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Construction details and general discussion of the 10 watt radio telephone transmitter at the Missouri School of Mines

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CONSTRUCTION DETAILS AND GENERAL DISCUSSION OF THE 10 WATT RADIO TELEPHONE TRANSMITTER AT THE MISSOURI SCHOOL OF MINES

by

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A

T H E S I S

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Approved by F. H. Frame
Professor of electrical engineering.

TABLE of CONTENTS

THE ANTENNA

In radio communication it is necessary to have a device to radiate electrical waves and a device to receive electrical waves. Devices used for this purpose are called antennas.

In radio communication work there are various and sundry means of receiving these electrical waves, or rather, there are many different types of antennas. These may be divided into two general classes. The first type is usually referred to as simply an antenna. The second type is usually referred to as a "coil antenna", "coil aerial", "loop" or, when used for a particular purpose, as a "direction finder." The most generally used types of antennas are the "inverted L", the "T" and the "cage aerial".

Antennas vary depending upon the service for which they are to be used. For short wave transmission the cage aerial is very popular. It is second only to the inverted L. The cage aerial may be used in places where the T and inverted L would be cumbersome as well as difficult to install. The cage aerial is credited with eliminating static disturbances to a certain extent.

Any of the above mentioned types may be used for receiving. For receiving only it is general practice to use one wire only because of cheap construction cost and ease of erection. One wire is sufficient for this service, no large radiating surface nor capacity being essential.

Following is a brief description of various types of antennae and their general applications:

The inverted L aerial consists of horizontal parallel wires supported between two masts and insulated from them. The lead in is attached to one end. This type is common to ships and most amateur stations. The wires are kept apart by spreaders which generally are made of wood. If the lead in is attached to the center of the aerial it is called a T type antenna.

The V antenna consists of two sets of horizontal or slightly inclined wires supported by three masts so that the horizontal portions form an angle. The V type is used to some extent in military work but is not much used elsewhere.

The fan or harp aerial consists of a number of wires radiating upward from a common terminal to various points of a supporting wire to which they are connected. The supporting wire is insulated at each end from the lower support. Practical advantages of the fan type are that there are only two insulators, which results in small leakage, and that the mechanical strain to be carried by the supports is small.

The cage type of antenna is used to a considerable extent particularly on ships. A numbef of parallel wires, generally six or eight, are supported from a single point, and are kept apart by star or circular shaped spreaders which are generally made of wood. One advantage of this type in military work is that if some of the wires are shot away the antenna may still be used.

For transmission over short distances a very simple antenna may be used, such as, for example, a single wire supported between two stakes a few feet above the ground. In some cases a long insulated wire may be laid on the ground or in a shallow trench forming a ground antenna.

The umbrella type of antenna consists of a number of wires which diverge from the top of a mast and are brought down to the ground. They are attached to anchors in the ground by means of insulators. Lead in wires are brought down from the junction of the wires to the apparatus.

For high power stations a type called the multi-tumed antenna is used. This type antenna has a very small value of effective resistance. The multi-tuned antenna is a long affair which is grounded at several points along its length through loading inductance, by means of which the individual sections are tuned to the wave length which it is desired to radiate. This is equivalent to connecting several antennae in parallel; the radiation resistance remains the same as for the antenna connected in the regular way, but the actual resistance of the ground connections of the whole antenna is the resistance of a single ground connection divided by the number of ground connections.

The behavior of an antenna depends upon its capacity inductance and effective resistance just as in any oscillatory circuit. The energy which is supplied to an antenna when it receives N charges per second is-

$$P = \tfrac{1}{2} C E^2 N.$$

where C= capacity, E= voltage. It is not practical to raise the rate of charging beyond one thousand to fifteen hundred sparks per second. Brush discharges and carona losses occur at very high voltagesand as a result the only remaining means of obtaining high power is to change C. This means a very long and very high antenna for high power.

Since the power depends so much on the capacity of the antenna circuit a convenient formula has been derived which will give with a fair degree of accuracy, the capacity from the physical characteristics of the antenna circuit.

$$C = 40\sqrt{A} + 8.85\frac{A}{h}$$

C= Capacity of antenna in microfarads.

A= Area of flat top of the antenna in square meters. (area inclosed by bounding wires)

h= Average value of actual height of antenna above the ground.

In the case of the antenna used at the Missouri School of Mines, since the length was more than eight times the breadth, the elongation factor (1+.011/b) was multiplied into the equation.

The principal factor in determining the value of the natural period of an antenna circuit is the capacity; however the inductance which the antenna wires possess is of equal importance. As has been pointed out, the antenna circuit is an oscillating circuit and must necessarily have both inductance and capacity.

If the natural frequency of the antenna circuit is known as well as the capacity, the inductance may be calculated by the formula: $f = 1/2 \pi \sqrt{LC}$

The natural period of an antenna determines largely its efficiency for transmitting at a given wave length. In general these circuits are calculated to have a natural period very close to the wave length which will be used for transmission.

In cases where the oscillations are forced at frequencies widely different from the natural period, the radiated energy may be very small compared to what would be radiated if the antenna circuit were in resonance with the transmitting set.

