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CONTENTS

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WASHINGTON SECTION

BOSTON SECTION

SEATTLE SECTION

SAN FRANCISCO SECTION

THE DEVELOPMENT OF TUBE TRANSMITTERS BY THE TELEFUNKEN COMPANY*

By

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As a result of the development of thermionic amplifiers for transmitting and receiving purposes, radio engineering has been practically revolutionized during the years of the war. The basis of this development was the principle of reaction coupling, as it was given in its general form by the author in March, 1913, for receivers and transmitters.[1] The first researches carried out by the author were with the well-known Lieben tubes, which had oxide-covered cathodes and were filled with gas. It was possible, as early as June, 1913, to carry on two-way telephonic communication between Berlin and Nauen, a distance of 36 km. (22.5 miles). At that time, the transmitter was of small power (10 to 15 watts). The life of the tubes when loaded to this extent was short, since the gases in the tube were gradually used up or absorbed; nevertheless, for small powers and with plate voltages of 220, the transmitters of that time were very useful in practice and of great significance in connection with beat reception. At that time, the Fessenden beat reception method had only a theoretical value, since no practically useful and constant auxiliary oscillator was available. By using a heterodyne oscillator in combination with a detector in the receiving system, the author succeeded in producing a receiving arrangement which immediately displaced all other methods for the reception of continuous oscillations. This method of reception was first suggested by the author in March, 1913, was developed in common with Franklin and Round in the dirce-

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* Received by the Editor, July 2, 1921. Translated from the German by the Editor.

[1] German patent 291,604 of April 10, 1913. The first claim of this patent covers "an electric relay provided with an incandescent cathode or ionized conducting path, which is connected to a circuit capable of oscillation, both on its input (primary) and output (secondary) sides, so that any oscillations originating in the circuit will be amplified by the relay and thereafter sustained by it."

tion of placing the tube with its reaction coupling in the receiving circuit itself, and thus permitting it to function simultaneously as a radio-frequency amplifier, as a device for the reduction of damping, as an oscillator, and also as a detector.[2]

Furthermore, the external oscillator made possible for the first time high power trans-Atlantic service between Nauen and America. At the beginning of October, 1913, the first heterodyne oscillator arrived in America. It was then used by Messrs. Pichon and van der Woude to receive signals originating from the alternator transmitter at Nauen. It was possible to receive the new high power alternators (8,000 cycles, 100 kw., with two steps of frequency doubling) on October 18, 1913, and thereafter to maintain the service. Figure 1 shows the apparatus used in Sayville for this purpose. The excellent results obtained by this new method of the producing oscillations aroused

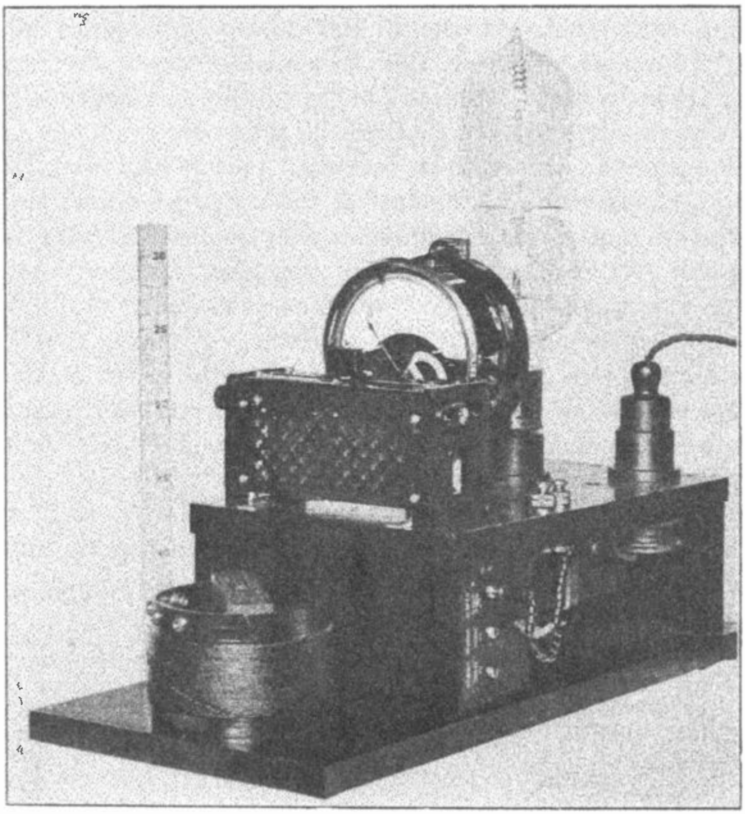


FIGURE 1

[2] German patent 290,256 of July 16, 1913, and English patent 13,636-13 of June 12, 1913.

great interest in professional circles, and led to the result that the same vigorous investigation of this subject was carried out in America as in Germany and England.

It was attempted to increase the short operating life of the Lieben tubes by using self-renewing oxide-covered cathodes, various sorts of gas content for the tubes, and automatic valves for admitting air to the device. However, the limitations of output remained. Since the middle of 1913, the Telefunken Company has also investigated high vacuum tubes as well as gas-filled tubes, and, by the beginning of 1914, had completely gone over to the use of high vacuum tubes for reception. The establishment of its own vacuum pump installation and tube factory by the Telefunken Company, under the direction of Dr. Rukop, led to the work proceeding more rapidly, and since March, 1914, it was possible to carry on vigorously the production of high vacuum transmitting tubes as well. Figure 2 shows the first high vacuum tubes for transmission, dating from the beginning of 1915. They were built with open construction. The right-

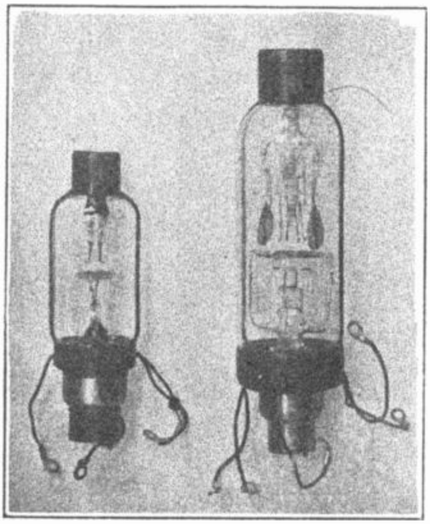


FIGURE 2

hand tube is seen to be provided with metal plates on each side of the filament in order to prevent electron streams which are produced by the magnetic field of the filament from reaching the glass walls. Figure 3 illustrates the first high vacuum tube transmitter (beginning of 1915).[3] This set was built for teleg-

[3] "London Electrician," 1914, page 702.

raphy and telephony on a single wave, and receiver and transmitter were in the same case. The circuit is shown in Figure 4. The intermediate circuit is provided by the coils L_1 and L_2 and the variable capacity C. The grid is connected across a portion of the coil L_1. The plate voltage is obtained from the coil

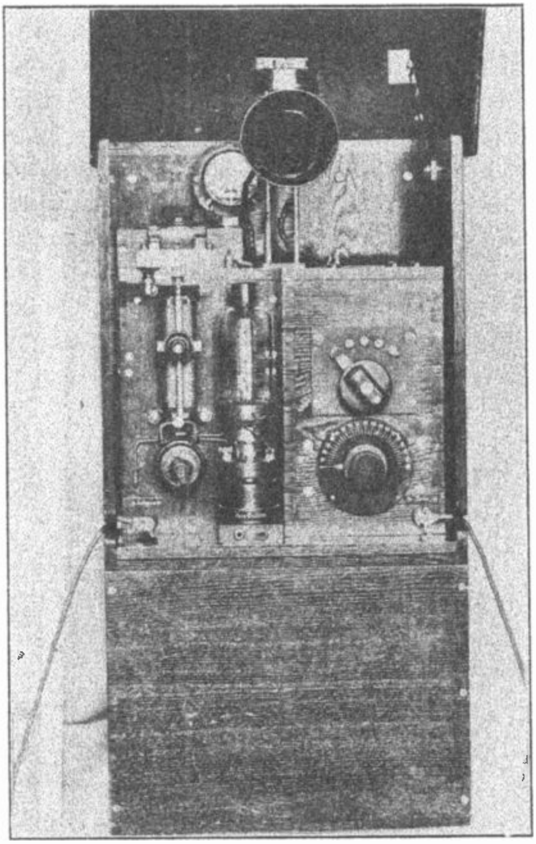


FIGURE 3

L_2. C_2 is a blocking condenser. The antenna is loosely coupled to the system thru a few turns of L_1. The plate voltage of 1,000 volts was provided by dry cells which were placed in the lower case of the transmitter. The filaments were lead by six-volt storage battery. The output of the transmitter was from 10 to 15 watts. Electrically considered, this is practically the same arrangement as the transmitter used experimentally by the Allies at the end of 1917 on the West Front.

