to slide over the outside of the winding, S, while the coils, P and P-1, at the same time telescoped inside it.

The necessity for having the secondary inductance of the receiving tuner of a fixed value is at once apparent, and if it is desired to work over a wide

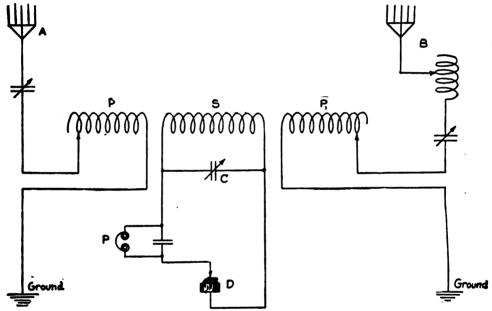


Fig. 115-Marconi's "balancing-out" Aerial.

range of wave-lengths, two or more of such coils having different values must be at hand,

Elimination of Arc Light Induction.—Amateurs frequently request a description of some method for the elimination of humming noises due to induction from nearby trolley, telephone or telegraph wires. It is a well known fact that when a wireless telegraph aerial is placed near alternating current power lines of high or low potential, particularly when in a parallel position, confusing noises are produced in the receiving head telephones. A number of experiments has shown that such effects can be reduced to a minimum in a remarkably simple manner.

In Fig. 116 P and S represent respectively the primary and secondary windings of an ordinary receiving tuner at a station. In this station the aerial, A, is practically parallel and about 400 feet distant from a 2,200- volt A. C. power line. In addition, the house wiring let us assume, is not placed in metallic conduit, which amplifies the effects. Very loud inductive noises are produced which seriously interfere with any except extremely strong signals, making long distance work entirely out of the question.



In an effort to eliminate the trouble, the wires, B, leading to a lamp socket in the radio room, were interrupted at C and two leads connected to the winding, S-1. S-1 was of the same dimensions as P and readily moved in or out of S. S-1 was also in magnetic opposition to S. By proper variation of the coupling between S and S-1 the humming noises were almost entirely eliminated. Of course the presence of the winding, S-1, had the effect of reducing the strength of the received signals, but it allowed the reception of messages which otherwise could not be heard.

Another case of induction trouble can be solved in the following manner: In Fig. 117 the aerial wires, A, lay parallel to an arc light circuit of considerable potential, B. The inductive noises generally produced under such conditions are terrific and defy all attempts at elimination. Of course the arc light wires cannot be tapped and the opposition coil method just described adopted. But the noise can be reduced if a single aerial wire, B, is strung un-

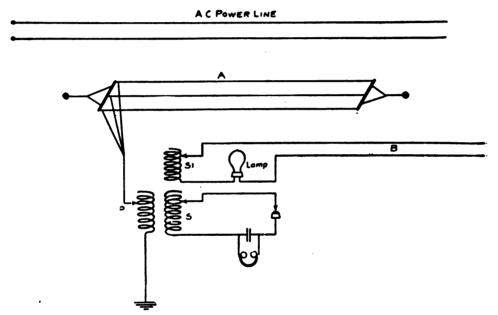


Fig. 116-Method of "balancing-out" Alternating Current Induction.

derneath or near the two power wires, C. This wire is then connected to a coil, S-I, which is inductively coupled to the secondary winding of the receiving tuner, S. The current induced in A, by the power lines will be opposed by that induced in the special aerial, B, and if proper coupling is maintained at S and S-I complete silence in the head telephones will result. Care must be taken to see that these coils (S and SI) are in opposition; otherwise the induced noises will be increased. It is advisable to place the single aerial wire, B, at a considerable distance from the receiving aerial, A, and if possible B should be placed in the opposite direction from A.

