MODERN RADIO OPERATION

J. O. SMITH

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By

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Preface

The single objective of this book has been the assembly and simplification of valuable and instructive information for those interested in the operation of present-day transmitting and receiving equipment. This volume contains neither mathematics nor theory. All the information given is in plain, understandable language and is based upon experience and knowledge gained in the actual operation of modern apparatus of the vacuum tube type.

Acknowledgment is made of the assistance and co-operation of Howard L. Stanley, of the Adams-Morgan Company; Harry Sadenwater, of the General Electric Company; and E. V. Amy, of the Radio Corporation of America, in the development of several of the transmitting circuits described in this book, by means of which many of the unprecedented results achieved by 2ZL station were made possible.

THE AUTHOR.

CHAPTER I

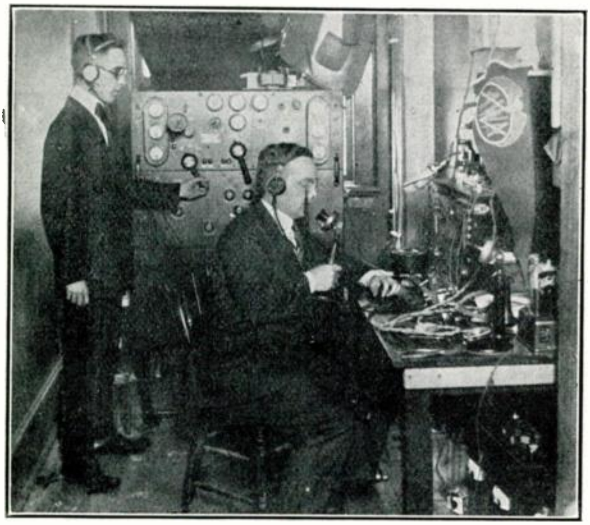
The Radio Telephone

The radio telephone, that latest contribution of science, by means of which entertainment and information may be broadcasted to thousands of listeners at once, is assuming an increasing importance and influence in the affairs of the people of this great country of ours. By it, instrumental and vocal music, speeches, lectures, and in fact all audible sounds and speech can be made simultaneously available to thousands upon thousands of listeners. This new branch of science has incalculable possibilities.

The usefulness of the radiophone was first demonstrated about 1905, but not until shortly after the close of the war was there regular use made of it outside of the military and naval branches of the government.

The first time that the radiophone was used on a really big scale in making information available to hundreds of thousands of listeners at one time, was on July 2, 1921, when the boxing contest for the championship of the world between Jack Dempsey and Georges Carpentier, at Jersey City, N. J., was broadcasted blow for blow and round by round, by voice, from the temporary station which had been installed by the Radio Corporation of America, at the Hoboken, N. J., terminal of the Lackawanna Railroad. A careful check of the reports as to the number of listeners to the voice description of the big bout on July 2nd has clearly established the fact that the number was very close to 300,000. The undertaking was successful in every way and the audibility and strength of the voice was such that the whole detailed description was heard as far as Florida, 1,000 miles away, which is an exceptional distance for daylight transmission of the voice.

In about fifty theatres and halls within a radius of 200 miles of the transmitter, amateur radio operators had installed receiving equipment and loud-speaker horns, and large audiences listened to the voice in the air that described the big event. Admissions were charged, and the proceeds were divided between the Navy Club, which aids the sailors of our Navy, and the American Committee for Devastated France.

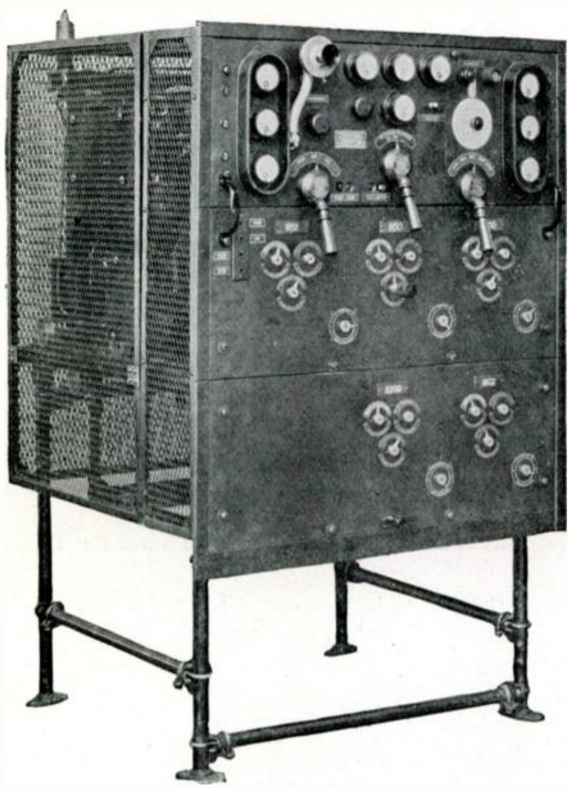


J. Andrew White and H. L. Welker conducting a preliminary test of the 3½ K.W. transmitter at Hoboken, N. J. by which the Dempsey-Carpentier fight was described by voice to 300,000 persons

The details of the big bout were described over a telephone circuit by J. Andrew White, editor of *The Wireless Age*, who was at the ringside, and were then retransmitted by radiophone from Hoboken.

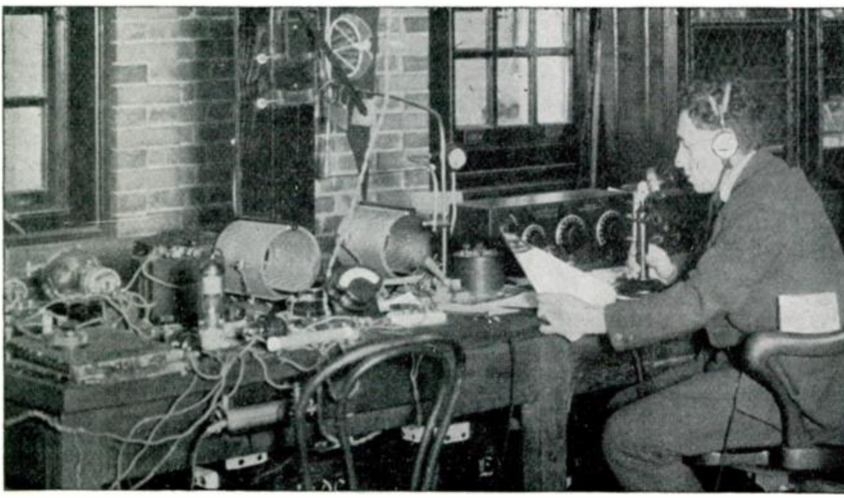
The whole project was of great magnitude and absolutely unparalleled in its scope, for never before in the history of radio had anything of the kind been attempted. That the undertaking was entirely successful in every respect is a source of the greatest gratification to the author, as he operated the 3½ K.W. General Electric radiophone set which was used at Hoboken, and it was his voice which was heard by the 300,000 listeners, the largest number of people ever talked to simultaneously by one person in the history of the world.

In October of 1921, the author had charge of the operation of a temporary radiophone station, erected by the National Amateur Wireless Association, at the Seventy-first Regiment Armory, New York City,



The 3½ K.W. Radiophone Transmitter used at Hoboken, N. J. July 2, 1921 in broadcasting the Dempsey-Carpentier boxing match to 300,000 people

in connection with the annual Electrical Show. This station was of limited power, as it was intended to cover only the metropolitan district. Prominent artists, including Miss Anna Case, of the Metropolitan Opera Company, and Miss Sophie Tucker, a headliner in vaudeville, entertained large audiences via radio during the show. The annual championship baseball games between the New York National and American League teams were being played in New York at that time and these games were described play by play, by voice. In every case, the broadcasted description was only a few minutes behind the actual play at the Polo Grounds.



Broadcasting the World's Championship Baseball games from the radiophone broadcasting station at the N. Y. Electrical Show.

In November, 1921, the author took charge of the operation of WDY station, of the Radio Corporation of America, at Roselle Park, N. J., which became famous throughout the eastern part of the United States through its high-grade programmes rendered in "human interest" style.

That these three undertakings in broadcasting have had a large share in the development of the present great public interest in radio there is no doubt. This interest has spread all over the country and has resulted in the establishment of a large number of radiophone broadcasting stations.

The number of broadcasting stations now in operation in the country is such that it is possible for anyone to listen to musical and other forms of entertainment, to official time signals, weather forecasts and reports, market quotations of all kinds, health and educational talks and much other interesting and instructive information, provided suitable receiving apparatus is installed.

The entertainment, information and instruction which are now being broadcasted become, in this way, available to anyone interested regardless of where they may be located with respect to the transmitting station, provided proper receiving apparatus and equipment is installed.

The broadcasting form of communication, which is distinctively radio's, has a future of unguessed possibilities. Dr. Alfred N. Goldsmith, professor at the City College of New York, Director of the Radio Telegraphic and Telephonic Laboratory at that institution, Secretary of the Institute of Radio Engineers, and Director of the Research Department of the Radio Corporation of America, made the following comment recently on the future of radio broadcasting:

"Radio broadcasting," said Dr. Goldsmith, "will provide the school, the theatre, and the lecture platform of the future. A man will be able to have in his own home, the news, the latest play, the opera, a lecture, or a political debate. He will not be required to accept one of these alternatives at any given time, but will be able to choose any of them, since they will all be sent out concurrently on different wave lengths.

"The result on the political life of the country will be incalculable. The United States is a particularly scattered nation, dependent almost entirely for its unity on the rapidity of its means of communication. The latter at present consists of the press, the periodicals, the wire telegraph and telephone.

"The two former are by their very nature, deferred in their effect in greater or lesser degree. The two latter are immediate, but personal, reacting generally only between individuals. They reach a definite point; the radiophone covers an area. In radio broadcasting is the means of immediate personal contact between the officials of the government and the citizens, and between the candidate and his possible constituents. As a result reactions to great issues will be direct, swift, and unaffected by geographical differences. The nation will be integrated to a degree never conceived of, and the resulting effect on our life and institutions is equally inconceivable.

"The effect on the Nation's artistic life will be equally great. As the motion pictures have stimulated people's artistic visual images, so will the 'Movies of the Ether' stimulate their aural images. It can reasonably be predicted that popular taste in music and the spoken drama will be immeasurably uplifted."

Dr. Goldsmith also pointed out another analogy between the radio and the movies, in that the former is a projection of a special sort of electro-magnetic or light wave, and the latter of an ordinary light wave.

"However," he continued, "the radio telephone has certain definite provinces. It will not, as some imagine, replace the wire telephone. Upon the latter will always depend the basic communications in congested districts: just as transoceanic communication, and communication affecting moving bodies and across inaccessible spaces must inevitably be the province of the wireless. Between these two extremes is a large field whose disposition between wire and wireless only the future can determine. But each has essential limitations which will prevent it ever crowding out the other."

Professor Goldsmith made it clear that in its own field the radio was as completely practicable as the wire. In the matter of privacy he explained that instruments have been invented, such as the cryptocode machines, which send out messages in code with tremendous speed, and decode them at the receiver. Anyone listening in would find it practically impossible to pick up the message, or if he did so, to decode it in time to be of any use. Furthermore, these machines can alter the code as often and as irregularly as may be desired.

In the field of radio-telephony there is being perfected an instrument which sends out the voice so greatly distorted that an ordinary listener would hear more gibberish; the receiver for which the message is intended, however, picks it up and renders it immediately intelligible. Further, the method of distortion is continually changing, so that no one listening in could be successful for a very long time.

CHAPTER II

Transmitting Equipment Used in Radio Telephony and Its Operation

Much of the equipment used in radio telephony operates as in wire telephony. As a general thing this wire telephone equipment consists of a microphone transmitter with a battery and microphone transformer at one station and a telephone receiver at the other. The function of the transmitting station is to produce pulsating current voltage at the output terminals of the transformer, this current changing in frequency and amplitude corresponding to the pitch and intensity of the sound waves produced by the human voice. The receiver on the other hand has imposed upon it a voltage similar to that at the output terminals of the transmitter transformer and produces sound waves of similar nature which are impressed upon the human ear. In wire telephony therefore it is the function of the electrical equipment to use the conductive properties of a wire line to produce sound waves at the ear of the listener corresponding to those at the mouth of the transmitter.

The function of the radio telephone is to utilize the properties of the ether of space to replace the conductive properties of metallic wires in producing audible sounds at the receiver corresponding to the audio frequency voltage at the terminals of the speech transformer. Equipment must be provided of course, for causing the speech transformer voltage to control or modulate the flow of energy in the antenna wires at the transmitting station and from the effect upon the ether of the electrical energy in these wires to produce similar voltage changes at the telephone receiver at the receiving station.

The systems of radio telephony most generally used secure audio frequency modulation of the radiated high frequency energy by varying it at audio frequency. The radio frequency is known as the carrier wave. When the amplitude of the radio frequency carrier wave, which of itself is of such high frequency as to be inaudible, is changed or varied and the rate of change in amplitude is within audible limits, a carrier wave of high frequency radio energy is said to be *modulated.*

Radio frequency is also used to secure the transmission of ordinary spark telegraph signals, but at the receiving end is made to disappear by the rectifying action of the detector which passes only audio frequency currents to the receiving telephone. Obviously therefore, a detector capable of receiving spark signals will also be capable of receiving radio telephone signals.

There will necessarily be some distortion of speech in the case of radio telephony, as the speech element goes through four different stages in passing from the mouth of the transmitter to the ear of the receiver. It is true, however, that distortions due to one stage of the process may be compensated for by opposite distortion of another stage.

In radiophone broadcasting transmission many problems are encountered in properly transmitting speech and music. When a radiophone transmitter is to be used for speech only, there is little difficulty in finding the proper arrangement and value of circuits and constants which will give the desired result, but when music, both vocal and instrumental, is to be transmitted, real problems are encountered.

For ordinary speech, a standard microphone will answer satisfactorily, but in transmitting music with the periods, or frequencies, of the many tones running from one extreme of the scale to the other, the ordinary microphone will not answer, because it has several periods of vibration of its own. When music of one or more of these particular periods is impressed upon it, the result is resonance and either reinforcing or absorption of the impressed note, or tone, resulting in its being either much stronger or much weaker than tones or notes either above or below it in pitch when heard at another station as radiated energy. In addition, it is apt to be considerably distorted.

The best microphone for transmitting music is, therefore, one which has practically no period or periods of its own, in order to minimize absorption and distortion, and special microphones of this type, known as condenser transmitters, are now in use in several of the big broadcasting stations.

Condenser Transmitters

The condenser transmitter consists of two parallel plates, with air as the dielectric between them. The rear plate is of heavy, gold-plated steel and forms the back of the instrument. The forward plate is of very thin steel, stretched to its elastic limit, which is used as a vibrating diaphragm. This arrangement presents a typical air-damped vibrating system, with high stiffness and damping provided by the air film between the plates. The narrower the air film, the more sensitive the transmitter to pressure upon the diaphragm.

When such a condenser is used the effect of impressing upon the diaphragm the sound waves from human voices or from musical instruments is to cause the diaphragm to vibrate, changing the capacity of the condenser at a frequency corresponding to the frequency of the sound. The result of this change in capacity is to produce an alternating potential drop across the high resistance. Thus, the condenser transmitter performs the same function as a telephone transmitter, with the important exception that the alternating potential drop across the resistance for a given amount of sound energy, by proper adjustment of the damping film of air and the area of the diaphragm, can be made nearly independent of the frequency impressed upon the diaphragm, and it is, therefore, a highly desirable type of transmitter for radiophone broadcasting.

While practically without a period, and highly desirable for that reason, these special transmitters are not nearly as sensitive as those generally used and present problems of a special kind in the way of modulation amplification. In view of it being necessary to have a certain amount of energy at the set to properly modulate the high-frequency output to approximately 60 per cent. of its total, and because the output of these special microphones is too small to properly accomplish the result directly, it is quite obvious that some method of amplification must be used between the microphone and the set in order to build up the output of the microphone to a proper value. The complete layout is shown in Fig. 1.

The circuit employed for modulation amplification, while similar to that used for ordinary audio-frequency amplification, employs trans-

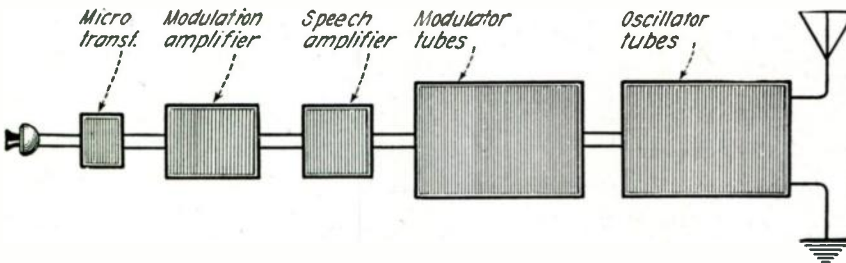


Fig. 1. Diagrammatic layout of a radiophone transmitter of high power

formers of a special type, and the amount of output is controlled by means of a variable resistance shunted across the secondary of the microphone transformer, also of special type. The amount of modulation can be determined by means of a modulation meter, or by audible means, and adjustments of the variable resistance made so as to get the best results.

The "Constant Current" System of Modulation

Modulation of the high-frequency output of the set is accomplished by means of modulator tubes and a speech amplifier tube or tubes. The plate of the modulator tubes are connected to the positive side of the high-voltage circuit through the plate circuit iron-core reactor. The plates of the oscillator tubes are connected to the positive side of the generator through the radio frequency choke. The filaments of the oscillator and modulator tubes being in parallel, the plate circuit is completed through the spaces between the plates and filaments and thence through the mid-point tap of the filament-lighting transformer to the negative side of the generator.

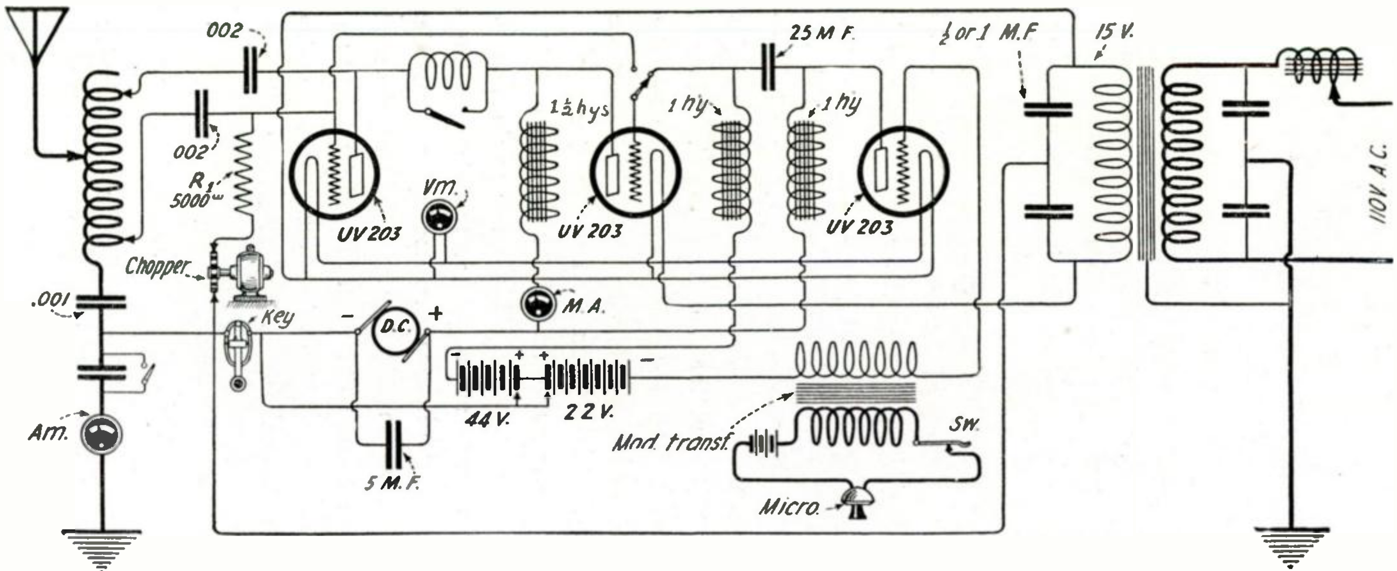


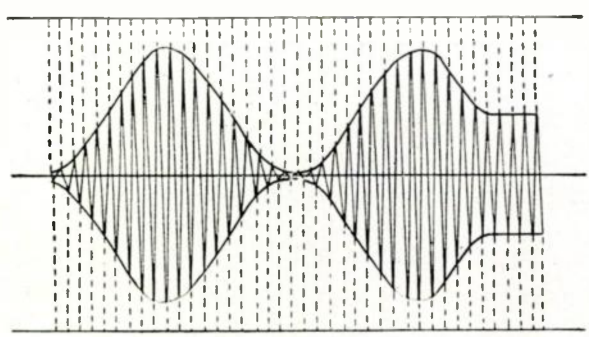
Fig. 2. A standard circuit diagram of a radiophone transmitter

The grids of the modulator tubes are connected through the biasing battery to the filament and also to the plate circuit of the speech amplifier tube by means of a condenser of approximately .25 microfarad. The plate of the speech amplifier tube is connected to the generator through an iron core reactor. The grid of the amplifier tube connects through the secondary of the microphone transformer and biasing battery to the filament. The primary circuit of the microphone transformer passes through the primary winding of the microphone transformer and the microphone.

When the current through the primary of the microphone transformer is varied, the secondary of the transformer impresses alternating potentials on the grid of the speech amplifier tube. These variations of potential are in accordance with the sound waves impressed on the diaphragm of the microphone. This variation of potential on the grid of the speech amplifier tube results in a similar change in the amplifier plate circuit, the amount of amplification obtained being limited to the characteristic of the tube and the circuit employed. These amplified variations are, in turn, impressed upon the grid of the modulator tube, by means of the capacitative coupling. These variations cause corresponding variations in the plate circuit of the modulator tubes, resulting in a corresponding increase or decrease in the power available for the plate circuit of the oscillator tubes. This is due to the fact that there is practically a constant current supply for the plate circuits of both tubes due to the action of the iron-core reactor in the positive lead from the generator and it is due to this characteristic that the method has been termed the "constant current" system of modulation. As a general thing, the plate current of modulator tubes when not modulating should not exceed 3/5 of the normal full load plate current when the tubes are modulating.

Placing of Artists With Respect to the Transmitter

When several artists are singing or playing ensemble for broadcasting, it is necessary that they be placed at certain distances from the recording microphone in order that the voices or instruments may be properly recorded as a whole. This placing of persons and voices is an important feature of conducting a broadcasting programme which has been ignored or improperly handled more often than otherwise. The phonograph companies have devoted years of study to this particular phase of recording and as a result have worked out definite methods for recording voices and instruments. The methods and placing used in phonograph recording, however, do not work out to good advantage in radio recording and it has been necessary, therefore, to make a special study of recording for radiophone broadcasting. There has been great improvement in the ensemble numbers broadcasted recently, however, and as time goes on there will undoubtedly be still more improvement made, until well-balanced ensemble numbers will be broacasted as satisfactorily as single voices and instruments have been in the pas.



Audio frequency modulation of a radio frequency, or continuous wave

CHAPTER III

Leading High Power Broadcasting Stations

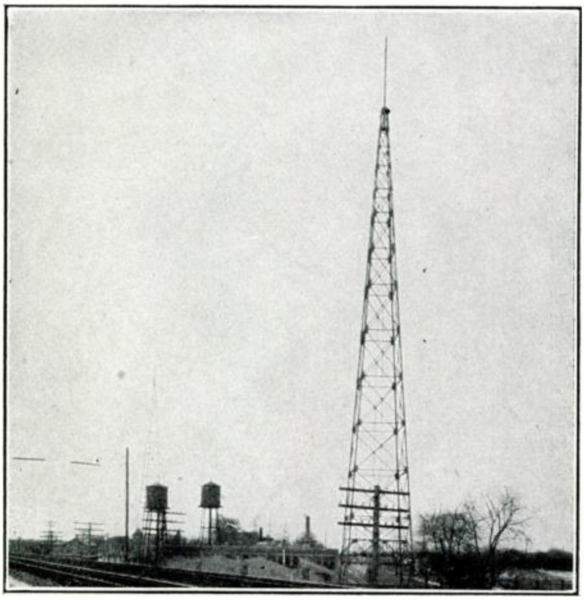
WDY, Roselle Park, N. J.

(Radio Corporation of America)

The Roselle Park station of the Radio Corporation of America, call letters WDY, is located in the General Electric Company's plant, formerly the old Marconi plant in the Aldene section of Roselle Park, New Jersey. It is about sixteen miles due west from New York City, in the central part of the State of New Jersey.

Two steel lattice towers each 175 feet high and 20 feet square at the base support a six-wire cage-type antenna 10 inches in diameter. These towers are 200 feet apart. The antenna is of the multiple-tuned type and has two cage leads, one of which is connected to the center of the horizontal part of the antenna, being connected through a tuning coil to ground. The other lead, which is connected to one end of the horizontal portion of the antenna, leads down to the set in the station. Both of these leads are of the cage type, 4 inches in diameter. This multiple tuning of the antenna gives much greater efficiency on the short wave of 360 meters than would be true of any other type of antenna arrangement. The total antenna current of the station is between 8 and 10 amperes.

The power for the station is furnished by the Public Service Corporation of New Jersey and goes into the power room at 2,200 volts, two phase. This alternating current is used to drive the alternating current motor-generator from which current for the direct current motor-generator of the set itself is secured. An auxiliary motor generator set

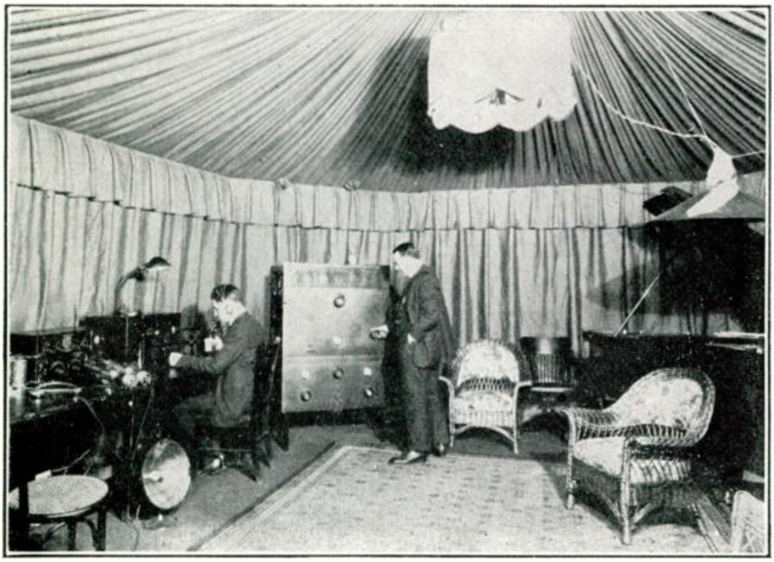


Antenna System of WDY Station, Roselle Park, N. J.

is also installed and this draws power direct from the alternating current supply.

The radio set is of General Electric Company manufacture. The filaments of all tubes are lighted with alternating current which is supplied from a special winding on the radio motor-generator set.

The voltage of the generator which supplies the plate potential for the large tubes used in the set is 2,000 volts direct current. Four 250-watt Radiotrons UV-204 are used in the set itself, two as power tubes, or oscillators, and two as modulators. A 50-watt tube is used as a speech amplifier in connection with a system of 5-watt tubes used as modulation



Studio of WDY Station. On the operating table at the left are located the receiving equipment of the station and all controls of the transmitting set

amplifiers, the latter in turn receiving their energy from several microphones of special type placed about the room at desirable points. By means of a set of resistances in the modulation amplifier circuit it is possible to regulate voice and music modulation to any degree desired.

WDY is really not a radio station—it is a studio. It is of hexagonal shape furnished in blue and gold draperies; the carpets and rugs carry out the same color scheme. This color scheme is also carried further in the lighting arrangements, a large chandelier in the center of the studio giving a soft, mellow light to the whole place.

By referring to the illustration it will be seen that on one side of the studio is a Knabe-Ampico piano which is used for piano selections and accompaniments. On the other side will be seen an Edison re-creation phonograph. The radio set used at WDY shows up clearly in the illustration.

An interesting feature of the station is a large map of the United States which hangs in the foyer of the studio. Tacks have been placed on this map on points from which reports of the reception of the music and speech from the station have been reported and examination of this map shows that the extreme range of the station while in operation extended from points in Eastern Canada to Porto Rico, Cuba and the Florida peninsula and as far west as Omaha, Nebraska. The station has not been operated recently and probably will not be used again. A new station, to contain apparatus of the latest design in broadcasting equipment, which will take over the previous schedules and services of the old WDY station, as well as those of the Radio Corporation and the Westinghouse station WJZ, at Newark, is now being built by the Radio Corporation in the heart of New York City.

WGY, Schenectady, N. Y.

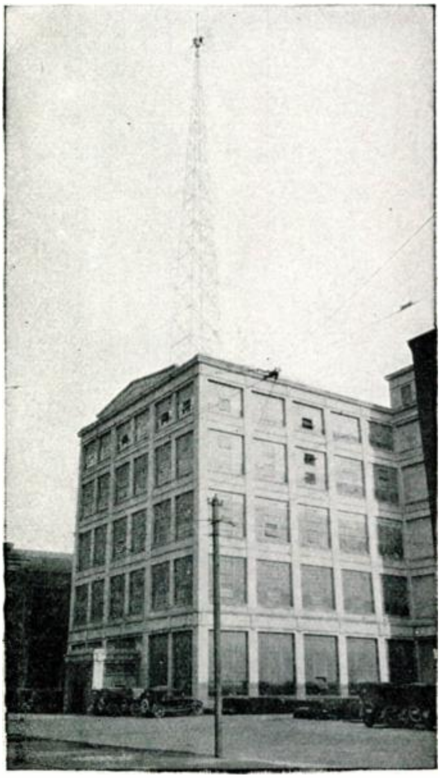
(General Electric Company)

A radio broadcasting station, more powerful than any now sending out programs, has been installed by the General Electric Company at its plant in Schenectady, N. Y.

From the roof of a five-story factory building, two towers 183 feet high and spaced 350 feet apart, support an antenna at such height as to give the wireless waves unobstructed freedom to travel equally well in all directions.