The type aerial used at the Missouri School of Mines is an inverted L antenna. This antenna embodies the simplest type of efficient transmitting outdoor structure. The supports are made of cast iron pipe. Each support consists of two sections. The first twenty feet of each mast is three inch pipe. The remaining ten feet is of two and one half inch pipe. The smaller pipe was inserted in the larger for a distance of three feet. A hole was then drilled in the large end all the way thru and an iron bar inserted in the opening. The two pipes were then welded together at this point, the bar acting as a support for the smaller pipe. Lugs were welded on the masts for the purpose of attaching guy wires. The first set of lugs are located a distance of two and one half feet below the joint. Four wires separated by 90 degrees, are hooked to these lugs and are brought down to the level of the base and are tied to the building wall a distance of approximately twelve feet from the base of the mast. There are two guy wires hooked to lugs which are located a distance of five feet from the top of the mast. These are brought down to to the same point as the two wires of the lower set which pull in the same direction as the antenna. The purpose of these latter wires is to pull in a direction which will oppose the buckling effect produced by the aerial.

These masts are located on top of the gymnasium. The bottom part of each mast is flanged and bolted to the board six inches wide, two inches thick and eighteen inches in length. To prevent the base from shifting its position it is braced from all four corners of the wall by four strips of board twelve feet by six inches by two inches. These boards rest on the floor of the tower on which the masts are located and are notched so that they fit around the base of the mast. They are of just the right length to prevent any slipping of the base in any direction. A good idea of these arrangements may be had from the photographs 2-3-5-6 which are shown on pages 34 and 35.

The antenna itself consists of two spreaders which are two inches by four inches by ten feet, and four strands of hard drawn copper wire. Number nine wire was used in this construction. These are attached to the spreaders by means of four inch composition strain insulators which are wired to eye hooks screwed into the spreaders. The spreaders are attached to eight inch insulators, one for each spreader, by means of quarter inch hemp rope. The other end of the insulator is attached to the main rope which runs to the pulley on the mast. This type construction was used because of its high strength and its quality of steadiness in a wind. The tips of the spreaders are anchored to the roof by means of quarter inch strands of hemp rope. This was done to prevent any possibility of turning over and also to insure further stability of the antenna.

The effective height of the antenna is 33 feet above the ground and is 78.6 feet in length. The wires are spaced two feet apart. The lead in is made of four strands of #9 hard drawn copper wire cabled together. These wires are fanned out, the distance from the connections to the apex of the triangle being four feet. The cabled wires are brought in thru a lightning switch to a clamp insulator and thence to a change over switch.

In order to reduce the inductance of the lead out as much as possible all sharp turns were avoided. The lead in wire was brought down to porcelain insulator mounted on a stick. This stick is mounted on the window frame and extends outward and upward a distance of seventeen inches and at an angle of approximately forty five degrees. From this point then, the lead in comes to the lightning switch as previously stated. From the point where the lead in wire leaves the clamp insulator to the change over switch there is one right angle turn. This could not be avoided due to conditions surrounding the construction. The connections from the antenna terminal on the transmitting set to the change over switch and from sending side of this switch to the clamp insulator are of number fourteen insulated copper wire. Larger wire could not be used because of the size binding posts.

In place of using a direct ground connection a counterpoise aerial was used. It was found by experiment that the radiation was increased approximately seventy five per cent over that value of radiation when a ground connection was used. Furthermore, the effective height of the antenna from the ground was reduced approximately sixty five percent, thereby considerably reducing the natural period of the antenna.

The counterpoise used in this case was probably not the best which could be built for the surrounding circumstances; however, the physical structure of the building was such as to encourage the putting up of the type structure used.

As will be seen from the photographs on the following pages, the aerial supports are built on top of the tower of the gymnasium, and set in the center. This leaves about ten feet of the tower under the ends of the masts sticking out in such a way as to prevent stringing the counterpoise in a length equal to that of the antenna. Ordinarily the counterpoise should be much longer and wider than the antenna, but in this case it was possible only to make it wider.

The counterpoise was built in the following manner:

Two spreaders ten feet long and two by two inches in cross section were marked off in eighteen inch sections, beginning at the center and marking each side of the center to insure stability. Eye hooks were then screwed into these marks. Porcelain insulators were wired to these hooks and the counterpoise strands run thru the other ends and tied. The length of the counterpoise from insulators on one spreader to the insulators on the other spreader is 53 feet, 7 inches.

In place of fanning out a cable and tying on to each wire separately, a jumper wire was run across one end of the counterpoise and tied to each wire. The lead out wire was then tied to the center of this jumper. The spreaders are supported by strands of cotton rope tied to a section of the tower. This allowed for rapid changing of height of the counterpoise in case a change in the natural period of the antenna circuit was desired.

The height of the antenna above the counterpoise was found to be thirty two feet at the time the data was taken.

The counterpoise, in its function, is merely a means whereby the ground may be replaced by another medium. Generally the counterpoise is used in places where good ground connections are impossible, such as in rocky or extremely dry earth. The counterpoise replaces the ground, that is, in place of attaching the transmitting set to the regular aerial and ground, it is connected to the regular aerial and the counterpoise.

Ordinarily speaking, the ground is the counterpoise of the usual transmitting set, however in C.W. work it has been found that by use of the counterpoise more radiation can be obtained in most cases, due to the decrease in radiation resistance.

As has been mentioned before, the counterpoise forms the secomd plate of the antenna condenser system. It is of utmost importance that the counterpoise be at least as large as the antenna in all directions. In any case where the counterpoise is much smaller, it acts like a condenser in series with the antenna, thereby cutting down the capacity. In such a case, in order to run the natural period of the antenna circuit up it is necessary to put considerable loading inductance in series with the antenna thereby greatly increasing the resistance and cutting down the radiation efficiency.