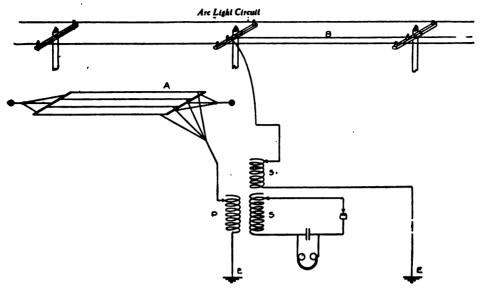


Fig. 117-Method of "balancing-out" Arc Light Induction

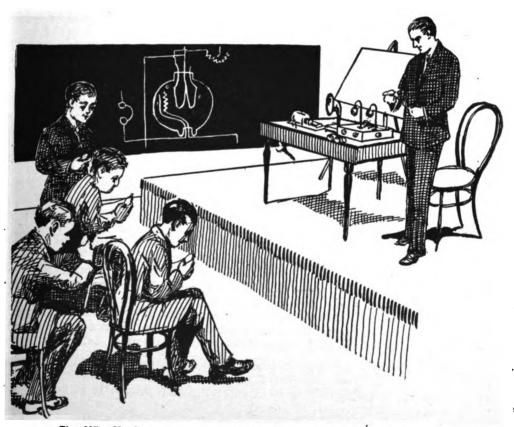


Fig. 117a-Members of a Radio Club Listening to the Time Signals of Arlington,

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Chapter XII

The Radio-Variometer

OME amateurs believe that the variometer is a form of the rotary receiving tuner. Others are not certain what it is, but believe it to be of little value in their work. The principle on which it works, however, is well understood in the electrical field.

The variometer may be defined as a device for the production of a variable value of inductance without the use of multiple-point switches or sliding contacts. It consists of two coils having a fixed value of inductance, connected in series with each other and so mounted that the mutual inductance between them may be progressively varied from a nearly zero value to a maximum value. That is to say, the coils may be placed in magnetic opposition or in magnetic attraction.

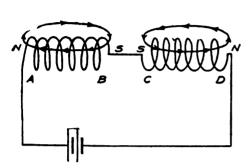
The Actions Explained.—The principle of the variometer will be better understood after looking at Fig. 118. Here the coil, AB, is wound in the opposite direction to the coil, C. D. The latter coil telescopes into the coil, AB, and for variometer requirements should be mounted so that it can be pulled in or out of AB to any desired distance. The coils AB and CD are connected in series as shown.

If current from a battery flows through the two coils, then the magnetic lines of force produced by each coil will take the path shown. It is at once evident that these lines of force are in opposition. Hence if the coil CD is placed entirely inside of the coil AB the resultant magnetic field is of nearly reduced to zero and the self-induction of the unit as a whole is practically nil.

Furthermore, it is plain that if the coil CD is drawn out of the coil AB the opposition of the fields decrease and the self-induction of the unit as a whole gradually increases. It is clear also that if alternating current flows through the two coils the actions are similar to those just described except that the direction of the magnetic flux reverses with each reversal of current. Thus a variable inductance element is produced which allows extremely close variations to be obtained. Further consideration of Fig 118 will reveal that if the B end of the coil AB is connected to the D end of the coil CD (in place of the connection shown) the magnetic fields are no longer in opposition, but flow in the same direction. Hence, if the coil CD is gradually moved into AB, then the total mutual inductance is progressively increased, the maximum being attained when the coils coincide.

General Design.—Variometers need not necessarily take the form shown in Fig. 118, but may be constructed after the general design shown in Fig. 119 Here the winding AB is in circular form; inside of it is placed the

winding CD. The coil CD may be rotated on the axis shown. When the planes of the two voils coincide in one position the coils are in opposition; but when the coil CD is turned completely around the self-induction of the two coils is additive.



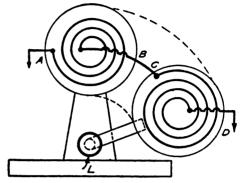


Fig. 118—Showing the Elementary Principle of the Variometer.

Fig. 120-Pancake Variometer.

Again the variometer may be of the type shown in Fig. 120. Here the coil, AB, is wound in the form of a flat spiral, likewise the coil, CD. The latter coil moves on the pivot L through the arc shown, and when CD is directly opposite AB the inductance of the unit is at a minimum, but it may be increased by moving the coil CD away from the coil AB.

Variometers are occasionally constructed on the hinge principle, as per Fig 121. In this case the coupling between the coils AB and CD is changed

by swinging one of the coils.

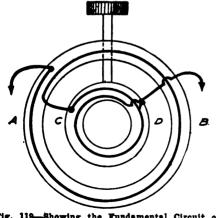


Fig. 119—Showing the Fundamental Circuit of, the Ball Variometer.