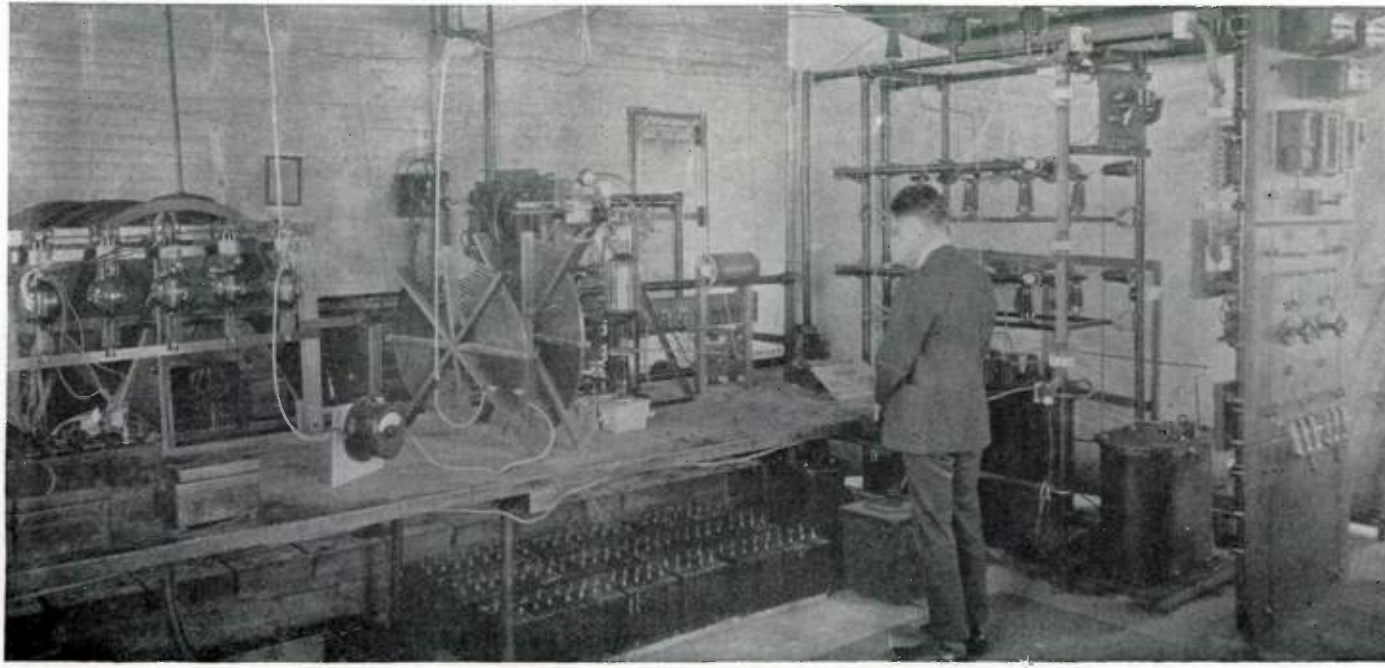
The General Electric station operates on 360 meters under the call letters WGY. It is equipped with the most modern of radio apparatus, including a multiple-tuned antenna of the same design as that which, because of its many advantages, has been installed in Radio Central, the world's most powerful commercial station, at Rocky Point, L. I., and at other transoceanic stations of the Radio Corporation of America.

A three-rom studio, where the programs are produced, is located in a Company office building, 3,000 feet from the transmitting station. One room is used as a reception room for the artists, where they may sit and chat until their time on the program arrives, without danger of interfering with what is going on in the studio. The second room is the



One of the 183-foot towers at WGY

studio, where a concert grand piano, a victrola, an organ and other equipment for the artists are to be found. Here are a number of portable microphones, which are commonly known as pick-up devices, which can be shifted about to locations best suited for the reception of announcements, musical numbers, or whatever may be sent out. In the room on the opposite side of the studio is apparatus for amplifying the sound waves before they are transmitted by wire to the broadcasting station.



Interior of transmitting room in WGY, the General Electric Co. radio broadcasting station located at Schenectady, N. Y. View shows control panel at right and oscillator and modulator at left

A red light when the station is in operation warns persons in the room that whatever they may say will be sent out to thousands of ears of an invisible audience. A switchboard in the studio is within reach of the studio director at all times. Not until he throws a switch can anything reach the antenna. A telephone attached keeps him constantly informed just how the program is going out and enables him to change the position of the artist or microphone to improve the tone quality of the entertainment. With the exception of the small pick-up devices or microphones and the switchboard, there is nothing in this room to indicate it as being different from any musical studio.

In the apparatus room, the sound waves are put through a number of steps of modulation amplification, by means of vacuum tubes, which increases their volume thousands of times. The amplified sounds are then put onto a wire and sent to the broadcasting station, where they enter the modulator tubes of the transmitter.

A 220-volt alternating current line, which is but little higher than the voltage used for lighting purposes in the home, is boosted to 30,000 volts by means of a transformer. This voltage is then applied to a number of kenotron tubes, acting as rectifiers, which change the voltage to direct current, and this rectified high-voltage is impressed upon the plates of the modulator tubes and of a high-power oscillator tube, which generates the power to be radiated from the antenna.

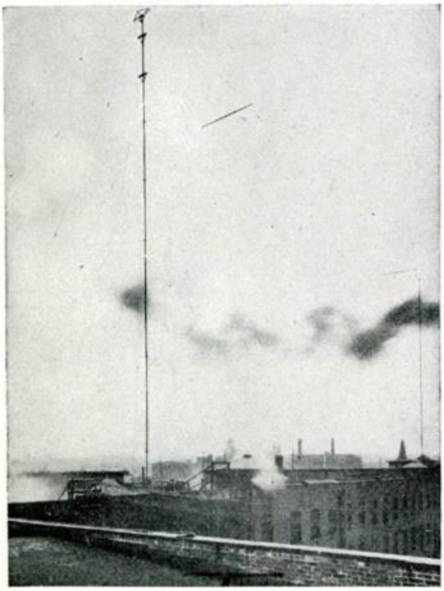
WJZ, Newark, N. J.

(Operated by the Radio Corporation of America and Westinghouse Electric and Manufacturing Co.)

This station is located at the plant of the Westinghouse Electric and Manufacturing Co., at Plane and Orange Streets, near the Lackawanna Railroad station, Newark, N. J.

The antenna is swung between two 120-foot guyed steel masts on the building top, so bringing the upper horizontal part about 200 feet above the street level. The aerial "flat top" consists of 6 wires extending between two 30-foot spreaders, and is 150 feet long. From the North-west end a plural wire cage down-lead drops directly to the radio station; from the opposite end a similar down-lead extends to the "multiple" tuning coil.

Below the antenna, and 12 feet from the roof level, is a twelve-wire counterpoise 150 feet long. The separation of the aerial from the counterpoise is thus about 108 feet, which is frequently taken as the "effective height" of the antenna system.

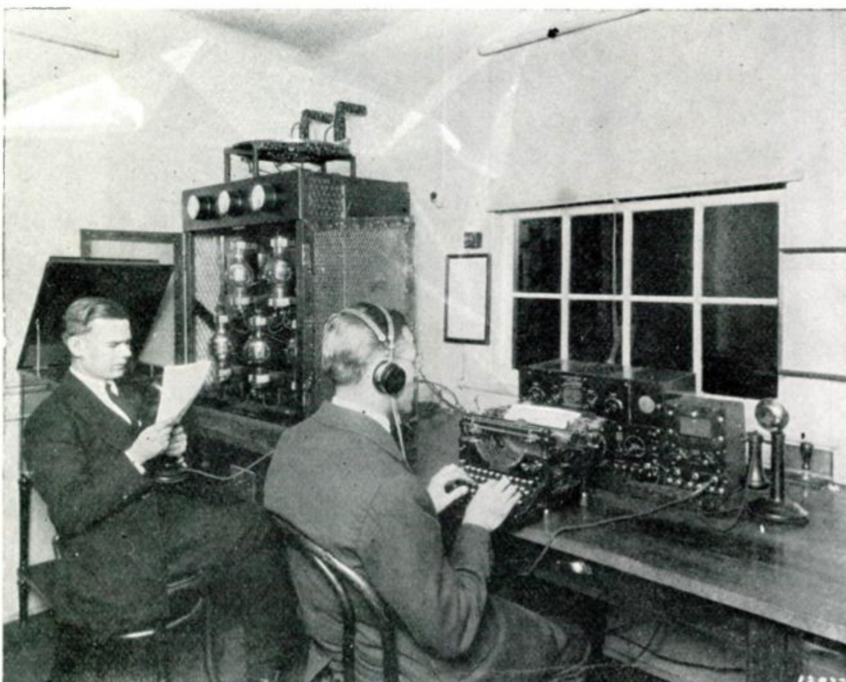


Showing the antenna of WJZ on the roof of the Newark (N.J.) Westinghouse plant

The natural wave length of the antenna-counterpoise structure is not far from 450 meters, so that for transmission on 360 meters (the normal operating wave length for broadcasting) series condensers of 0.0005 microfarad are inserted in each connection. These are placed directly below the lead-in insulators in the interior of the station.

Two three-electrode vacuum tubes are used as oscillators for radiophone transmission and three somewhat similar but specially designed high-impedance tubes modulate the radio frequency currents generated by the other pair. The antenna, counterpoise, grid and plate leads are all connected in the split-coil oscillation circuit to the flat spiral inductance on top of the radio set. This coil is made of flat copper strip mounted on micarta spokes, and is grounded at the minimum potential point nearly midway between antenna and counterpoise.

The oscillator and modulator tubes run on 2,000 volts direct current, which is produced by a single-commutator generator driven by a direct-



Operating room of WJZ. The transmitting set, employing three large modulator tubes and two high-power oscillator tubes is shown at the left

connected two-phase 60-cycle 5 horsepower motor. Special filter circuits are provided to suppress the commutator hum of this machine, with the result that outgoing traffic of speech and music is heard with very little extraneous noise from the dynamo. The filaments of the five large tubes are lighted by alternating current at 10 volts, this being drawn from a transformer. In this circuit again it has been found necessary to provide a grounded filter arrangement to eliminate the foreign noise of the 60-cycle alternating current used.

The three modulator tubes are connected on the plate modulation plan and are supplied with voice frequency current from a speech amplifier containing several three-element vacuum tubes. An ingenious arrangement compensates for the inherent distortion which is so often found when vacuum tube transmitters are operated at full power for

Olga Petrova formally opening the new studo at WJZ

radio telephony, and the clarity of the speech and music sent out from WJZ is limited only by the characteristics of the microphones used to pick up the sound waves and transfer them in electrical form to the speech amplifier.

Not the least interesting feature of the station lies in the completeness with which its details have been worked out. The complete radio transmitter is enclosed in metal screening and glass, and a blower is provided to hold the tube temperature at the best operating value. A switchboard is mounted on the right hand side of the transmitter so that the set may be connected to the station microphone for announcements, etc., to the shielded pick-up device used for phonograph reproductions, or to the studio which has been built on the first floor of the factory building.

This studio is specially designed for concert work. It is attractively furnished and is located where it is convenient of access to artists. A grand piano and other musical instruments form part of the equipment, and the walls are hung with heavy curtains in order to deaden echoes and eliminate outside sounds. Different types of microphones are used for various kinds of work, such as solos, quartettes, lectures, etc. An interlocking system of light signals and switches connects this room with the transmission station on the roof.

The radio station is also equipped with a standard Westinghouse medium wave receiver, with a range of 150 to 5,000 meters wave-length. During the nightly musical program which runs from 7 to 10.15 o'clock, the 9.55-10.00 time signals from Arlington are received on this outfit, using a long single-wire antenna, and transferred electrically to the radio telephone transmitter. Thus the time signals themselves, with the characteristic spark tone of Arlington "NAA," are retransmitted on 360-meter wave length for the benefit of listeners having short-wave receivers. Obviously, there is no appreciable time lag in this transmission, and consequently, accurate Naval Observatory time is made available in the amateur wave length range.

This station is one of a series of broadcasting stations established by the Westinghouse company. Others are located at Pittsburgh, Pa. (KDKA), Springfield, Mass. (WBZ), and Chicago, Ill. (KYW), all broadcasting on 360 meters.

CHAPTER IV

Receiving Equipment for All Purposes and Its Operation

When a receiving station is located within a few miles of the transmitting station, the receiving apparatus required is of a type which can be easily and readily installed by anyone not familiar with or versed in radio communication. A receiving outfit which will give satisfactory results up to a distance of 20 miles from the transmitting station can be bought of any dealer for about the same number of dollars. Outfits of this type usually employ crystal detectors as the sensitive element for making the speech and music audible and in the case of such sets it is necessary to use the head telephone type of receivers. It is possible, however, to use several of the headsets in parallel, so that several persons can listen at one time.

It is not possible, however, to use a loud speaker horn, so that the speech and music can be thrown out into a room for the benefit of several listeners, when a crystal detector is used. In order to do this it is necessary to employ a more comprehensive type of receiver, employing vacuum tubes and with the extra amplification of incoming speech and music so obtained it is possible to reproduce the speech and music with any degree of intensity desired.

The signals of a transmitting station diminish in intensity as the distance from it increases. At points nearby, that is, within a 20-mile radius, it is possible to hear the speech and music with a very small set with one end of it connected to a bed spring, gas stove or other metal object of large surface, and the other to a water, steam or gas pipe.

At distances of over 50 miles or so, it will be necessary to employ a standard receiving set of good design, and also several steps of amplification, to insure signals of good audibility. There is no fixed rule for the amount of amplification which may be necessary in order to produce good signals. As a general rule it might be stated that a crystal detector set will answer up to 20 miles, a good receiver and detector tube up to 30 miles, and one or more stages of amplification for greater distances.

At night, especially during the cold months of the year, the range of signals of a given station will often be several times its daylight range. Under these conditions, due principally to dry, clear and calm atmospheric conditions, it is frequently possible to listen to the speech and music of a station located a thousand or more miles distant from the listener. This uncertainty as to conditions from night to night, with the possibility of listening to other stations situated at exceptionally long distances, is one of the great fascinations of radio. The query "Who did you hear last night?" has become as common as "How are you this morning?" since the great public has come into radio.

Variation of Strength of Radio Signals.

Variation in the strength of radio station signals, both code and voice, particularly in long-distance night communication, is a phenomenon concerning which comparatively little is known even by advanced radio enigneers. That signals and voice often gradually increase to unusual strength and then fade slowly or rapidly until entirely below audibility is of course of itself well known, but while many theories have been advanced nothing definite has as yet been determined upon as a cause for what has frequently been referred to as "fading." But is it fading? Isn't it true that it is really a rising instead of a falling characteristic? The fact that stations can be heard at night which cannot be heard in the daytime would indicate that the range of such stations had increased many times during the night as compared to the daylight range.

It has been definitely determined that daylight restricts the range of a station to a definite area. It has been definitely determined, further, that as a rule, signals from distant stations are more likely to be stronger during a night following a cloudy day than following a day of bright sunshine.

This would seem to indicate that the daylight effect is the sole determining factor. If this were true it might be expected that with the coming of night the range of all stations in all directions, especially those employing short wave lengths, would increase proportionately. This, as is well known, does not happen.

What does happen is that the range of stations to the west of New York, for instance, may increase greatly, while not a single station in New England will be heard. On another night New England stations may come through strong, and not a single station in the Middle West be heard from. On another night signals will be strong from all directions.

This shifting condition would seem to indicate that the condition of the atmosphere is a main factor, but this is disproved by the fact that it is possible to determine whether a station is located in the west, or in New England, by the manner of the rise and fall in signal strength.

The signals from New England stations increase and decrease very rapidly. In fact, it is a common occurrence to hear a New England station fade completely out in the middle of a four letter word, and come up strong again in the middle of the next word.

The rate of rise and fall in the case of Middle West stations is much more gradual. These stations fade out slowly, over a period of 10 or 12 words usually and then swing back again in the same gradual way. This would seem to indicate that the country intervening in both directions between New York and New England and the West was the controlling factor.

Why should signals fade rapidly in one case and gradually in the other? Is it a question of distance, topography, terrain, or what? The old theory of attributing "fading" to conditions at the transmitting station won't stand in the face of the foregoing facts.

There are many spots on the ocean known to commercial radio operators as dead pockets. One of these is along the New Jersey coast, near Barnegat. Another is on the Gulf of Mexico, near the lower Mexican coast. Why dead pockets on the ocean? The same thing is true, however on land. For instance, the owner of an amateur radio station at Fall River, Mass., can work stations near New York easier than stations in New England, half the distance away. He is in a pocket. New England, in fact, seems to be in a pocket by itself. It is easier to work New England from Ohio or Illinois than from Long Island or New York City, 75 miles away.

There are, in fact, a large number of dead spots throughout the country, which have caused much interest and speculation on the part of operators of amateur stations as to their definite size and effects on signals from various directions, and much experimental work has been done in an effort to evolve a satisfactory solution of the matter.

What were known as "fading tests" were conducted recently during the winter months, to endeavor to solve the "fading" problem. A lot of information has been printed from time to time as to what was accomplished by these tests, but a solution of the "fading" problem appears to be as far off as ever.

The only way the disadvantages of "fading" can be overcome is by means of increased amplification. If, with certain receiving equipment at one station the signals of another station swing out, or fall below audibility, the solution is, of course, to employ additional amplification, so that the signals will be kept at sufficient strength to be audible while at minimum strength.

Receiving Antennas

An antenna for receiving purposes may be any one of several types. A good type for the purpose is a single wire, about 150 feet long, suspended between two buildings, or poles, or between a building and a tree. The wire should be at least 30 feet above ground. Forty or fifty feet above ground will give still better results. Where it is not possible to stretch a wire of 150 feet, less length, down to 50 feet will

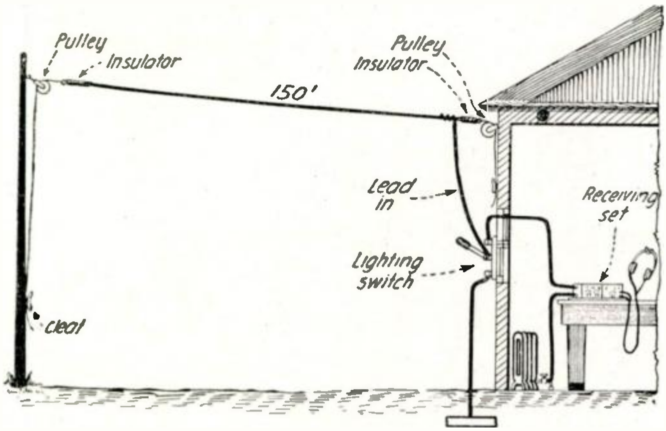


Fig. 3. Suggestion for the installation of an antenna and receiving set for reception of broadcasting

probably answer, but the strength of incoming signals will be less than if the longer stretch were used. Several wires, in parallel, mounted on

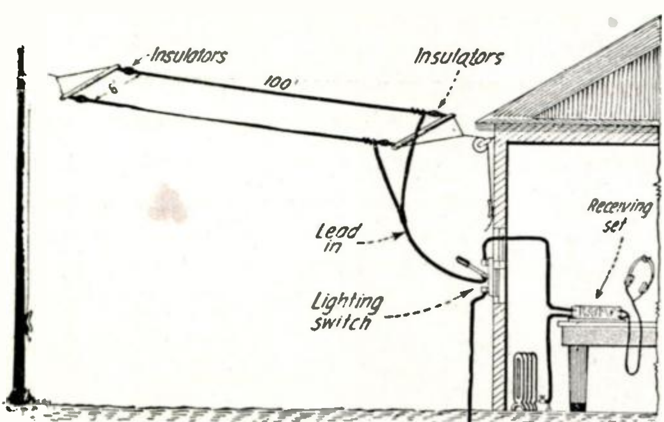


Fig. 4. A two-wire antenna will give somewhat better results in receiving than a single wire

spreaders, can be used. These can be of any length between 50 and 150 feet. For receiving purposes, however, the number of wires in an antenna need not be more than two in number, as very little will be gained by the additional wires. However, where it is not possible to construct an outdoor antenna of sufficient length to make it worth while, an antenna of four or five wires in parallel can be constructed in the attic of a detached dwelling, for instance, and fairly good results obtained.

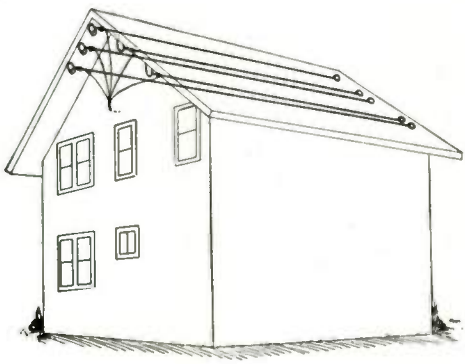


Fig. 5. Suggestion for an indoor antenna to be installed in the attic

It will probably surprise many readers to know that in building an outdoor antenna, particularly for receiving purposes, insulated wire should be used. The insulation will not interfere in the least in the reception of signals, but will, on the other hand, protect the conducting antenna wires from the elements, consequently from corrosion, and this is a very vital point in connection with the efficiency of receiving antennas.

It is well known that the high-frequency oscillations of a transmitting station do not penetrate the antenna wires of the receiving station to any conceivable depth. They travel practically only on the surface, or skin, of the wires. It therefore follows that the less corrosion, consequently resistance, there is on the skin, or outer surface of the wires, the less energy will be consumed in the course of the incoming signals as they travel along to the receiving station. It must be remembered that the amount of energy which reaches a receiving station from a distant transmitting station is exceptionally small, consequently any great amount of conductor resistance at the receiving station will seriously affect the final result at the detector. Several tests were made in England recently to determine the effect of corrosion of antenna wires. Two antennas of the same size were used. One had been in use for a year and another one of the same size and proportion, in which new copper wire was used, was erected alongside the first one. Comprehensive tests showed that signals when received on the new antenna were at least 25 per cent. stronger than when the old antenna was used, the wires of which were badly pitted and corroded.

As shown in the diagram, small porcelain insulators should be inserted in the antenna wire where it is connected to whatever supports it.

Lightning Protection

A lightning switch should be installed on the outside of the building. While it is practically true that an antenna is no more of a menace during an electrical storm than a telephone wire, an electric light wire or perhaps even the wiring of doorbells and other interior communicating systems, the fire insurance regulations require that certain forms of protection against lightning must be provided, in order to reduce the possibility of danger to a minimum.

There are several ways of protecting a building where an outdoor antenna is used. One way is to disconnect the antenna lead-in and drop the end to the ground, outside the station. This, however, is not a good method unless a ground pipe is provided and the antenna lead clamped to it each time the antenna is grounded, in order to provide a path of low resistance. When the antenna lead is merely thrown on the ground, a high resistance still exists between the antenna and ground, which is liable to cause a lightning discharge to jump from the antenna to other nearby objects which may offer a path to ground of lower resistance.

Two devices for lightning protection have the approval of the National Electric Code—the manually-operated switch and the grounded short gap.

The manually-operated lightning switch, when thrown to the grounded position, provides a practically positive protection, in that heavy electrical surges induced in the antenna system by nearby lightning discharges, will pass harmlessly to ground.

The grounded short gap operates automatically. It consists of two electrodes held in a fixed position in a sealed chamber from which the air has been exhausted, and it has been found that inductive currents readily pass through the gap in the thin air in the chamber.

A good ground connection should be provided for whatever device may be installed. This can be in the form of two or three lengths of galvanized pipe driven at least 4 feet into the ground, metal plates buried in the ground, two or three feet below the surface, or a water pipe. The conductor running from the lightning protective device to ground should be not smaller than a No. 4 copper wire, copper tubing ¼ inch outside diameter or copper ribbon ⅜ inch wide. The conductor must be mounted on insulators and must be at least 5 inches clear of the building. All connections should be soldered.

There are very few cases on record of lightning having actually caused any damage to radio stations although the number of stations in the United States has been over 100,000 for the last two or three years, and is about 600,000 at the present time, due to the widespread interest of the public in radiophone broadcasting. The chances of lightning damage to a radio station are no greater than for any other building.

A well-grounded antenna is not only itself protected against the effects of lightning, but is also a protection to the building on which it is installed, for if lightning should strike the building the effects of it will be minimized by the easy path to ground which is afforded by an antenna when suitable grounding devices have been installed and properly connected to a good ground.

A circuit diagram of an antenna and other connections for a crystal detector set, which will operate efficiently over a considerable band of wave lengths, is as follows:

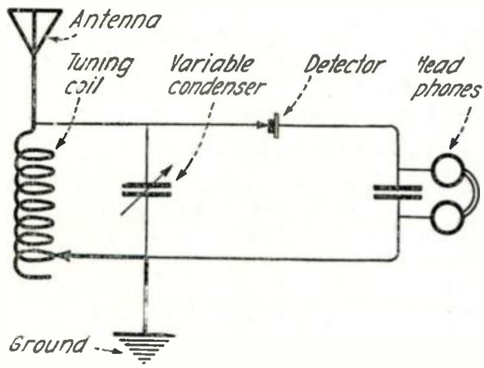


Fig. 6. Circuit diagram of a receiving set employing a crystal detector

A diagram for a regenerative circuit employing honeycomb coils and a detector tube, for use on 360 meters, which is much more sensitive than a crystal detector hook-up, is shown in the following diagram:

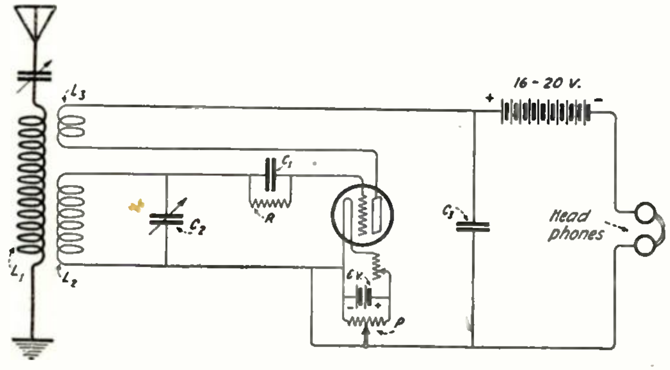


Fig. 8. The tickler regenerative circuit using honeycomb or duo-lateral coils. Amplifiers can be added, by inserting the primary of an amplifying transformer in place of the phones, as in Fig. 7

In the feedback, or regenerative circuit, the incoming signal is impressed upon the grid, and, because of the feedback connection, regeneration of the incoming signal takes place. As energy is returned to the grid circuit by the plate circuit with each incoming oscillation, the process continues to build up the strength of the incoming signal. This effect is limited only by the fact that after a certain amount of energy has been transferred to the grid circuit the tube will oscillate, and so become a generator of independent oscillations. In this condition it establishes a certain period of oscillation which may be controlled by adjustment of the circuits until its period may differ from incoming oscillations of continuous nature (which are themselves of a frequency so great as to be above audibility), by 500 or 1,000 cycles. Thus is produced what is known as the "beat" note, or difference of frequency between two high-frequency oscillations of almost, but not quite the same frequency. It is in this way that the signals of other continuous wave stations, which of themselves are inaudible, are made audible. The method is known as heterodyning.

A circuit diagram for a regenerative receiver, using a vario-coupler and variometers, for the reception of either spark or continuous wave (C.W.) signals, including two steps of audio-frequency amplification to which a loud-speaker horn may be attached, is shown on page 35.

It is advisable to avoid the use of regeneration, as far as possible, in the reception of radiophone speech and music, if signal strength is such that satisfactory results can be obtained without it, for the reason that regeneration will cause some amount of distortion, which, particularly in the case of music, is, of course, undesirable. Where speech or music of a radiophone station is not sufficiently strong to be heard clearly without considerable regeneration, it is desirable to employ one or two steps of radio-frequency to amplify the incoming energy to whatever degree is necessary for satisfactory reception. This will obviate the distortion caused by regeneration.

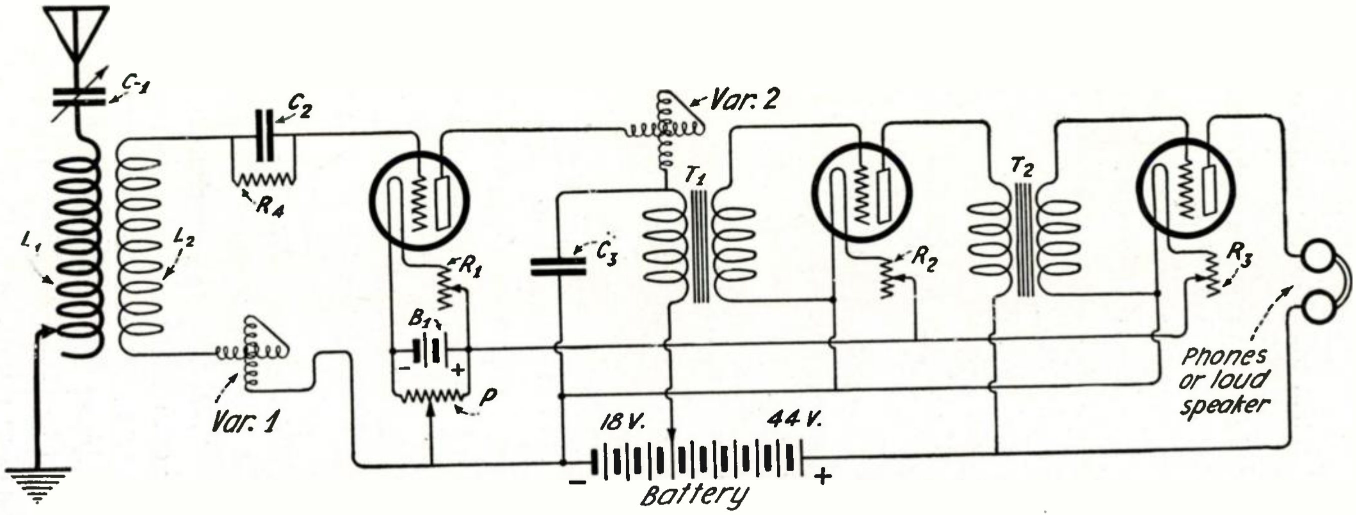


Fig. 7. A standard vario-coupler, variometer regenerative receiving set, with two steps of audio-frequency amplification. This circuit is widely used by operating amateurs

Radio Frequency Amplification

There are marked advantages in high, or radio frequency amplification over the low, or audio frequency method of amplifying in reception. Audio frequency has its place in land wire communication and in the modulation circuits of a radiophone transmitter, but when amplification at the radio receiver is desired it is certainly not good engineering practice to first rectify the incoming high-frequency current and then amplify the rectified current at audio frequency. For one thing, static and other undesirable noises are of audio frequency, and when that form is used in reception they are amplified to the same degree as incoming signals. When radio-frequency is used, static, induction and other disturbances are amplified only slightly, if at all. This one big advantage of high-frequency amplification appears to be sufficient reason for its general adoption.