In view of the great demands on the Telefunken Company's factories in connection with the production of receiving amplifiers, at that time, the further development of the tube transmitter was limited for a time. Because of this situation, it be-

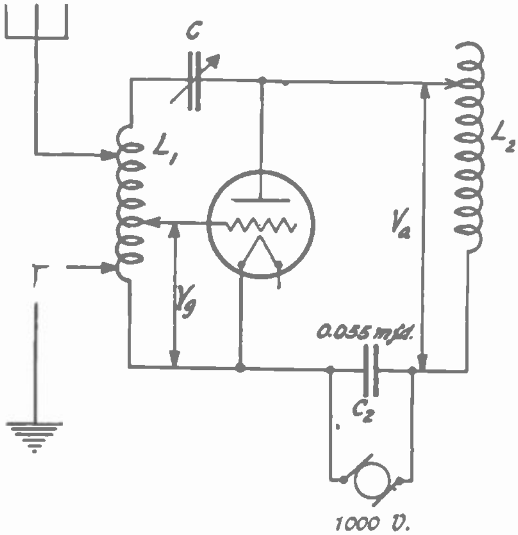


FIGURE 4

came necessary to develop high vacuum technique from the very beginning, and a whole series of physical and mechanical problems had to be solved. The work of Langmuir became known in Germany in 1915. A particular difficulty was experienced in the construction of the grid, and in securing it firmly in place. After attempts, lasting for months, to wind the grid on frames of hard glass, a satisfactory solution was found in the use of a construction due to the author wherein the grid was wound upon its own metal frames. This was so simple a matter that fine wire and narrow mesh grids, such as are necessary for tubes of high efficiency, were readily produced. Several forms of modern tube construction are shown in Figure 5. The plates are almost always made of tantalum sheet, the grids of tungsten. The usual sizes of tube deliver outputs in the antenna of 10, 75, 200, 500, 1,000, and 2,000 watts respectively. For higher powers, tubes are placed in parallel, as many as 20 being used in this fashion. Disturbing short waves, of approximately 100 meters wave length, appear quite regularly under such conditions, but are eliminated thru the use of small capacities, inductances, or resistances between the grid and filament or in the plate leads.

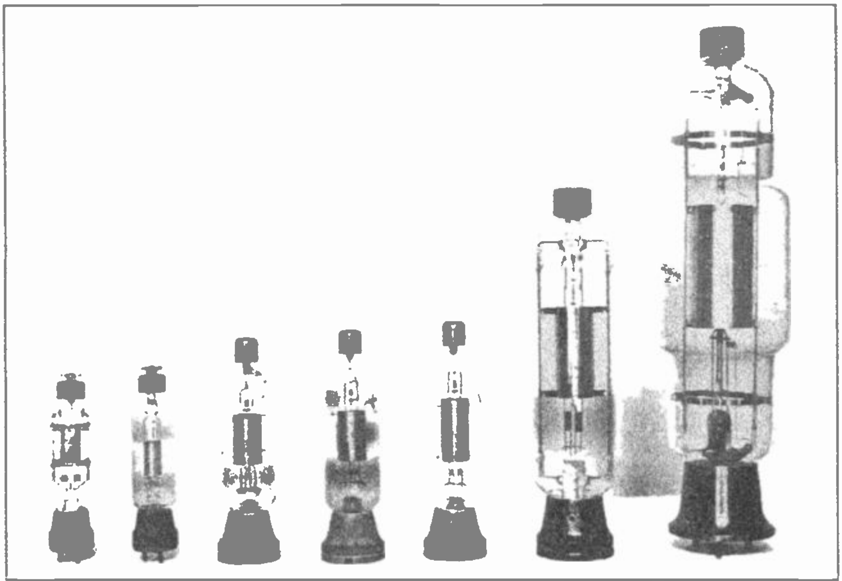


Figure 5

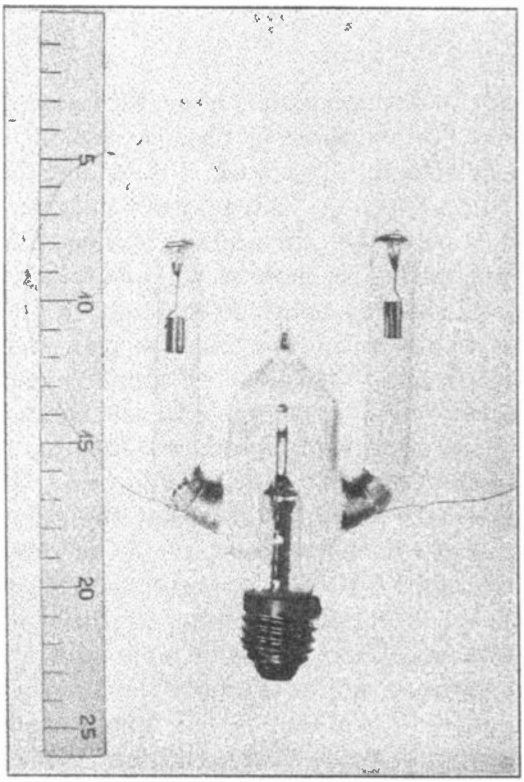


Figure 6

As sources of power for the plate circuit the following are available:

—for voltages up to 500, small direct current converters (dynamotors) with a single armature, operated from a 12-volt storage battery.
—from 1,000 to 2,000 volts, direct current generators.
—up to 3,000 volts, 50-cycle or 500-cycle alternating current, converted into direct current by an oxide cathode argon-filled rectifier produced by the Haagener Storage Battery Manufacturing Company.
—for voltages above 3,000, kenotrons or mercury arc rectifiers

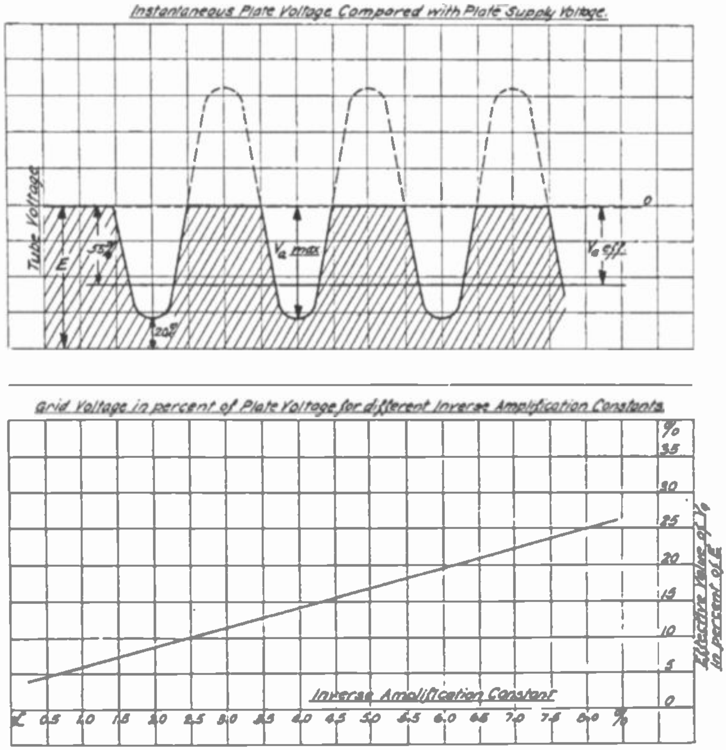


FIGURE 7

The bases of the design of transmitters are always the simple relations which exist between the radio frequency voltages impressed on the plate and grid and the direct current supply voltage The effective alternating plate voltage is 45 to 60 percent of the direct current supply voltage (as shown in Figure 7, part 1), the grid voltage from 4 to 20 percent. Figure 7, part 2, shows the relation between the grid voltage and the inverse amplification constant.[4] If the output of any particular tube is known (for