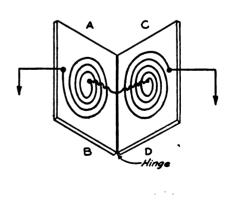


Fig. 121-Hinged Variometer.

Uses of the Variometer.—Variometers are of use when extremely fine variations of the frequency of a tuning circuit are required. They are often employed in the open oscillatory circuit of the transmitter, particularly when a spark discharger of the quenched type is included in the condenser circuit. Occasionally they are inserted in the closed oscillatory circuit for variation of the inductance, or they may be used as the coupling element for transferring the oscillations generated in the spark gap circuit to the aerial wires

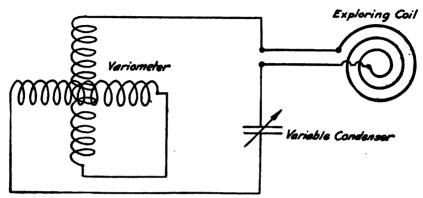


Fig. 122-Variometer as an Element of a Wavemeter.

The variometer is again useful in the antenna circuit of a receiving tuner particularly in the type employing multiple-point switches on the primary winding or on the loading coil which do not give close enough adjustments of inductance. It allows intermediate values of inductance to be obtained between the taps which in certain apparatus is extremely desirable.

The variometer is also often employed as the variable element of the wave-meter, being connected in shunt to a condenser or several condenser units of fixed value. If used for this purpose a small coil known as the exploring coil is connected in series for purposes of coupling the wave-meter to the circuit under measurement. This arrangement of the circuit is shown in Fig. 122. To those familiar with the wave-meter it will be readily understood how the wave-length of the meter is varied as the coil of the variometer is turned on its axis. There is an objection to the use of the variometer in a wireless telegraph circuit in that it is productive of energy losses when any other but the maximum value of inductance is employed. A little time devoted to careful consideration of the device will show that when the coils are placed in opposition the current flowing through them encounters the D.C. ohmic resistance of the entire coil. It may, therefore, in some instances be more desirable to use a single coil of the proper value of inductance rather than the variometer. The resistance losses will be less, to say the least.

The variometer shown in Figs. 118 and 119 may be employed in the receiving apparatus of a wireless telegraph set, while the types indicated in Figs. 120 and 121 often are used in connection with the transmitting apparatus.

Amateur wireless stations located in the vicinity or within the range of stations radiating undamped waves require a variable element, giving extremely fine adjustments of inductance in the antenna circuit. For this reason the construction of two different sizes of variometers will be described.

Many amateurs who are somewhat familiar with the variometer are under misapprehension as to the maximum and minimum values of inductance to be expected. Some believe that it will take the place of a loading coil,

which is quite incorrect. A variometer designed after the general plan shown in Fig. 119 will not give a large range of inductance values, but is intended to be employed as a variable element to give the necessary fine adjustment between the tap-offs of a loading coil.

The Variometer as an Element of a Wave-Meter.—The first variometer to be described is suitable for the variable element of the wave-meter, while the second variometer is intended to be used in the antenna circuit of a receiving set when receiving from stations employing the longer wave-lengths.

A top view of the first variometer is shown in Fig. 123, which is drawn to scale and gives the general over-all dimensions of the lid, the knob for turning the inside coil, the binding posts for connection, and the placing of the 180-degree scale. A front elevation is shown in Fig. 124 with the relative dimensions of the inside dimensions of the inside and outside windings. It will be observed that the inside winding (ball winding) is supported by a brass rod which at the bottom rests on a brush for making contact with one terminal of the ball winding. Another brass rod is connected to the second terminal of the ball winding and the final connection from this rod to the binding

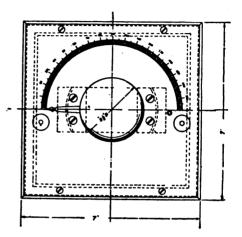


Fig. 123-Top View of Small Variometer.

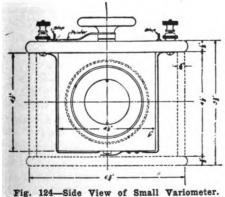
post is made by a brush underneath the lid (not shown).

The ball for the inside winding and the support for the outside winding are turned from a piece of hard maple on a wood-turning lathe. The support for the outside winding is gouged so as to allow the ball to move freely.