There is another reason of equal importance, however.

The detector tube of a receiving circuit rectifies, and so makes audible incoming high frequency signals of either continuous or discontinuous waves. On weak signals, however, the tube will function only to a certain point. Where signals are too weak to be detected and rectified by the detector tube, they are lost, and no amount of audio frequency amplification will help matters. The proper thing to do, therefore, where reason or desire exists to warrant it, is to amplify the radio frequency of incoming signals, then detect it, and again amplify the resultant audio frequency.

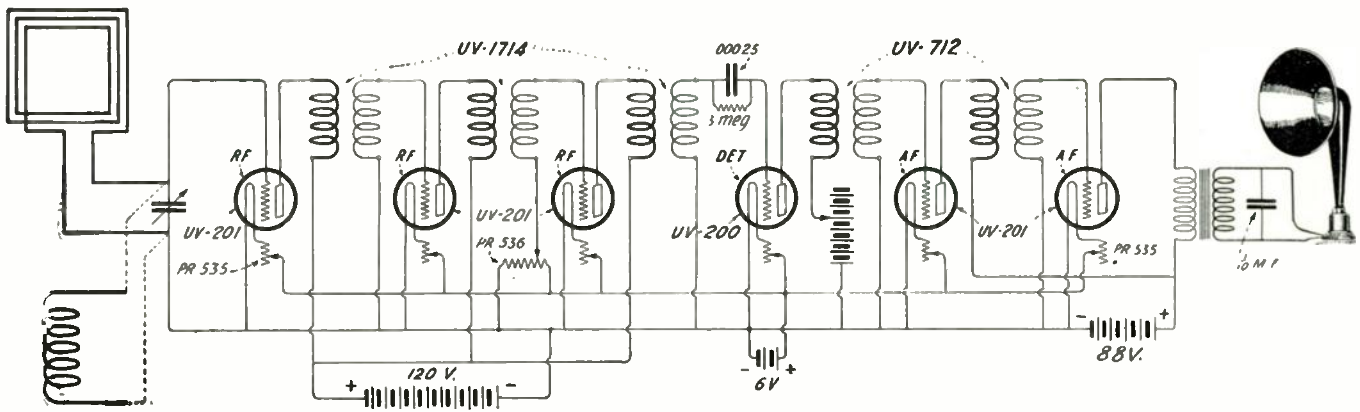
A number of textbooks contain diagrams of radio frequency amplification circuits, but while all of these will operate satisfactorily on frequencies from 500,000 down (or wavelengths 600 meters and up), there has been only one circuit up to the present time which will operate efficiently on frequencies in the neighborhood of 1,500,000 (200 meters), that being the resistance-coupled super-heterodyne circuit developed by Armstrong and used by Godley at Ardrossan. This super-heterodyne circuit, while affording marvellous amplification, calls for the use of so many tubes that its use is practically prohibitive to the average amateur.

In the super-heterodyne arrangement used by Godley (which, by the way, was not unduly elaborate), nine tubes were used for spark signals, and an additional external heterodyne, ten in all, for C.W. reception. This number of tubes is required because a considerable proportion of the incoming energy is lost in the transfer coils which this type of circuit makes necessary between the high and intermediate circuits and again between the intermediate and low, or, audio-frequency circuit. Roughly, this arrangement, while extremely sensitive and reliable, is beyond the average amateur, for, in addition to first outlay for assembly and installation, there is an exceedingly heavy drain on the facilities for filament heating, the average current for the number of tubes used by Godley being 10 amperes.

The new iron-core transformers which are now available to the market have undoubtedly solved the problem of amplification at high frequencies, having been designed to work on a broad band of frequencies, without tuning, at which most amateur operation is carried on and also over a wide band of lower frequencies. A detailed circuit for radio and audio frequency amplification is shown on the following page.

Reception of Continuous Wave Signals

Operators of receiving sets, who can read Continental Code, will find considerable entertainment in listening to transmitting stations, many of them at distant points, which use continuous waves for amateur message relay work. The usual and easiest way of exploring for straight C.W. signals is to bring the receiving tube into oscillation, with about 50 per cent. coupling between primary and secondary and then tune slowly over a wide range of wave lengths by means of the secondary variometer or condenser. Once a C.W. signal is located, the antenna condenser should be brought into resonance, and the plate variometer adjusted to the dead point, which indicates absolute resonance of all the circuits. Variation of the coupling will then give any beat note desired. It is possible to locate a C.W. signal, whether it is straight C.W., Inter-



Combined radio and audio frequency amplification receiving circuit which can be successfully used with a loop or coil as an antenna rupted C.W. (I.C.W.), or voice modulated, as some percentage of the C.W. energy comes through without modulation. As a general thing when listening for spark signals amateurs carefully avoid allowing the detector tube to come into full oscillation, bringing it up only to a regenerative point. This is really a mistake, as the ether these days is pretty well filled with C.W. signals and phenomenal ranges are being covered every night.

The Super-Regenerative Receiver of E. H. Armstrong

The super-regenerative method of reception, a new invention of E. H. Armstrong, was described and demonstrated by the inventor at a meeting of the Institute of Radio Engineers on June 7, just as this book was going to press. The apparatus used in the new circuit was not unduly elaborate, neither was the arrangement of it complicated, but the amount of amplification obtained with the new circuit, as compared to the ordinary regenerative circuit, was amazing.

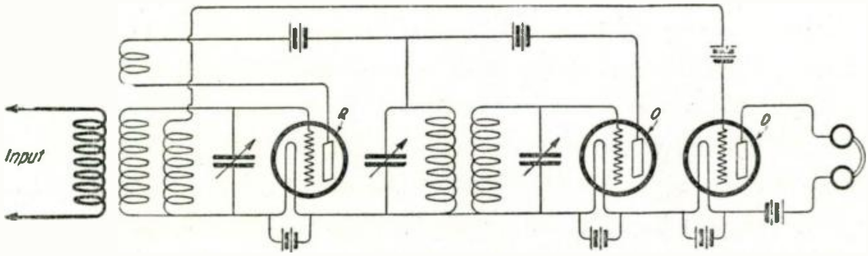
When the ordinary regenerative circuit is used, the energy can be fed back from the plate to the grid circuit, or the incoming signal regenerated, up to only a certain point. In other words, if the inductance of the plate circuit is being increased by means of a variometer, an increase in regeneration, resulting in increased signal strength, is obtained up to a certain point, which we may assume arbitrarily to be 50 degrees on the variometer scale. Somewhere between 50 and 55 degrees, the ability to further regenerate or increase signal intensity is lost, if the incoming signal is other than a continuous wave signal, due to the fact that the tube begins to oscillate and becomes a generator of independent oscillations, at a frequency based on the constants of the circuit. It is a well-known fact that in the last few degrees, just before oscillation occurs, the greatest amount of regeneration is obtained, due to the fact that the steep part of the characteristic regenerative curve of a tube is just being approached. The problem has been, therefore, to *prevent* the tube from oscillating, so that regeneration of incoming signals might be carried on to the limit of the tube. Armstrong, in his new circuit, has solved this problem, and the resultant amplification is so far beyond anything ever yet obtained as to be impossible of adequate description on the printed page. It can be done adequately only by actual demonstration.

During the course of the lecture by Armstrong an actual demonstration was carried on, several set-ups of regenerative and super-regenerative circuits being employed, with a small loop as an antenna. An ordinary regenerative receiver, with two steps of audio-frequency amplification, with a loud-speaker horn, in the last step, was tuned to WJZ radiophone broadcasting station. The music and speech with this arrangement was just barely audible to listeners seated about 10 feet from the horn. The loop and horn were then transferred to the super-regenerative circuit and the result, as a comparison, was astounding, for the amplification obtained was so great that the speech and music literally filled the entire hall where the lecture was given. It was estimated by Armstrong that the amount of amplification obtained by means of the super-regenerative system was approximately 100,000 times greater than was possible with the regular regenerative system. It was stated that in some cases that amplification could be increased to the ratio of 1,000,000 to 1.

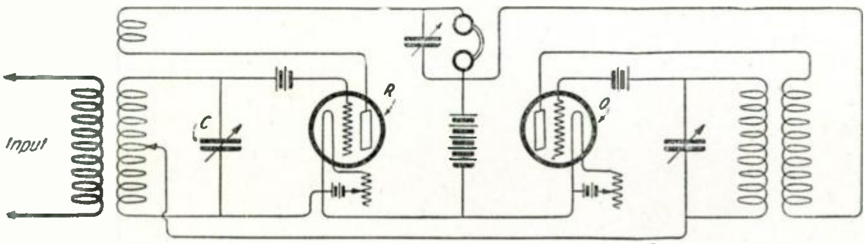
This new super-regenerative system is peculiar in one respect, in that it does not amplify spark, or discontinuous wave signals, due to its inherent quality of rejecting free oscillations. Its greatest field lies, therefore, in the reception of either continuous wave or modulated continuous wave signals, which makes it of the greatest value in broadcasting reception, or in continuous-wave telegraphy. The circuit works best on wave lengths below 1,400 and is, therefore, one which can be employed in its greatest usefulness on the lower wave lengths, for commercial, broadcasting and amateur work.

It is unfortunate that complete details and values of this new super-regenerative circuit cannot at present be given, owing to the patent situation. In a general way, however, the results described in this article are accomplished by means of either two or three tubes in the circuit. Detail diagrams are shown on page 41.

It seems rather unusual to say the least, that the amazing results accomplished with this apparatus should be based upon a circuit employing two, or at the most, three vacuum tubes. Judging by the results



Method of varying the plate voltage coupled into the plate circuit. In this arrangement a third tube acts as a detector



Manner in which the variation is introduced into the positive resistance of the tuned circuit. This is done by means of an oscillating tube O, the grid circuit of which is connected through the tuned circuit LC of the amplifying tube R

Demonstrating the Armstrong Super-Regenerative Receiver

Detailed values of the component parts of the Armstrong Super-Regenerative Circuit will be found in Appendix I, page 134 of this book.

obtained during the demonstration at the Institute of Radio Engineers, wherein signals of sufficient audibility were obtained from a small loop to flood the entire lecture hall, which, in itself, is situated in a steel and stone building, would seem to indicate that the use of audio frequency amplification with its many objectionable features, had at last been made unnecessary and soon to be relegated with amateur spark transmitters, to the past history of radio communication.

CHAPTER V

Spark vs. Continuous Wave Transmission

A great many amateurs who have used the spark method of transmission for many years have been known in the past to utterly refuse to be interested in continuous wave transmission, and to give many reasons why C.W. transmission would never supplant, or even equal, the old familiar spark method. It is a notable and interesting fact also that after C.W. had been used a while by others many of these same amateurs were the first to comment on the readily-apparent advantages of it, especially its low decrement, or rather lack of decrement, the amazing distances it would cover on small power and its great flexibility.

In the case of the spark transmitter, employing alternating current of some frequency, it is good for one thing—telegraphing. It has frequently been stated that the only way to get anywhere with a spark set is to use power to the limit. It is true that while his intentions are of the best, in many cases the amateur is limited in a mechanical way in the construction of his antenna and ground system and does the best he can instead of the best for results. The writer has personally visited a great many amateur stations throughout the country and in almost every case noted that the antenna and ground system was entirely inadequate to handle properly the amount of energy put into it by the spark transmitter. The necessity of designing the transmitter and antenna system for each other is an important point generally overlooked by amateurs.

If one were to attempt to use pressure and force two gallons of liquid into a one-gallon receptacle, something would be likely to happen. In the case of the station using a 1 K.W. spark transmitted on a ¼ K.W. antenna, the something that happens is the emission of energy on a hundred or so wave lengths, even with a loose coupling. The effect is the same as in the case of a too closely coupled set—where energy is radiated over a wide band of wave lengths.

The result, especially in congested localities, is readily apparent. About 75 per cent. of the amateur interference (QRM) we hear so much about, is due to the fact that energy is being radiated over a wide band of wave lengths, instead of on a narrow band as it should. Certainly the receiver can be tuned only to one wave length at a time, consequently all the energy radiated on other wave lengths is wasted energy, accomplishing nothing but interference with other stations that are endeavoring to receive on neighboring wave lengths.

The legal decrement of a transmitting station is fixed at .2, and even where, in a few cases, this feature of the radio law is complied with, there is interference on other wave lengths when a nearby station is endeavoring to receive signals. In the case of C.W. transmission, the energy is practically all radiated on one wave length.

It will readily be seen that C.W. transmission eliminates practically all the unnecessary interference caused by a spark set of reasonable power. The fact that the signals from a C.W. transmitter can be heard at only one place on the receiving set is one reason why many amateurs have objected to its use as a means of communication. These objections are based on both ends of the transaction:—the operator of the transmitting station experiences difficulty in raising a distant station, unless the receiver of the station happened to be set on the transmitting wave length, and the receiving operator complains of the unusual sharpness of tuning the received signals, which calls for more than ordinary care in the adjustment of circuits, etc. These objections, however, seem trivial in the face of the great advantage of C.W. transmission over the spark method, especially as they can be overcome easily. As the power of C.W. transmitters gradually increases, as will certainly be true in the future, there will be less difficulty in "raising" practically any station within working range without resorting to previous notice and agreement.

The complaint of sharpness of tuning at the receiving end usually dissipates quicker than last week's salary once the advantages of it are experienced. Once the signals from a C.W. transmitter are located, the possibilities of tuning them away from QRM and QRN (interference and static) are there and it is a simple matter to accomplish this very desirable result. It is quite a common thing nowadays to get a card from some fellow hundreds of miles away saying that the "C.W. signals were QSA (strong) and could be read through local QRM," etc., without trouble. This is often true even when the antenna input of the transmitting station was in the neighborhood of only 20 or 25 watts, and the antenna current approximately one ampere. On nights when the air is "dead" and no distant spark stations can be heard, there is usually some distant station using straight or unmodulated C.W. whose signals can be easily read.

When the output of a C.W. set is modulated with a buzzer or tone wheel, the received signal can be regenerated and amplified to a much greater extent than a spark signal, especially of the 60-cycle variety. Another great advantage in the use of C.W. by amateurs for short distance work particularly is voice modulation. The fact that the law requires that work shall be carried on with a minimum of power necessary to effect successful communication is a point generally overlooked, intentionally or otherwise, by many operators of 1 K.W. spark transmitters and it is a frequent occurrence to hear a 1 K.W. station using full power to communicate with another station on the next block. This phase of amateur radio has been repeatedly criticised, more often by operators of spark coils and low powered transmitting sets, than otherwise. Everyone is familiar with the tales of the interfering spark coil station, whose operator is usually accused of being able to transmit, but not receive, and the misuse of power by the big station is a favorite method of counter-attack on the part of the small station operator. It is, however, quite true, that the high-powered amateur stations are frequently interrupted in relay work by small stations and spend much precious time and use many K.W.'s of good energy trying to make the operator of the small station understand that he is interfering—at the end of which the operator of the small station often comes back and informs the high-powered stations that his "signals are strong tonight."

The use of a voice modulated C.W. set obviates all such disputes. The operator of the small station can usually understand English, even though he never heard of Morse, and if he understands that he is creating interference is usually entirely willing to "stand by" or "go to bed."

In the case of the spark transmitter of high power (1 K.W. or more) all sorts of mechanical and electrical difficulties are generally present. "Kickbacks" are the bugbear of an amateur's life. The matter of insulation is another matter of great importance, both in the case of interior wiring and the antenna system. It is generally possible to insulate interior wiring properly without great trouble, but where high voltages are imposed upon an antenna it is a different matter. Where more energy is impressed upon an antenna system than the system can properly take care of brush discharges occur to such an extent as to cause aerial fireworks of considerable magnitude, resulting in a loss of efficiency. Frequently the antenna insulators break down under such unusual strain and cause further losses and trouble.

Another phase of spark transmission which has caused amateurs generally to sit up and take notice the country over is the stand the power ~~and telephone companies have taken~~ where high-powered amateur spark sets were operated. In many cities and towns the power companies have recently refused to allow transmitting sets to be connected to house lines, insisting that a separate service transformer and separate power line be installed. The cost of installation of the separate transformer and service asked by the power companies has been generally declared exorbitant, and in many cases the situation has resulted in a deadlock, the result being that the amateur has had to be content with a spark coil, or no transmitting set at all. The other phase of the question, that of interference on neighboring telephone lines, is a common occurrence and one which has caused no end of hard words on the part of neighbors and the telephone company concerned. While not vital to the effective operation of the offending station, such occurrences certainly do not add to the peace of mind of the operator.

With a C.W. set, however, unless the set is of unusually high power, the pull on the service lines is so small as to make connection on the regular house service lines entirely feasible and safe, and consequently no separate service is necessary or required. Neither is there any danger of overloading the antenna.

Unless the set is of very high power as amateur sets go, the difficulty is liable to be in the other direction, in that the capacity of the antenna system might be so great as to absorb energy faster than the set could supply it. The result of such condition would be that the set would not oscillate. Here, again, the rule that transmitters and antenna systems should be designed for each other also holds good. In the case of C.W. transmission, however, the matter is more favorable to the amateur field, in that a smaller antenna system, involving less expenditure of money for erection and upkeep, will answer every requirement of successful transmission.

In view of the fact that practically all the energy of a C.W. transmitter is radiated on one wave length, a low power set of such characteristics will usually accomplish as much at the receiver as a spark transmitter of many times the power, making a C.W. transmitter a comparatively inexpensive, safe and wonderful method of communication.

CHAPTER VI

Vacuum Tube Fundamentals

The three main elements of a transmitting or receiving tube are:

A plate.

A filament.

A grid.

When it is desired to use a tube as a generator of energy, whether as a producer of a wave whose frequency is close to that of an incoming C.W. signal, thereby producing a "beat" at audible frequency (heterodyning), or for the purpose of supplying energy for charging an antenna for transmission purposes, certain definite rules of tube operation must be followed in order to obtain proper results.

In the first place, it must be understood that when the filament of a tube of any type is brought to a state of incandescence the filament emits electrons. As the filament, or cathode, of a tube is invariably connected to the negative pole of a source of high voltage, and the plate, or anode, of a tube to the positive side of the source of supply, an electron flow takes place from the negative filament to the positive plate and the amount of this electron flow between the two elements is in proportion to the difference of potential between the filament and plate. This means, in effect, that the more positive the plate becomes with respect to the filament, or the greater the difference in potential between the two elements becomes, the greater will be the flow of electrons from the filament to the plate, omitting for the moment consideration of the action of the grid of the tube, to be covered later.

When electrons are emitted by the filament and form a path through the space of the tube to the plate, this path becomes a conductive medium, and allows a certain amount of current to flow from the plate to the filament. This flow is known as space current and can be measured by means of the proper indicating instruments. The space current is a direct result of the plate circuit voltage applied to the tube. The circuit, therefore, begins at the positive and negative poles of the generator, or battery, employed as a source of "high" potential, the positive is connected to the plate of the tube, the negative to the filament and the circuit is completed through the space in the tube between the filament and plate which, as has been explained, is made a conducting medium by reason of the electron flow from filament to plate. This electron flow occurs, of course, only when the filament is made incandescent and a source of high voltage impressed on the plate and filament, and, as above stated, this electron flow takes place in the opposite direction to the plate current flow. In other words, the space current of the high potential plate-filament circuit flows from plate to filament; the electrons flow from filament to plate. The electron flow, which consists of a stream of negative ions released by the filament when in a state of incandescence, while of prime importance in the operation of a tube can be ignored insofar as ordinary operation is concerned, as it is an action which takes place automatically providing the tube is properly operated.

The control of the space current from plate to filament, however, is of the greatest importance and this phase of tube operation in transmitting sets should be carefully studied and thoroughly understood by every operator of this type of transmitter. Excessive continual space current through any type of tube will soon destroy the tube, or, at least, so change its characteristics as to make it unsuitable for the purpose for which it was intended. The amount of space current which any tube will handle is specified by the manufacturer and allowing space current in excess of the specified amount to flow through any tube will soon destroy its usefulness.

Excessive plate current invariably causes heating of the plate in a tube and if the degree of heating is so great as to cause the tube to become bright red or white-red, the result will be that gases, which are lodged in the metallic parts of the tube, will become liberated and instead of a high-vacuum tube the result is a gaseous, or soft, tube. By this is meant that the liberation of gases has changed the tube from a "hard" to a "soft" tube, and once this occurs it will thereafter be impossible to use the proper high voltage across the plate and filament of the tube without causing excessive space current to flow, resulting in undue heating and further softening of the tube.

When a transmitting or power tube has become gaseous, or soft, it will be necessary to cut down the voltage of the plate-filament circuit below the normal amount for best output and consequently the efficiency, or, perhaps, usefulness of the tube, has been destroyed.

The operator of a power tube should, therefore, be sure that at no time does the normal space current of any type of tube exceed the amount definitely specified by the manufacturer. Very little will be accomplished by overloading a tube in the way of increased output, but, on the other hand, this slight additional output gained by overloading will result in rapid deterioration and ultimate destruction.

Abnormal plate current in the case of a tube transmitter is usually the result of one or several of the following conditions.

A—Excessive plate voltage, as compared to the specified voltage for the type of tube employed.

B—Excessive positive potential on the grid.

C—Excessive resistance in the antenna circuit.

D—Improper adjustment of the circuits.

In the case of A and B, the remedy is to follow the specifications of the manufacturer and not exceed them.

The result of excessive resistance in the antenna circuit is the same as that of resistance in any other circuit—limitation of current. The current flowing in the antenna is cut down by the excessive resistance and this condition, perhaps more than any other, is responsible for operators overloading their tubes in order to push the antenna current up to the point where they believe it should be. The obvious answer in the case of low antenna current is, of course, the reduction of antenna resistance, by the rebuilding or re-designing of the antenna system. As a usual thing amateur operators use an earthed ground of some kind, and such grounds usually have a very high resistance to high-frequency currents, naturally limiting the output of the set.

CHAPTER VII

Operating Characteristics of Vacuum Tubes

W. C. WHITE, General Electric Co.,
in The Wireless Age

It is very desirable to operate the tungsten filaments of transmitting tubes at constant voltage rather than constant current. The filament life at constant voltage is approximately three times the life at constant current.

The emission during life at constant voltage drops slightly, but this can be easily taken care of in design if it is desired to maintain absolutely full output to the end of life. The filament current at constant voltage decreases 5 to 10 per cent. during life. For this reason it is not possible to obtain full life from a filament when an ammeter is used for adjustment.

The variation of life and electron emission with filament voltage is shown in figure 9. These curves show the poor economy in forcing a tube, because it will be seen that to double the emission reduces the life to one-quarter. Conversely they show the advantage of operating a tube conservatively, for by reducing the electron emission to one-half, which allows half the rated output, the life is quadrupled. This is even more forcibly shown in figure 10, which shows the variation of high frequency output current (radiation current), for a 5-watt tube in a typical oscillating circuit, plotted against filament amperes. At low filament temperature the output is entirely limited by the electron emission whereas beyond a certain point increased emission does not appreciably increase the output, which becomes limited by other factors in the tube.

A life curve plotted on the same chart with filament current shows that, in order to gain an increase of 5 per cent. above rated output by filament temperature increase alone, the life is decreased to approximately 40 per cent. of the normal.

In making filament adjustments the three following points should be kept in mind:

(1) Do not materially raise the filament current to get a small increase of output. The curves of figure 10 show the poor economy of this. Considering operation over a period of one year it would be more economical to operate conservatively two tubes in parallel and get even a greater output than from one running with an excess filament temperature.

(2) For long tube life the best circuit adjustment is the one showing the lowest value of plate current. It is for this purpose that an ammeter in the plate circuit was suggested in a previous paragraph. It is well worth while to experiment with various circuit adjustments in order to get a satisfactory output with a minimum input current. Expressed in another way this simply means getting as high an oscillator efficiency as possible. If a milliammeter is not available for use in the plate circuit, a miniature incandescent lamp may be employed during adjustment and the lowest current judged roughly by the filament brilliancy.

(3) The maximum rated filament voltage of the tube should not be exceeded for any length of time. In all cases the filament should be maintained at as low a temperature as possible, consistent with satisfactory results. As noted in a previous paragraph the filament current at constant filament voltage decreases during life, therefore, adjustment by current is sure to result in abnormal temperature of the filament as its life progresses. All tubes are given a certain rated filament current plus or minus an allowance at a rated voltage. This, as above stated, can apply only to a tube when it is new, as the filament resistance increases during life. This rating denotes or should denote the filament voltage at which the tube will give rated output at rated plate voltage throughout its average life under

specified conditions. Therefore, it is a distinct advantage if the user can obtain the result he desires by operating the filament at a voltage under normal. Operation at 95 per cent. normal filament voltage should double the life of the tube. Under many conditions this is possible. Under some abnormal conditions the filament must be operated at an over-voltage. Under the latter condition the user must expect and accept a shorter tube life.

This question of rating is a difficult one, but not entirely unlike the rating of other electrical apparatus. Consider the case of a direct current motor rated 1 horsepower at 110 volts. This rating is fixed by a commonly accepted set of standardization rules which govern permissible temperature rises and other factors. Both the manufacturer and the user know that probably 2 horepsower is obtainable from the motor, but both also know that if this overload is persisted in, disastrous results are sure to follow sooner or later and the useful life of the motor greatly shortened. Also both know that the motor will operate at an over-voltage, say 150 volts, but they also both know that this lowers the factor of safety of the commutator and that a flashover or bad sparking is almost sure to result. Eventually vacuum tube ratings will also be fixed values, but this standardization must await a wider understanding of the technical features involved before it reaches the same status as in the case of highly standardized forms of electrical machinery.

In the case of the larger sizes of power tubes a fixed filament rating is maintained principally to insure uniformity and establish a definite tube rating. In all cases the filament should be operated at as low a temperature as possible.

It should be remembered that the variations of life, electron emission and other factors do not bear the same proportionality to filament current as to filament voltage. This is due to the temperature coefficient of resistance of the filament resulting in an increase of resistance with an increase of current. Owing to this factor a 5 per cent. change of filament voltage causes about a 3 per cent. change in filament current in the useful range of filament temperatures.

In experimenting with different circuits and circuit adjustments it is advisable first to operate at one-half or one-third normal voltage. In case of abnormal adjustment or faulty connections the tube itself then has a much larger factor of safety against destruction.

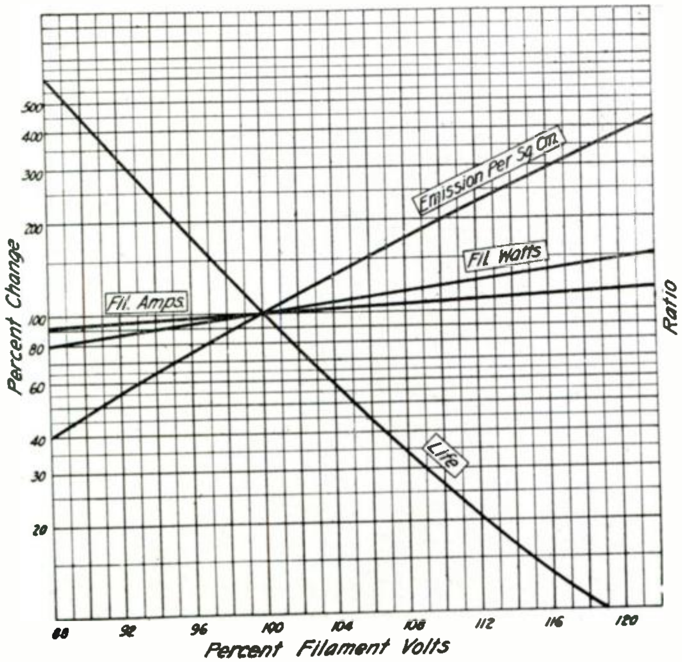


Fig. 9. Graph showing variation of life and electron emission with filament voltage

This same precaution should also be observed when the set has not been operated for some time. Then in case some part of the circuit has, through accident, been changed, no harm will come to the tubes and the voltage may be turned off and the circuit corrected.

Most well-made tubes will stand a great overload on the plate for a few seconds, but a continuation of an abnormally high plate temperature is sure to deteriorate the vacuum.

Most transmitting tubes have a definite plate voltage rating. As in the case of a filament voltage rating this voltage should be the value which will give rated output throughout the average life of the tube. It is to the interest of the manufacturer to make this voltage as high as possible as it allows a higher power rating of the tube, but in all cases some factor limits this voltage. These factors are usually electrolysis of the glass of the seal, dielectric strength in the base or stem, overheating of the metal parts or glass due to the increased energy to the plate, or puncturing of the glass.

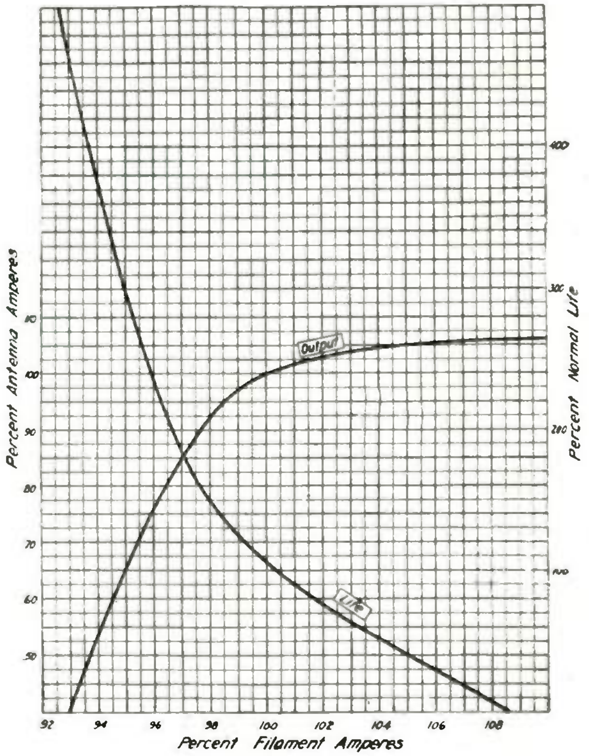


Fig. 10. Radiation current for a 5-watt tube in an oscillating circuit plotted against filament amperes

On the small types of tubes in which all the leads are brought through a common stem, electrolysis in the seal of this stem is the factor usually limiting the plate voltage. At plate voltages above rated value electrolysis causes air leakage through the seal and thus unduly shortens the life of the tube. Even at rated voltage a slight, but harmless amount of electrolysis takes place, which can be detected by a blackening of the grid leads in the glass of the seal. This blackening is due to electrolytic deposition on the grid leads which form the negative electrode for the electrolysis.