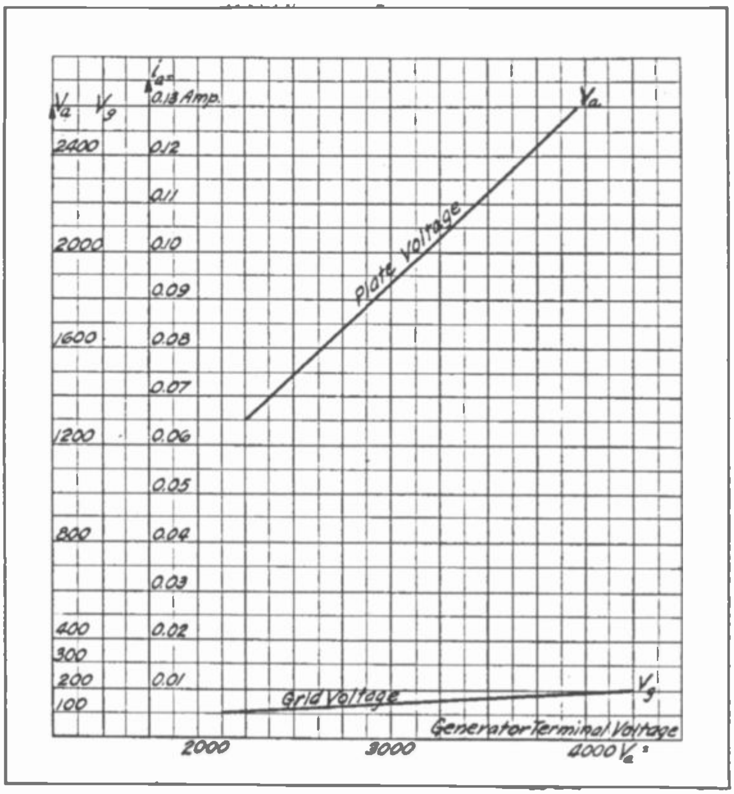


FIGURE 8

example, Figures 8 and 9 show the working curves of a 500-watt tube), and also the resistance of the oscillation circuit, then there can immediately be obtained for a transmitter with any chosen supply voltage and wave length, the values of the inductance or capacity which must be connected to the grid and plate. The condition which must be satisfied is that the above plate and grid voltages using inductive coupling must be equal to

$$2 \pi n L I$$

or using capacitive coupling

$$\frac{1}{2 \pi n C} I$$

[4] (The term "Durchgriff" has been translated as "inverse amplification constant" since it is the reciprocal of the amplification constant, as defined by van der Bijl (PROCEEDINGS OF THE INSTITUTE OF RADIO ENGINEERS, 1919, page 106) and Carson (PROCEEDINGS OF THE INSTITUTE OF RADIO ENGINEERS, 1919, page 188).—EDITOR.)

regardless of whether the grid and plate have voltage applied to them directly or thru an oscillating circuit. If high efficiency is required, it is desirable to couple the plate circuit more closely to the oscillation circuit and the grid circuit more loosely. In

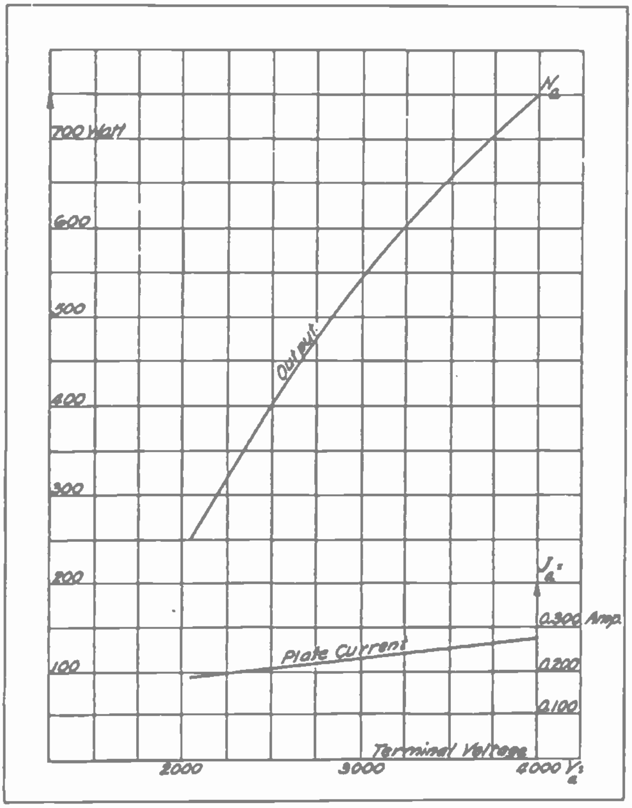


FIGURE 9

order to draw still greater output from the tube, there are produced in the plate circuits currents of special wave form (Rukop) or else an auxiliary voltage of triple frequency is impressed on the grid (Meissner). The losses are then greatly reduced, since during the operation of the tube the time during which the highest voltages are applied to the tube is reduced, and, furthermore, because at the time when the highest voltages are applied to the tube, the passage of current thru it is prevented. Under such conditions there will be produced powerful overtones or harmonic oscillations of higher frequency. When using transmitters directly coupled to the antenna circuit, such harmonic currents are avoided by the use of absorbing circuits or of an intermediate circuit, or by the control of a power tube amplifier by a small tube oscillator (German patent 298,484, Meissner).

Several forms of a modern transmitter will be described below. In the first transmitters, an inductance in the grid circuit was generally used either with or without grid circuit tuning, and more or less closely coupled to the plate circuit, either inductively or capacitively. In the latter transmitters, using more stable tubes, practically only direct coupling between the grid and plate circuits was employed. Figures 10 and 11 show a small type of transmitter, with an output of 20 watts, for use in the trenches. In order to meet the difficult military requirements for such a transmitter, it was designed for a continuous wave length range of from 300 meters up to almost 2,000 meters. The oscillating

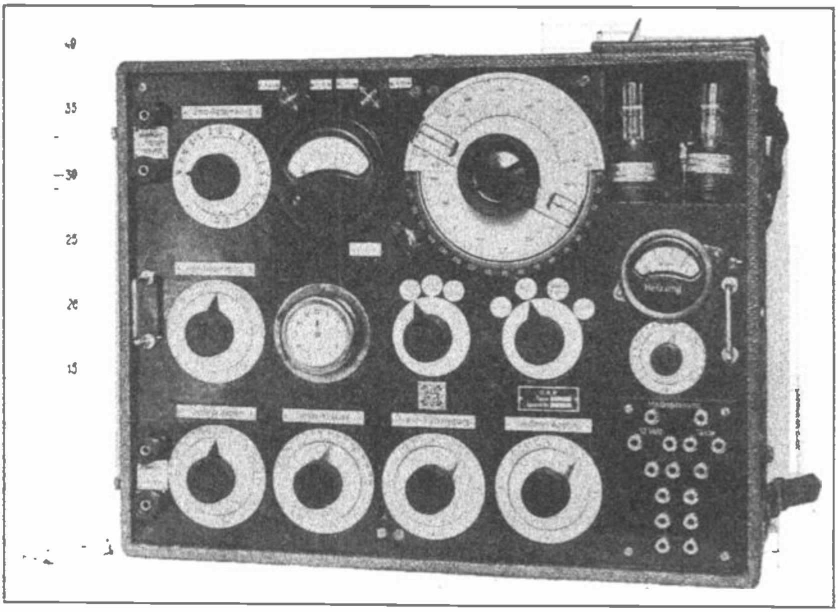


FIGURE 10

tube receiver is contained in the same case. The transmitter can be used with any desired antenna. These requirements could be met only thru providing the transmitter with an intermediate circuit.

An aircraft transmitter and receiver are illustrated in Figure 12 and shown with the cover removed in Figure 13. In this case as well, a long range of wave lengths from 300 to 750 meters is

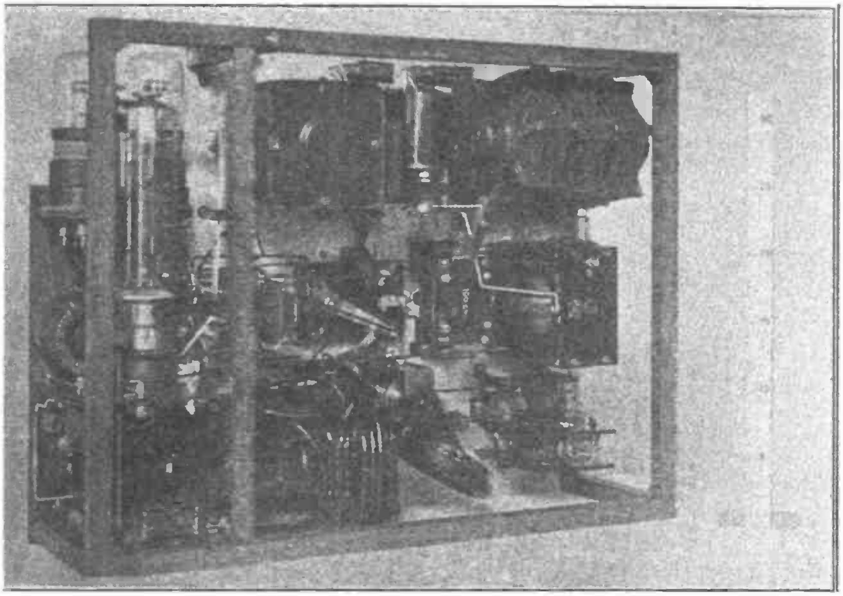


FIGURE 11

provided. The transmitter is set to a definite wave length while on the ground, and the antenna is tuned in flight. The operator then has no further opportunity to alter the circuits. For radio telephony, the microphone transmitter is generally inserted into the antenna.