The Transmitting apparatus.

The transmitting apparatus used at the Missouri School of Mines consists of a model ET-3619 Radio Transmitter and a model ET-3620 Kenotron Rectifier. This apparatus was furnished by the Radio Corporation of America.

The design of the Radio Transmitter Model ET-3619 incorporates circuits used in commercial hook ups, including the Heising scheme of modulation. Ample clearance between all high tension leads and circuits has been provided. Bus wiring has been used thruout to secure freedom from breakdown and ready accessibility to circuits. All metal parts are grounded to the frame in order to insure against shock.

External connections are made in the rear so that the installation provides a neat appearance. The tube sockets are on cushioned cradles to prevent vibration and the resultant distortion of signals.

The transmitter is designed for operation on telephone, C.W. and interrupted C. W. The method of signalling is controlled by a two position switch: one for telephone and the other for key operation. In order to secure I.C.W. an externally connected motor driven chopper must be placed in the circuit. The rated output of the transmitting set is twenty watts on C.W. and ten watts on the phone.

In order to operate the set the following supply is required:

1) .16 amperes at 350-400 volts D.C.

2) 10 amperes at 7.5 volts A.C.

3) 6 volts D. C. (Battery)

The wave length of the set depends largely upon the characteristics of the antenna circuit with which it is used. A range of about 180-240 meters is obtained on the antenna at M.S.M. By loading the antenna circuit wave lengths up to three hundred meters have been obtained.

The Kenotron Rectifier

The kenotron rectifier, model ET-3620, is especially designed to operate in conjunction with the model ET-3919 transmitter. It is arranged to operate on a power supply of 102 1/2 to 115 volts, single phase, 50 or 60 cycle, current.

The main functions of the rectifier are as follows:

1) The 110 A. C. supply is stepped up by a transformer to approximately seven hundred volts and rectified by the kenotron tubes.

2) The output of the rectifiers, which is a pulsating direct current, is smoothed out by means of a filter system which is embodied in the rectifier unit. This is absolutely necessary, otherwise the signals which are transmitted would be greatly distorted.

3) The supply voltage is stepped down to the operating voltage of the tube filaments by means of taps on the main power trans.

The rectifier delivers the following output under normal conditions:

.16 amps at 400-450 volts D.C.

10 amps. at 7.5 volts A.C.

On the front of the panel of the rectifier unit there is a tumbler switch for main line control and a voltage control switch. The latter changes the taps on the primary side of the power transformer so that practically constant secondary voltage may be maintained.

Four UV-216 kenotron tubes are used as rectifiers. Back of the panel are mounted the filter reactor, filter condensers, and power transformer, the latter providing filament excitation for both kenotrons and radiotrons as well as plate supply for the kenotrons.

<u>The Radiotron Unit.</u>

This unit performs two functions.

1) The power supplied to the plate circuits in the form of high voltage D.C. is converted into radio frequency energy.

2) For telephony, the CW switch on the panel of the radiotron unit, changes the connections over to the Heising scheme of modulation.

The operations which are automatically performed by the signal switch are as follows:

In phone position:

1) Selects plate tap on oscillation transformer.

2) Connects modulator plates to plate reactor.

3) Connects modulator grids to microphone transformer.

4) Short circuits the telegraph key.

In C.W.position:

1) Selects plate tap on oscillation transformer.

2) Parallels modulator and oscillator tubes.

3) Parallels modulator and oscillator grids.

4) Short circuits biasing resistance.

Operation of the Set

In every case where the station is licensed, a specified wave length is designated. This, of course, necessitates the adjustment of the set to this wave.

In making these adjustments the primary consideration is to get the maximum possible radiation without overloading the tubes. Assuming that the natural period of the antenna circuit is within the range of the set so that too much forcing of the oscillations is not necessary, the max radiation will be obtained when the antenna circuit is made to be in resonance with the transmitting apparatus.

The frequency of oscillations of the set is governed by an oscillation transformer and an antenna condenser. The location and method of connection may be ascertained from the wiring diagram on page .

In starting up the set for the first time the following procedure was adhered to:

Signal switch was placed in the C.W.position and the antenna condenser placed at fifty degrees. The ground tap, CW tap, antenna tap and phone tap were placed on the oscillation transformer at random. The transmitting key was then short circuited and the line current turned on.

At first there was no reading noticed on the ammeter. This was due to the set not oscillating. The taps on the oscillation transformer were changed slightly and the current again turned on. This time a reading of three tenths of an ampere was noticed. After making several adjustments a maximum reading of one and seven tenths of an ampere was read. When the wave meter was placed near the set for this adjustment it was noticed that the wave length was one hundred and fifty meters: the set was then readjusted until it read two hundred meters. This cut the radiation down to one and four tenths amperes.

For operation on the phone, the switch on the panel was placed on the phone position and the line switch turned on. It was found to be necessary to readjust the antenna condenser before the set would oscillate at two hundred meters. This was probably due to the added capacity and inductance of the phone circuit. The wave length went up in place of going down is the reason I reached this conclusion.

Wiring diagrams for both the rectifier unit and the oscillator unit are given on pages 32, 33 and 34. These give clearly the scheme of connections altho the drawings are very much simplified.

Theory of the Oscillation unit.