At higher plate voltages where this electrolysis is more severe the glass of the seal in the vicinity of the grid lead changes to a dark brown color.

In a radio telephone transmitting circuit of the usual type a modulator tube is employed and a buzzer is often substituted for the microphone when it is desired to send out interrupted continuous waves. This imposes very severe voltage strains on the oscillator tube and if an over-voltage is also applied to its plate the voltage between grid and filament may be excessive. The protective gaps described in a previous paragraph are a safeguard against breakdown due to this voltage.

Unless the constants of the oscillating circuit are changed the plate current will go up when the plate voltage is increased, causing the energy loss to the plate to be rapidly increased. This, of course, is liable to cause deterioration of the vacuum.

Puncturing of the glass occasionally is met with and is caused by the heat of electron bombardment or dielectric losses softening the glass or it may be caused by excessive voltage when the glass is a dielectric.

In most types of tubes, if puncturing does occur, it will take place through the stem, between the leads inside the stem and the sleeve on the outside which supports either the grid or plate structure. Such puncturing is much more liable to occur when the glass is very much heated due to overload. It is most effectively provided against by the protective spark gap previously mentioned which should be set as close as possible and still permit normal operation. Puncturing of the bulb itself is rare at plate voltages under 5000.

Some of the principal precautions to be observed in the use of power tubes have been explained. The experimenter with the larger sizes of tubes will find many interesting conditions and discover many new phenomena. However, he must be careful and use good judgment or an undue destruction of tubes and apparatus is almost sure to result.

Although in the past it has usually been the custom to operate the tungsten filaments of vacuum tubes at an approximately constant current by means of an ammeter, operation at constant voltage is to be recommended as giving a much longer life to the filament in about the ratio of three to one.

In operating tungsten filaments in vacuum tubes, observance of the three following rules will greatly increase the useful life of the tubes:

(1) The most favorable adjustment of the set, of which the tube is a part, is the one which gives the desired result with the *lowest value of plate current.*

(2) The filament *current* or *temperature* should *not be materially raised* to give a *slightly increased output,* or signal, which is not vitally necessary.

(3) *Do not,* for any length of time, *exceed the maximum filament rating,* and in all cases *reduce* the filament temperature to as *low* a value as is consistent with satisfactory operation of the apparatus.

Most tubes are designed for operation in one or two designated positions; that is, vertically, or horizontally, with a certain side, or end, up. It is advisable to observe this feature, because a hot tungsten filament has a tendency to sag very slowly, and if this is not prevented, or compensated, by operation in a certain designated position, there are liable to be changes in the electrical constants of the tube, caused by changes in the distance between the electrodes.

If for some reason the vacuum in a tube becomes faulty, it is usually noted by the characteristic glow due to ionization of the gases present. If gases evolved from the metal parts or glass, due usually to the heat from an overload, are the cause of this glow, it will be blue in color; whereas, if it is due to leakage of air, it will appear purple or pink.

Occasionally a tube will be met with which, when the filament is energized, shows a sort of yellowish-white smoke in the interior near the filament or it fails to come up to normal brilliancy at rated amperes and a dark-blue powder forms on the plate and grid. Both these effects are due to considerable amounts of leakage of air, but take place under different conditions.

The smoke or powder formed is an oxide of tungsten which exists in several forms and varied in color from a very light yellow to a very dark blue, depending upon the conditions at the time of its formation.

One limit to the possible output of a tube as an oscillator is the amount of energy that can be dissipated safely in the form of heat. If it is attempted to dissipate too much energy, the glass and electrodes will be liable to evolve gas which reduces the vacuum. If the tube is enclosed in a small unventilated space, normal operation may overheat the glass of the bulb and cause it to evolve gas. This is most likely to occur where a number of tubes are operated in parallel, thus causing a considerable energy dissipation in a small area.

When the filament of a power tube is operated from a direct current source through a regulating resistance, the plate current causes an inequality in the filament current. This action is represented in figure 11.

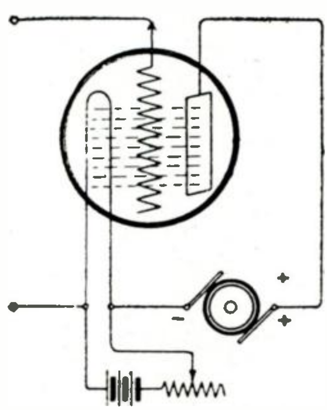


Fig. 11

The electron emission occurs along the length of the filament and therefore one end of the filament will carry more total current than the other end; this causes one end of the filament to be the hotter, which for the same amount of emission will shorten the life. The relative resistance values of the regulating rheostat and the filament, and also the location of the point of connection between the filament and plate circuits, determines the amount and direction of this effect. As shown in figure 11 the plate current causes the filament temperature to decrease at the positive filament terminal. This is the safest and best mode of connection.

If, however, the filament is operated from a few cells of storage battery, or directly from a low-voltage direct-current generator, so that the resistance in series with the filament is small, it is immaterial whether the return from the plate circuit is made to the positive or negative terminal of the filament; the heating current in the negative side of the filament is increased by the same amount. A considerable resistance in series with the filament is essential to any alteration in the distribution of the flow of plate current through the filament circuit as a safety precaution. As the plate current is usually in the neighborhood of 2 per cent. to 7 per cent. of the filament current, and as a 3 per cent. increase of filament current halves the life of a tungsten filament, the importance of this effect is evident.

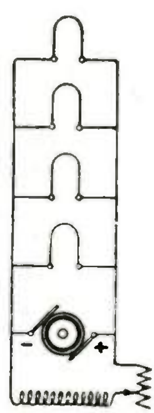


Fig. 12

If a low-voltage direct-current generator is used for filament lighting, it is usually connected in circuit as shown in figure 12, the filaments being directly connected to the armature leads, the adjustment of filament temperature being made by a rheostat in the field circuit of the generator. With such an arrangement difficulty may be experienced with the generator not building up if the filaments are left in circuit. This is owing to the fact that the cold resistance of a tungsten filament is very low, only one-thirteenth to one-sixteenth of its normal operating resistance. Therefore, if a small low-voltage direct-current generator is used at full load to supply tungsten filaments, the cold resistance of the filaments may be so low that it acts as practically a short circuit on the armature and prevents the generator from building up.

On power tubes it is preferable to use alternating current for filament excitation. The chief reason for using A.C. is that it obviates the unbalanced condition of a D.C. filament current, as described in a previous paragraph. It is also more practical to generate and distribute the low-voltage high-current energy for filament operation by means of A.C.

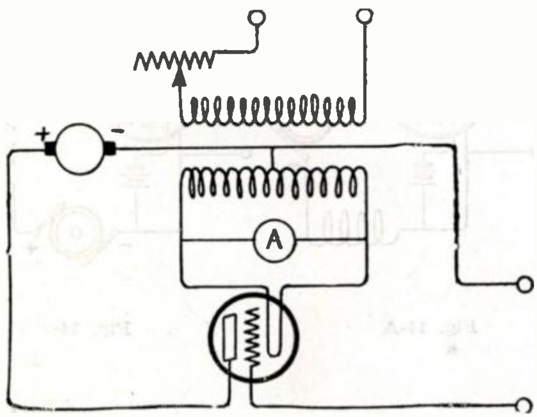


Fig. 13

In using A.C. for filament excitation the filament terminals should be connected directly to the transformer low-voltage terminals, the regulating resistance being placed on the power side. Also the return of the grid and plate circuit should be made to a center tap of the coil supplying the filament. This mode of connection assures minimum disturbance in the plate and grid circuits from the frequency of the filament source. Both of these points are shown in figure 13.

Some points in connection with the use of tubes as oscillators will next be taken up.

In the various diagrams of connections which are shown in this book, each one is simplified so as show more clearly the point under discussion. For this reason many diagrams for clearness or simplicity omit features which in another paragraph are shown to be advisable.

In all tube oscillator circuits there is an inductance in the plate circuit across which the high-frequency voltage is set up. Care should be taken that this inductance is not placed between the filament energy source and the plate energy source, as shown in figure 14-A. Both of

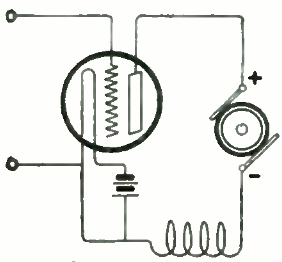


Fig. 14-A

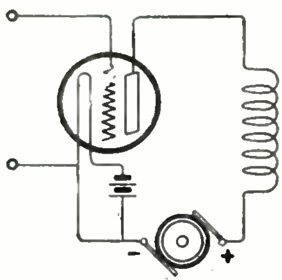


Fig. 14-B

these sources have, usually, a large capacity or a certain resistance to ground, so that a circulating current will flow through the coil and through each source to ground. For the type of circuit shown, the correct arrangement is shown in figure 14-B. The importance of having the circuit correct in this respect becomes greater the larger the power and the higher the voltage used.

In arranging an oscillating circuit to deliver high-frequency energy, it is important to reduce to a minimum the losses in the high-frequency circuits. Not only should the wires used be of low resistance and the condensers have low losses, but it is best to trace through the circuits carrying high-frequency currents, to be sure that the resistance is a minimum.

Three common errors in this respect are shown in figure 15-A, which represents a capacity coupled oscillator circuit. In this diagram the high-frequency current of the oscillating circuit must pass through a resistance path comprising the filament in parallel with its resistance, and battery source. Also it must pass through a fuse in the plate circuit and through the plate voltage source. In figure 15-B the same circuit is shown with these three errors corrected; the first, by changing the wiring so that the return of the grid and plate circuits is brought back to the same filament terminal; the second, by change of the fuse position, and the third, by shunting the plate circuit generator with a by-pass condenser.

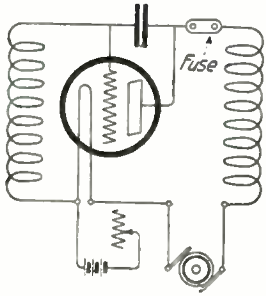


Fig. 15-A

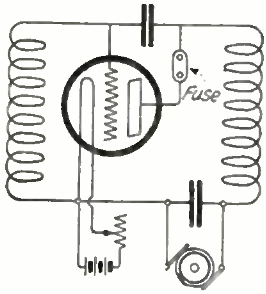


Fig. 15-B

For miscellaneous laboratory work the capacity-coupled type of circuit is a very convenient one to set up and operate, usually giving little trouble. However, if the circuit happens to be set up in a certain peculiar way, very puzzling results and failure to operate may sometimes occur, particularly if a tube of low impedance or resistance is used, or several tubes are connected in parallel.

This arrangement is shown in figure 16-A. If, as shown in this diagram, the leads from the coupling condenser C are connected to the plate and grid coil terminals rather than to the corresponding tube terminals, as shown in figure 16-B, very high-frequency oscillations may occur, a second capacity coupled circuit being formed, the capacity between the electrodes acting as the coupling condenser and the leads between the grid and plate coils and the corresponding tube terminals acting as the grid and plate inductances. This condition is accentuated by having these leads long and the leads to the coupling capacity short.

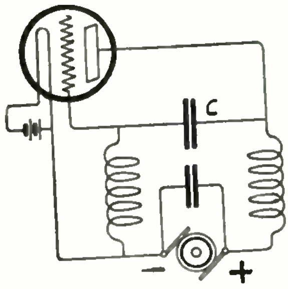


Fig. 16-A

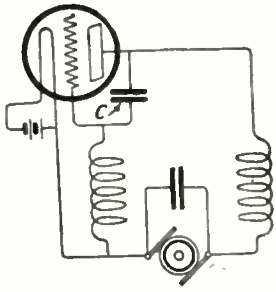


Fig. 16-B

This unexpected production of ultra high-frequency oscillations is often a very troublesome problem in high-power tube apparatus when a considerable number of tubes are operated in parallel. The low impedance or resistance of the tubes in parallel accentuates the effect. One expedient which often aids in overcoming this difficulty is the insertion of a very small inductance (a few microhenries) in one or more of the grid leads close to a tube grid terminal.

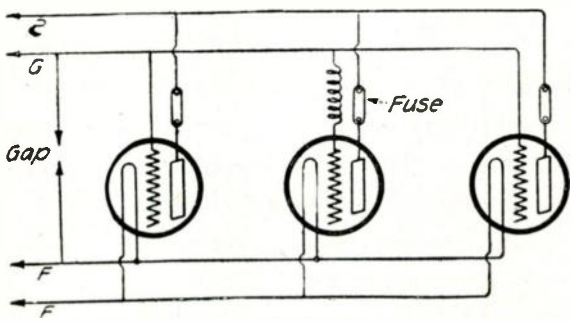


Fig. 17

This coil is shown in figure 17. This figure also shows fuses in the plate circuit of each individual tube, a very desirable feature on high-power, high-voltage tubes. This fuse should blow at two to four times the rated plate current of the tube.

This figure 17 also shows another desirable feature for high-voltage, power-tube circuits. In experimental work with oscillating circuits unusual conditions may occur which will cause transient voltages to be set up between the grid and the filament, which will reach peak values many times higher than that set up in normal operation. It is impractical to design and construct a tube and its base to stand up under this very abnormal voltage, which only occasionally occurs, due to incorrect adjustment.

A safety spark gap should therefore be provided between the grid and filament terminals at or near the tube socket or mounting. This gap should be adjusted to between one-thirty-second and one-quarter inch, depending upon the plate voltage employed and the number and type of tubes used. This precaution should be taken on any tube or group of tubes delivering over 50 watts of alternating current energy or operating at a plate potential above 2000 volts.

In one of the simplest and most frequently used forms of capacity-coupled circuit there is a precaution that should be observed.

This is illustrated in figure 18. It will be noted that the coupling capacity C has one of its terminals connected through the grid coil to the negative terminal of the high-voltage source. Very often this capacity C is a variable air or oil dielectric condenser, and its breakdown, due to high-frequency and high voltage, will therefore short-circuit the generator. The resultant arcing inside the condenser may also burn the plates badly.

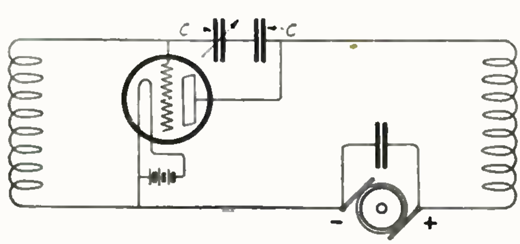


Fig. 18

This possibility may be prevented by the use of a second capacity C, which should be large in capacity in comparison with the first C. The condenser C, if it is at least one hundred times the value of the first C, need not be a low-loss condenser. It is necessary, of course, that the condenser C. safely stand the voltage of the D.C. source.

In a typical form of oscillating circuit, as shown in figure 19, the frequency of oscillations is principally determined by the value of the capacity C and inductance L.

As far as the natural frequency of oscillation is concerned, it will remain constant as long as the product of L and C is constant. However, it will be found that the type of circuit shown in figure 19 will

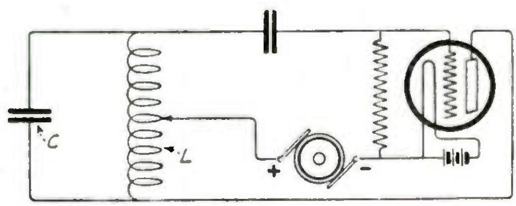


Fig. 19

only oscillate at a given frequency in a satisfactory manner when the capacity C is under a certain limiting value. This is explained by the fact that certain values of high-frequency voltage are necessary on the grid and plate. If the capacity C is very large, the tube will not supply sufficient energy to pass enough current through C to set up across it the necessary grid and plate high-frequency voltage. The lower the value of resistance and the lower the losses in the oscillating circuit, the larger the value of C that may be used and still maintain oscillations.

For the type of circuit shown in figure 19. the limiting value of C, for the usual types of small tubes running at reasonable values of plate voltage, is in the neighborhood of a maximum of .001 microfarad for a frequency of one million cycles (300 meter wave-length). This is necessarily a very approximate figure because of the many factors which are involved, but it at least gives the experimenter an idea of what not to use.

In the use of high-voltage direct-current generators operated singly or in series, it has been found that when they are employed for supplying energy for tube-plate circuits, a considerable strain is imposed on the insulation of the armatures. This is particularly accentuated when the tubes are used for radio telegraphy and telephony where the load fluctuates rapidly, or is switched off and on suddenly. For the usual types of circuits, one of which is shown in figure 20, the negative side of the generator is practically at ground potential.

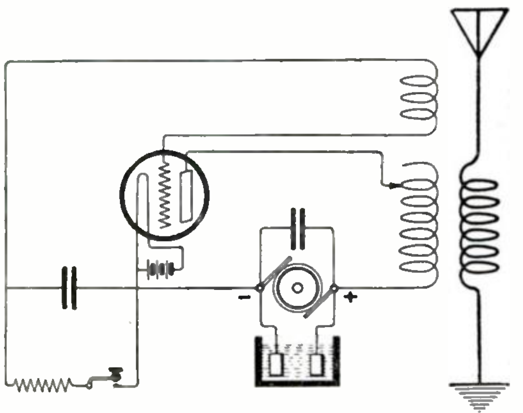


Fig. 20

The train which is imposed on the machines is in the form of a voltage surge which momentarily raises the generator voltage several fold. One terminal being grounded, the strain occurs on the insulation between the frame or armature core and an armature conductor which at the instant is near the positive terminal or brush.

In a radio-telephone transmitter correct wave-lengths and normal antenna current are not, as in telegraphy, indications that the set is functioning properly. Neither of these factors give any information as to the degree of modulation. The amount of modulation is most satisfactorily obtained by means of an oscillograph, but this is seldom available for use when and where desired.

A simple device to indicate modulation is a miniature tungsten filament lamp in the plate circuit of the modulator tube. This should be chosen of such a rating or so shunted that normally it burns at a dull red. When the microphone is spoken into, it should flash up and the degree of this brightening soon becomes a very good indication as to whether the modulation is normal or not. This arrangement is shown in figure 21.

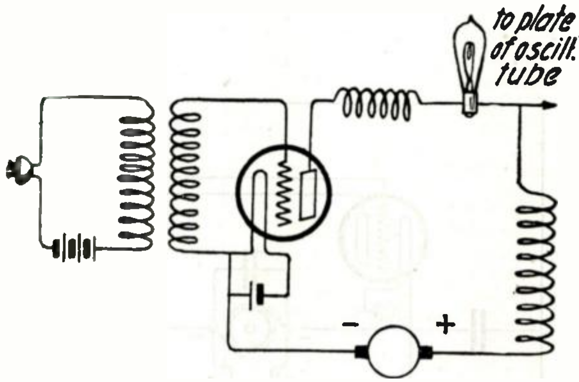


Fig. 21

There are so many things that may prevent a radio-telephone transmitter from properly functioning while showing full radiation current, that an indicator, as described above, is very useful.

CHAPTER VIII.

Methods of Obtaining Plate Potentials and Types of C. W. Transmitters

"B" Batteries

There are several means of obtaining a proper plate potential for a tube transmitter and the one decided upon should be the method most desirable for the type and intended service of the set. Ordinary "B" batteries can be used for furnishing the plate potential for one "hard" receiving tube, which can be operated as an oscillator, although the

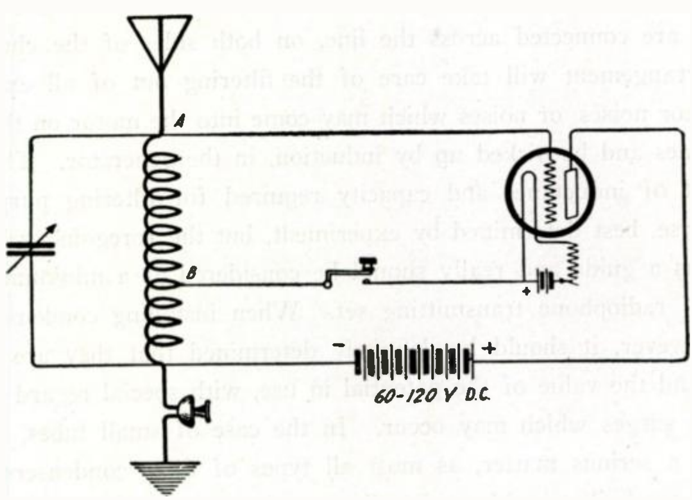


Fig. 22. Circuit diagram of a simple CW transmitter

amount of current used will cause a marked drop in voltage in a short time and completely exhaust the batteries after approximately 30 operating hours. Many amateurs, however, have made up sets of this type for use over short distances, for both voice communication and C.W. telegraphy. While a small transmitting set of this type will generate sufficient power in an antenna to work over distances of a mile or so, the use of "B" batteries is not desirable because of the necessity for constant renewal of the batteries.

Direct Current, or Kenotron Rectified A.C.

In the event that the main object is to carry on communication by voice, two methods of supplying plate potential, either one of which will be satisfactory, are available: namely, direct current, from a special high-potential generator, or rectified alternating current. The advantage of the direct current method is, of course, that it is constant in amplitude and direction and if the generator is of proper design, very little filtering will be necessary to take out the hum of the generator, or other noises, in order to provide noiseless carrier energy for speech or music. In the case of a well-built generator, it is usually desirable to use an iron-core inductance in each side of the circuit, of a value of approximately 1 henry. Several filter condensers, of a total of at least 5 microfarads are connected across the line, on both sides of the chokes and this arrangement will take care of the filtering out of all extraneous generator noises, or noises which may come into the motor on the power feed lines and be picked up by induction, in the generator. The actual amount of inductance and capacity required for filtering purposes is, of course, best determined by experiment, but the foregoing values will serve as a guide and really should be considered as a minimum in any type of radiophone transmitting set. When installing condensers in a set, however, it should be definitely determined that they are built to withstand the value of the potential in use, with special regard to high-voltage surges which may occur. In the case of small tubes, this will not be a serious matter, as most all types of filter condensers on the market are built to withstand ordinary voltages. In the case of 50-watt and 250-watt tubes, however, the matter is of great importance and due care should be used in the selection of condensers.

When used for telegraphic communication, the energy radiated by a C.W. transmitter employing direct current on the plates, heterodynes into a clear liquid note, the pitch of which is determined by the frequency of oscillation of the tube in the receiving set.

In the case of tube-rectified A.C., the proper voltage is obtained by means of a step-up transformer and the problem of filtering the current becomes a more difficult matter, in view of the constant change of direction of the current and the resultant hum. In the case of single-phase A.C., a rather elaborate filtering process is required, embracing several times the amount of capacity and inductance necessary in the case of direct current, before a good operating condition is reached, where the hum has been practically eliminated. The great advantage of the A.C. method over the D.C. is not only its greater efficiency, but the fact that it makes unnecessary any rotating unit, it is ready for use at the throw of a switch, while a motor-generator takes a little time to get going and uses a lot of power while doing it.

On frequencies below 60 cycles, however, the rectifying method is rather unsatisfactory for radiophone work. On the other hand, two, three, six and nine-phase 60-cycle current, where available, are to be preferred in the order named, over single-phase current, it being progressively easier to eliminate the hum with an increased number of phases.

A. C. Plate Supply

When it is desired to use a tube transmitting set only for telegraphic communication, the voltage for the plate supply of the tube to be used is obtained by means of a transformer. Three types of circuit, each one of which has its advantages, can be used when A.C. is applied to both the plate and filament of a tube, or tubes.

The use of kenotron rectifier tubes, in conjunction with a proper filter, on an A.C. supply of a frequency of 60 cycles, will give a result closely approximating the result obtained with direct current. When heterodyned at a receiving station, the signals of such a set will be found to be of good "liquid" quality, that is, most of the characteristic roughness of the 60-cycle current will have been smoothed out and the resultant heterodyned note will be fairly clear.

Another type of circuit, which gives a note approximately 80 per cent. liquid, or clear, with A.C. on both filaments and plates, is the self-rectification, also known as full-wave rectification circuit. This circuit is shown in detail on page 95.

The third type of circuit previously referred to, which employs A.C. on both filament and plate, is known as half-wave rectification. In this circuit one terminal of the high-voltage transformer secondary is connected to the filament and the other to the plate. The output obtained with this type of circuit is good, but the note is rough and hard to read through atmospheric disturbances. When heterodyned the note of a circuit of this type is extremely rough and a very small proportion of it is liquid in character. Many excellent transmitting records have been made with this type of circuit by amateurs, however, and it is extensively used by the amateur fraternity.

As a summary, the kenotron-rectified circuit is efficient, it can be used for both telegraph and telephone, and when used for telegraphic communication the note heterodynes at 80 per cent. of a liquid character. It involves the use of at least two extra tubes, but the output is approximately 40 per cent, more than can be obtained with a self-rectification circuit, the heterodyned note of which is of practically the same quality. For example, the output of a kenotron circuit under test, employing two 50-watt tubes as oscillators, was 4¼ amperes. Using the same secondary voltage on the two oscillator tubes in a self-rectification circuit the current dropped to 3 amperes. In addition, it was necessary to raise the filament voltage one volt above normal to obtain that result. The self-rectification circuit is not, therefore, a very efficient one, but the final result, the effect at the receiver of another station, is practically the same as that of the kenotron-rectified circuit,—which means that the expense and operation of two additional tubes is avoided.

If it is desired to increase the output of a transmitter employing two tubes in a full-wave rectification circuit, the addition of two tubes, one on each side will increase the output 40 per cent. That is, if the output of a transmitter is 3 amperes, the additional two tubes will increase it to 4.2 amperes. With the addition of still two more tubes, the increase will be 20 per cent. of the original amount, or a total of 4.8 amperes, based on an original output of 3 amperes for two tubes. Increasing the number of tubes will, of course, necessitate increased load capacity in the source of plate and filament current.

When a single tube is used, with D.C. or A.C. on the plate, the ratio of increase above specified will hold true in the case of the addition of single tubes in the circuit.

Method for Reducing Excess Plate Current

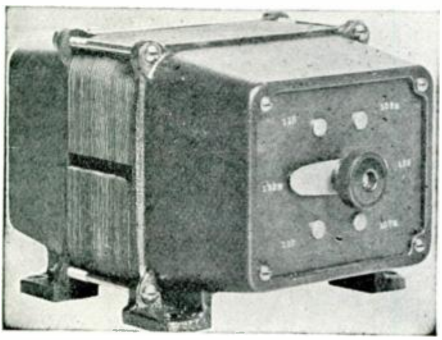
Excess plate current which no amount of adjustment of the circuits will remedy is frequently experienced by operators of assembled C.W. transmitters of all types. As a usual thing the trouble is more pronounced and more dangerous to tube life in sets of high power, as amateur sets go, especially when A.C. is used.

When D. C. is used on the plates for phone work, plate reactors, having an inductance of several henries and some sort of a filter system containing inductance and capacity is generally used in the high voltage lines from the generator and this, as a rule, prevents the leakage of high frequency currents through the generator windings to ground, through the power lines.

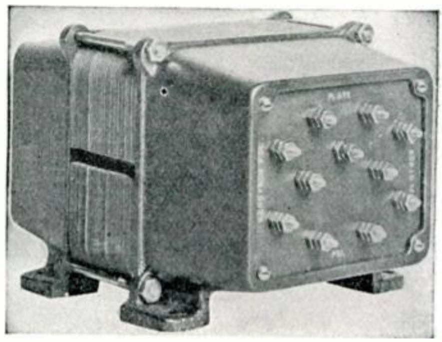
When A.C. is used on the plates in a one-half wave or full wave rectification circuit the system of filtering used in D.C. sets is not installed and as a result a comparatively easy path is offered for high frequency leakage to ground through the windings of the high voltage transformer. It is desirable, therefore, to insert radio frequency chokes in the high voltage leads of the transformer and if full wave rectification is used these chokes should be inserted in the leads from the ends of the transformer and also in the neutral lead to the center of the transformer. In the case of high voltages and the larger size tubes it may be necessary to take unusual precautions in order to prevent the high frequency currents from grounding through the transformer windings. Unmounted duo-lateral coils, L-500, make excellent high-frequency chokes for this purpose. One in each of the three leads where full wave rectification is used, may be sufficient in the case of voltages up to 1,000, but where higher voltages than this are used, especially on the plates of the UV-204 tubes, it may be necessary to use two or three of these coils in series in each of the leads.

In order to make these high frequency chokes permanently effective it is desirable to prepare them by means of a baking-out process in an oven for half an hour or so in order to be sure that no moisture is left in the insulation of the wire. After baking they should be immersed in liquid paraffin which has been heated almost to the boiling point. The heat can then be turned off and the paraffin allowed to cool; the chokes being cut out of the paraffin after it has solidified.

The coils can then be covered with insulating tape if desired, and this will insure a moisture-proof choke which can be depended upon to



Amateur radio plate and filament transformer. Front view showing the switchboard



R.C.A. UP-1016 Amateur radio plate and filament transformer. Rear view showing the terminal board

function under any weather conditions. Where trouble has been experienced from excess plate current prior to the use of these high-frequency chokes, it will generally be found that the trouble is immediately remedied upon their insertion in the circuit, and as a general thing, the plate current will fall below normal, while the same output of the set will be maintained. Rearrangement of the circuit may then be made until the output of the set and the plate current bear normal relation to each other. The plate, or space, current should never exceed the amount specified by the manufacturer for the particular type of tube in use. The best operation is that where a satisfactory output is secured with a minimum amount of space current. If the space current is kept below the normal, or specified amount, the life of the tube, or tubes, will be greatly reduced.