A side elevation of the variometer is shown in Fig. 125 where the ball winding is partially turned on its axis. A detail of the ball itself is given in Fig. 126, showing the general dimensions and the placing of the windings.

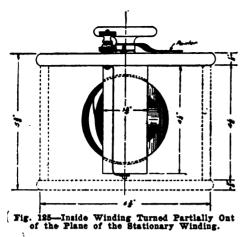
While it may not be clear from the drawings, it should be thoroughly understood that the ball for the movable winding has a flange on both edges so that when put in place the winding is at a level with the top of the flange. The same statement applies to the inside winding which is gouged out for the same reason.

There are two windings on each ball as shown, consisting of nine complete turns of No. 18 D. C. C. annunciator wire. The stationary winding also is split into two sections so placed that they are directly opposite the mov-



able winding (in the o° and 180° position). The stationary winding is also made of No. 18 D. C. C. annunciator wire.

It may be of interest to experimenters to know how this inside winding is put into place. This is accomplished in a very simple manner by turning out a wooden ball split in the center which just fits inside the stationary winding. This ball is split so it can be wedged. The stationary windings are then wound on the ball and the



inside of the stationary support covered with two or three coats of shellac. Before this shellac dries the winding on the ball is slid into place and is firmly pressed against the sides of the stationary support by means of a wedge driven into the split of the ball. The wedges are allowed to remain in place until the shellac is thoroughly dry, when they may be removed. It will then be found that the stationary winding is firmly in place and it may be given a coat of shellac on the outside to further insure against the possibility of the wire coming loose.

One terminal of the stationary winding is connected directly to a binding post mounted on the top of the box. The other terminal of the stationary winding is connected to a brush which is in contact with the rod supporting the hard rubber knob. Connection is made from this rod to one terminal of the ball winding, the second terminal of the ball winding being connected to

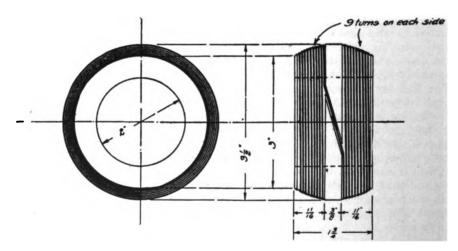


Fig. 126-Detail of Ball Winding.

the second binding post by means of the brush at the bottom, as shown in the drawing.

The variometer as described, when connected in shunt to a variable condenser having capacity of .001 microfarad gave, in the 180 position, a wave-length of 675 meters, and in the 10° position a wave-length of 180 meters. The amateur constructing a variometer of this type, who also has available a fixed condenser of .001 microfarad capacity, will have a wave-meter just suited to his requirements. When connected in shunt to a condenser having a capacity of .0025 microfarad, in the 180° position, it gave a wave-length adjustment of 460 meters, and in the 20° position a wave-length of 145 meters.

It is important that the inside and outside windings move closely to each other in order to secure the maximum and minimum values of inductance.

A Variometer of Increased Range.—A variometer suitable for use in the antenna circuit of a receiving set when receiving from stations using the longer wave-lengths is shown in Figs. 127, 128 and 129.

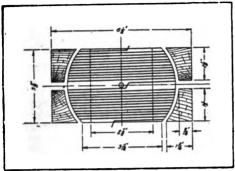


Fig. 197-Plan of Variometer.

Fig. 127 is a plan view looking down from the top, giving the dimensions of the ball and the support for the outside winding. Both the support and the ball are made of hard wood and, of course, must be turned out on a wood-turning

> The ball for the inside winding, at its greatest diameter, measures 5 inches, gradually tapering to 3-11/16 inches at both edges. While the ball is shown as being hollow, it may, if desired, be made of solid wood. The ball has two windings which are separated to allow the brass rod to pass through. It is wound full to the edge with No. 22 S.S.C. wire. To facilitate the placing of the stationary winding, the support is split into two sections which also has the effect of giving the inside windings and the outside windings similar dimensions, and therefore nearly similar inductance values.

The supports for the stationary winding are turned from a solid, square piece of wood and of course must be gouged out on a wood-turning lathe. The two halves of this frame may be fastened together by the top and base of the box of strapped

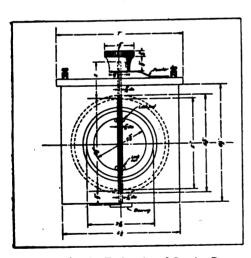


Fig. 128-Plan for Variometer of Greater Range.