A very simple 20-watt transmitter for use on two wave lengths is shown in Figure 14. It is arranged for two-way opera-

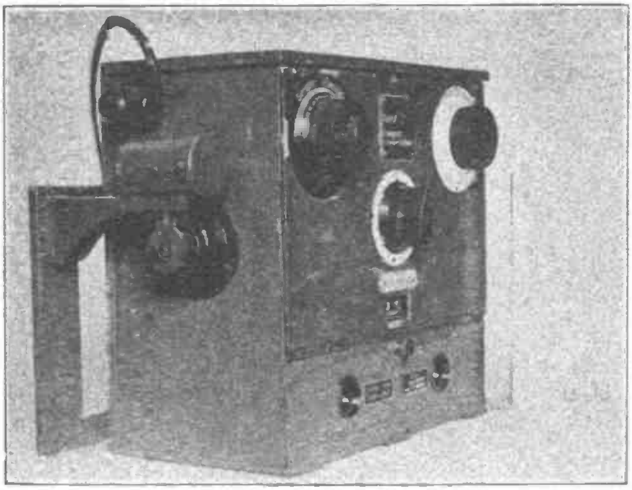


FIGURE 12

tion. The right hand case contains the tuning circuits necessary for this purpose, together with the tube detector and three-step amplifier. This set is intended for radio telephony between fishing boats. The speech voltages in this set are introduced into the grid circuit in series with the radio frequency voltages.

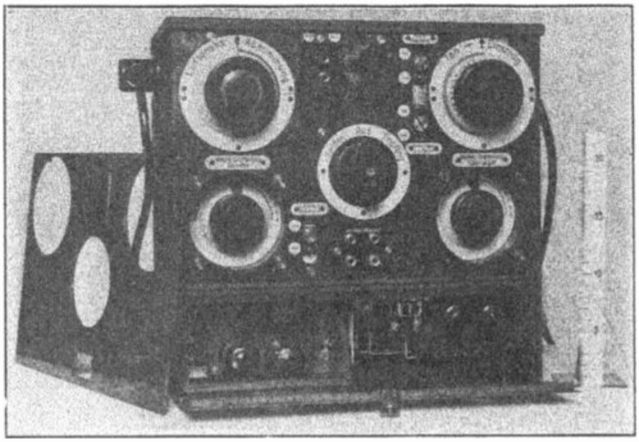


FIGURE 13

Figure 15 shows the schematic circuit of a one-kilowatt tube transmitter. Both filament and plate voltages are obtained from the same 500-cycle alternator of 1.5 kw. output. The transmitter is provided with two 500-watt tubes, requiring four amperes and six volts for the filaments; while the alternating current is rectified by an oxide cathode rectifier using five amperes and two volts. T_1, T_2, and T_3 are the three filament cur-

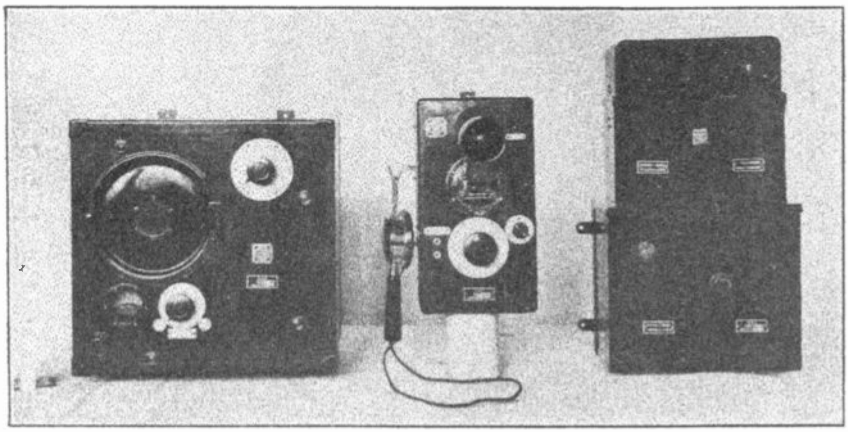
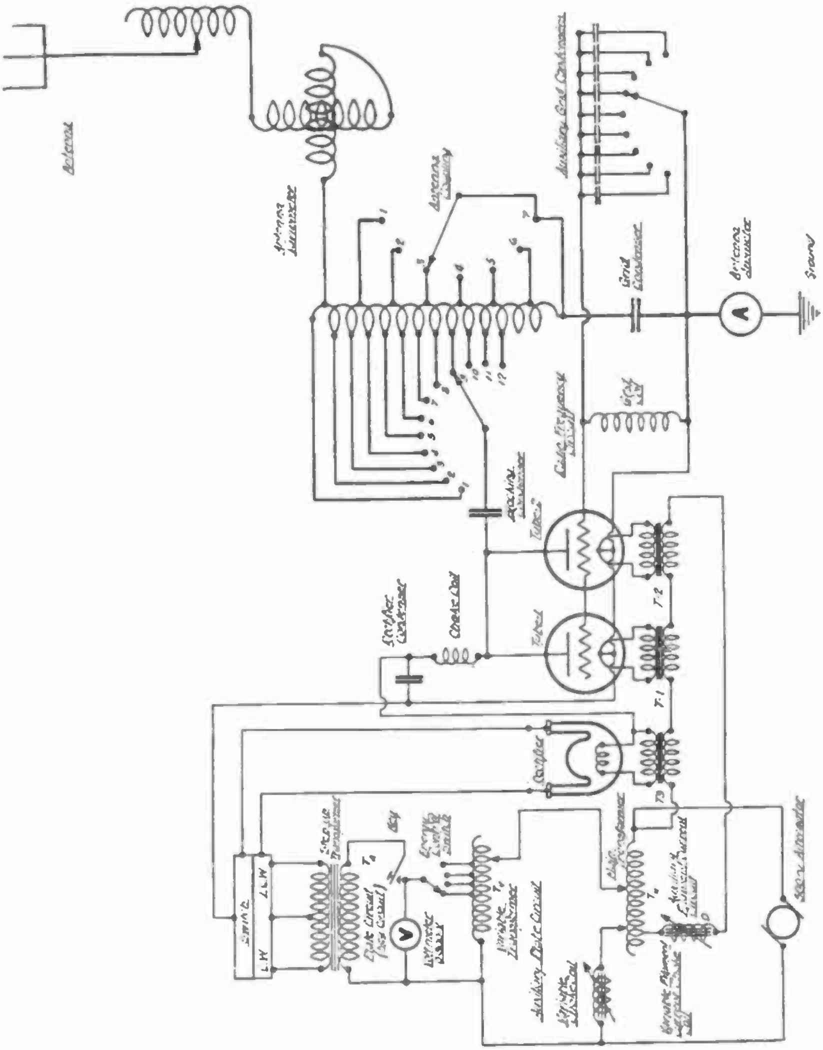


FIGURE 14

rent transformers. To avoid changes in filament current while operating, due either to variations in the speed of rotation of the alternator, or due to fluctuations of the load in the plate circuit when transmitting, a compensation transformer, T_r, is provided.