Precautions in Starting Operation

When applying power to a tube set of any type it is highly desirable, as a matter of safe operation, to apply in both the plate and filament circuits about one-quarter of the normal power to be used. If, when low power has been applied, there is no indication of trouble of any kind, half and then full power may be applied. In the event of any trouble becoming evident, all power should be instantly cut off and not put into the set again until the cause of it has been found and removed. Many sets have been completed destroyed because of failure of the operator to use proper precautions when first applying power to it, or in failing to cut off power the instant that trouble became evident, as trouble in one spot will usually result in outbreaks in other parts of the circuit if allowed to continue even for a few seconds.

Before power is first applied to a C.W. set it is advisable to insert a 100-milliammeter in the grid-leak line and adjust the grid current to approximately 10 per cent. of the proper amount of plate current for the tube of tubes in use. The plate current should then be adjusted to the minimum amount that will insure a satisfactory output. After the circuits have been properly adjusted, the milliammeter in the grid circuit should be short-circuited or removed.

In the case of the full-rectification circuit, where two tubes are used, one on each side of the cycle, the foregoing values given for grid and plate current should be followed, as they apply to both A.C. and D.C. types of circuits. The reason is that where tubes are used on each side of the cycle, each tube works only 50 per cent. of the time, or when the half-cycle of current on one side acts as a positive potential on the plate. Many operators of full-wave rectification sets have made the mistake of allowing excessive plate current to damage tubes in such cases, in the belief that the proper value of plate current should be that for two tubes. This, however, is wrong practice, for the reason specified.

Some Helpful Suggestions for Operators of Tube Sets

Following are a few helpful suggestions which may aid in determining the cause of trouble in tube transmitters:

Failure to Oscillate

Plate circuit open
Grid circuit open
Improperly adjusted circuits
Defective tubes
Filament voltage below normal
Open antenna or ground circuit
Grounded antenna
Leaky or partially grounded antenna
Antenna ammeter open

Failure to Modulate

Plate circuit of modulator or speech-amplifier tube open
Defective microphone or open microphone circuit
Improper value of grid biasing battery
Defective tubes
Shorted condenser between modulator and speech amplifier tubes.

An easy method for determining the amount of power in an antenna is by squaring the antenna current and then multiplying the product by the resistance of the antenna. For instance, if the antenna current were 3 amperes and the antenna resistance 10 ohms, the formula would be 3 x 3 = 9 x 10 = 90, or 90 watts of power in the antenna. When the antenna resistance is not known, comparative values of power may be obtained by multiplying the antenna current by itself. A few examples are as follows:

Amperes		Comparative Values of Power
2 x 2	=	4
3 x 3	=	9
4 x 4	=	16

It will be readily seen that 3 amperes represents more than double the power of 2 amperes, while 4 amperes represents four times the power of 2 amperes, as the antenna resistance would be the same in all cases. Bulletin No. 74, of the Bureau of Standards, contains an excellent and at the same time, easy, method for determining antenna resistance.

CHAPTER IX

Continuous Wave Transmission by Amateurs

For a long time before the war the operators of amateur radio stations had discussed the possibility and practicability of the use of continuous wave transmitters for amateur work. Many theories, data and a few facts were submitted from time to time to prove that continuous wave transmission on short wave lengths was both possible and impossible.

The advantages of continuous wave transmission, especially its economy and greater flexibility as compared to spark transmission, made its general use by amateurs highly desirable. The deterrent features were the impossibility of easily securing the means of generating undamped waves, and the important fact that continuous waves on short wave lengths were declared by many to be impractical, as it was believed that the slightest change in the characteristics of the transmitter, or the transmitting antenna system would cause audibility changes that would make successful reception impossible.

After the ban on amateur transmitting had been lifted, a small supply of transmitting tubes became available and amateur experimenting with C.W. transmitting outfits started in earnest.

Thousands of amateurs had used continuous wave transmitters on short wave lengths during the war in various branches of the service. consequently had become more or less familiar with the general methods and results. As their actual experience with these sets had been more or less confined to attaching wires to binding posts on the outside of cabinets, they found considerable difficulty in securing and assembling the various parts and elements necessary. But it takes brains, energy and perseverance to be a successful amateur, and what might have proved a tough proposition to any other class or set of human beings didn't stop the determination of Young and Old America to possess a reliable, practical C.W. transmitting set. And so the work went on, causing more than one enthusiast to lose more hours of sleep than would possibly be sacrificed by the average person, that is, provided said average person desired to continue to live. As one amateur aptly expressed it, paraphrasing a well-known song—"The hours I spent with thee, dear set."

But perseverance will generally win out sometime or other and the result of the untold hours of study and work on the part of the amateurs finally resulted in a finished product. A professional systematizer would undoubtedly suffer mental torture and anguish could he see the numberless types and specimens of C.W. outfits in use by amateurs today, for it would be practically impossible to find two that look as though they were even distantly related, but the important fact is, they work.

Starting with the basic parts, a source of plate potential, a tube, or tubes, a home-made coil or two and what other miscellaneous junk could be begged, borrowed or otherwise secured, these ambitious amateurs have always managed to get some amount of undamped energy into an antenna.

Some of the circuits which have been tried and tried and tried were really wonderful creations. Some were plain and simple. In fact some were so simple as to be foolish. Others were complicated beyond description. The writer can readily recall his early attempts to secure reliable information on C.W. sets. To the best of his knowledge and belief, the crop totalled something like seventy-five different circuits, all of which were thrown into the waste basket with disgust after many weary hours of wasted trial and effort. One of the successful circuits tried, that worked very well on low-power sets, is shown in the following diagram:

With a set using the circuit shown in Fig. 23, with two 5-watt tubes, plate voltage of 400, it has been found possible to put 1.5 amperes into an antenna, in connection with a counterpoise ground. The antenna resistance was in the neighborhood of 7 ohms, which is, of course, rather low for an amateur station antenna, and which accounts for the large amount of antenna current as compared with the general result where an carthed ground is used.

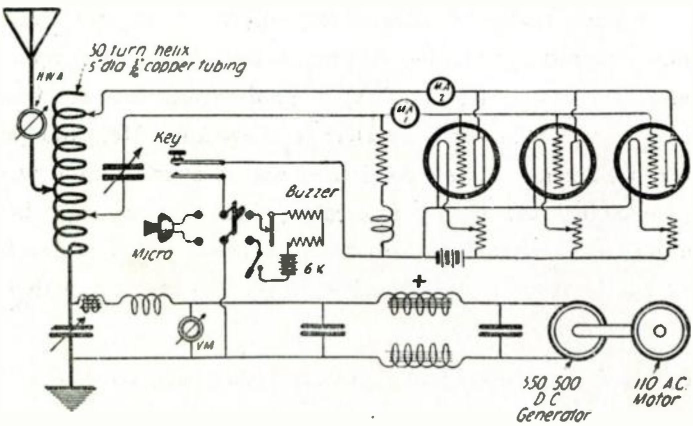


Fig. 23. Circuit diagram showing method of modulating the output

An unusual feature of the circuit is the method of modulating the output. It will be seen that the buzzer and telephone transmitter are inserted directly in the negative high potential lead to the filament, below the point where it branches to grid leak and filament. This method causes only the slightest deflection of the space milliammeter and, judging by this alone, as is generally done, it would be perfectly logical to assume that the output was insufficiently modulated to be of much use. Actual experience, however, has shown that this method of modulation has great carrying power, and further does not cause the slightest voice distortion. The speaker's voice can readily be recognized as far as it can be heard.

A distinct improvement made in this circuit was in the adoption of a tone wheel, driven by a six-volt battery motor, which was inserted in place of the buzzer. Buzzers, even the best of them, sometimes sing badly off key, but the voice of the tone wheel is always steady and even. Further, it has no contacts to stick and cause trouble. When using straight C.W. or the telephone transmitter, it is only necessary to stop the wheel with the brush making contact on the metal of the wheel. It has been found desirable to have the proportion of make and break 50 per cent. each. This can be followed, regardless of the size of the disc used. The note can be regulated by the speed of the wheel.

It may be of interest to know that a C.W. transmitter of the type previously described, located about thirty miles out on Long Island, has successfully covered remarkable distances, considering the input, which was about 75 watts. Straight C.W. signals from this set have been reported from Canada, north of Detroit, Lewiston, Me., and points in Missouri and Florida. A test conducted with a spark station at Columbus, O., developed the highly interesting fact that the signals of the C.W. outfit were reported at Columbus as being steadier and stronger than the signals from a well-tuned 1 K.W. transmitter located at the same eastern station.

Interrupted continuous wave (I.C.W.) has been tried, the methods of interrupting having been of various kinds. In the early stages the signal was interrupted by the buzzer, as shown in figure 23. Then a change in the method of modulation was made and a tone wheel of brass, 4 inches diameter, with bakelite insulating studs set in its face was mounted on the shaft of a 1750 R.P.M. synchronous motor.

This arrangement gave a musical note to the interruptions that could be varied at will by using a variable speed 6-volt battery motor, instead of the induction motor.

When the owner of the set grew ambitious and increased the size and power of the set, the amount of current flowing in the filament grid-leak line made too much of a fuss to be handled without trouble, and another method of modulation, shown in figure 24, was tried. This consisted of placing the secondary of a modulation transformer in the grid-leak line, and making it serve the double purpose of grid-leak and modulation transformer. The secondary resistance of one type of commercial modulation transformer now on the market is about 1,000 ohms.

Other resistance was added in series with the secondary according to the amount desired.

This method of modulation permits the handling of low potential by the key and buzzer or tone wheel, and is a great advantage over the

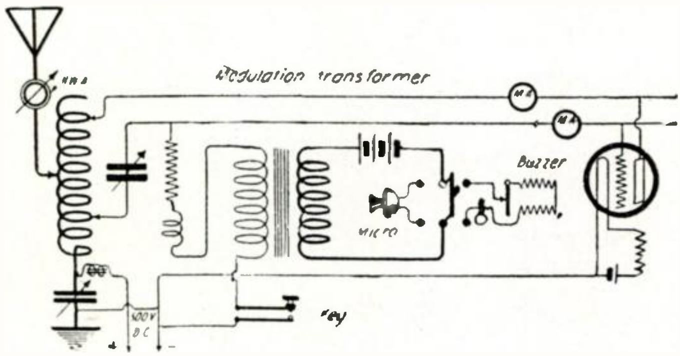


Fig. 24. Circuit diagram having the secondary of a modulation transformer in the grid leak

negative type of modulation for this reason, and it is also slightly more efficient.

Another type of modulation used is the well-known Heising system, wherein the grid circuit of a modulator tube is acted upon by the impulses of a transmitter, buzzer or tone wheel through a modulation transformer,

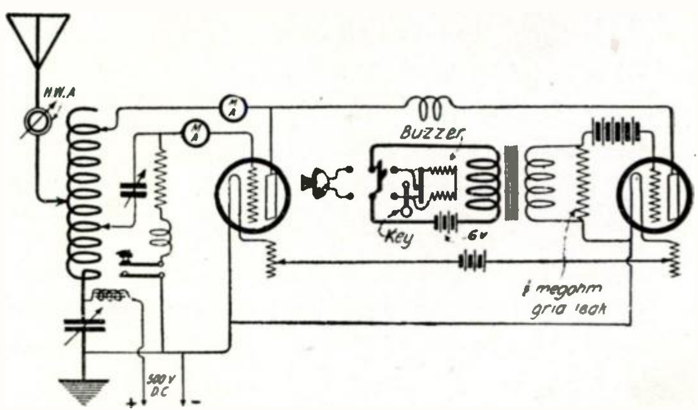


Fig. 25. Diagram showing the Heising system of modulation

as shown in figure 25. This is undoubtedly the most efficient method of modulation, although it is necessary to use at least one modulator tube for each oscillator tube.

In all the experiments so far carried on the ranges of the three methods of transmission have been comparatively as follows:

C. W.	100 per cent.
I. C. W.	65 per cent.
Voice	40 per cent.

There have been occasional times when the voice has been reported over unusual distances, but the proportions shown above as a general thing are substantially correct. In almost every case it seems that the carrier energy, or straight C.W., was very strong, even when the voice could be scarcely heard, indicating that only a small percentage of the output of the set was being modulated. This phase of C.W. transmission is one which can be profitably studied by amateurs, for there is a great deal to be desired in the modulation of most of the amateur radiophone sets now in operation.

Thousand-Mile Amateur Radiophone

The remarkable distance records made by amateur radio stations using continuous wave transmitters with several 5-watt tubes in multiple, are matters of common knowledge. The fact that a set, employing two or three of these small tubes, with approximately an ampere or more of current in the antenna, has been heard and worked by stations 1,000 or 2,000 miles away, causes no special interest at the present time.

Experiments at 2ZL station, Valley Stream, Long Island, covering several weeks, during 1920, with transmitting sets employing 5-watt tubes, clearly demonstrated that the signals from such sets are subject to practically the same conditions as damped transmitters, where the distance between the transmitting and the receiving station is more than the regular daylight range of the transmitting station, especially where the C.W. output is modulated in some manner. The foregoing, however, applies only to general conditions.

On nights when the stations of the Eighth District, particularly those in Ohio, were inaudible on Long Island, 2ZL, using straight or modulated C.W., was also inaudible at several Eighth District stations, listening on a pre-arranged schedule. When the signals from Eighth District stations were audible on Long Island, the signals of 2ZL were copied in Ohio. During these tests one point of considerable importance developed. On nights when spark stations in the Eighth District "swung" so badly as to make consecutive reading of their signals impossible with two steps of audio-frequency amplification, the straight C.W. signals from 2ZL were reported as being good and steady, and consecutive reading was entirely possible. Summarized, this established the fact that, while the signals from 2ZL were subject to general conditions over long night distances when they were heard at all they were much more steady and reliable than spark signals. It should be remembered also, that the input of the tube transmitter at 2ZL was about 160 watts, plate and filament, as compared to 1,000 watts input—without counting the energy used to run the usual non-synchronous rotary spark gap—in the case of the Eighth District spark stations.

After the experiments with the transmitter employing the 5-watt tubes had been carried on for several weeks at 2ZL, and the reports of the listening stations carefully studied, it became evident that the signals of such a small set were entirely satisfactory over distances up to 100 miles. Later on it was decided to increase the power of the set. It was not practical, of course, to use more than three or four 5-watt tubes, because the small added output of more tubes does not warrant the additional expense of the tubes or the extra filament and plate power.

As the only obtainable tubes of increased size over 5 watts are of 50-watt output capacity, it was decided to install a transmitter employing tubes of that size, in accordance with figure 26. Right here is where the writer got into the same predicament as the man who caught a wildcat by the tail—he sure started a fine bunch of trouble for himself. It seemed logical to suppose that to install the 50-watt tubes it would only be necessary to insert the new tubes and sockets, supply proper filament and plate voltage and shoot the moon. But it was somewhat different before a smooth working 100-watt set was finally developed.

The characteristics of the larger tubes were such that their output was 50 watts on 1,000 volts plate pontential. Of course, it was decided, amateur fashion, to get every single possible watt out of the tubes, so a motor-generator—110 volts 60 cycle A.C., 1,000 volts D.C., and also a 12-volt 80-100 ampere hour storage battery to heat the 10-volt 6½ ampere filaments, were procured and installed. When all was ready the outfit was started and the key pressed. In about 1-1000 of a second two variable condensers, a couple of choke coils, two or three meters and some other odds and ends went to heaven, or wherever such things go when they go up in smoke. The motor-generator was a sturdy cuss or it probably would have gone too.

In the course of time, new parts, meters, etc., were installed and the set was started up again. This time trouble broke out in a different place. The tuning, or coupling coil, which had been made up of Litzendraht wire, according to expert advice, got so hot that it ceased doing business and burned up. A new coil was wound with heavy, solid insulated wire, and it also got hot. In order to avoid losses it was decided to wind a coupling coil with 3/16 inch copper tubing. This proved to be a good step and no more heating was detected in the set after long stretches of transmission with as much as 5 or 6 amperes in the antenna.

It was found that a storage battery would not answer for filament heating purposes on tubes of this size and an A.C. transformer was decided upon. This was a new one on the manufacturers of amateur radio apparatus at that time and one had to be made up specially. The final result was a transformer with secondary voltages of 8 and 10, and a total secondary capacity of 150 watts—more than sufficient to properly heat the filaments of two 50-watt tubes. A tap was provided in the center of the secondary winding to minimize the effect of the A.C. hum on the filaments. This transformer was used successfully for a time; then it also went up in smoke, which occurrence was presumed to be due to poor insulation. A second one went the same way in short order. It was then decided that it was probably full of high-frequency currents, induced directly or indirectly by the set, so a system of protective condensers was installed. Two were used on the primary side of the transformer and the middle point grounded. Two were also used across the secondary side, with the middle points connected to the neutral tap, and the core and framework were directly grounded. After that no further trouble was experienced with the transformer.

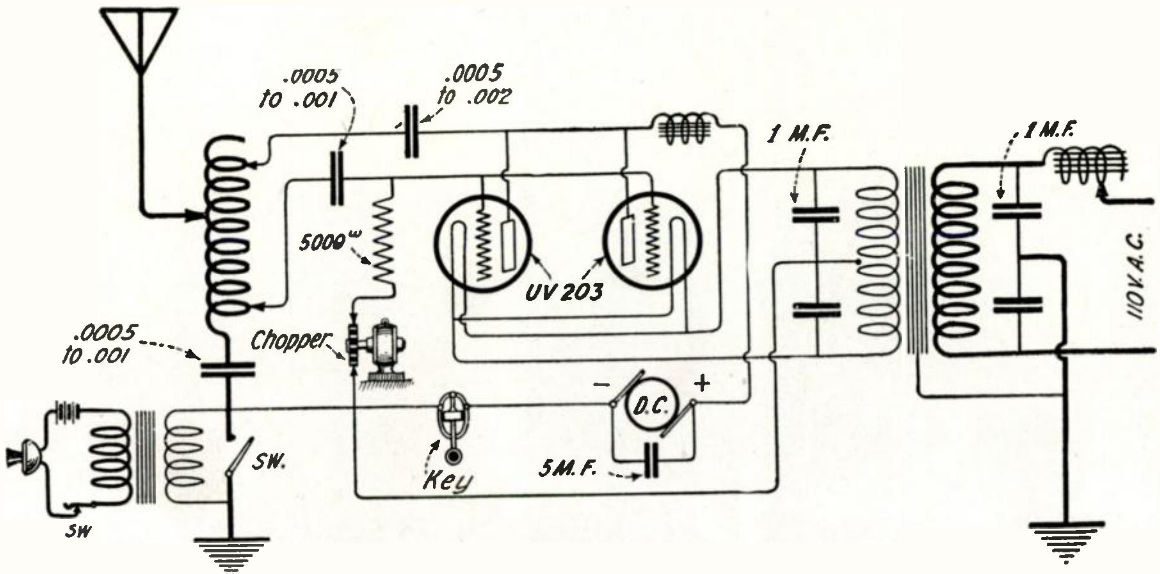
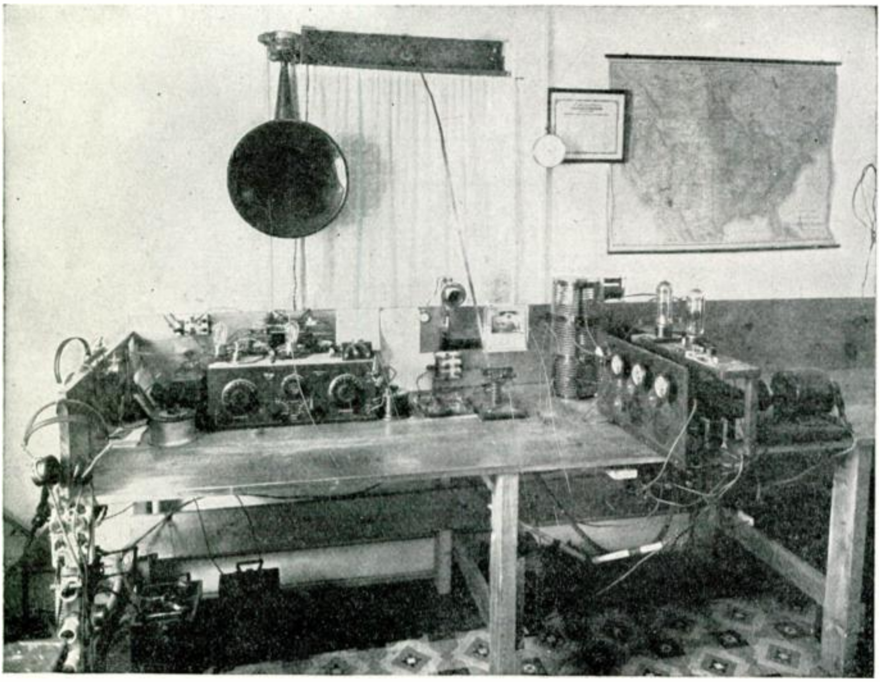


Fig. 26. A C.W. transmitter with magnetic modulator and motor driven chopper. With this arrangement 100 watts are available for C.W., I.C.W. or voice transmission



A 100-watt C.W. transmitter as shown in Fig. 26, and receiving equipment, at 2ZL station

In the case of the set just described the oscillator grid leak was 5,000 ohms, the negative grid battery potential 60 volts, and the proper polarity of the 6-volt battery on the primary of the modulation transformer was determined, of course, by experiment. It was found desirable to reverse the polarity of the 6-volt battery as between the telephone transmitter and the buzzer, in order to obtain the best modulation.

It was sometimes found difficult to "raise" a distant station when modulating the output by buzzer, because of sharpness of tuning at the receiving station, local interference, etc. It was therefore decided to utilize the two tubes of the set as oscillators, and insert a tone wheel or chopper, in the common grid-leak line. A disc of brass four inches in diameter, one-quarter inch thick, was turned off and twenty holes, one-quarter inch in diameter were drilled around the outside edge through the flat surface of the disc and bakelite studs inserted. The face was then turned down and the disc mounted on a 1700 R.M.P. induction motor. Two brushes were brought to bear on this disc, one on the flat surface and one in a position to run over the bakelite studs as the motor revolved. It is readily seen, of course, that this chopping arrangement is perfect modulation, in that it breaks up the C.W. output into groups between which no current is flowing in the antenna, because oscillation of the set stops as the brush runs over the studs and is renewed as it comes in contact with the metal of the wheel. With the two tubes used as oscillators and chopped in this way the apparent antenna current, as shown by the meter, was three amperes, the same as with one oscillator and one modulator. As a matter of fact, however, the full amplitude of the antenna current was considerably in excess of that figure, probably double.

The signals of 2ZL were reported from stations at the following points while using the set just described and 2ZL worked with a number of them:

	Miles—Air Line from 2ZL		*Miles—Air Line from* 2ZL
Palm Beach, Fla.	900	New Orleans, La.	1,079
Stanbridge East, Quebec	350	St. Paul, Minn.	1,025
Little Rock, Ark.	1,025	Kansas City, Mo.	1,080
Chicago, Ill.	725	Louisburg, Nova Scotia	550
Detroit, Mich.	500	Montreal, Quebec	350
St. Louis, Mo.	850	Marion, Mass.	220
Houston, Tex.	1,286	Memphis, Tenn.	925
Port Arthur, Tex.	1,265	Grand Forks, N. D.	1,300
Ellendale, N. D.	1,330	Minneapolis, Minn.	1,025

Using one tube as an oscillator and one as modulator the voice has been reported from Marion, Mass.; Boston, Mass.; Memphis, Tenn.; Anderson, Ind.; Niles, O.; Washington, D. C.; Rochester, N. Y.; Pittsburgh, Pa.; Cambridge Springs, Pa.; and Montreal, Quebec, and many other points, and two-way communication has repeatedly been carried through successfully; 2ZL by voice and the other stations replying by spark.

The work done when using straight or unmodulated C.W., established new records and distances for amateur C.W. transmission, at that time, in that daily schedules were maintained with the following points: Savannah, Ga. (4XB); Salem, Ohio (8ZG); Canton, Ohio (8ZV); Langley Field, Va. (XF-1). Occasional communication was established with Madison, Wis. (9XM), and Minneapolis, Minn. (9XI).

On one or two occasions when communication had been established with Western stations, it developed that no Eastern amateur spark stations had been heard at Western stations, and no Western ones at 2ZL. The straight C.W., however, was going through without any trouble. Slight fading was noticeable, but of a longer period and more gradual character than in the case of spark signals.

Insofar as the dependable daylight range of the set was concerned, distances varied with the method of transmission or modulation. Using straight C.W., 2ZL was copied repeatedly during daylight over varying distances up to 200 miles, the greatest distance having been Boston, Mass. Conclusive tests to determine the maximum C.W. daylight range were not made, but it is believed that with three amperes of straight C.W. in the antenna it should be possible to communicate with stations 300 miles distant during fairly favorable daylight conditions.

With the output of the set at 2ZL modulated by buzzer, daylight communication has been successfully carried on with stations 150 miles distant, although the reception, of course, called for careful tuning and generally much preliminary transmitting for adjustment of the receiving sets. With voice modulation, during daylight, conversation with stations seventy-five miles away has also been successfully carried on. When the two tubes were used in multiple, with the tone wheel chopping the grid-leak current, the received signals were several times the audibility of buzzer or voice modulation.

As a summary, the dependable daylight ranges of a set with approximately three amperes in the antenna, can be reasonably assumed to be as follows:

Straight C.W.	200 miles
Buzzer modulated	75 miles
Voice	75 miles
Tone wheel chopper	100 miles

When these ranges and the flexibility of the set are considered, and also the fact that the total input of the set, plate and filament, under all conditions of transmission never exceeded 350 watts, the very great advantage of C.W. transmission over the usual spark method is readily apparent.

As a side light on the voice transmission tests made at 2ZL, at that time a letter was received from an amateur in a little town with a population of 160, located thirty miles South of Memphis, Tenn., saying that he frequently heard the phone at 2ZL station. He stated that he used a small aerial and only a single tube as a detector. He said that he and his people liked to listen to the phone and requested that the voice be used often, that music be played occasionally as he and his people enjoyed listening to it.

Wonderful and mysterious are the ways of C.W. transmission when an amateur in Tennessee, 925 miles distant, regards a radiophone concert for his benefit by another amateur station in the vicinity of New York as an ordinary matter.

With the set previously described all then known amateur C.W. transmission records were broken by 2ZL and 5XB stations on February 11th and 12th, 1921. The latter is the station of the Agricultural and Mechanical College of Texas, located at College Station, Texas. The transmitter used there consists of three 5-watt tubes, the total input plate and filament being approximately 175 watts. The overland air line distance between the two points is 1,500 miles. The two stations were in communication occasionally during the winter of 1920-21 and messages were exchanged successfully in both directions.

A variation of the circuit shown in figure 26 to include a magnetic speech amplifier and omission of the speech amplifier tube, as shown in figure 27 also gave excellent results.

Another set with which interesting amateur work was done at 2ZL station was one employing A.C. on both plates and filaments of two 50-watt tubes in a self-rectifying circuit, most of the work being done on wave lengths below 200 meters. This 100-watt continuous wave transmitter, employing alternating current on both plates and filaments, was used at 2ZL station for several months early in 1921 for amateur message relay work and proved to be a very satisfactory transmitter for relay work. The circuit used was the same shown in figure 27 except that two UV203 and slightly different constants were used.

The plate current of the set was 150 milliamperes per tube at 1,500 volts on each side of the split secondary transformer; the filament current, sixty-five watts per tube, a total of 355 watts for both tubes (plate current figured intermittently, filaments continuously). The antenna current on 325 meters was three amperes.

In working the regular traffic schedules it was found possible to work Boston, Salem and Canton, Ohio, without trouble. Mr. S. B. Young, Dorchester, Mass. (1AE), reported that the signals of 2ZL were steady and the audibility sufficient at all times for regular relay work. The signals of the A.C. set were found to be more easily controlled than the signals of the D.C. set previously used at 2ZL and there was less trouble in picking them up than in the case of D.C. signals.

It might be well to mention here that a regular schedule was maintained between 2ZL and 1AE stations for a period of three months while the 100-watt A.C. set was in use at 2ZL. Even when difficulty was experienced in the reception of the signals from 1AE at 2ZL station, the signals from the latter station were read without trouble at 1AE. While the distance between the two points is about 200 miles, the territory, has always been known as being difficult for amateur short wave spark transmission. Swinging and fading of signals between the two points are usually very pronounced. It will be noted, however, that it was specifically reported that the signals of 2ZL station were generally steady at Boston and that no difficulty was experienced in their reception.

In addition to Boston, regular schedules were maintained between 2ZL station and stations 8ZG at Salem, Ohio, and 8ZV at Canton, Ohio, over a period of several months. Mr. Manning, at 8ZG, reported that the signals from the A.C. set were always of good audibility, and entirely sufficient for regular relay work, and that the signals were preferable to those from the D.C. set previously used at 2ZL because of their steadiness and greater ease in locating and handling in reception. He further stated that the signals of the A.C. set were being copied regularly at Salem without having a detector tube oscillate or in other words without heterodyning. Practically the same report was received from Mr. Ley, 8ZV, at Canton, Ohio. The circuit employed in the case of the 100-watt A.C. transmitter at 2ZL station was selected after long experiment as being one which is entirely practical and which can be depended upon to work under practically any conditions.

The filaments are lighted by means of a split winding on the transformer. In line with the more recent practice in tube transmission, constant voltage was maintained on the filaments of the tubes rather than constant current. An A.C. voltmeter was connected to the terminals of the tubes and the voltage kept constant at the proper rating for the tubes employed by means of a regulating rheostat in the primary of the filament transformer.

The value of the grid leak resistance used in shunt to the grid condenser was approximately 2,500 ohms. The grid condenser was a small mica-condenser of .0005 microfarad. Mica-dielectric condensers of .002 microfarad capacity were used in the plate circuit. Condensers of higher or lower capacity can be used in this part of the circuit, providing the dielectric is of sufficient strength to withstand the potential employed in the plate circuit. The tuning inductance used was one of twenty turns approximately five inches in diameter. In connection with the system at 2ZL this arrangement gave the set a transmitting wave length of 325 meters. A short wave condenser was used for reducing the wave to approximately 200 meters.