The electron tube can be made to generate high frequency currents and thus act as a source of radio current for the transmission of signals and other purposes. Any regenerative circuit can be made to generate spontaneous oscillations, if it is so arranged that any change in grid voltage makes a change in plate current of such magnitude that there is induced in the grid circuit a larger voltage than that originally acting. In any electron tube much more power is produced by variations in the current to the plate than must be expended in changing the grid voltage to produce these variations. There are a great variety of circuits in which the plate circuit is coupled back to the grid circuit in such a manner that this small power is supplied to the grid and makes the surplus power available for use in an external circuit in the form of continuous or undamped waves of any frequency from less than one per secomd to ten million or more. This feed back action can be obtained by the use of direct coupling from the plate back to the grid circuit, by inductive coupling or by electrostatic coupling. The only requirement for continuous oscillations is that the voltage induced in the grid circuit must vary the plate current thru an amplitude which supplies to the external or coupling circuits power sufficient or more than sufficient to maintain this voltage in the grid circuit.

The feed back system used in the set at The Missouri School of Mines is the direct coupling method. This may be readily seen from the wiring diagram given on page 32.

Scheme of Modulation

The function of a modulating device in radio communication is to vary the output current of the oscillating unit at a frequency or frequencies lower than the radio frequency involved. In a certain sense, practically all radio communication using single wave length signals is by a modulation method. In C.W. transmission, the keying by which the signals are conveyed constitutes a dot and dash modulation of the antenna current. In the operation of a spark and other tone transmitters, the radio frequency wave trains are sent out at more or less regular intervals at an audio frequency, so that an audible note is heard, upon rectification with a detecting device. In addition to this audio modulation, a second order of dot and dash modulations is required for conveying the telegraph signals. In radio telephony the message which is conveyed depends upon the first order modulations. The antenna current is made to vary, not at a single tone frequency, but with frequencies and in degrees corresponding to the pitches and intensities of the sound waves produced by the voice of the speaker. In consequence, upon rectification of the received radio signals, there are produced in the receiving telephones electrical currents which are precisely the same nature as would be produced by communication by wire telephony.

With the generating device of the electron tube generator speech modulation is accomplished usually by one of three general methods. The simplest is by variable absorption of the radio frequency output of the circuit, as, for example, by the insertion of a speech operated microphone in the antenna lead from a continuous wave generator. A different method of variable power is by shunting the generator tube, or parts of the output circuit, with another electron tube. The grid voltage of this power absorbing tube is varied at speech frequencies by the use of a microphone and speech transformer. The combination of microphone and power tube is capable of absorbing more radio power than the microphone itself would be able to handle, otherwise the operation is quite similar to modulation with a microphone directly in the antenna lead.

A second method of modulation is by varying the operating grid voltage of a generating tube at speech frequencies. In such apparatus the secondary of a speech transformer is inserted in the grid lead, this secondary being shunted with a radio condenser so that the operation of the generator circuit will not be influenced by the high reactance of the transformer windings. A microphone and battery in the primary of the transformer cause variations in the average grid voltage taken over successive radio cycles, and therefore change the operation of the radio generator. This method of modulation is not extensively used, chiefly because the radio frequency output of the generator is usually not readily altered by varying the operating grid voltage. This, of course, produces distortion. The grid voltage operating point is important in determining efficiency, but not the output current, provided the conditions are such that good articulation results. By reducing the operating grid voltage on a generating tube sufficiently, usually a point is reached at which the oscillation suddenly breaks and the radio output current immediately drops to zero. Grid modulation which thus cuts off the antenna current suddenly and completely results in very poor articulation. While with careful adjustments the breaking of the oscillation may be sufficiently gradual to permit good speech, this method is not considered to be one in which the modulation process is inherently reliable in telephone sets.

A third method of modulation is by varying the input plate power of a generating circuit; that is, the average plate voltage and plate current of the generating tube or tubes of a radio circuit are caused to vary at the lower or modulating frequencies. This method is employed in practically all present commercial sets and is the type modulation used in the set at the Missouri School of Mines. It possesses the advantage over the first method in that practically all the radio power is used in the transmission signals. On account of the nearly linear relations between cause and effect with this method, it is inherently superior to both the other methods as to articulation. In the transmission of speech signals, the plate power of the generating tube is altered by the use of a power tube which from its functioning, is called a modulator tube.

This last scheme of modulation is due to Heising. A complete diagram of this system is shown on page 34. In this system (see diagram) the part to the left of the dotted line represents the oscillator circuit. When the telephone transmitter is not operative the potential difference across the points Q and O is constant, and hence the amplitude of the high frequency antenna current, as well as the plate current for the modulator tube is constant. However, if the telephone transmitter is spoken into,electromotive forces are induced in the coil S, which change the potential of the modulator grid in accordance with the vibrations of the transmitter; this changes the plate current of the modulator or the current between the points Q and P, this change taking place at speech frequency. In virtue of this the battery B will be called upon to supply a current varying at audio frequency, which current must flow thru the iron core inductance D; since the impedance of this is very high at audio frequency, it follows that it will cause a large audio frequency drop of potential over itself, and thus the potential difference between the points Q and O will be varied at audio frequency and in accordance with the vibrations of the telephone transmitter. Again, since the potential difference impressed upon the plate of the oscillator (across Q and O) is being varied, it finally follows that the amplitude of the antenna current increases with increase of the plate voltage, and will vary with this increase. Thus, the vibrations of the telephone transmitter are finally reproduced in the antenna as variations in the amplitude of the antenna current or, in other words, the antenna current is thereby modulated.