This is an open core auto-transformer, with several taps for different outputs, which is connected to the high-voltage plate current transformer T_a. The compensation for load is accomplished by T_h. When the key is depressed, the main current induces an extra voltage in T_h which, with correct adjustment of the choke coil *D*, compensates for the effect of the drop in voltage of the machine, resulting from the increase in load when the key circuit is closed. Thus the filament current remains unchanged. Energy passes from the high-voltage side of the transformer T_a to the rectifier and the tubes thru a switch arranged for transmission either with or without a musical tone. For transmission without tone, for the sake of simplicity the rectifier condenser is disconnected from the circuit. This transmitter was much used on the submarines. Figure 16 shows its appearance when provided to cover a continuous range of wave lengths. To the left

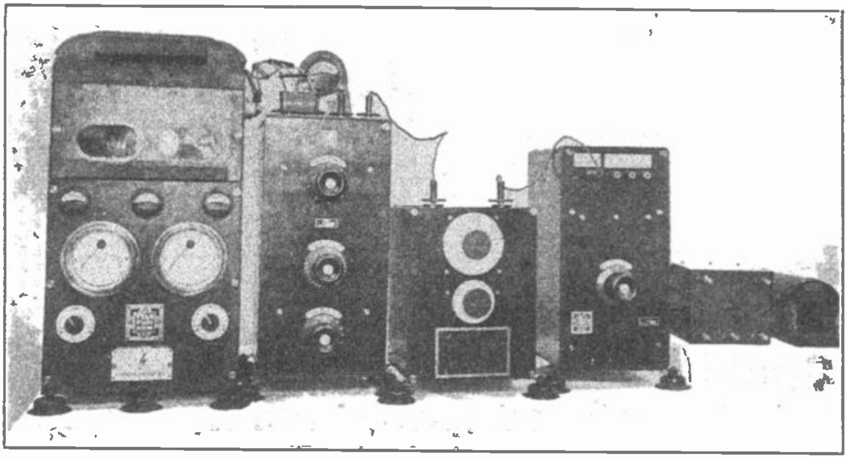
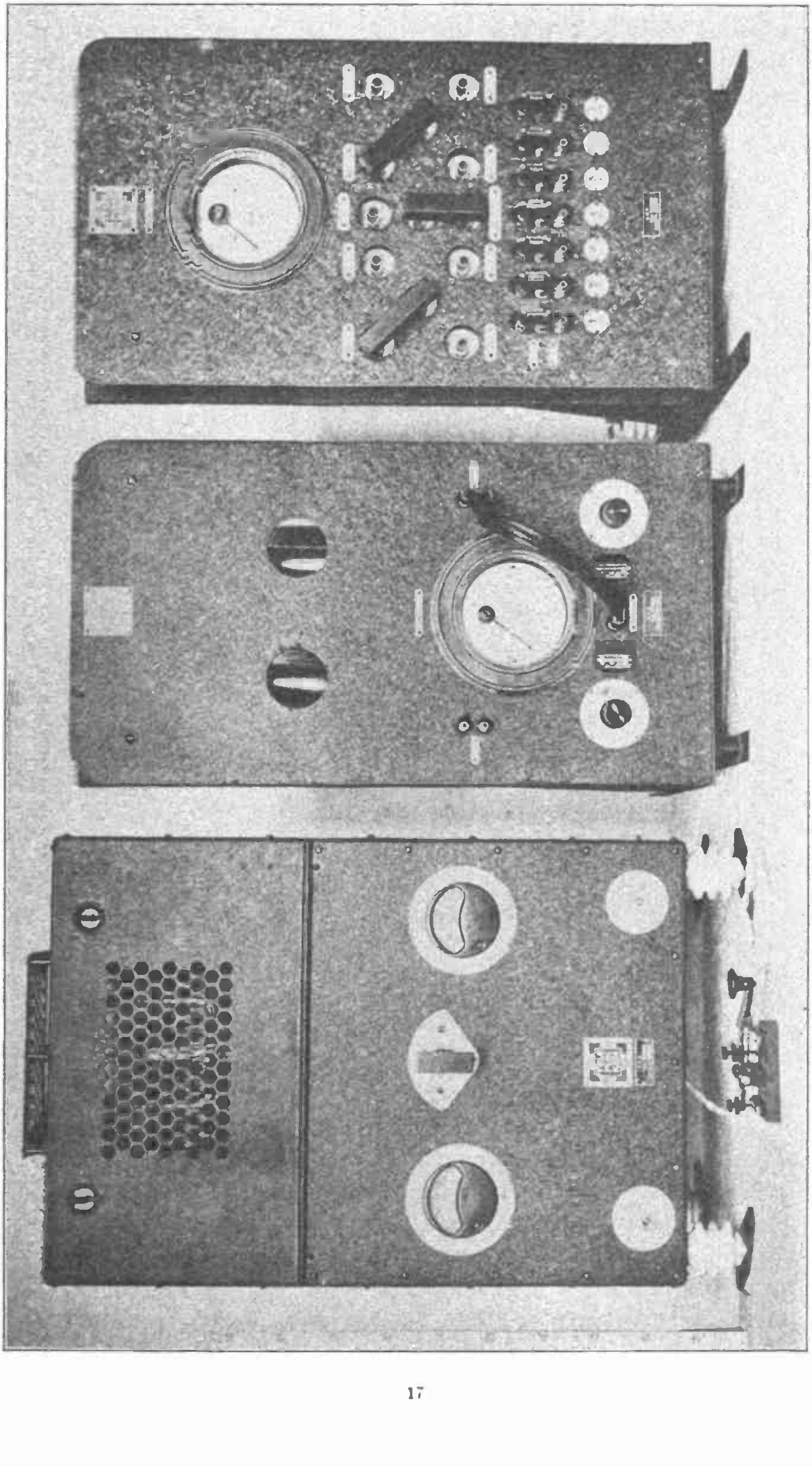


FIGURE 16

is a container holding the bulbs, rectifier, and transformers, and next to this a case containing the plate and grid couplings. The third case contains a variometer and the fourth the antenna loading coils for use on exceptionally long waves. Figure 17 shows a recent form of this transmitter for several fixed waves. In these sets, a new type of antenna loading inductance is used, which is shown in Figure 18. These are constructed according to a method given by the author (German patent 309,203), involving the use of multi-layer coils so arranged that between all cross sections there is the same separation of several millimeters. This design leads to the smallest possible damping where large inductances are required of fairly small volume. One-kilowatt transmitters are now used in several of the larger German cities in connection with the postal service network and especially for press service. When these transmitters are used for radio telephony, a tube is inserted



into the plate lead so that the entire plate current passes thru it. By impressing the amplified speech voltages on the grid of this control tube, the plate current of the main tube is suitably varied.

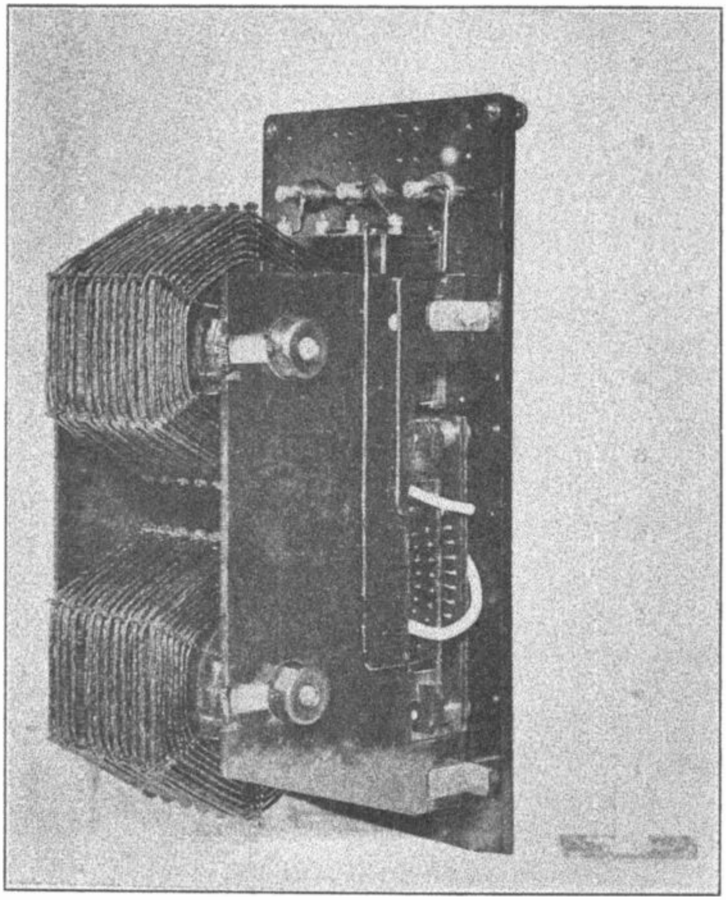


FIGURE 18

A tube transmitter using 20 bulbs in parallel is shown in Figure 19; and another transmitter with 8 tubes, each delivering 1.5 kw. and placed in parallel, is illustrated in Figure 20. In these larger tube transmitters, both telegraphy and telephony are carried out by the master control system; that is, a small tube transmitter of approximately 1 kw. output is used to impress the necessary voltages on the grids of the larger tubes. Such transmitters have been used for some time in Königswusterhausen and Prague with entire satisfaction, and it is expected shortly to carry on the transmission of press material for all of Germany by means of such a set.