Some experiments were made at 2ZL to determine the practicability of employing wave lengths below 200 meters in connection with tube work. A separate antenna, considerably smaller than the main antenna regularly used, was used for this short wave work. This smaller antenna was about 60 feet long overall and consisted of four wires. Considerable work was done on 175 meters. The antenna current on this wave length being two amperes, it was found entirely possible to work 100 miles in daylight on this wave length without trouble with that amount of current in the antenna. The antenna current on 150 meters was in the neighborhood of 1½ amperes. As practically no amateur stations were equipped with receiving apparatus which would accommodate a wave length of 150 meters, however, it was found impossible to make any experiments on this wave length to determine the daylight range of the set. When the transmitter was adjusted to a wave length of 175 meters it was found, in at least three instances, that the receiving operators had to adjust their secondary circuit variometers at zero in order to hear the signals. When the wave was further reduced it was found impossible to "raise" any of the listening stations. After communication had been carried on for some time on 175 meters considerable comment was made by other amateur stations on the desirability of working on that wave length because of the absence of interference and very little trouble was experienced from atmospheric disturbances on nights when static was giving considerable trouble on wave lengths above 200 meters. A great deal has been heard from various points to the effect that it is difficult or impossible to secure sufficient antenna current on a wave length of 200 meters to enable the transmitting station to work any respectable distances. It would seem that this condition is due entirely to the fact that many amateurs attempt to adjust C.W. outfits to a 200-meter wave on an antenna with a fundamental wave length of 200 meters, which arrangement, of course, precludes sufficient coupling in the tuning arrangement to allow free oscillation of the set. It is, however, entirely possible to work on 175 meters with tube transmitters, without trouble, providing the antenna system is of the proper size for that wave length. The idea that tubes will not operate and generate power on 200 meters is an absolute fallacy which has evidently arisen through lack of knowledge, or because of misinformation. Tubes will oscillate on short wave lengths just as well as on long wave lengths, providing an antenna of the proper characteristics is used.

The Amateur Trans-Atlantic Transmissions of December, 1921

The story of the amateur trans-Atlantic tests of December, 1921, is so well known, that it seems unnecessary to tell more than a condensed story of the unprecedented accomplishment in these pages. At the first national convention of the American Radio Relay League, held at Chicago, during the summer of 1921, it was decided to send Paul F. Godley to

Europe, with proper receiving equipment, to determine if the signals of American amateur stations could be heard across the ocean, an approximate distance of 3,000 miles. Preliminary trials were held during November and all amateurs were invited to participate, with the understanding that 1,000 miles must be covered to make any station eligible to enter the trans-Atlantic trials on an individual basis. Twenty-seven stations qualified and to each one a group of code letters was assigned, as well as a definite period of transmission. Free-for-all periods for each district were also set apart each night and all stations were invited to participate.

The result was not at all what had been expected. Many of the stations which had qualified in the 1,000-mile preliminaries were not heard on the other side at all, while several stations which failed to qualify or which had not participated in the preliminaries were heard, either by Mr. Godley or by English and Dutch amateurs. One station, 2AJW, heard by Godley, employed 5-watt tubes, the input being approximately thirty watts. Several other stations which were not heard at all by Mr. Godley were copied by English amateurs and the code-words verified, precluding any error in reception.

A complete list of stations heard by Mr. Godley at Adrossan, Scotland, is as follows:

Spark:

1AAW, not yet located;
1ARY, Burlington, Vt.
1BDT, Atlantic, Mass.
2BK and 2DN, Yonkers, N. Y.
2EL, Freeport, L. I.
3FB, Atlantic City, N. J.
8BU, Cleveland, Ohio;
9ZJ, Indianapolis, Ind.
3BP, Newmarket, Ontario.

Continuous Wave:

1ARY, Burlington, Vt.
1BCG, Greenwich, Conn.
1BDT, Atlantic, Mass.
1BGF, Hartford, Conn.
1BKA, Glenbrook, Conn.
1RU, Hartford, Conn.
1RZ, Ridgefield, Conn.
1XM, Cambridge, Mass.
1YK, Worcester, Mass.
2ARY, Brooklyn, N. Y.
2AJW, Babylon, L. I.
2BML, Riverhead, L. I.
2EH, Riverhead, L. I.
2FD, New York City
2FP, Brooklyn, N. Y.
3DH, Princeton, N. J.
2ACF, Washington, Pa.
8XV, Pittsburgh, Pa.

with the probability that 4GL, Savannah, Ga., was also heard.

During the tests the following American stations were heard by English amateurs:

1BCG, Greenwich, Conn.
1AFV, Salem, Mass.
1UN, Manchester, Mass.
1XM, Cambridge, Mass.
1ZE, Marion, Mass.
2FP, Brooklyn, N. Y.
2BML, Riverhead, Long Island.
2ZL, Valley Stream, Long Island.

All the stations heard by the English amateurs used C.W. transmitters during the tests. Practically every type of circuit was employed, as 1BCG used D.C. on the plates, 1ZE Kenotron-rectified, 60-cycle A.C., 2FP 500-cycle A.C., 2BML half-wave rectification of 60 cycle A.C., and 2ZL full-wave rectification, 60-cycle A.C.

In commenting on the result of the tests, Mr. Godley made the following statement:

"In glancing over the above lists one is struck by the preponderance of the C.W. stations, and by the fact that the British heard C.W. stations only. That can mean only one thing, that C.W. is far superior, and I should like nothing better than to see all amateurs change over to continuous wave at once. Spark methods are horribly out of date and are so inefficient, comparatively, as to be ridiculous, were it not that many have invested good money in spark equipment. Station 1AFV, since the tests, has gotten three messages across to England (London) on 200 watts of C.W. Many stations of the Atlantic seaboard are reaching to the California coast with similar powers, while the west coast stations have been shoving signals into the Hawaiian Islands. The day is not far distant when amateurs the world over will be exchanging greetings in many languages, and by the same token, the day is almost here when spark stations will be of interest as having to do with history only."

The set used at 2ZL station at Valley Stream, L. I., when signals from the station were heard in England, employed two 250-watt Radiotrons, UV-204, in a full-wave rectification circuit, as shown in the accompanying diagram, Figure 27.

A transformer, with a split secondary, supplied A.C. for plate potential, at 2,200 volts for each tube, 4,400 over all. The filaments of the tubes were heated with A.C., by means of a transformer, also with split secondary. The value of the grid leak resistance used in shunt to the grid condenser was 20,000 ohms, and the capacity of the grid condenser .002.

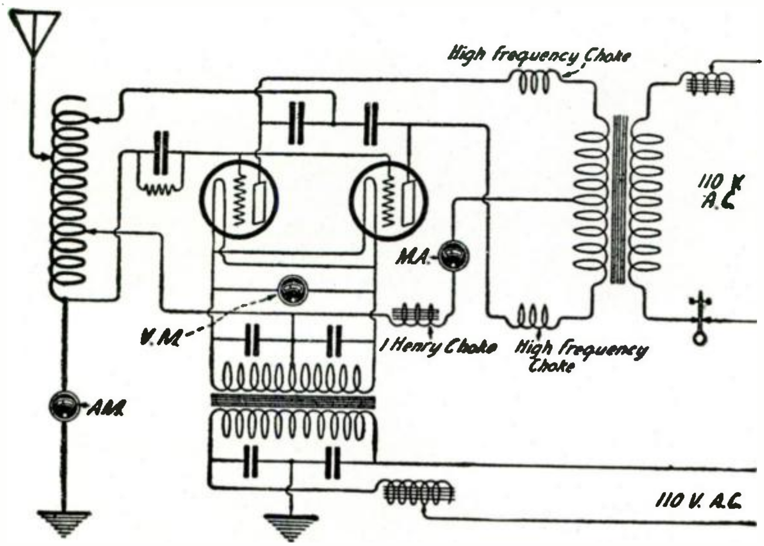


Fig. 27. Circuit diagram of the 500-watt full-wave rectification set of 2ZL Station, which transmitted signals to England

The antenna at 2ZL is an inverted L, 85 feet high at the end away from the station and 65 feet high at the station end. The flat top is 120 feet long. The leads, four in number, are from the low end. The fundamental wave length of the antenna is 210 meters. The antenna points southwest-northeast, with the leads on the southwest end. The fact that the station was heard in England and at Monterey, Calif., at practically the same time, seems to indicate that there are no directional effects. A counterpoise ground system is used, consisting of eight wires on spreaders, directly under the antenna, and fanned out at both ends beyond the antenna. The antenna current is 10 amperes on 325 meters, 7 amperes on 250 meters and 5 amperes on 200 meters.

Antenna system of 2ZL Station

THREE WELL-KNOWN AMATEUR STATIONS

The three amateur stations, 1ZE, 8ZG and 9ZG (formerly 9AKR), all equipped with 100-watt Kenotron outfits, have become so well known on the air that a detailed description of them and their accomplishments will undoubtedly be of interest.

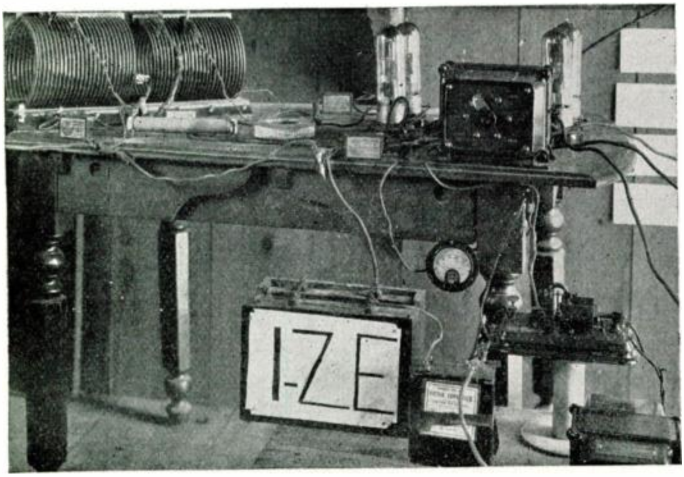
The transmitting sets used at these three stations are identical. A 750-watt transformer, with 110-volt, 60-cycle primary, has three windings, one providing high voltage, approximately 1,200 volts for the plates of the Kenotron tubes, another supplies 10 volts for heating the filaments of the Kenotrons and the third provides 10 volts for the filaments of the oscillator tubes. All windings have central taps. Two Kenotrons, UV-217 and two oscillators, UV-203, are used in each of the sets.

The station of Irving Vermilya, at Marion, Mass., 1ZE, is shown in the illustrations. The station is operated by remote control. The antenna of the station is of vertical fan type, of 20 wires, suspended from two poles approximately 90 feet high. A counterpoise ground, also of 20 wires, suspended under the antenna, is used.

The vertical harp type of antenna installed at 1ZE

The C.W. signals of 1ZE station have been reported from Cristobal, Canal Zone on the Pacific side of the Isthmus, and this station was one of those heard, and the code letters verified, by amateur stations in England during the recent trans-Atlantic amateur tests.

In addition to these extreme and exceptional night distances, the station has carried on regular communication with the Eighth and Ninth districts. The daylight range of the station, with straight C.W., is approximately 150 miles. A magnetic modulator is used for voice communication and distances up to 75 miles are regularly covered during daylight by voice. A separate receiving antenna, consisting of a long, single insulated wire laid on the ground, enables duplex operation with other stations. The normal antenna current of the station is 5.2 amperes on 375 meters.



The 100-Watt Kenotron installation at 1ZE

8ZG, Salem, Ohio

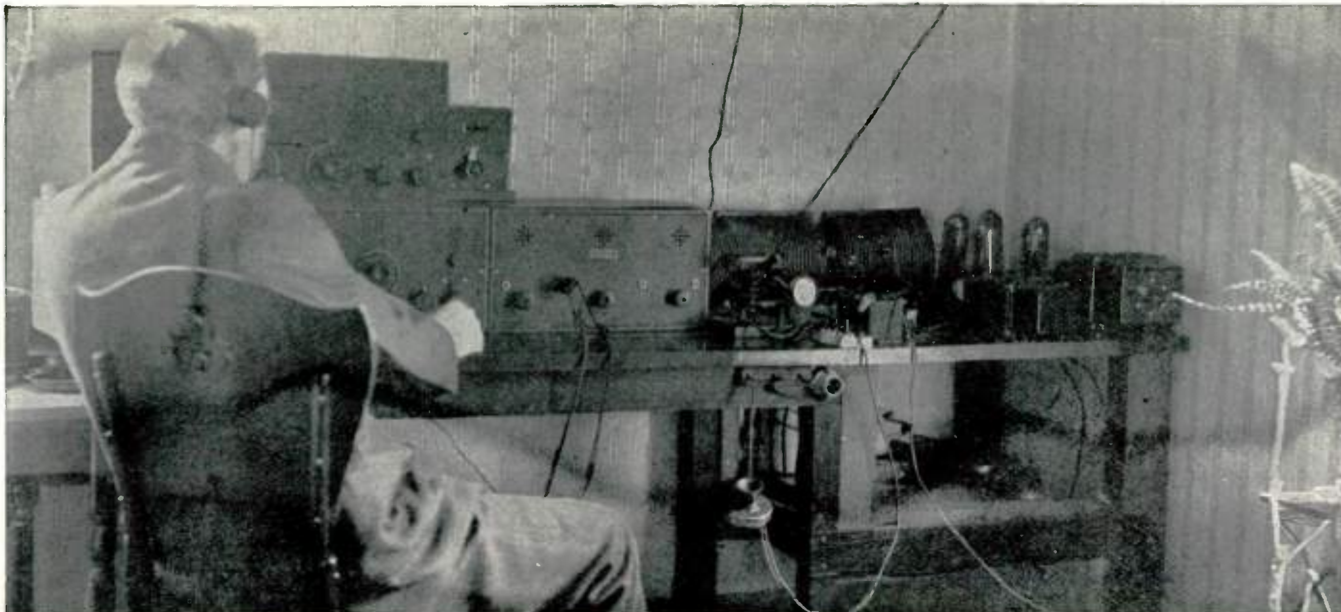
The station of A. J. Manning, Salem, Ohio, 8ZG, has made many exceptional transmitting records during the winter months. The set was installed on October 19, 1921, and on the same night signals from 8ZG were heard in the First, Second and Ninth Districts, and a complete message which was transmitted from 8ZG to 2EL, Freeport, L. I., was copied at Havana, Cuba.

On the night of November 12, 8ZG and 5ZA, at Roswell, New Mexico, were in communication for an hour, exchanging traffic,—an overland distance of 1,400 miles. On January 6 the signals of 8ZG were reported as of good audibility by 6ALP, at Long Beach, Calif., an approximate distance of 2,100 miles.

A magnetic modulator is used at 8ZG and a daylight range of 100

Vertical harp antenna and counterpoise of 8ZG station

miles is regularly covered by voice. The dependable daylight range of the set for telegraphing, using straight C.W., is 200 miles, and the regular night range 400 miles. The antenna current of the station is normally 4 to 5 amperes, on 375 meters.



Rev. A. J. Manning, Salem, Ohio, operating 8ZG station, which is equipped with a 100-watt Kenotron set

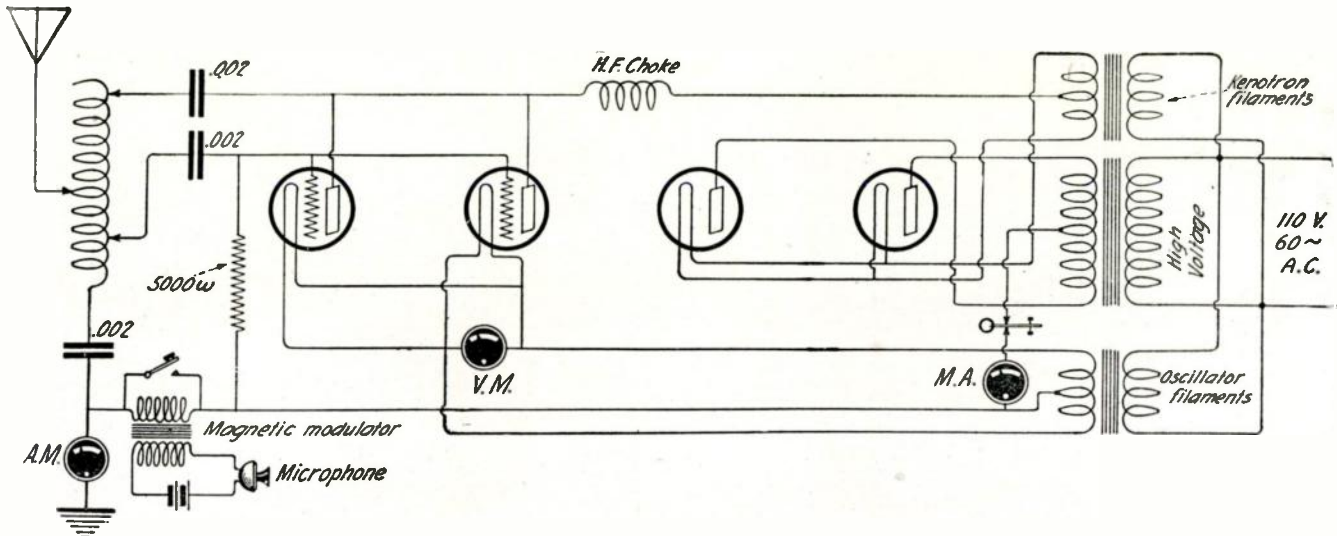
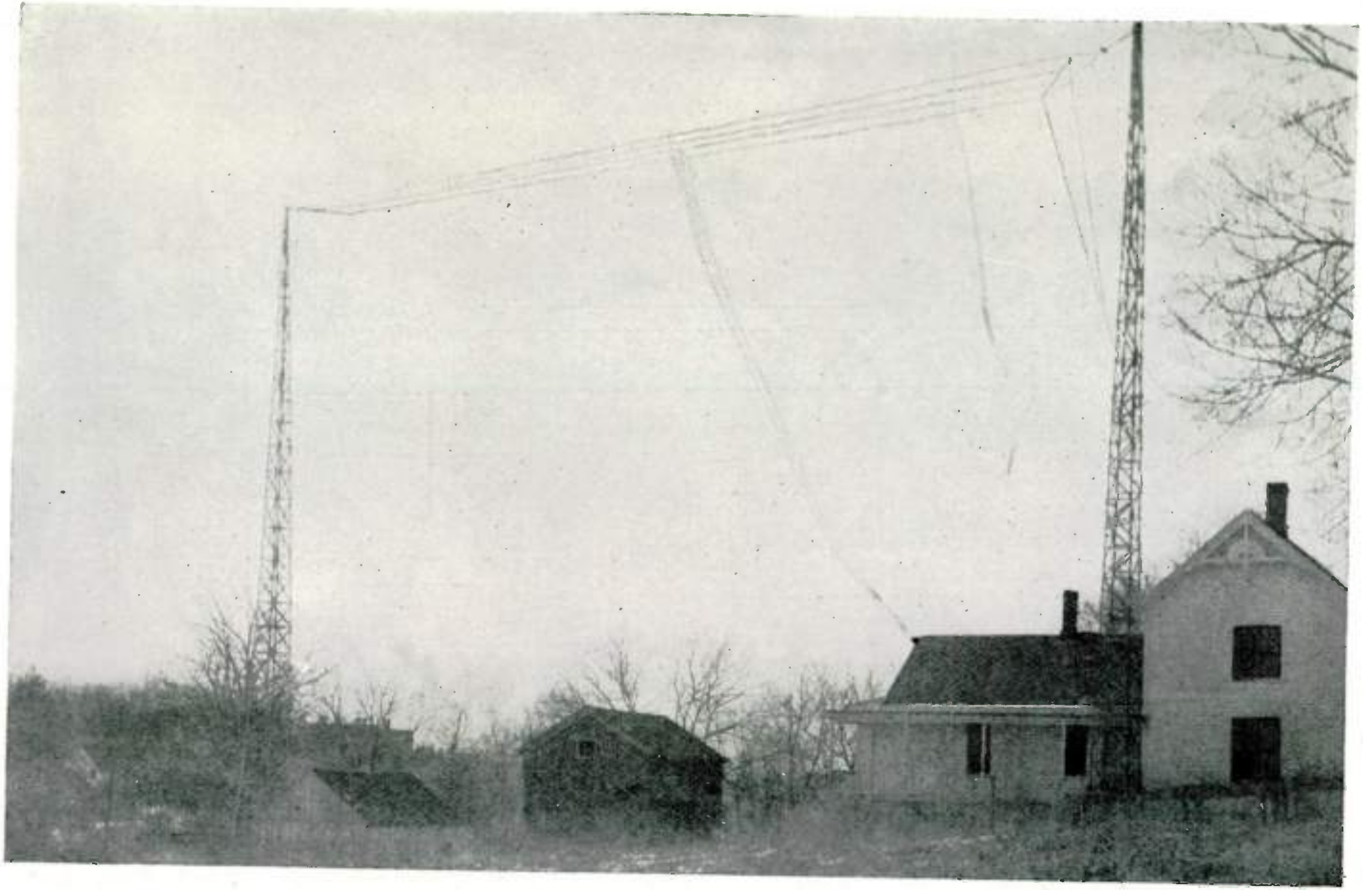


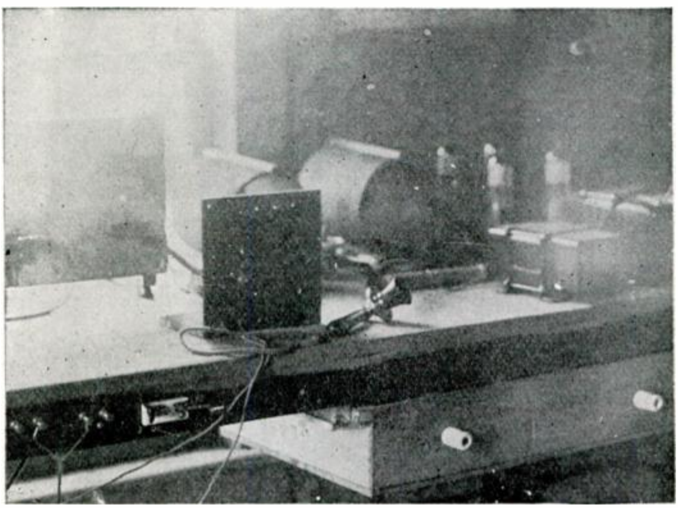
Fig. 28. Circuit diagram of the 100-watt Kenotron rectification transmitters used at 1ZE, 8ZG and 9ZG stations



The antenna system installed at 9ZG, Mt. Carroll, Ill., is of the T flat type at an elevation of 100 feet

9ZG, Mt. Carroll, Ill.

The third station of the group, that of A. C. Mertz, Mount Carroll, Ill. 9ZG (formerly 9AKR), in the northwestern corner of the State, has been heard several times on both coasts. As in the case of 8ZG, this station was reported from exceptional distances the first night it was operated, and communication was established with 8AWP, Syracuse, N. Y.; 5ZA, Roswell, New Mexico, and 9AMB, Denver, Colo., through



100-Watt Kenotron Transmitter of 9ZG Station, Mt. Carroll, Ill.

considerable static. During January the signals of 9ZG were reported from several points on the Pacific Coast and also by stations in Massachusetts and Rhode Island. The dependable daylight range of 9ZG is 200 miles, using C.W. for telegraph communication, and voice communication, using a magnetic modulator, is regularly carried on over 100 miles. The normal antenna current of the station is 4.2 amperes, on 375 meters.

1600-Mile Amateur Radiophone of Station 5ZA, Roswell, N. Mex.

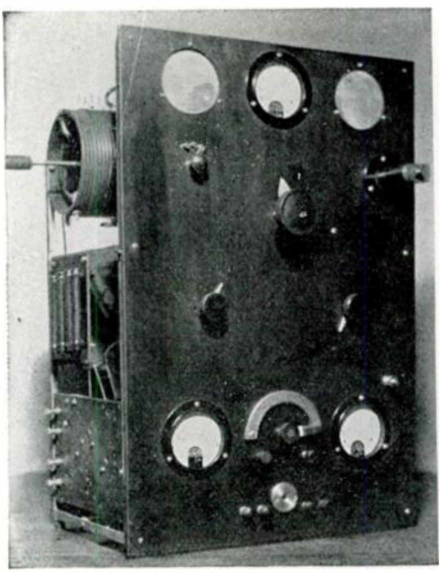
The 100-watt C.W. transmitter used by Louis Falconi, Roswell, New Mexico, Station 5ZA, has made some remarkable records for amateur transmission, having been reported from points in every state in the country, Canada, Mexico, Honolulu, and by ships on both the Atlantic and Pacific oceans.

This transmitter was built for four 50-watt tubes and one 5-watt speech amplifier. For C.W. all power tubes are connected as oscillators for phone, two as modulators and two as oscillators, with a 5-watt speech amplifier. The circuit has a common plate-antenna coil and a separate grid coil, which coil is variable in coupling to the plate antenna coil, and is adjustable in inductance. By making the grid coil adjustable in coupling and inductance, variable condensers can be eliminated and the set that much simplified. The Heising method of modulation is used. The set is designed so that almost any wave from 200 to 400 meters can be instantly used and the results seem to be equally efficient on all waves. The only disadvantage experienced with a C.W. transmitter is the trouble in raising the station desired, unless that station happens to be right on the wave being used. With the set at 5ZA, however, which can be instantly tuned to any wave, it is only necessary to estimate the wave the station wanted is listening on, change the set to that wave and call. After the station has answered, the wave length can be changed to the usual working wave.

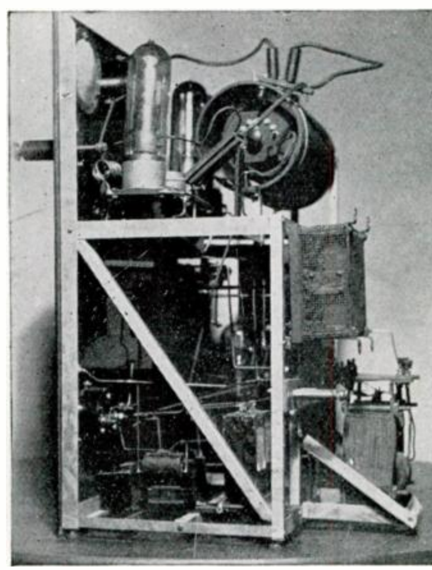
To date only two 50-watt tubes have been used. With both power tubes as oscillators, the antenna current is 4¼ amperes on 200 meters and 5 amperes on 375 meters, using 1,000 volts D.C. on the plates, the space current being 225 milliamperes. When using the phone, with one power tube as a modulator and one as an oscillator, the antenna current is 3½ amperes without speech and 4 amperes when the microphone is spoken into. The plate current is 150 milliamperes without speech and goes to 250 milliamperes with speech. All reports indicate that the modulation is fairly complete and the speech clear.

The set is mounted as a unit on an aluminum frame, with a front panel of bakelite, 18 x 24 inches. Everything is mounted on the framework except the motor-generators, key and microphone. The unit is rigid and easily moved about.

Referring to the back view of the set, the inductance is plainly seen at the top. The large coil is on a tube 5½ inches in diameter. It is threaded five turns to the inch and 40 turns of No. 8 hard drawn bare



Front view of the transmitter



Rear view of the transmitter

copper wire are wound on the tube. For connections, lengths of the same wire ½ inch long are soldered to every other turn. Two such rows of contacts are soldered on, one for the antenna connection and one for the plate connection. Plugs are made out of brass rod, bored to fit the short lengths of wire contacts and handles of bakelite or hard rubber fitted so that the adjustments can be made while power is on. The grid coil is on a four-inch tube and has fifty turns of No. 14 silk-covered copper wire tapped every ten turns and the taps brought to a switch fitted to the end of the tube. The switch shaft is made very long so as to project from the side of the set, thus allowing the same handle

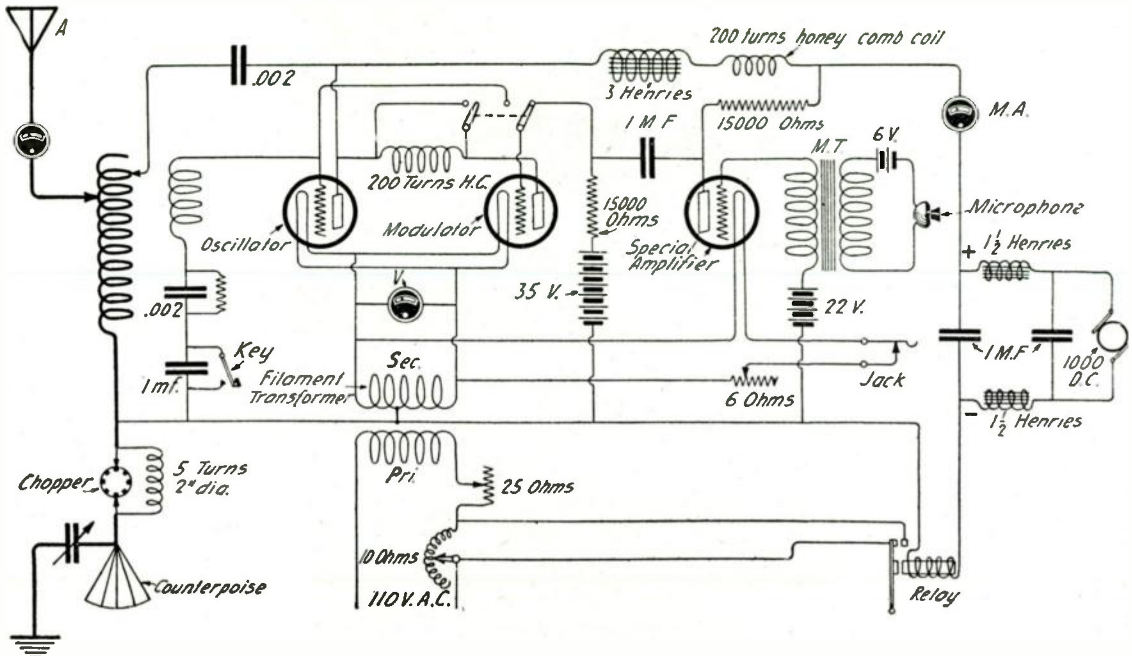


Fig. 29. Circuit diagram of the C.W. transmitter at 5ZA Station, Roswell, New Mex. Direct current is used on the plates

to adjust the coupling and also the inductance of the grid coil, making it unnecessary to reach inside the set to adjust the grid coil inductance. The grid coil slides on two brass rods attached to the big coil. The rheostat under the inductance is in the primary of the filament transformer. The filament transformer, which is under the rheostat, is homemade, with sufficient capacity to light four 50-watt tubes and also the amplifier tube. The socket assembly is also homemade and has places for four power tubes on a single bakelite base, with inter-grid chokes and protective gaps built in. Details as to the rest of the apparatus can be obtained from the diagram.