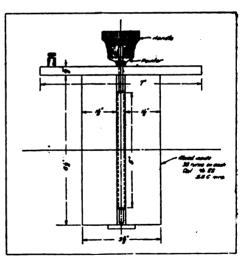


Fig. 129-General Details.

together by a brass strip. The outside winding also consists of a number of turns of No. 22 S.S.C. wire. The stationary winding support and the ball should have a slight flange (not shown) to assist in holding the windings in place.

The inside coil is held in place by a brass rod 8 inches in length, tapered at the bottom where it rests on the brass bearing, B. This bearing may be made to suit the builder. The rod has a diameter of 3/16 of an inch from the end in the hard rubber knob to a distance of 2 inches; for the next 51/6 inches it has a diameter of 1/4 of an inch and is threaded as shown; for the remaining 3/4 or 7/8 of an inch, it has a diameter of 3/16 of an inch, and is tapered at the extreme end. The nuts, N and N-1, hold the ball for the inside winding in place.

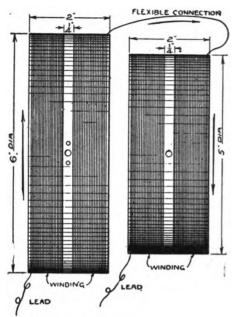
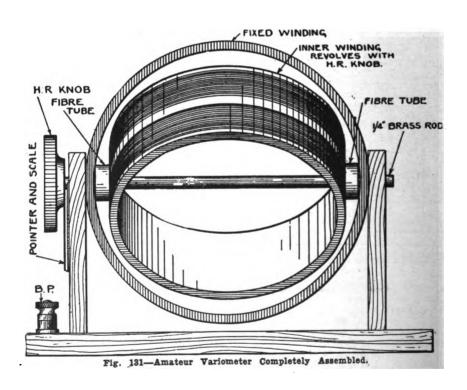


Fig. 130—Details of the Winding of Simple Amateur Variometer.

The windings for the outside coil are put in place by the same method as described in connection with the variometer previously referred to, the wood first being shellaced and the windings then pressed into place. A 180-degree scale may be fastened to the lid and pins placed in the latter to limit the movement of the ball winding. A hard rubber or wooden knob having the general dimensions shown may be affixed to the rod. The complete case, the binding posts and scale, etc., may be constructed to suit the builder. Flexible leads should connect the inside winding with the outside winding.

When the variometer just described was connected in series with an antenna circuit already adjusted to a wave-length of about 7,000 or 8,000 meters it changed the wave-length about 450 or 400 meters.

If the amateur experimenter employs the first described variometer in connection with a wave-meter he should use the connections shown in Fig. 122. The exploring coil may consist of three turns of No. 18 D. C. C. annunciator wire wound on a form 4 inches in diameter. The connecting leads to this coil may be 2 feet in length.



A Variometer of Simple Construction.—For cheapness and ease of construction, the design of variometer about to be described is recommended. The method of winding the individual coils is shown in Fig. 130 and a per-

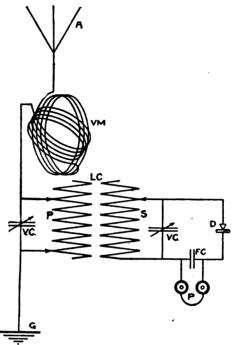


Fig. 132—The Variometer as an Aerial Tuning Inductance.

spective view with the inner coil partly outside of the field of the outer coil in Fig. 131. Two methods for the use of the variométer as the variable element of a receiving tuner are shown in Figs. 132 and 133.

The details of construction are as follows: Two cardboard tubes, one 6 inches in diameter, the other 5 inches in diameter and each 2 inches in width, are wound with a single layer of No 24 S. S. C. wire. A space should be left in the winding in the middle of the tube for about 1/4 of an inch, as shown in Fig. 101 Care, should be taken to get the same amount of wire on each tube. The wires should be thoroughly shellaced to prevent them from loosening up.

The tubes are then connected as shown in Fig. 130. A hole is drilled in both sides of each tube and through these holes is placed a piece of 14-inch round brass rod, 8 inches in length. When mounting the variometer, a small tube should be fastened to the brass rod so that it will revolve with the knob. A pointer may be fastened to the knob, which will work over a scale, as shown in Fig. 131.