The apparatus developed for radio telephony has found a large field of usefulness for multiplex telephony along conductors ("guided radio"). Even during the war experiments were carried

FIGURE 19

out by the Telefunken Company in telephony along wires by using radio frequency currents, and also, in cases of need, for telephoning over broken conductors. While the researches carried on at that time did not lead to finished apparatus, they furnished the basis for the later development of this process and for its use on a larger scale immediately after the end of the war for the improvement of the German Post Office telephone network. At the present time, a considerable number of channels of communication using radio frequency multiplex telegraphy are in existence in Germany for distances up to more than 600 km. (375 miles). Some of these have been in use with excellent results for over a year. In general, two radio frequency communications are carried on over each wire. The wave length range employed is between 5,000 and 20,000 meters. Speech modulation is obtained thru direct control of the plate voltage or thru separately excited generator tubes. In order to operate with the least possible intermediate amplification and the simplest circuits, fairly considerable power is employed (from four to eight watts), resulting in currents in the conductor of 0.1 ampere. The protection of the receiver from the transmitter is accomplished thru a suitable choice of the radio frequency resistance of the circuits or thru Wheatstone bridge circuits. Figure 21 gives a view of the radio frequency room of the Berlin central or ex-

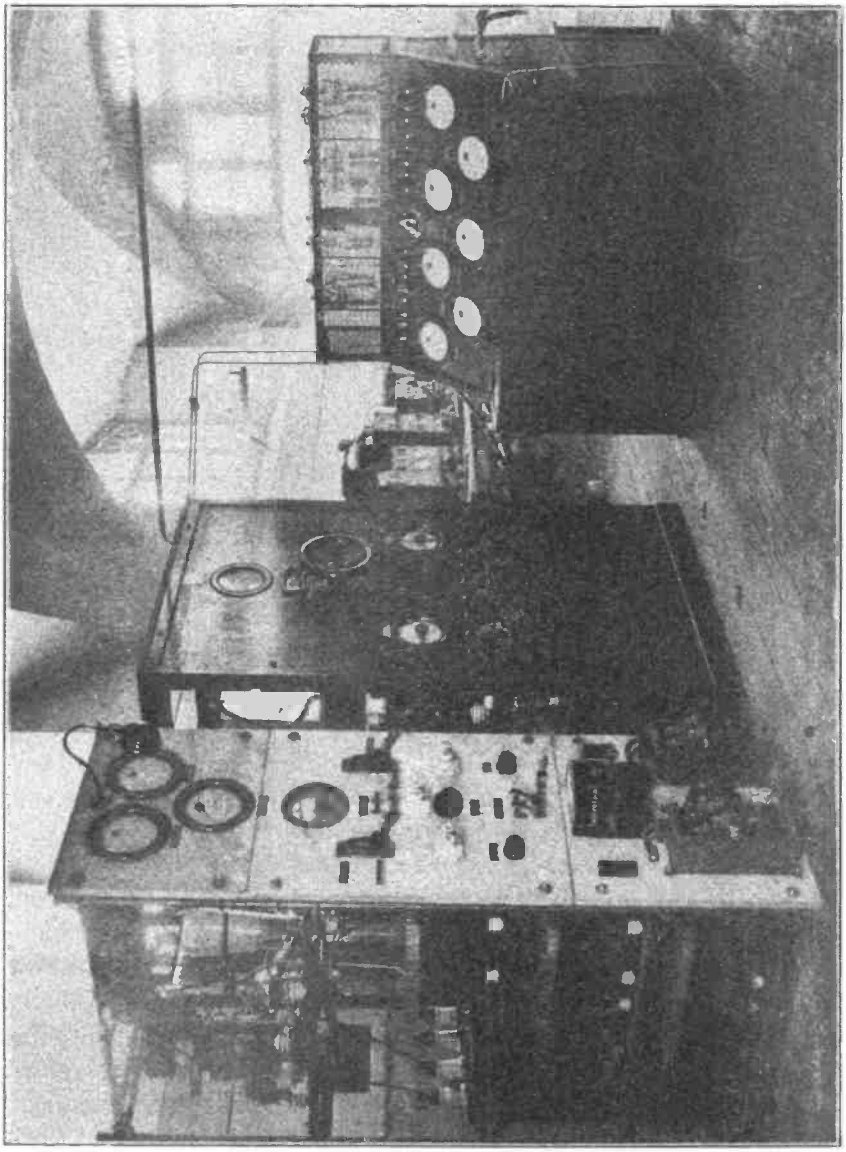


FIGURE 20

change. To the right can be seen the transmitters, and to the left the receivers, while in the middle are shown the circuits necessary for connecting the receivers and transmitters properly to the nearby central equipment. Figure 22 shows a small set for multiplex telephony. Multiplex high speed telegraphy

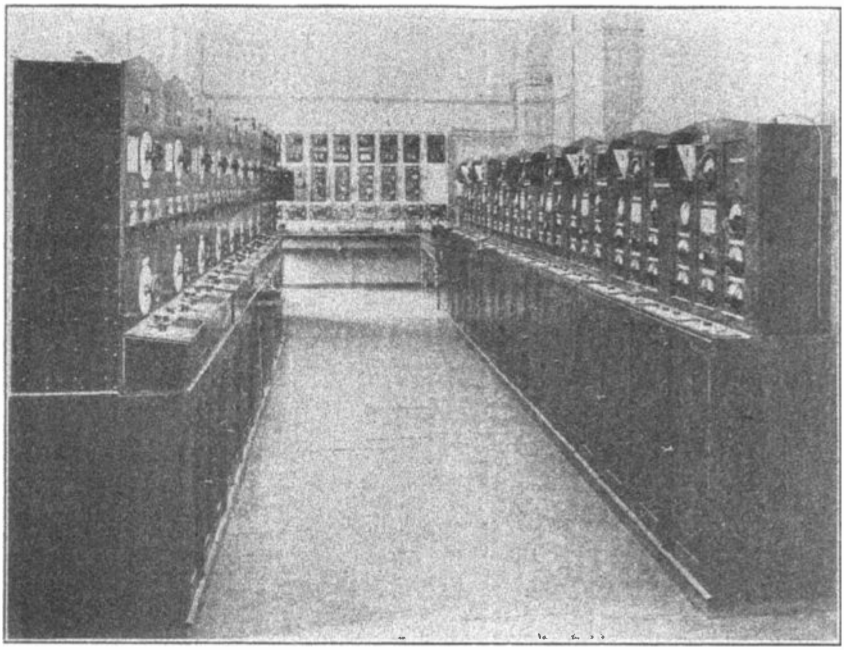


FIGURE 21

on a single wire (quadruplex-duplex) has been established between Frankfort and Berlin, permitting perfect transmission of 4,000 words per minute. For this purpose there are generally used shorter waves than for telephony (below 8,000 meters). The Siemens high speed telegraph equipment (printing telegraph) working at 600 to 1,000 letters per minute, which is here used, is an ideal solution, and is also equally applicable to high speed radio service.

Figure 23 shows a transmitter for telephoning along high voltage lines, such as is now frequently used to connect the large power plants with their sub-stations. Such transmitters are provided with a simple modulation system with direct application of the speech voltages to the grid. In view of the low damping of high voltage lines and the short distances generally covered by such sets (usually less than 200 km. or 125 miles), these transmitters work at wave lengths below 2,000

Figure 22

meters. The apparatus is built in very rugged form, is provided with two 10-watt tubes, and is arranged to work thru the line even if the line switches are open. A call signal device is provided with this set. Transfer of the radio frequency energy to the line is thru either one or two wires stretched parallel to the high voltage line for a distance of about 100 meters (300 feet). Recently these sets have generally been connected to the line directly thru small capacities or else the leading-in insulators are arranged to serve as such transfer capacities.

SUMMARY: The development of gas-containing and high vacuum transmitting tubes in Germany is described. The main forms of tube transmitters are illustrated and their circuits given. The application of such transmitters to multiplex telephony or telegraphy along high voltage lines is described.

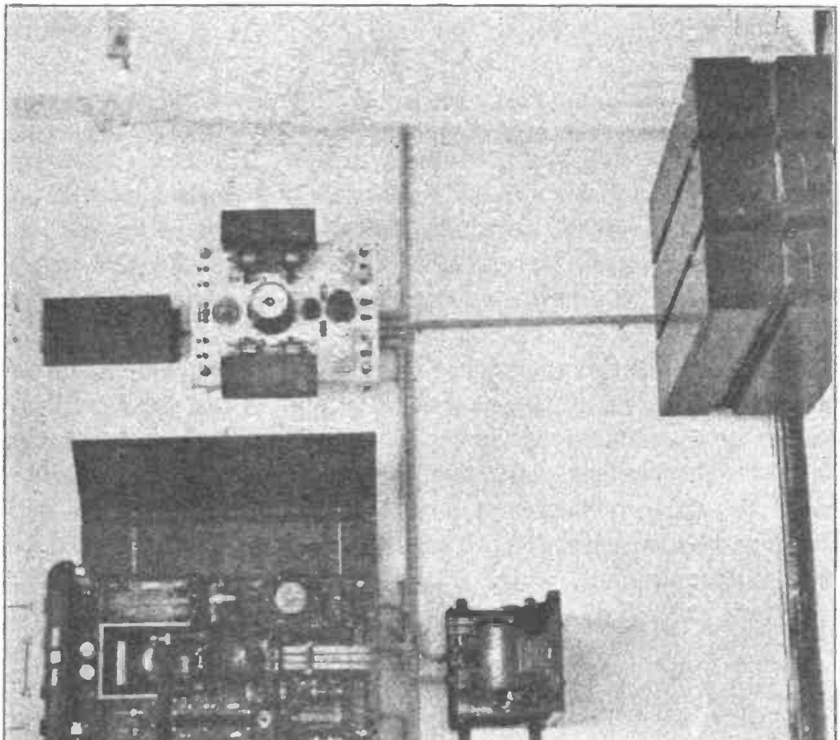


FIGURE 23

IMPROVEMENTS IN PILOTING CABLE RECEIVING APPARATUS*

By

A. Crossley

(Expert Radio Aid, Navy Department, Washington, D. C.)