The function of the coil D may be more clearly seen if the coil were assumed to be short circuited. Under these conditions, no matter how much the plate current were caused to vary by the action of the transmitter, the potential difference across the points Q and O would remain constant, and no change would be effected in the amplitude of the antenna current.

The function of the choke coil A, which is an air core coil, is to prevent the plate circuit of the modulator tube from taking from the antenna circuit any of the high frequency power which the oscillating tube is supplying to it; the proper amount of inductance for coil A depends upon the types of tubes used, but, in general, its reactance should be considerably greater than the plate circuit resistance of the modulator tubes.

The essential operation of the modulator tube in the modulator unit is as an aperiodic amplifier; the essential load into which the tube operates is a resistance as given by the external characteristics of the generating unit.

Procedure for obtaining data.

Considerable difficulty was encountered in getting the constants of the antenna circuit. Due to the high frequency character of the current it was impossible to use any resistance in the circuit which was inductive. In order to obtain the correct value of the antenna resistance it was necessary to use a long section of resistance wire supported by some insulating material to prevent grounding. In this case a piece of resistance wire about thirty feet long was strung around the room, one end being attached to the antenna connection of the transmitting set, the other end being left open.

With the resistance wire out of the circuit the transmitting set was turned on and the maximum reading on the antenna ammeter read. The antenna lead was then disconnected and the resistance wire put in its place. The outgoing lead was then tapped on to the resistance wire until the radiation was reduced exactly one half. This, then, gave directly the antenna resistance. This value of resistance also includes the resistance of radiation.

In order to determine the natural period of the antenna it was necessary to excite the antenna circuit with the transmitting set. The wave meter was not sufficiently strong to excite the antenna circuit. That is, when the wave meter was placed in such a way as to link the aerial, insufficient energy was radiated to be heard in the phones in the antenna circuit. The transmitting set was then used.

A few turns of wire were placed in series with the antenna circuit and placed in such a manner as to link the flux around the oscillation transformer of the transmitting set. The search coil, that is, the few turns of wire, were then placed in series with a hot wire ammeter. The transmitting set was then turned on and reading taken on the ammeter. The wave length of the transmitting set was varied by means of the oscillation transformer and the antenna condenser until maximum reading was obtained on the antenna ammeter. The antenna circuit was then assumed to be in resonance with the transmitting set. The wave length was read from the wave meter.

The inductance was determined by means of the same hookup. When maximum reading was obtained on the ammeter, the set was left as it was and some calibrated inductance placed in series with the antenna. The same procedure was followed as before, reading the value of inductance and the wave length when maximum reading on the antenna ammeter was obtained.

With the natural period of the aerial known and the inductance known, the capacity was calculated from the formula: Wave length = $1885 \sqrt{LC}$.

Data and calculations.

Determination of antenna resistance:

Voltage applied to resistance = 3.75

Current thru resistance =.2075 amperes.

The resistance of the antenna from the above values of current and voltage = 18.07 ohms.

Determination of natural period of antenna:

Maximum antenna current was induced when the wave meter read 155 meters. This then was taken as the natural period.

Inductance of the antenna circuit:

In this determination the capacity of the antenna circuit was assumed to be constant, no change being due to the added inductance.

The variable inductance was placed in series with the antenna circuit and the taps on the oscillation transformer changed along with the variable inductance until a reading on the antenna ammeter was obtained. This was refined by adjusting the inductance until maximum reading was obtained. The wave meter reading was taken at this point.

Wave meter reading= 265 meters. The phantom antenna and capacity in parallel was necessary before the transmitting set would reach this value. The reading on the inductance was found to be .150 Milli-henrys.

$$155 = \sqrt{LC} \times 1885$$

$$265 = \sqrt{(L+150)+C} \times 1885$$

solving for L from above; L = 78.5 Micro henrys.

substituting in the above equations the value of C for the antenna was found to be .0000865 Micro farads.

No reasonable check was made on the value for C. According to the formula given on page 4 of this thesis the following results were obtained:

A= 720 sq. ft. or 73.5 sq. meters.

h= 32 feet, or 9.85 meters.

Substituting in the formula given

$$C = 40 \sqrt{73.4} + 73.5/9.85 \quad \times 8.85$$

C= .000411 micromicro farads.

This above given value of the capacity is probably off, due to the fact that a counterpoise was used in place of a regular ground connection. The area of the counterpoise was so much smaller than the antenna that considerable error naturally would result. Furthermore, the height of the antenna was taken to be the height above the counterpoise. The effective height of the aerial, being so far above the ground, would probably introduce considerable error also.

Explanation of Photographs:

Number one shows the arrangement of the transmitting apparatus including the relative positions of the key and microphone.

Number two shows an arrangement of the lightning switch and the clamp lead in insulator. It also shows the spring copper connection.

Number three shows the aerial and aerial support. Note the relative position of the counterpoise.

Number four shows the means of bracing the bottom of the mast to prevent slipping.

Number five shows the means of supporting the lead in wire to prevent sharp turns. The ground wire connection to the lightning switch may be noted in the bottom of the picture.

Number six is a picture of the mast. This picture shows the lugs which were used for bracing the aerial support. Note the joint where the size of pipe is reduced.

Number seven shows the counterpoise. This picture is not very clear but a general idea may be had. Note the two spreaders. This picture was taken from the top of the south tower.

Number eight shows the north tower and the section of the antenna which it supports.