If a greater range of inductance is desired with the same size coils, it is suggested that they be wound with No. 30 S. S. C. wire, rather than No. 24.

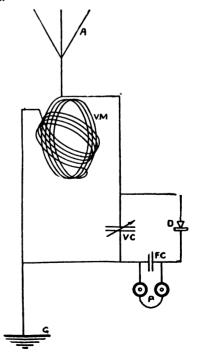


Fig. 188—The Variometer as an Oscillation Transformer.

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Chapter XIII

An Experimental Wireless Telephone

The reader is familiar with the fact that the vacuum valve can be employed as a source of oscillations for the production of electro-magnetic waves. It is also known that a large battery of vacuum bulbs were employed at the Arlington Radio Station for the recent wireless tele-different construction than those usually supplied to the amateur market; one of the principal points of difference being that the bulb is exhausted to a practically perfect vacuum.

Although the usual vacuum valve is not exhausted to the degree of the bulbs used in long distance experiments, it may be employed for experimental wireless telephonic transmission by connecting several bulbs in parallel as

disclosed in the diagram in Fig. 134.

It will be noted from this diagram that three vacuum valve bulbs are connected in parallel—filaments, plates and grids and the filaments of all bulbs are brought to incandescence by the battery B-I with the control rheostat R connected in series. The local circuit for the three bulbs is supplied with current from the 30-60-volt battery, B-2. This circuit also includes the variable condenser C-3, the variable inductance L-4 and the coupling coil L-3, for reinforcing the undamped oscillations of the local circuit through the grids of the three valves. Thus the oscillations passing through L-2 are transferred by electro-magnetic induction to L-I, where they are radiated in the form of wireless waves.

Now, while the amplitude of the oscillations in the antenna circuit may be modulated according to the variations of the human voice by a microphone transmitter connected in series with the antenna circuit, more effectual results may be obtained by connecting the microphone in the circuit at another point. It will be seen from the drawing that the condenser C-4 is connected in series with the closed oscillatory circuit and connected across its terminals we have the secondary winding of an ordinary telephone induction coil L-5, having the primary winding L-6, which in turn is connected in series with the battery B-3 and the telephone transmitter, T.

By careful adjustment of all apparatus associated with the vacuum valves, the antenna is supplied with a continual flow of alternating current; and when the transmitter T is spoken into, the potential of the grid is varied

in accordance with the human voice.

Since the oscillation of the vacuum valve is more stable at frequencies corresponding to wave-lengths above 2,500 meters, the dimensions here given are for coils and condensers that will permit radiation at the wave length of 3,000 meters. Care must be taken to adjust the receiving apparatus to a similar wave-length in order to obtain a response.

Dimensions.—Data for the various coils and condensers of the apparatus follow:

L-1—4 inches in diameter, 8 inches in length, wound with No. 24 S.S.C. wire.

L-2—3½ inches in diameter, 5 inches in length, wound full with No. 30 S.S.G. wire.

L-3—4 inches in diameter, 5 inches in length, wound full with No. 28 S.S.C. wire.

L-4—4 inches in diameter, 14 inches in length, wound full with No. 28 S.S.C. wire.

C-1—Maximum value, .0005 microfarad (variable).

C-2—Maximum value, .001 microfarad (variable).

C-3—Maximum value, .005 microfarad (variable).

C-4—Maximum value, .005 microfarad (variable).

B-1—4-6 volts.

B-2—30-60 volts.

B-3—6-10 volts.

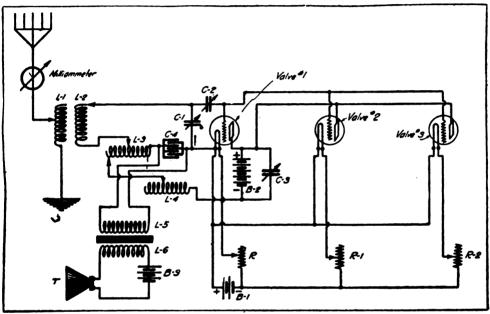


Fig. 134-A Simple Amateur Wireless Telephone Set for Short Distance Communication.

All coils are of course fitted with a multi-point switch for close variation of the inductance, with the exception of L-3, which generally may be left at a fixed value of inductance.