When first placed in operation, trouble was experienced with flickering of the filament voltage due to the voltage drop on the power line when the generators took power. Unfortunately the power line was not of sufficient capacity for the work and thus caused the flicker. That made the note very bad, giving it a squealing effect. The hook-up shows how this trouble was cured. A relay was connected in the negative lead of the 1,000-volt D.C. line and arranged so that every time the relay closes, a small resistance in the primary of the filament transformer is cut out, thus allowing the filament voltage to rise every time the key is closed and juice flows from the high voltage generator. By making the resistance variable, any drop can be taken care of in that manner, a heavy drop requiring a greater resistance, of course, than a slight drop. By proper adjustment, however, an absolutely steady filament voltage can be obtained.

Another arrangement used, which is unique, but very satisfactory, is the method of connecting the chopper. It is placed in the ground lead and a small inductance shunted around the chopper. The chopper then alters the wave by a few meters so many times per revolution and any note can be obtained. This method of chopper modulation has proven quite effective and has good carrying qualities.

The power for the set is furnished by two generator sets, each giving 500 volts and 400 milliamperes. Allowing 100 milliamperes per tube, it is seen that the power unit is just large enough to feed four 50-watt tubes for C.W.

Although using only two 50-watt tubes to date, the results have been remarkable, both with speech and C.W. The speech amplifier, however, has just recently been installed and the results reported on the voice operations were made during a few short periods of operation. The following stations have been worked by voice and no trouble experienced, the stations reporting signals as of good audibility and modulation O. K.

	Miles
9BHE, Glen Ellyn, Ill.	1,000
6AWP, Santa Anna, Calif.	700
6ZG, Los Angeles, Calif.	750
9ZJ, Indianapolis, Ind.	1,050
9WU, Ellendale, N. D.	875
9AAS, Owensboro, Ky.	975
9AIG, Sioux Falls, S. D.	800
9TI, Milbank, S. D.	900
9PI, Eureka, S. D.	900
9AVZ, Pierre, S. D.	850
9AEQ, Shenandoah, Iowa	700
9AAS, Owensboro, Ky.	975
9SL, Milton, Iowa	750
9AAY, Chicago, Ill.	1,050
9ZG, Mt. Carroll, Ill.	1,000

In the case of the above stations two-way communication was carried on and in most cases 5ZA was the station called.

Using straight C.W. two-way communication has been carried on with the following stations: 2ZL, XF1, NMW, 8VY, 8XF, 4FT, 8ZG, 8ZZ, 8XV, 8XH, and others closer. The foregoing are all over 1,000 miles distant from 5ZA. The voice has been reported as follows—a few maximum distances only being given:

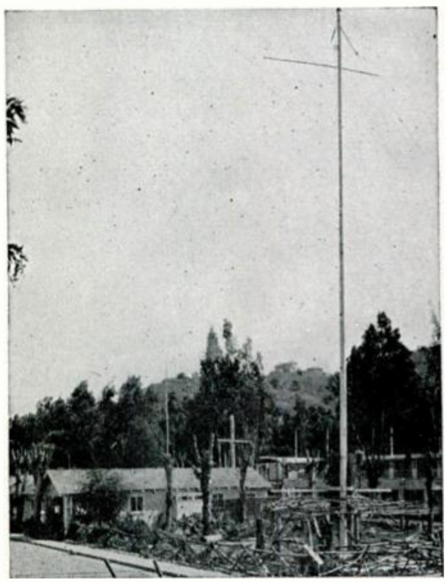
	Miles
Stenen, Saskatchewan, Canada	1,400
8YR, Miami University, Oxford, Ohio	1,150
8BYN, Detroit, Mich.	1,275

The voice of 5ZA has been heard in 25 States, Canada and Mexico. The C.W. has been heard in all States, Canada, Mexico, Hawaii and on both oceans.

Station 5ZA and the experimental station of the Navy Department, at Washington, D. C., NOF, have also carried on a two-way communication by voice. The reception at 5ZA was perfect and the same seemed to be the case at NOF, as no difficulty was experienced in understanding the speech from 5ZA. The distance between the two points is approximately 1,600 miles and the two-way voice communication established a record for amateur power and wave lengths such as were used by both stations.

AMATEUR STATION 6XAD, AVALON, CATALINA ISLAND, CALIF.

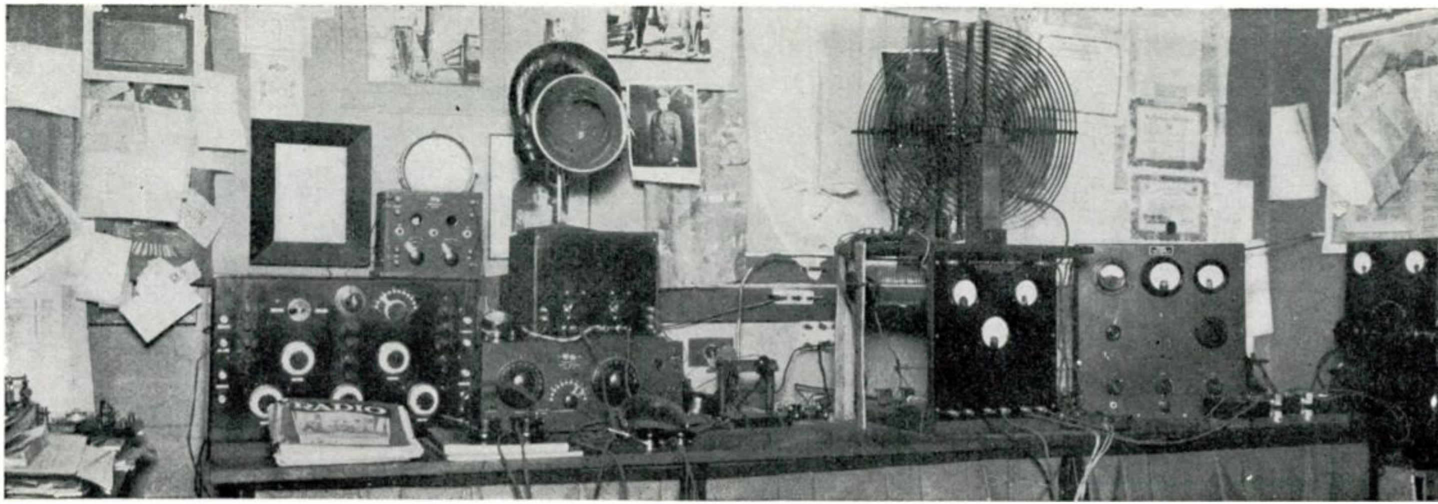
Probably the most remarkable distance work ever done by any amateur station of equal power using four 5-watt tubes is the station 6XAD, Avalon, Catalina Island, Calif., owned and operated by Lawrence Mott, Major, Signal Division O. R. C., U. S. Army, and President of the Continuous Wave Association of America.



The antenna system of 6XAD

The consistent long-distance work done by Mr. Mott has attracted the attention of the regular army and quite recently the Chief Signal Officer of the Army, Major General George O. Squier, had several of the Signal Corps engineers make a comprehensive study of the station, including its equipment, geographical surroundings and accomplishments, in order to determine, if possible, the reason for the unparalleled results obtained.

The antenna itself, of flat top design, is supported on two masts, one sixty feet and one ninety-four feet high. There are seven wires in the



Transmitting and receiving apparatus of Station 6XAD, Avalon, Calif.

antenna, standard Navy wire of seven strands, supported on an eight-foot spreader at the low end and on a sixteen-foot spreader at the high end, thus giving double spacing at the free end. Two-inch copper ribbons run along the spreaders, and each antenna wire is soldered to these strips, thus minimizing losses as much as possible.

The counterpoise ground of the station is of the same material and size as the antenna itself, and is stretched tightly nine feet above and parallel to the ground. The counterpoise is, of course, well insulated.

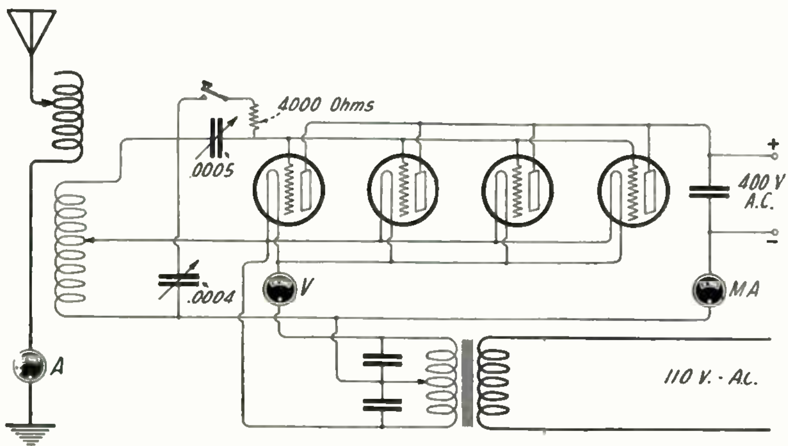
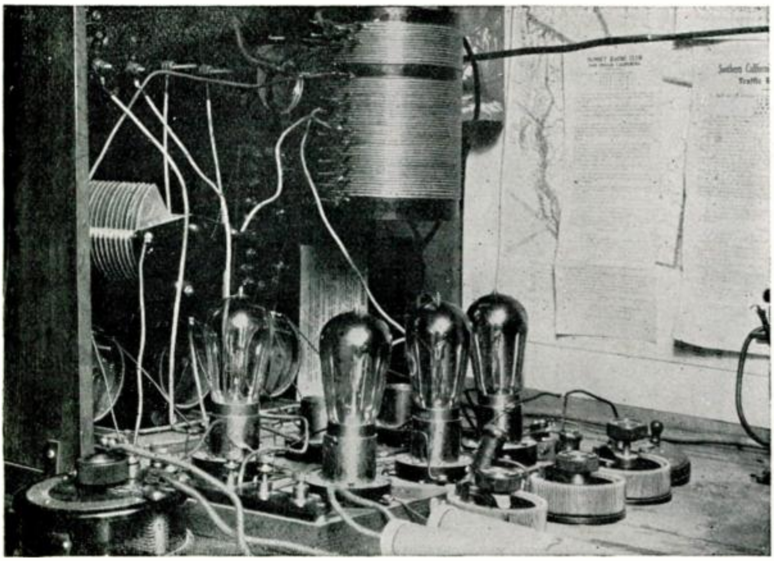


Fig. 30. Circuit diagram of the 20-watt half-wave rectification tube transmitter at 6XAD Station, Avalon, Calif.

In addition to the counterpoise, an earthed ground is used, consisting of 240 metal plates, each three by four feet, buried three feet underground. These plates are connected together by one-inch copper ribbons, leading in turn to a twelve by twelve-foot copper sheet buried five feet in the ground, directly under the operating table. In addition to these copper sheets, there are copper ribbons radiating out thirty degrees from the antenna. In order to insure a good earth ground connection the year round, metal stand-pipes have been put in and into these salt water is pumped every few days, thus insuring a moist condition of the ground over the whole area of the station. These metal standpipes are three inches in diameter and lead down to the buried metal sheeting at regular distances.

The station is equipped with the following transmitting and receiving apparatus.

The transmitter employing four 5-watt tubes, Radiotrons UV-202, is used principally for I.C.W. on 220 meters. The average antenna current is 2.6 amperes. It is with this set that practically all the unusual distance work of the station has been done.



Four 5-watt tube transmitter at 6XAD with which the exceptional distance work was done

Another transmitter employs two 50-watt tubes for C.W. on 370 meters. The average antenna current is 4 amperes.

Another transmitter employs two 50-watt tubes for I.C.W., on 240 meters. Considerable experimental work has been done with this station in connection with some forthcoming tests which are to be made with Australia.

Receiving equipment: Grebe CR-5, which has been used in all the unusual long-distance work of the station; a specially designed two-step Western Electric amplifier; a Kennedy long-wave receiver used in conjunction with a Grebe two-step audio-freuency amplifier.

A specially designed motor-generator set, capable of delivering up to 1,500 volts D.C. with 110-volt 60-cycle drive, is used to supply plate potentials for the various transmitting sets.

The stations which have been worked by 6XAD are as follows:

3ALN, Washington, D. C.
3AQR, Hershey, Pa.
5HK, Oklahoma City, Okla.
5ZA, Roswell, N. M.
6AWP, San Francisco, Calif.
6JX, San Francisco, Calif.
6ZZ, Douglas, Arizona
7LY, Bozeman, Montana.
7YJ, Corvallis, Oregon
7ZU, Polytechnic, Montana.
8AWP, Syracuse, N. Y.
8AXK, Cincinnati, Ohio
8JL, Cleveland, Ohio
8ZAC, Barnesville, Ohio
8BRL, Crafton, Pa.
8LX, Crafton, Pa.
9DVA, Denver, Colo.
9AIF, Sioux Falls, S. D.
9AIG, Sioux Falls, S. D.
9ZN, Chicago, Ill.
9AJA, Chicago, Ill.
9AMB, Denver, Colo.
9NX, Wichita, Kansas
9ZAF, Denver, Colo.
9WD, Chicago, Ill.
9DTM, Topeka, Kans.
9AQR, Kansas City, Mo.
9XI, Univ. of Minnesota, Minn.
9XM, Univ. of Wisconsin, Madison, Wisc.
9XAQ, Univ. of Colorado, Boulder, Colo.

In the case of several stations in the Third and Eighth Districts these stations either worked or heard 6XAD after daylight had been in the east for approximately an hour.

The number of stations which have reported the signals of 6XAD is so great that it was not possible to include a detailed list of them. Included among them, however, were stations in Vermont, Massachusetts, New York, New Jersey, Pennsylvania, Virginia, District of Columbia, Georgia, Oklahoma, New Mexico, California, Arizona, Montana, Washington, West Virginia, Ohio, Kansas, Missouri, Nebraska, North Dakota, Colorado, South Dakota, Wisconsin, Illinois, Minnesota, Ontario and Saskatchewan, Canada.

Unusual Long Distance Work by Amateur Stations

That all types of C.W. transmitters are efficient seems to have been established recently when three-cornered communication between amateur stations 2ZL, 5ZA and 8ZG was maintained; this communication breaking all distance records for two-way work by amateur radio stations. Each station taking part in this work used a different type of tube transmitter.

Stations 2ZL and 8ZG, at Salem, Ohio, had exchanged traffic and it was noted that conditions for long distance work were good. About 11.30 P. M. 8ZG heard signals from 5ZA, and called, and 5ZA answered. Traffic was then exchanged between 5ZA and 8ZG, an air-line distance of 1,400 miles, and among the traffic sent from 5ZA was a note to 2ZL, saying that 5ZA was hearing 2ZL well. All the traffic sent to 8ZG had been heard at 2ZL including the note. As soon as 8ZG had finished with 5ZA, the former station called 2ZL and passed along the note. 2ZL immediately called 5ZA and the latter answered, reporting the signals of 2ZL as of good audibility there. Once communication had been established, several messages were exchanged without difficulty. The airline distance between the two points is 1,800 miles.

All the stations concerned in this exceptional work used tube transmitters, but as stated before, of different types. At 8ZG, the station of A. J. Manning, a 100-watt Kenotron set is used employing two Kenotrons UV217 and two UV203 Radiotrons. The set used by Louis Falconi, at Roswell, is of 100-watt output capacity, employing two Radiotrons UV-203, with D.C. plate voltage supply. The set at 2ZL employs two Radiotrons UV-204, in a full-wave rectification circuit, A.C. being used on both filaments and plates.

Reports have been received that the signals of 2ZL were clearly heard at Tuscon, Ariz., Station 6AMT, Nogales, Ariz., WJK, Taft, Calif., and 6GZ, Los Angeles, Calif., during the time 2ZL and 5ZA were in communication, a maximum overland airline distance of 2,500 miles.

A 5-Watt Vacuum Tube Transmitter Employing an Electrolytic Rectifier*

A 5-watt vacuum tube transmitter, employing an electrolytic rectifier for the A.C. supply for use on the plate, is shown in detail in the following circuit diagram.

This set has given satisfactory results, both with voice and C.W. The voice range is 25 miles, but it has been reported at 33 miles. The C.W. range is in the neighborhood of 150 to 200 miles.

*Geo. L. Gates, in The Wireless Age.

If the constructor has no apparatus at all the set would cost about thirty dollars to duplicate, but as the average amateur no doubt has some old apparatus he can easily build one considerably cheaper. The expense is itemized below:

Transformer core	$ .30
1 lb. No. 22 enameled wire	.75
2 lbs. No. 28 enameled wire	1.50
Lead strips	.10
20 Mule Borax	.12
Aluminum strips	.25
5-watt Radiotron	8.00
Socket	1.00
Grid Leak	.10
Grid condenser	.10
Choke coil	.50
Variable condenser	4.25
Inductance	.25
H. W. A.	7.00
Buzzer	2.00
Microphone	2.50
Modulation transformer	.50
	$29.22

The transformer is, probably, the hardest part of the set to build, but if properly constructed it will give much better results than a motor generator or B Batteries, besides being lower in cost of construction and upkeep. The core is made of stovepipe iron which is cut in the shape of an L. The size of the core when completed is 7 x 5 x ¾ inches. About 150 pieces of stovepipe iron 7 x 5 will be needed. Almost any hardware concern carries the iron and will cut it to your specifications. The primary and secondary can easily be wound on a lathe made from a breast drill. The primary has 425 turns of No. 22 enameled wire. The secondary has 2,550 turns of No. 28 enameled wire. No center tap is taken. The filament winding has 40 turns of No. 22 enameled wire. The filament winding is tapped at the twentieth turn. It is important to separate each layer of wire with a layer of paper. The primary and filament are wound on the same leg while the secondary is wound on the opposite leg.

The rectifier is of the aluminum-lead type which gives very good results. The rectifier consists of eight Mason pint jars, eight lead strips 5 x ¾ inches and eight aluminum strips 5 x ¾ inches. The solution is

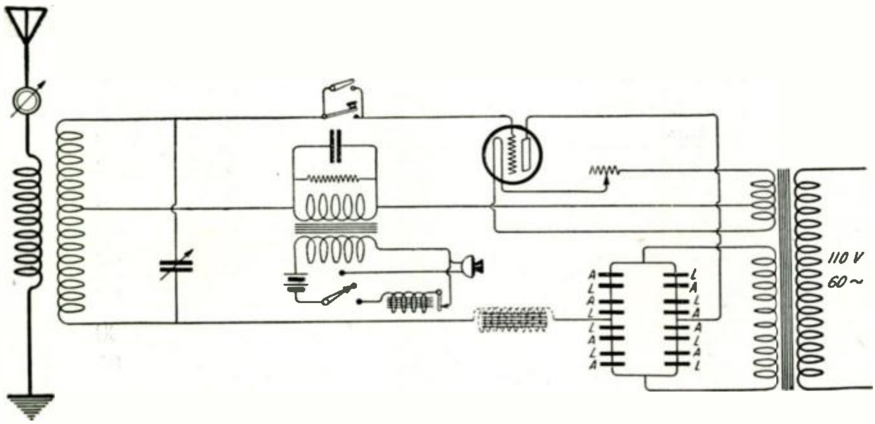


Fig. 31. Five-watt transmitter with electrolytic rectifier

made up of a half pound of 20 Mule Team Borax dissolved in ten pints of water. In filling the jars with the solution care should be taken that none of the sediment remains in the jars. The jars should be filled about three-quarters full. The diagram shows the order in which the plates are connected together.

Although there is, locally, a noticeable hum if no filter system is used, the modulation is not distorted. This hum can only be heard a short distance from the transmitting station. The hum may be reduced considerably if a Ford coil secondary is used as a choke coil.

The modulation transformers put out by the various manufacturers are very good, but a Ford coil will give good modulation and is considerably cheaper. The vibrator should be tightened up so as to insure good contact. The fixed condenser shunted across the secondary should be of about .001 mfd. capacity. The grid leak is a Venus pencil No. 2B, which may be connected from the grid to the filament to afford a slight increase in radiation, though the modulation is somewhat distorted.

The primary of the inductance is wound with No. 18 bell wire on a 3½-inch cardboard tube. The coil has 26 turns and is tapped at the thirteenth turn for the filament lead. The secondary has 8 turns of the same size wire without taps. The windings should be separated about a half inch.

Any standard radiation ammeter with low reading scale may be used. If the constructor wishes he may substitute a 3-volt flashlight bulb for the ammeter with fair results. Of course, the flashlight bulb will not tell when the maximum radiation is obtained, but the set will give good results if tuned only with the flashlight bulb.

A few words concerning the operation will no doubt be useful. The plates of the aluminum-lead rectifier must be formed before the rectifier will work. A simple way to form the plates is to connect in a 50-watt incandescent bulb and let the 110-volt 60-cycle current run about ten hours. The plates will form faster if a larger bulb is used, though the slower the plates are formed the better the results.

In applying the high and low voltages to the transmitting tube the filament should always be lighted before the high voltage is turned on. The high voltage should never be left on the plate of the power tube unless the filament is lighted as the high voltage will tend to break down the construction and insulation inside the tube.

In order to make the set operate the key in the grid circuit must be closed when voice modulation is desired. The set is tuned by turning the variable condenser until the flashlight or ammeter shows the greatest reading. The beauty of this circuit is that it requires no skill to tune the set and is therefore easily kept in operation. The microphone should always be disconnected from the battery when not in use as the carbon granules will become packed and the modulation will become distorted or entirely eliminated.

CHAPTER X

Tube Transmitters in Commercial Work

Duplex Ship and Shore Radiotelephony

For the first time in the history of maritime radio, docking instructions were given verbally to the captain of a big trans-Atlantic liner by the manager of the line, seated in his office in New York, while the ship was 360 miles at sea. This pioneer work in radio communication was accomplished by utilizing one of the latest developments of radio engineering, duplex radio-telephony, in conjunction with the usual land-line telephone.

While the America of the United States Lines was 360 miles east of New York, Thomas H. Rossbottom, general manager of the steamship company, picked up the ordinary telephone on his desk and asked central to connect him with the S. S. *America,* at sea. His line was connected through to the Deal Beach, N. J., station, and thence by radio to the ship.

Within ten minutes after the call was made Captain William Rind, of the *America,* was on the telephone. After an exchange of greetings, Captain Rind told Mr. Rossbottom the speed he was making, and the time he expected to reach Quarantine. Mr. Rossbottom in reply gave his instructions to Captain Rind concerning the special arrangement which had been made with the public health officials at the Quarantine Station for the passing of the vessel after the sunset hour.

Mr. Rossbottom and Captain Rind conversed for several minutes. Mr. Rosbottom used the telephone at his desk, the one that is normally used in his daily business, and without any special appliances.

The interesting feature of a shipboard duplex installation is the fact that the antenna is being used to radiate several hundred watts of power while at the same time the radio receiver detects and makes audible the extremely small amount of energy that is being picked up from the distant transmitting station. Much research has been done to allow this simul-

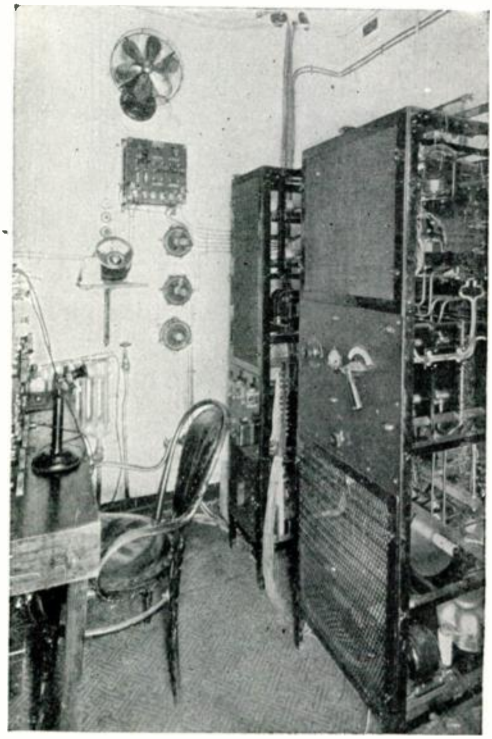
Thomas H. Rossbottom, General Manager of the U. S. Lines, talking by wire and radio to Capt. Rind of the S. S. *America* 360 miles out at sea.

taneous transmission and reception to be carried on and a ship equipped with apparatus of this nature may communicate with any subscriber on land who has an ordinary telephone in his home.

Radio telephony, heretofore limited to a simple operation—reception or transmission—has been revolutionized as a result of these tests. Up to this time the radio telephone has been handicapped by conditions similar to those of the ordinary apartment house speaking tube. It has been necessary for the operator to throw a switch when he desired to talk after listening, or vice versa. This prevented a landline telephone from being linked up with the radio telephone system, as it is not practical to provide a control or "send-receive" switch at each land phone.

With the advent of the duplex wireless equipment, however, a conversation may be carried on through the ether as simply and as naturally as between land telephones.

The equipment installed on the *America* consists of three main units—the Kenotron or power panel, the vacuum tube transmitter and the radio receiver. Power is supplied to the Kenotron panel in the form of low-frequency, low voltage alternating current and after being transformed into a high voltage is rectified by Kenotron tubes into direct



Duplex radio telephone equipment on the S. S. *America*

current at a very high voltage. This high voltage is fed into the Radiotron power tubes, where it is transformed into radio-frequency energy. Other Radiotron tubes are used to control, or modulate, the high-frequency current.

This duplex radio-telephone service will be made available for general use by the public just as soon as the demand for it warrants the installation of proper apparatus afloat and ashore.

Recent developments and improvements which have been made in both the transmitting and receiving apparatus of radio telephony are of a nature which will insure the secrecy of all voice communications, and equipment of this type will undoubtedly be used when this new service is made available to the public. An eavesdropper, in endeavoring to "listen-in" on a secret communication of this kind hears only a buzz—somewhat resembling the sound made at an ordinary receiver by a nearby arc light, or a leaky power line. Not a single word is intelligible except to those for whom the conversation is intended, through the agency of special receiving equipment.

Tube Transmitters in Ship-to-Shore Work

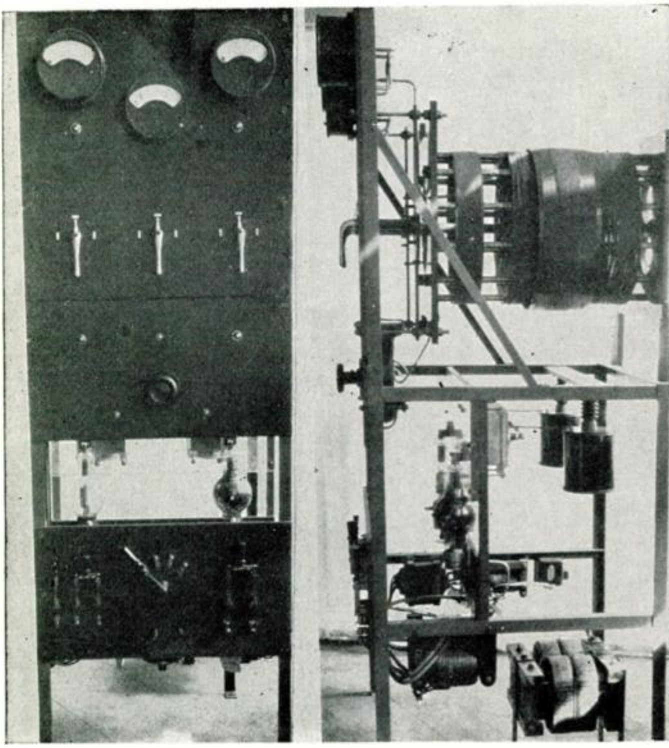
Several tube transmitters of medium power have recently been put into service by the Radio Corporation of America for ship and shore work. One is installed at Marion, Mass., and operated from Chatham, Mass., on Cape Cod, call letters WCC, wave-length 300, 425, 600 and 2,200 meters, and the other at Bush Terminal, Brooklyn, N. Y., call letters WNY, wave-length 300, 425, 600 and 1,800. These tube transmitting sets are of three-kilowatt capacity, employing three 1 K.W. tubes as oscillators and two high-capacity Kenotrons for rectifying the 12,500 volts A.C. supply. The normal range of the Cape Cod station is 1,800 miles daylight. This station is used for ship and shore message work, broadcasting traffic on regular schedules and also transmits press on regular schedule on a wave-length in the neighborhood of 2,200 meters in connection with the "Ocean Wireless News," the daily newspaper of the sea.

These new stations of the Radio Corporation are connected by direct wires to the main traffic office at 64 Broad Street, New York, from which point the trans-oceanic stations of the Radio Corporation are also controlled.

These new tube sets, the first to be used in ship-to-shore work, are built upon an iron framework seven feet high, 32 inches wide and 36 inches deep. Three panels of dilecto provide mountings for the necessary control switches and indicating instruments. Three Radiotron tubes

UV205 are used in the set, in vertical position, each tube being of 1,000 watts output capacity.

The sets have been designed to work on a line carrying 220 volts, 60 cycles, single phase, this voltage being stepped up to 12,500 volts.



Front and side views of the ship-and-shore station tube transmitter

A self-rectifying circuit, which has recently been developed by the engineers of the Radio Corporation, has also been employed in the operation of these sets, the tubes acting as oscillators and rectifiers at the same time. In this circuit a transformer with a secondary voltage of 25,000 was used, the secondary being provided with a middle, or neutral tap, resulting in full-wave rectification, each tube working alternately on the two halves of the cycle.