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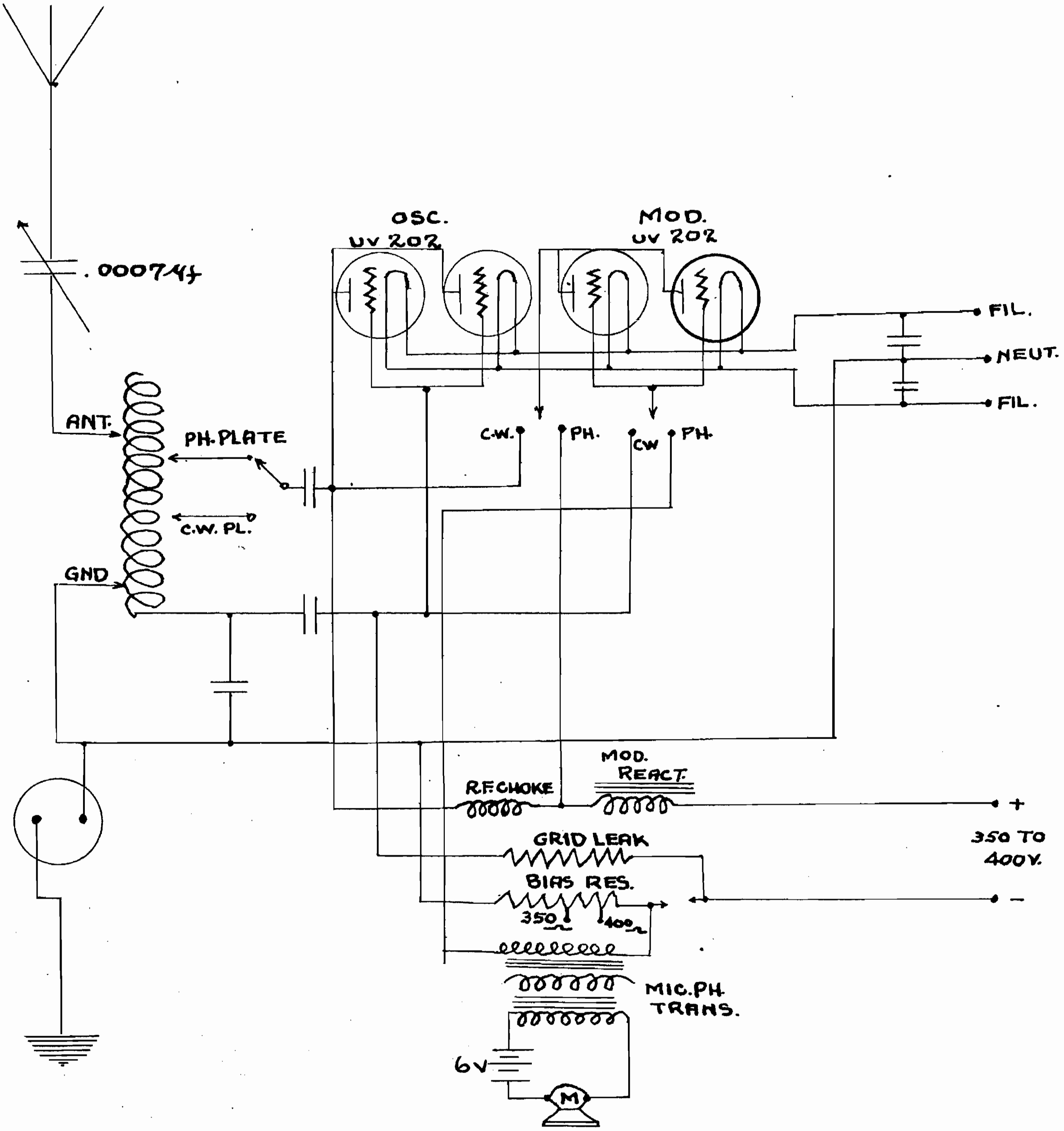
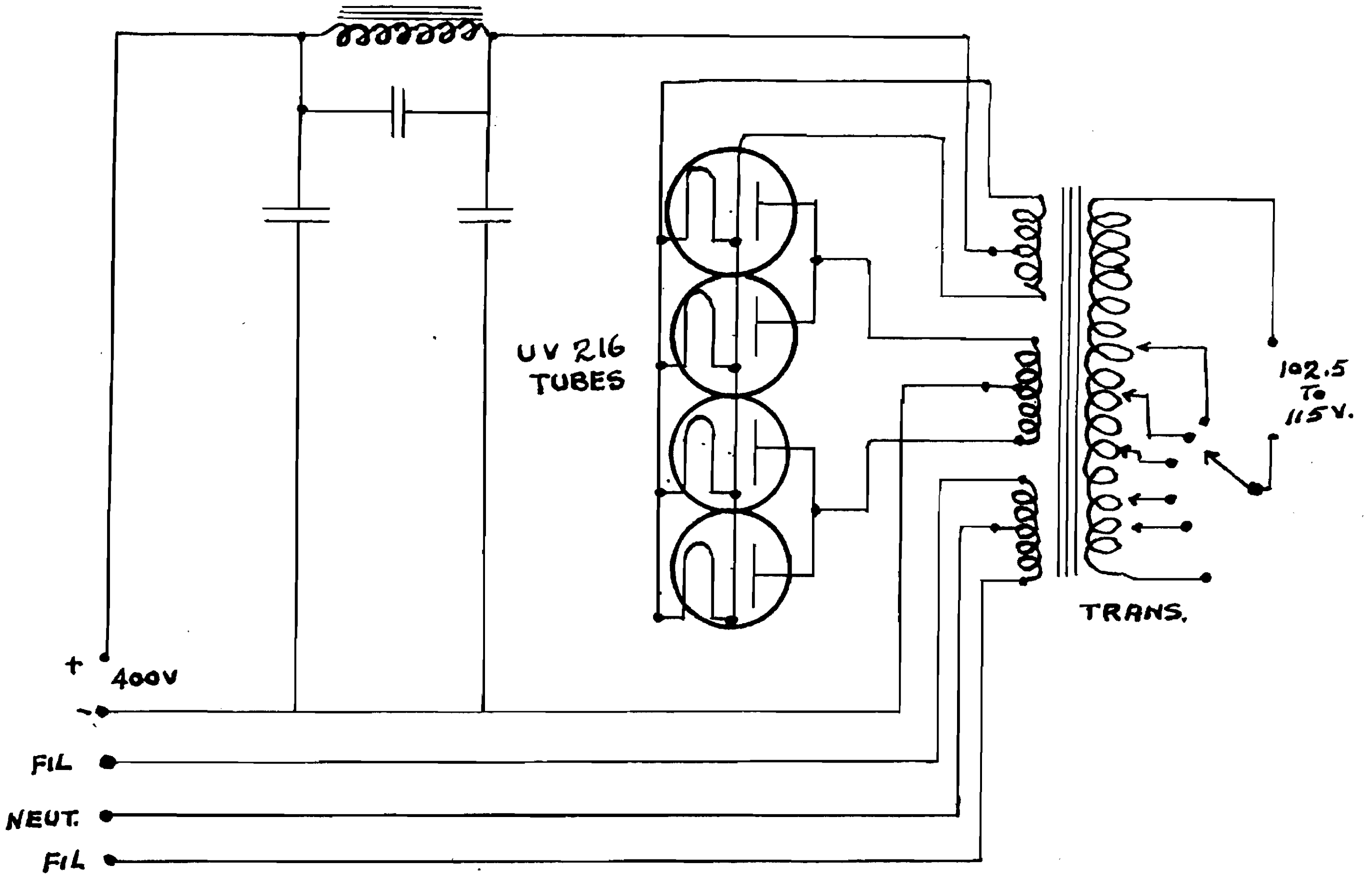