Adjustment.—Experimenters lacking familiarity with the adjustment of the vacuum valve to a state of oscillation can quickly obtain the desired result by connecting a pair of telephones in series with the battery B-2 and then by a corresponding variation of the variable elements of the grid and local circuits make an adjustment that will cause a thumping sound in the telephones. Near this point the valves are in oscillation. It is better for the amateur to make the initial experiment with one vacuum valve bulb: other bulbs may be added until a battery is obtained capable of transmitting to a distance of one or two miles. It facilitates the adjustment of all apparatus to place a wavemeter excited by a buzzer in inductive relation to the earth. lead of the antenna system. In this manner all associated circuits may be placed in almost exact resonance and then by a few experiments, the correct value for all coils and condensers may be found. If desired, a very sensitive indianneter, can be inserted in series with the antenna circuit to denote the value of current flowing:

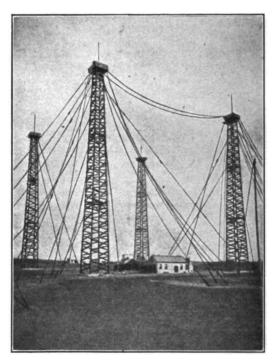
After the experimenter is assured that the battery of vacuum valves is in stable oscillation, the telephone transmitter T is spoken into and corresponding variations made of the capacity of the condenser C-4. It should, however, be remembered that when the values of this condenser are altered, a complete readjustment of all other apparatus in the local circuit is necessary. It will probably be found that there is a distinct value of capacity at this condenser which will afford the best results. In the first experiment, a receiving apparatus tuned to a wave-length of 3,000 or 4,000 meters

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should be placed in near-inductive relation to the transmitting aerial at a distance of not over 300 feet and careful adjustment made of the transmitting apparatus until a loud response is heard. Afterward, tests may be made at a greater distance and the

maximum transmitting range of the set determined.

During the preliminary experiments, the connections of the battery B-3 to the microphones should be reversed and left at that connection which gives the best results. Like all circuits of this type, the apparatus functions best with high values of inductance and low values of capacity in the circuits of radio-frequency. Some experiments have been made with the secondary winding of the induction coil shunted across the grid-condenser C-2, but it is generally better to place it in the circuit at a point of low potential. The maximum value of antenna current is obtained by very except adjustment of the coupling between the coils Let and Let. careful adjustment of the coupling between the coils L-1 and L-2.



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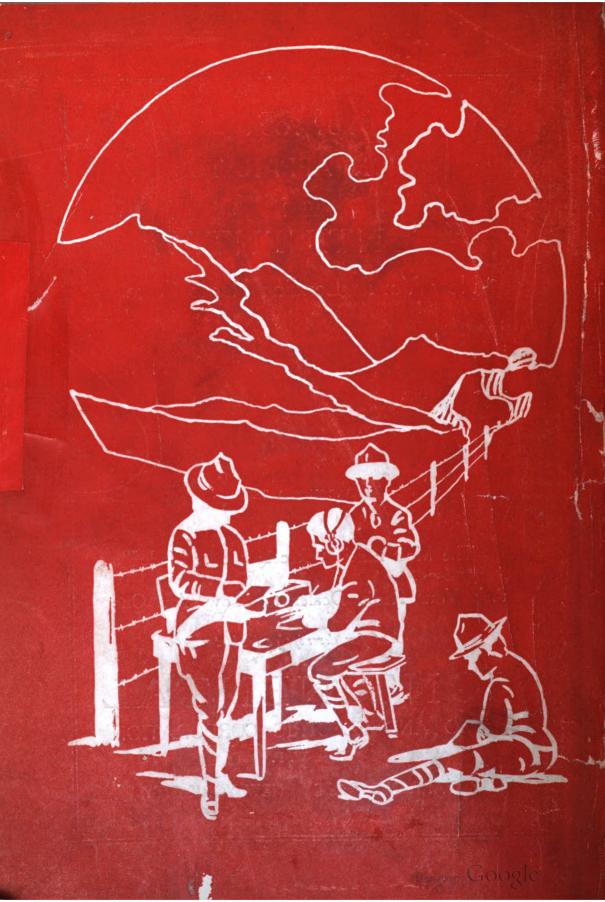
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