Since the writing of a previous article on "Piloting Vessels by Electrically Energized Cables"[1] many improvements have been made in the receiving apparatus for the piloting cable system. These improvements have greatly increased the effective range of the receiving apparatus which in turn reduced the power input into the cable.

The object of this paper is to describe the improvements made in the receiving apparatus and thereby add to the meager information now available on the subject of piloting vessels by means of electrically energized cables. The following paragraphs describe the different stages of development of the apparatus and the general characteristics of the final model of piloting cable-receiving equipment, which is now being given service tests in the New York Harbor.

New London Experiments

During experiments conducted at the Submarine Base, New London, Connecticut, an attempt was made to tune the receiving apparatus to resonance by means of a 0.0025 microfarad variable condenser (air dielectric) inserted in series with the 240-turn four foot (1.3 m.) square collector coil and the primary of the first audio frequency transformer of the SE-1600 two-stage audio frequency amplifier. A schematic diagram of this circuit is shown in Figure 1. Due to the small value of capacity of the condenser only a slight increase was noted in the strength of the received signal from cable.

Efforts were made to obtain condensers of larger capacity at the Submarine Base, but no condensers were obtainable that were of a capacity less than 1 microfarad. Further experiments

*Received by the Editor, June 30, 1921.

[1]See Proceedings of The Institute of Radio Engineers, volume 9 number 4, August, 1921, page 273.

to improve the apparatus were not attempted at New London, in view of the lack of proper condensers and other laboratory equipment.

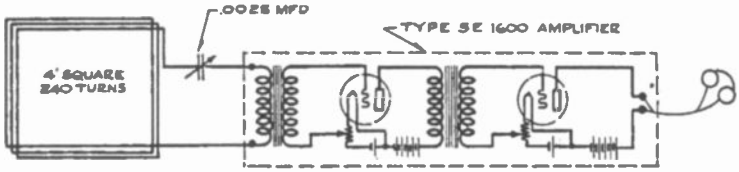


FIGURE 1

NEW YORK EXPERIMENTS

The experimental work was continued at New York in November, 1919, but because of defective cable installation and the delay incurred in obtaining new cable and installing it in the New York Harbor, the major part of the experimental work was not undertaken until August, 1920.

During the interim between October, 1919, and August, 1920, various types of receiving circuits were evolved by the writer for test by the New York Navy Yard, and arrangements were made to test these circuits immediately when the cable was available to determine the relative merits of each circuit. In order to expedite the experimental work, the New York Yard was requested to construct and test three types of coils having 400, 600, and 800 turns of number 20 double cotton covered wire[2] wound on a wooden frame four feet (1.3 m.) square, to determine which coil received the greatest power from the cable. When tested the 800-turn coil gave twice the signal strength of the 400-turn coil and one-third greater strength than the 600-turn coil. The results were in accordance with theoretical conclusions, and showed that the problem was the same as any straight electrical engineering problem and could be handled in the same manner. Upon reviewing the results of these tests and after noting the weight of the respective coils it was decided that the 400-turn coil would be best suited for the receiving system. This decision was based on the fact that the 800-turn coil was too heavy to be classed as portable and the loss of signal strength when using the 400-turn coil could be easily made up by a slight increase in power input in the amplifier. Having decided upon the 400-turn coil, in view of its portability, measurements were

[2]Diameter of number 22 wire = 0.032 inch = 0.082 cm.

made to determine the impedance at 500 cycles of this coil. The result of these measurements showed that the average impedance of a number of 400-turn coils was 2,000 ohms.

Working on the principle of maximum power transfer from one circuit to another, the Washington Navy Yard was requested to manufacture an audio frequency amplifier, the primary of the first audio frequency transformer of which was to have an impedance of 2,000 ohms at 500 cycles. This primary was to be connected direct to the collector coil and thereby produce an ideal condition for the maximum power transfer inasmuch as the collecting and input circuits were of equal impedance.

To check the theoretical conclusions of the efficiency of the new circuit, experiments were conducted on board the United States steamship *Algorma*, with the new type amplifier and the regular SE-1600 two-stage amplifier in conjunction with the 400-turn coil. The primary of the first audio frequency transformer of the SE-1600 amplifier when measured was found to have an impedance of 30,000 ohms at 500 cycles. The outcome of the tests on the *Algorma* showed that when directly over the piloting cable, the audibility of the received signal when using the SE-1600 amplifier was 500, while when using the new type amplifier the audibility recorded was 10,000 or an increase of 1,900 percent.

The excellent results obtained with the new circuit caused the writer to investigate the cause of the efficiency of the circuit, and especially to consider the idea that the great increase was due to the use of equal impedance in the collecting and input circuits. Upon closer study of the circuits it was noted that one other factor had to be considered, namely, the step-up ratio of the transformer. The step-up ratio of the new transformer was found to be one to ten while the original transformer had a ratio of one to three. Considering the increased step-up ratio of the new transformer as producing approximately three times the original voltage on the grid of the first vacuum tube, it may be granted that the use of equal impedance was responsible for the greater part of the increased signal strength and therefore is of importance in the design of piloting cable receiving equipment.

The encouraging results obtained with the new circuit led the writer to suggest a further improvement in the equipment wherein another attempt should be made to tune the circuit to resonance by means of a suitable condenser placed in series with the primary of the transformer and the collector coil as shown in Figure 2. The total inductance of the collector coil and the primary of the transformer was measured and the value substituted in the formula, $F = \frac{159.2}{\sqrt{LC}}$, where F is the frequency of the received signal, L the total inductance in henrys, and C the capacity in microfarads, in order to obtain the value of capacity needed for tuning the circuit to resonance at 500 cycles. The result of substituting the value of the total inductance in the formula showed that a 0.05 microfarad condenser would be required to tune the circuit to resonance.

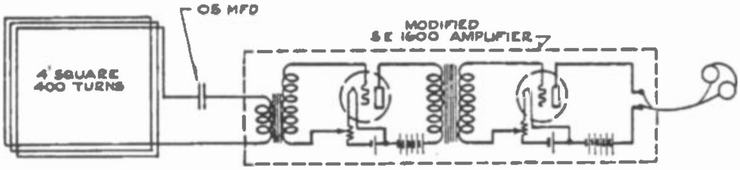


FIGURE 2

Experiments were again conducted on board the *Algorma* to determine the value of tuned circuits. In order to obtain low audibilities of received signals from the cable for comparison purposes, it was necessary for the *Algorma* to operate close to the channel buoys, which position was approximately 1,100 feet (360 m.) from the piloting cable. In this position with the equal impedance circuit the audibilitv of the received signal was ten, when while using the tuning condenser the audibility was increased to 100 or an increase of 900 percent. During these experiments it was noted that there was an optimum position for the coils with respect to the side of the vessel and this position is shown in Figure 3, at an angle of fifteen degrees to the side of the vessel. In this position the beneficial shielding effect of the hull of the vessel assists to a great extent in sharpening the differences in strength of received signals from the respective collector coils and thereby telling the operator which coil is nearer to the cable. The close proximity of the coil to the steel hull of tbe vessel was thought to have an effect on the proper tuning of the circuit by increasing the inductance of the coil, but because of the lack of time this subject was not investigated, especially since the signal received with the new equipment was sufficient for all practical needs.

During the experimental work with the tuned circuit, signals were heard at a distance of 1,000 yards (980 m.) from the cable, which was supplied with the usual current flow of three amperes.

This distance is a very important factor from a navigational standpoint, for with a given radius of 1,000 yards from the cable it will be comparatively easy for the pilot or person conning the vessel to pick up the cable, which previously was not possible with the old equipment, due to the limited range of the receiving equipment.