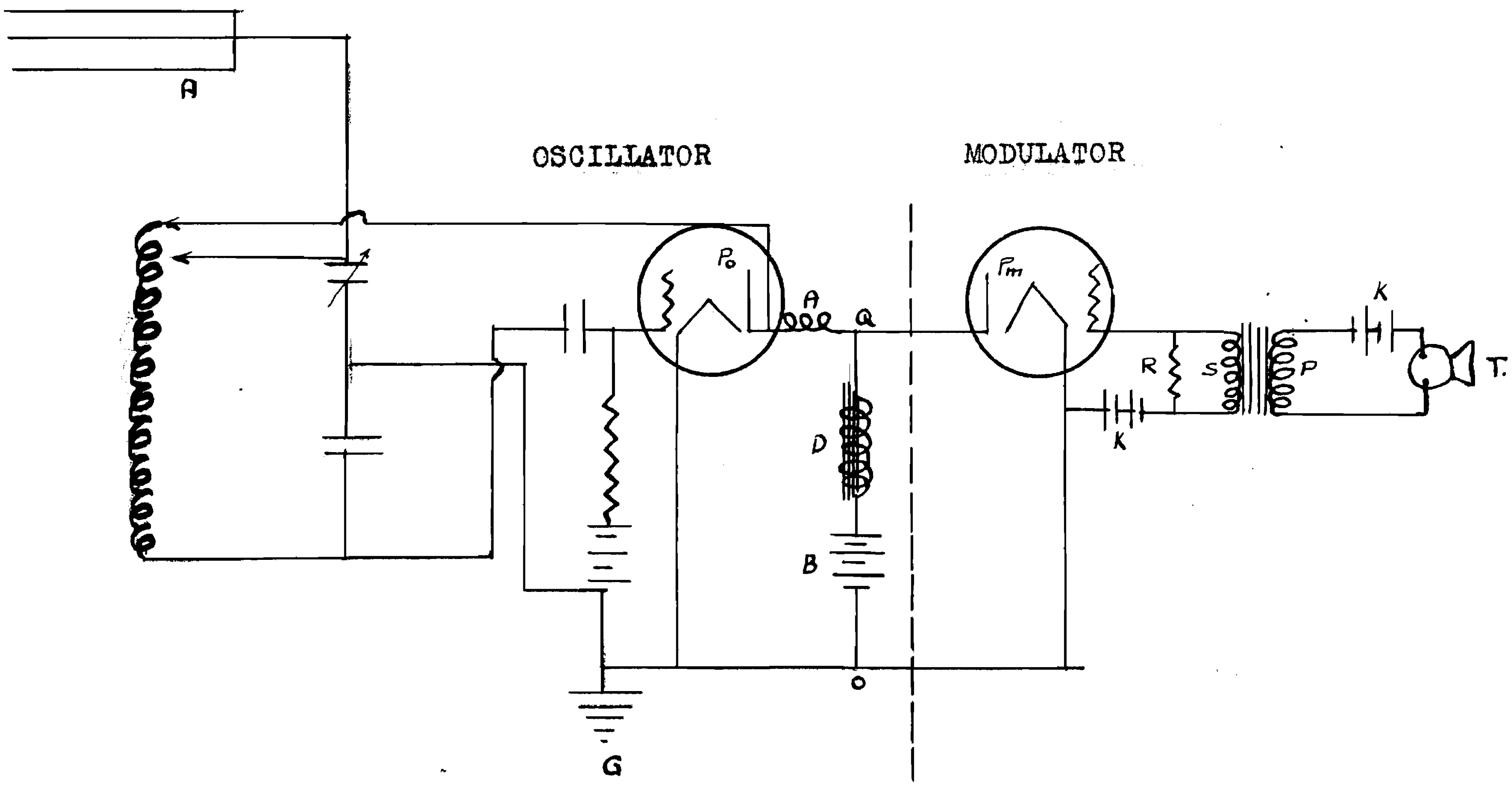
Scientific Paper No. 74.............Bureau of Standards.