A 2-K.W. Kenotron Tube Set for Panama

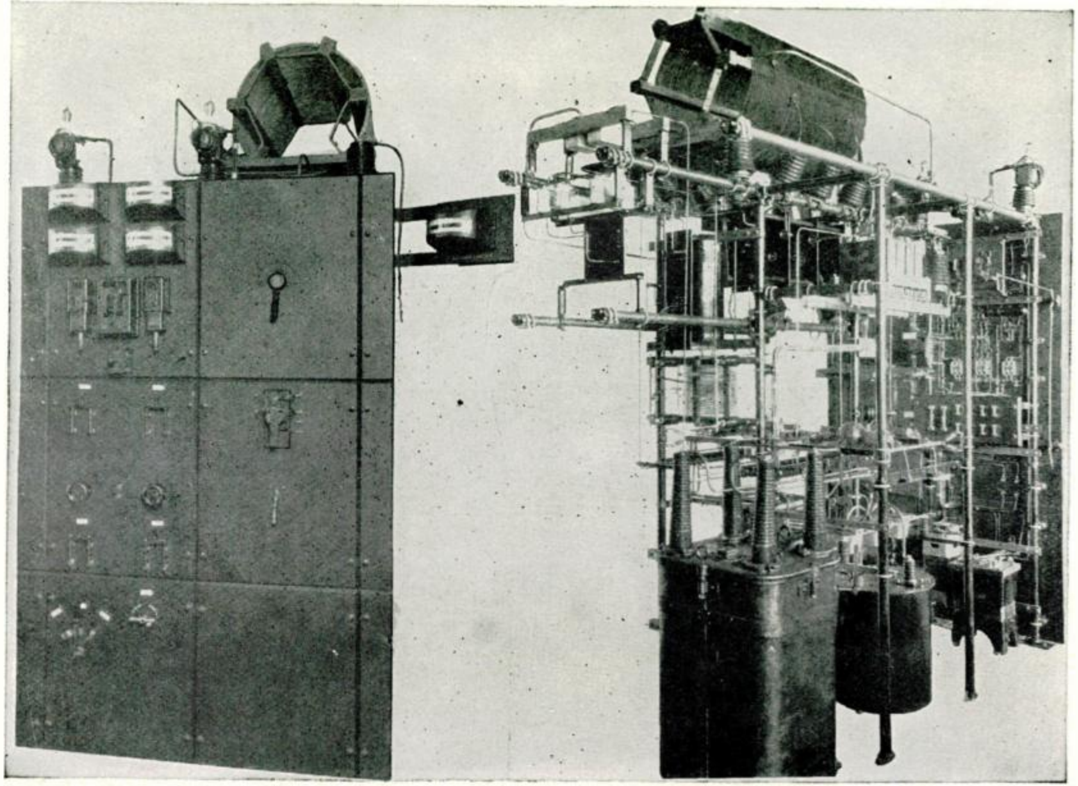
A 2-K.W. tube transmitter built recently by the General Electric Company for the Radio Corporation of America is now installed and in operation at Almirante, Panama.

The set consists of equipment for supplying direct current at 12,500 volts for the plate supply of the Radiotron tubes, and for converting this power into radio frequency. Power is supplied to the transmitter at 440 volts, single phase, 60 cycles, and stepped up to high voltage by means of a transformer, the output of which is fed into the rectifying system.

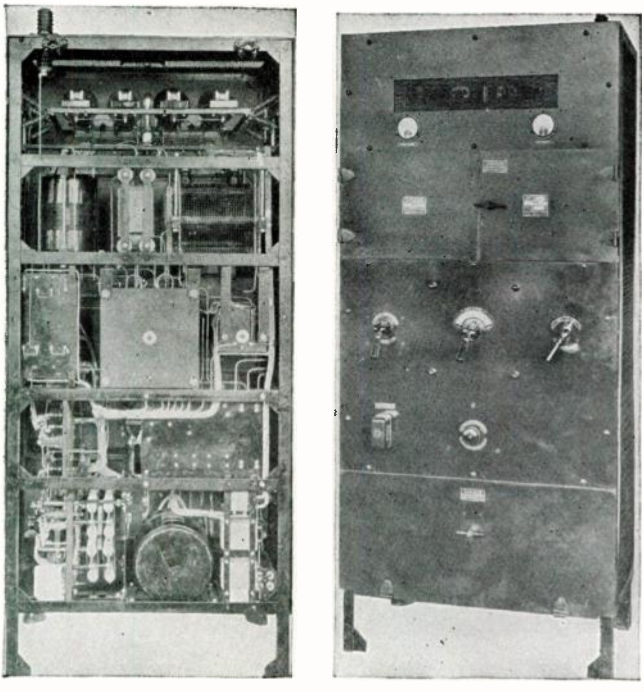
The rectifying system consists of two 2 K.W. Kenotron tubes which supply 12,500 volts D.C. to the plate circuits of the Radiotron generators. The ripple in the output of the rectifying system is smoothed out by means of a suitable filter system. The radio frequency power is generated by a system consisting of two 1 K.W. Radiotrons with the necessary grid and plate coils, together with an antenna loading coil. Provision is made for controlling the power by a power change switch which alters the voltage on the primary of the plate transformer. The filaments of all tubes, Kenotrons and Radiotrons are operated on A.C. through transformers, which step the supply voltage down to the operating voltages of the filaments.

The set is equipped with a wave-changing switch which, by a single operation, changes the transmitted wave to any one of three lengths—600, 1,000 and 3,000 meters. The switch automatically selects predetermined points on the loading, plate and grid coils. Provision is also made for transmitting on interrupted continuous (I.C.W.) as well as on continuous waves (C.W.) This is accomplished by means of a motor-driven interrupter in the grid circuit of the Radiotron tubes, which starts and stops oscillations in the antenna at audio frequency, approximately 1,000 interruptions per second.

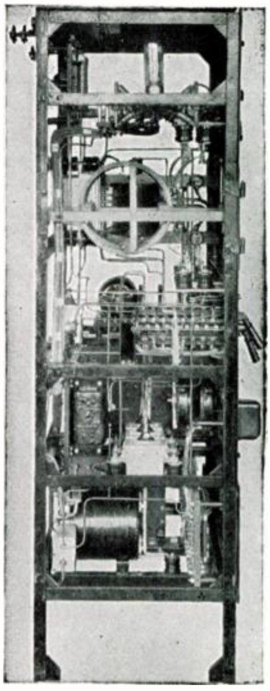
The rating of the transmitter is based on the power input of the antenna circuit, instead of on the output of the power equipment as is usual with spark transmitters. The rating of the tube transmitter is



Front and rear view of the 2 K.W. radio telegraph transmitter for C.W. and I.C.W. communication. Wavelength 600 to 3,000 meters the product of the antenna resistance times the antenna current squared, equalling two kilowatts. While it cannot be predicted exactly what the range of this set will be, it is expected that it will equal, if not exceed, the range of a 50 K.W. spark transmitter. As an example of its initial effectiveness, the set, as installed in Panama, is now carrying on reliable and satisfactory communication with New Orleans, La., twenty-four hours a day.



Front and rear view of the 1 K.W. rdaio transmitter.

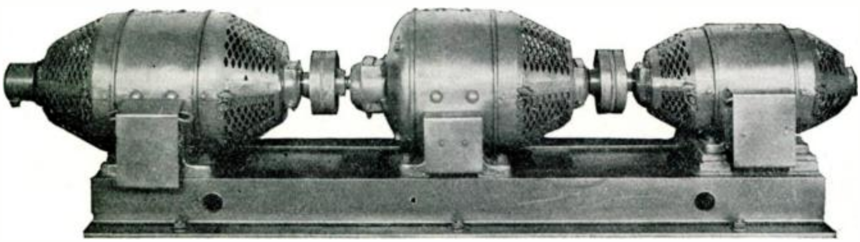


200-Watt transmitter side view

Two New Types of Tube Transmitters for Commercial Work

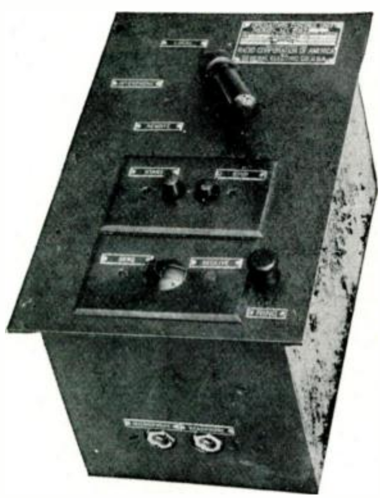
Two new types of tube transmitters, one of 1,000 watts and the other of 200 watts output capacity, manufactured for the Radio Corporation of America by the General Electric Company, are being installed on many vessels on both coasts and also on the Great Lakes. These new types of transmitters embrace all the latest developments in equipment of this kind. Both types of sets can be used for telegraphy by means of C.W. or I.C.W., and also for voice communication.

The 200-watt model employs a number of Radiotrons, UV203, as oscillators and modulators, and has control switches for voice, C.W. or I.C.W. When using C.W. or I.C.W. all tubes are used, of course, as



Motor generator, with field exciter, used with the new commercial tube transmitters of the Radio Corporation of America

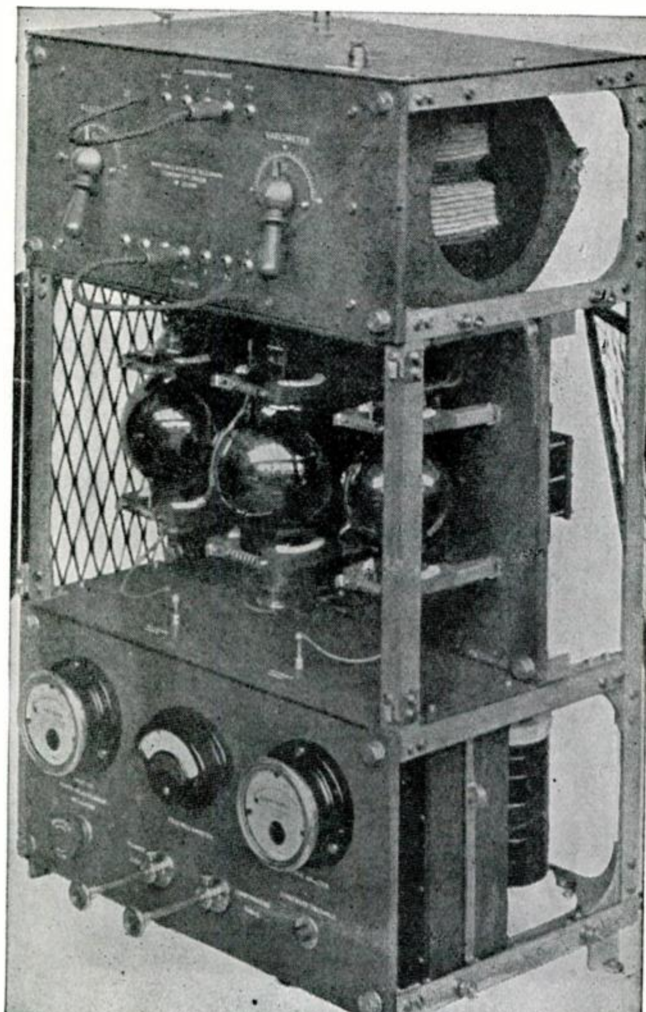
oscillators. This new type of transmitter is rated at 200 watts when used for telegraphy or at 100 watts when used for voice communication. This rating is based on the power output of the antenna.



Remote control box used with the new sets

The larger model, employing four Radiotrons, UV204, gives 1 K.W. output to the antenna when used for telegraphy, and 500 watts of modulated energy when used for voice communication.

Both models are equipped with motor-driven choppers for I.C.W. and with wave length changing switches for the following wave lengths: 300, 450, 600, 750, 800, 1,000 and 2,000 meters. Both of these sets are equipped with remote control apparatus.



Front and rear views of an English type ¾ K.W. tube transmitter

The normal daylight range of the 200-watt model for voice is 50 to 75 miles; for I.C.W. 75 to 100 miles; and for C.W. 300 to 400 miles. The normal daylight range of the 1,000-watt model for voice is 150 to

200 miles; for I.C.W., 200 to 300 miles; and for C.W., 800 to 1,200 miles. These figures are based upon tests made overland; the receiver consisting of a detector and two-stage audio-frequency amplifier.

High-Power Tube Transmitters

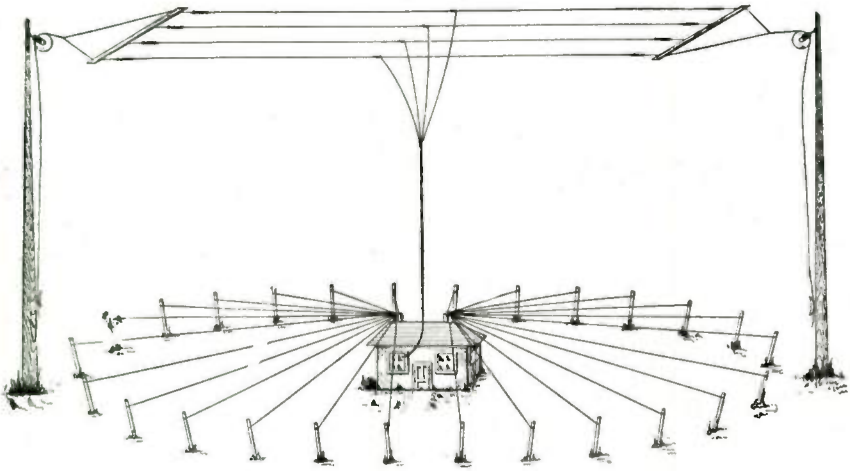
The power and consequent range of commercial tube transmitters are being steadily increased. Tubes of 1 K.W. output are now on the market as regular equipment. Tubes of 5 K.W. output capacity are being regularly used in broadcasting by the General Electric Company. Still larger tubes, of 20 K.W. output capacity, employing an extremely high voltage on the plate, are now being manufactured for commercial use and it is more than likely that they will be used regularly in the trans-Atlantic work of the future. There is now in service at the Carnarvon, Wales, Marconi station, a battery of 48 high-power tubes, the output of which is equal to a 200 K.W. alternator—approximately 4 K.W. each. This station communicates regularly with Australia.

CHAPTER XI

Advantages of a Counterpoise Ground in Connection With Tube Transmitters

In the case of land stations, there are three types of earth for a ground,—excellent, medium and poor. The first designation covers soil of marshy nature, especially contiguous to bodies of salt water and which is, as a result, itself salty in nature, offering an excellent earth. Moist ground of other type also falls partly within this classification, and where a radio station is built upon earth of this type the usual arrangement of buried plates, pipes and wires will answer satisfactorily and the resistance of a well-constructed ground system in earth of that kind will be sufficiently low as not to warrant the construction of a counterpoise ground system. In fact, it has developed in several instances that when a counterpoise ground system is built directly over moist ground, considerable leakage of energy to the earth takes place resulting in less efficiency of the transmitter than if the regular earth ground were used. Where the earth is of such a nature as to be a good conducting medium the regular system of plates, pipes, wire and wire mesh, buried far enough so as to be in continually moist earth, should be used.

In the case of the second and third classifications, it will undoubtedly be advisable to build a counterpoise ground, consisting of approximately double the amount of wire of the antenna itself. The counterpoise can be suspended on spreaders high enough off the ground to clear an automobile, or a person walking and should be suspended under the antenna and also beyond it at both ends. The ends, outside of the antenna, should be fanned out. Where an earth ground of the second or third classification has been used, change to a good counterpoise system will undoubtedly result in doubling the antenna current, an increase of four times the amount of energy flowing in the antenna system. As actual radiation is proportional to the amount of energy flowing in the antenna circuit, the great increase in energy in the antenna system so obtained will naturally result in the actual radiation of a greater amount of energy which, after all, is the ultimate object for which a transmitter is used.



Counterpoise ground

The resistance of the average amateur antenna ground circuit, when an earth ground is used, is likely to be anywhere between 20 and 50 ohms. The use of a counterpoise will frequently reduce this resistance to 7 or 8 ohms, or even less, according to the size and shape of the counterpoise and also depending upon its immediate surroundings. Trees, large metal objects or telephone wires, if in the field of the antenna or ground, will frequently keep the resistance at an abnormal value. It is, therefore, highly desirable, that both antenna and counterpoise ground are kept clear of and away from all structures or wires not necessary for the support of the antenna system.

CHAPTER XII

General Information for the Amateur

There are at the present time approximately 25,000 amateur radio transmitting stations in the United States, and probably eight receiving stations to every transmitting station, making a total of 200,000 amateur stations. The large majority of these stations use only a small amount of power for transmitting; consequently, their range is small. There are organizations of amateurs which include primarily those who are interested in the relaying of messages from one station to another, and during the cooler months of the year, when the air is clear of static, it is frequently possible to relay messages through such stations clear across the country within a few hours. As a general rule such messages are relayed over fairly well established lines of communication, including the most efficient stations operated by the best amateur operators of the country. The *National Amateur Wireless Association,* which includes in its membership most of the leading amateurs of the country is one of the organizations which maintains a national traffic organization and relays messages to all points of the country without charge. The stations which are a part of this relay system of the *National Amateur Wireless Association* include many of the leading amateur stations which employ tube transmitters, and, because they use C. W. transmitters, exceptional results are obtained, the range of these tube stations frequently exceeding 1,000 miles. During the warm months of the year, when there is considerable disturbance from atmospheric electricity due to thunderstorms, repeated tests have proved that tube transmitters can work successfully through heavy static caused by thunder showers, while spark stations of the same power could not be heard.

One of the problems of amateur activities is that of interference between stations. This is largely the result of the use of spark transmitters which radiate their energy over a wide band of wave lengths. In the case of continuous wave transmission the energy is radiated on substantially *one wave length,* thereby eliminating to a great degree the objectionable interference caused by spark stations. The character of transmitted energy is such that the effect at the distant receiver is much greater, power for power, than a spark set, principally for the reason that the undamped wave transmitter permits the use of highly refined and efficient methods of reception.

CHAPTER XIII

Radio Laws and Regulations of the United States

The owner of an amateur radio transmitting station must obtain a station license before it can be operated if the signals radiated therefrom can be heard in another State; and also if such a station is of sufficient power as to cause interference with neighboring licensed stations in the receipt of signals from transmitting stations outside the State. These regulations cover the operation of radio-telephone stations as well as radio-telegraph stations.

Station licenses can be issued only to citizens of the United States, its territories and dependencies.

Transmitting stations must be operated under the supervision of a person holding an *Operator's License* and the party in whose name the station is licensed is responsible for its activities.

The Government licenses granted for amateur stations are divided into three classes as follows:

Special Amateur Stations known as the "Z" class of stations are usually permitted to transmit on wave lengths up to approximately 375 meters.

General Amateur Stations which are permitted to use a power input of 1 kilowatt and which cannot use a wave length in excess of 200 meters.

Restricted Amateur Stations are those located within five nautical miles of Naval radio stations, and are restricted to ½ kilowatt input. These stations also cannot transmit on wave lengths in excess of 200 meters.

Experimental stations, known as the "X" class, and school and university radio stations, known as the "Y" class, are usually allowed greater power and also allowed the use of longer wave lengths at the discretion of the *Department of Commerce.*

All stations are required to use the minimum amount of power necessary to carry on successful communication. This means that while an amateur station is permitted to use, when the circumstances require, an input of 1 kilowatt, this input should be reduced or other means provided for lowering the antenna energy when communicating with near-by stations in which case full power is not required.

Malicious or wilful interference on the part of any radio station, or the transmission of any false or fraudulent distress signal or call is prohibited. Severe penalties are provided for violation of these provisions.

Special amateur stations may be licensed at the discretion of the *Secretary of Commerce* to use a longer wave length and higher power than general amateur stations. Applicants for special amateur station licenses must have had two years' experience in actual radio communication. A special license will then be granted by the *Secretary of Commerce* only if some substantial benefit to the science of radio communication or to commerce seems probable. Special amateur station licenses are not issued where individual amusement is the chief reason for which the application is made. Special amateur stations located on or near the sea coast must be operated by a person holding a commercial license. Amateur station licenses are issued to clubs if they are incorporated, or if any member holding an amateur operator's license will accept the responsibility for the operation of the apparatus.

Applications for operator's and station licenses of all classes should be addressed to the *Radio Inspector* of the district in which the applicant or station is located. *Radio Inspectors'* offices are located at the following places:

First District	Boston, Mass.
Second District	New York City
Third District	Baltimore, Md.
Fourth District	Savannah, Ga.
Fifth District	New Orleans, La.
Sixth District	San Francisco, Cal.
Seventh District	Seattle, Wash.
Eighth District	Detroit, Mich.
Ninth District	Chicago, Ill.

No license is required for the operation of a receiving station, but all persons are required by law to maintain secrecy in regard to any messages which may be overheard.

APPENDIX I.

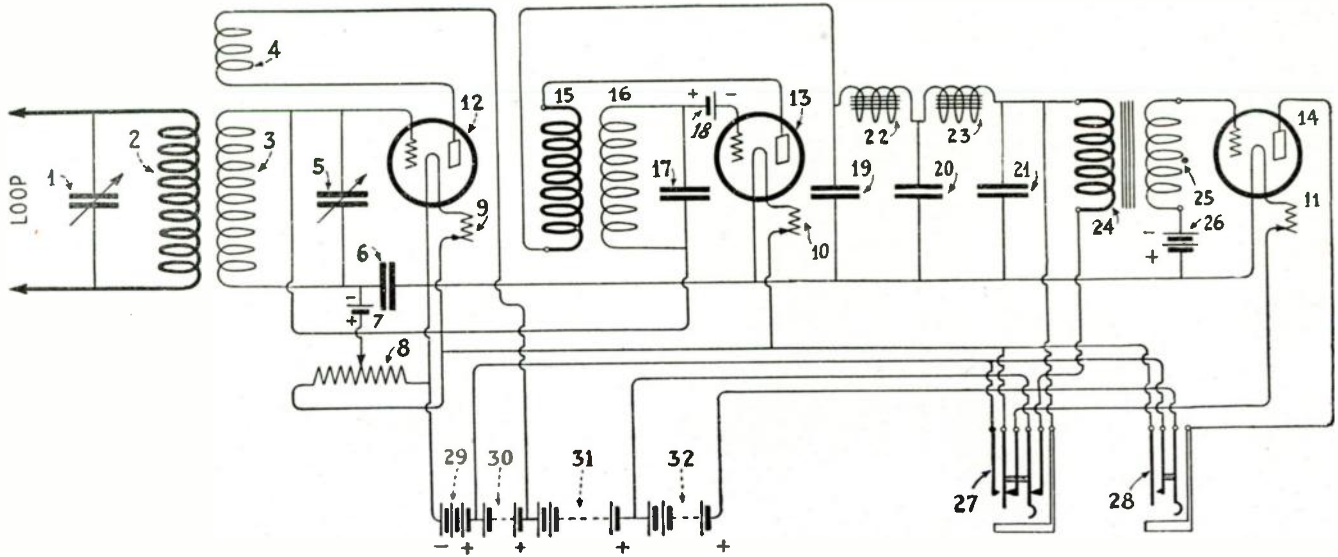
Detailed Values of the Component Parts of the Armstrong Super-Regenerative Receiver

The Super-Regenerative Circuit recently developed by E. H. Armstrong, will give results which far surpass those obtained with any other circuit using the same number of tubes. It is especially adapted to the reception of radio telephony and is undoubtedly the universal broadcast receiving set of the future.

It is unnecessary here to go into the action of an ordinary regenerative receiver as this is now clearly understood by practically everybody. It is, of course, well known that a signal, or speech, can be increased by regeneration up to a certain point, where the tube breaks into oscillation. In the super-regenerative circuit the benefit of the limit of regeneration is secured by the use of an additional oscillator tube, which alternately stops and starts the oscillations of the detector tube, so that regeneration can be carried to the limit.

The action of the super-regenerative circuit consists in varying the negative resistance of the circuit, with respect to the positive, or vice versa, so that the negative resistance is alternately greater and less than the positive, but with the average resistance positive. Such a circuit will not of itself produce oscillations and during the periods when the negative resistance is the greater the current in the circuit will reach exceedingly high values. The general operation of the super-regenerative circuit is practically the same as that of the ordinary regenerative circuit.

A detailed diagram, with definite values of all parts of a three-tube super-regenerative circuit, using one tube as an audio-frequency amplifier, will be found on the following pages.



1. Loop tuning condenser .001 M.F. variable.
2. Loop tuning coil 30 turns 22 d.c.c. 4¾" tubes.
3. Grid tuning coil 25 turns 22 d.c.c. on 4¾" tubes.
4. Tickler coil-rotor of variometer.
5. Grid tuning condenser .0005 M.F. variable.
6. Fixed condenser .01 M.F. or larger.
7. Negative "C" battery 2 or 4 small flashlight cells.
8. "A" battery potentiometer.

9, 10 and 11. Filament rheostats.

12, 13 and 14. Hard vacuum tubes.

15. Oscillation plate coil 1250 turns Honeycomb or Duo-Lateral coil.
16. Oscillation grid coil 1500 turns Honeycomb or Duo-Lateral coil.
17. Oscillation grid condenser .003 M.F. fixed condenser.
18. Negative "C" battery 1 or 2 flash-light cells.

19 and 21. Filter condensers .00181 M.F. fixed condenser.

20. Filter condenser .00362 M.F. fixed condenser.

22 and 23. Filter choke coils 2.28 henry choke coils.

24. Primary of audio-frequency transformer.
25. Secondary of audio-frequency transformer.
26. Negative "C" battery, 3 or 4 small flashlight cells.
27. First stage automatic filament control jack.
28. Last stage automatic filament control jack.
29. Storage battery.
30. "B" battery 44 to 88 volts.
31. "B" battery 44 to 88 volts.
32. "B" battery 110 volts or over.

1. This condenser is a 43 plate variable condenser of .001 M. F. capacity. A smaller or larger condenser will be equally satisfactory, the only change being in the wavelength range covered.

2. This is the loop coupling coil. By referring to the drawing it will be observed that this coil is wound in three sections. In the actual set 30 turns of No. 20-38 Litz was used, but No. 22 d.c.c. may be used with practically the same results.

3. This coil is the grid tuning coil, 25 turns of 20-38 Litz were used. Here again No. 22 d.c.c. may be used with good results.

4. This is the plate, or tickler coil. It consists of a rotor of a variometer. The fixed winding of the variometer is removed from the frame and the outside part merely forms a support for two tubes. These tubes, which may be of laminated wood, bakelite or cardboard, are fastened to the variometer housing with small pieces of brass suitably bent and drilled.

5. The value of this condenser need not exceed .005 M. F. With this capacity as maximum the set will cover a wavelength range of 190-500 meters.

6. This condenser is a fixed paper condenser, the value may be anything above .01 M. F.

7. This is the negative "C" battery, used to regulate the potential of the grids of both tubes. The value of the battery voltage must be changed to suit the particular tubes used, and the "B" battery voltage. Two to four small flashlight cells are suitable.

8. This is an "A" battery potentiometer, to permit fine regulation of the value of the grid potentials. If desired this may be eliminated and the regulation effected entirely by the battery No. 7.

9-10-11. Filament rheostats of any type.

12-13-14. Hard vacuum tubes such as UV-201.

15. This is a 1250 turn Duo-Lateral coil, mounted.

16. This is a 1500 turn Duo-Lateral coil, also mounted, with rather close coupling to coil No. 15. The coils should be so placed that the outside of the winding connects to the plate and grid when they are arranged for oscillation.

17. This is a .003 M. F. fixed mica condenser and with coil No. 16 gives a frequency of the order of 7,000 to 8,000 cycles. This frequency is sufficiently high to be readily filtered out and at the same time low enough to give good amplification results.

18. This is a separate "C" battery for regulation of the negative potential of the oscillator tube. It is not necessary in some cases, though frequently with certain tubes, both negative "C" batteries must be varied to obtain proper results. One or two small flashlight cells are suitable.

19-20-21-22-23. These units comprise the filter system. They are fixed condensers of .00181 M. F., and the inductances are of 2.28 henries.

24. Primary of audio-frequency transformer.

25. Secondary of audio-frequency transformer.

26. Negative "C" battery for use with audio-frequency transformer when the plate voltage is above 100 volts. This battery should have a voltage of 3 to 4½ volts.

27. Filament control jack, first stage type.

28. Filament control jack, last stage type. Both these jacks may be dispensed with if it is desired to do so.

29. Six-volt storage battery.

30. 44-88 volt "B" battery.

31. 44-88 volt "B" battery depending on the tubes used and the value of battery No. 30. In other words both batteries No. 30 and No. 31 must be varied to give best results.

32. Battery for plate of amplifier tube. This may be as great as 300 volts or more depending on the amount of power required and what the tube will stand.

The foregoing values should give the reader a fair idea of the method of constructing and operating the receiver. No rigid iron bound rules must be followed; the descriptions are given more with an idea of guiding the line of thought, and not to dictate the method to be followed.

For full constructional data and operating instructions for this and the other super-regenerative circuits, the reader is referred to the new book by George J. Eltz, "The Armstrong Super-Regenerative Circuit," which contains specific values for the several types of super-regenerative circuits, as furnished by E. H. Armstrong. This book can be obtained through the Wireless Press, Price $1.00.

APPENDIX II.

During the summer of 1922 some very interesting experiments in transmission on wavelengths considerably below 200 meters have been carried on by a few stations in the Second, Third and Eighth Radio Districts. Not much definite information is available at present, but it is known definitely that communication has been maintained over considerable distances during times when very bad conditions, because of static and interference existed on 200 meters, without any appreciable difficulty having been experienced on the shorter waves. In fact, it is believed that these experiments have pretty definitely established that the transmission curve for a given power takes an upward bend after the 200 meter point has been passed. Contrary to what has been generally believed, the greatest difficulty in maintaining communication on 125 and 150 meters has not been at the transmitting end, but at the receiver, where a special type of receiver, well shielded, was required. At the transmitting end, there has been little, or no difficulty in getting a considerable amount of power into the antennas of the stations participating in this unusual work.

At 2ZL station, Valley Stream, L. I., the transmitting antenna consisted of four vertical wires, in a 5 foot square cage, the total height being 50 feet above ground. A counterpoise was used, consisting of 7 wires, 20 feet long, directly under the cage and about 7 feet above ground. It was possible to tune the transmitter, consisting of two 250 watt Radiotrons UV 204, in a full-wave A.C. rectification circuit, to 150 meters, without the use of a series condenser. The antenna current on this wavelength was 5 amperes. With the use of a series condenser of a value of .0003, the wave was reduced to 125 meters, and the antenna current on this wavelength was 4.2 amperes. By adding still more capacity in series, the wavelength was reduced to an even 100 meters, with 3 amperes in the antenna.

Comprehensive experiments, to determine the range, variation in signal strength and other matters of interest are being carried on.

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