WIRING DIAGRAM OF OSCILLATOR UNIT.



WIRING DIAGRAM OF KENOTRON RECTIFIER

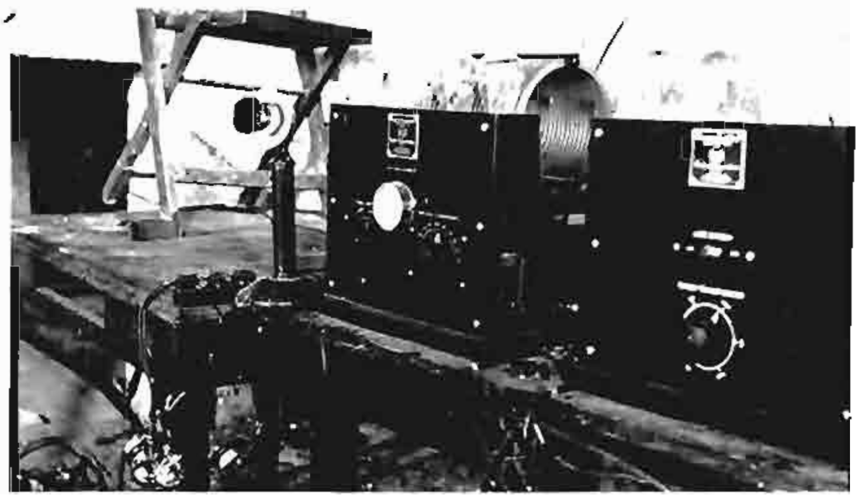




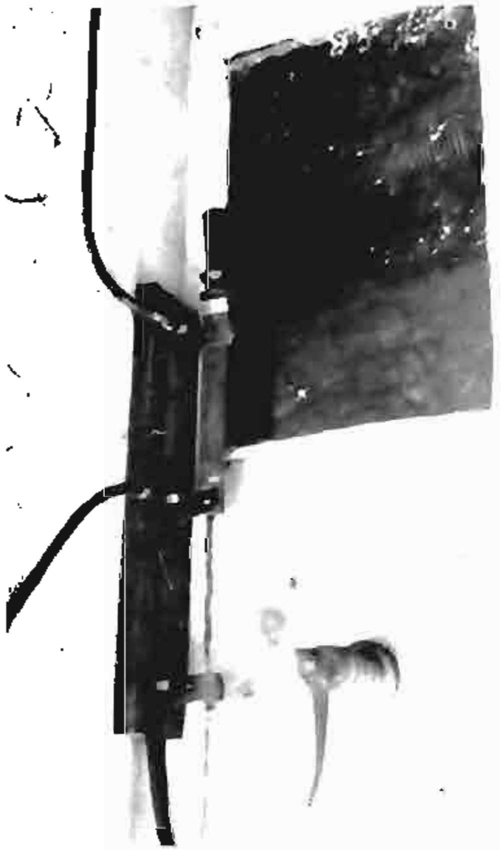
WIRING DIAGRAM SHOWING THE

HEISING SCHEME OF MODULATON

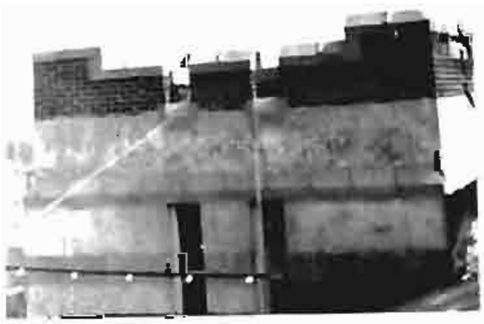
1



2



3



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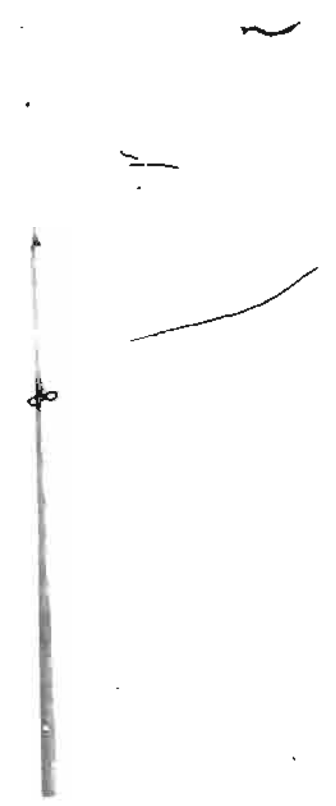

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