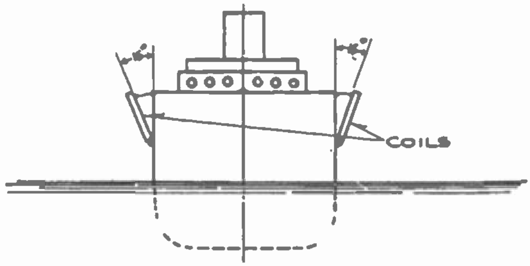


FIGURE 3

DESCRIPTION OF APPARATUS

Having satisfactorily developed the receiving apparatus to meet service requirements, the New York Yard was instructed to proceed with the design of the equipment, which would incorporate a two-stage audio frequency amplifier and a special switching device, which device would allow the use of one or two stages of amplification and the tuning condenser.

A front view of piloting cable receiver is shown in Figure 4. As shown, the receiver is placed in a watertight container and has only two switches (2) and (3); switch (2) connects either the port or starboard coil to the receiver while switch (3) connects the coil to the telephones in the "Off" position, one stage of amplification in position (1), two stages of amplification in position (2) and two stages of amplification with tuning condenser in position (3). Vacuum tube plate batteries, one spare vacuum tube, and a spare ballast lamp for the filament circuit are included in the container, the only external accessory being the 6-volt storage battery for supplying current to the filaments of the vacuum tubes. This battery can be placed in the chart house and connected to the receiver by armoured cable thru the middle stuffing tube shown in the lower part of the receiver.

The collector coils are suspended over the opposite sides of the vessel by the means of a special fitting which is shown in Figures 5 and 6. This fitting renders the coils portable and easy to handle when entering and leaving port. Armoured cable connects the coils with the two other stuffing tubes in the base of the receiver, and from there to the respective binding posts on the panel. The cable connection to the coil is made with a special watertight box which is situated on the upper part of the coil. The two binding posts at the bottom of the receiver marked "Telephone" connect to the telephone receivers, which can be stowed in the compartment under the panel. The

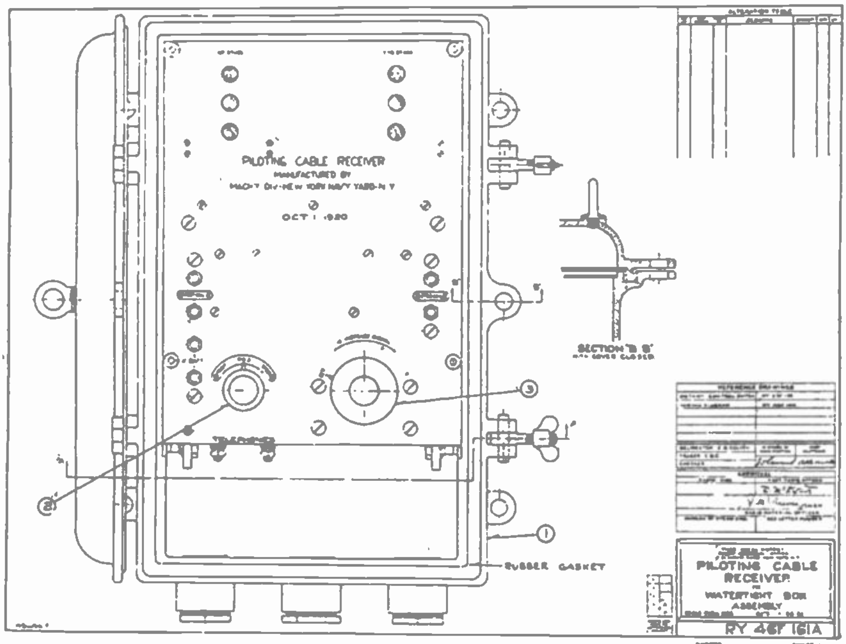


FIGURE 4

interior of the receiver is accessible for renewal of batteries, and so on, by removing knurled nuts on the front of the panel and pulling the panel forward until it stops.

Ballast lamps are used in the vacuum tube filament circuit and automatically regulate the current flow over a voltage range from 4.5 to 6.5 volts, so that the current is maintained at 0.65 ampere for each tube. These lamps eliminate the usual rheostat and trouble experienced due to the tendency of operators to burn the filaments at a greater brilliancy than is necessary for reliable operation, thus shortening the life of the tubes.

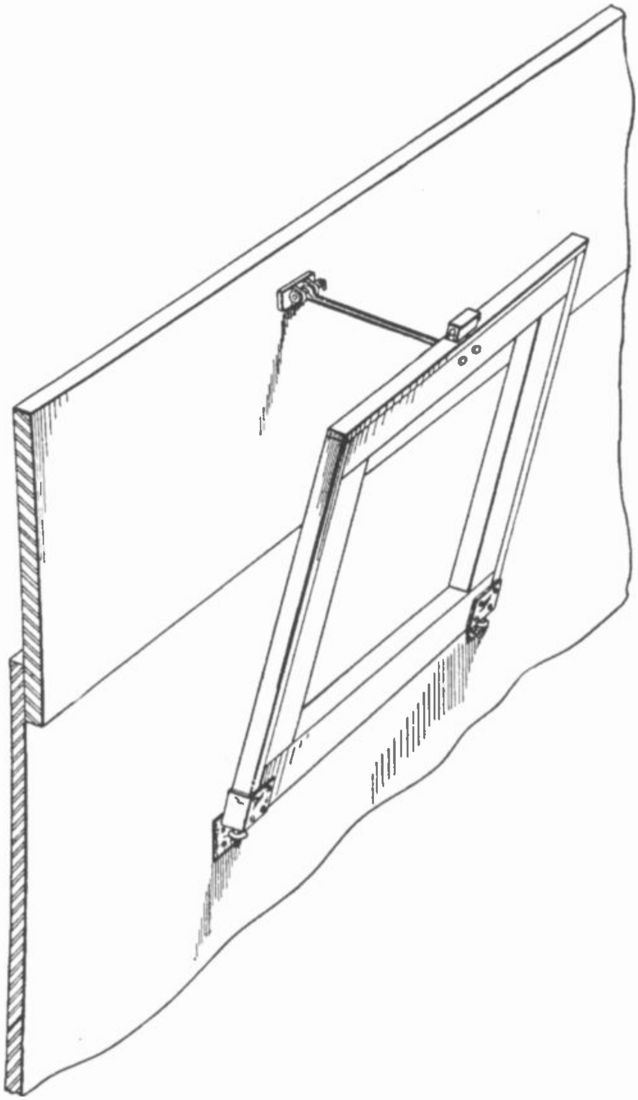


FIGURE 5

CONCLUSIONS

The piloting cable receiving equipment in its present form fulfils all the requirements for the aural method of reception. The use of two stages of amplification with the tuning and equal impedance features covers reception of signals when first picking up cable at entrance to harbor, while the application of one or two stages of amplification is sufficient for following the cable into the harbor either by steering directly over the cable or to the starboard side of cable at any desired distance.

The switching devices on the receiver are simple in operation and easily mastered by the average person, while the ballast lamps render the apparatus foolproof. The watertight container permits the installation of the receiver at any part of the bridge where easv access is had to the equipment when needed.

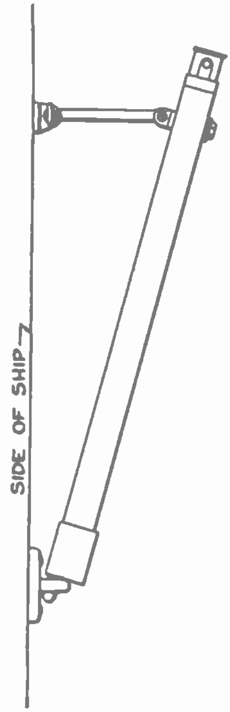


FIGURE 6

Using the four-foot (1.3 m.) 400-turn coils with receiver, no additional apparatus is necessary for entering any harbor the channel of which is not deeper than 200 feet (60 m.). The equipment is easy to install and of such size as not to interfere with other structures on board ship, while the coils can be rigged over the side when in use and stowed awav when alongside dock or at sea.

Altho the equipment described is satisfactory for immediate application as an aid to navigation it may be stated that many improvements will be made on this equipment in the near future, but such improvements will generally consist of refinements of the basic equipment described in this paper.

The extreme simplicity of the apparatus and the ease by which it is applied to navigation are factors which favor the early adaption of the system and the only factor which will retard its early adaption is the present absence of cable installations in the different harbors other than New York Harbor. The future installation of cables in the important harbors will most likely be undertaken in the near future, when further information is obtained on the operation of the new cable which is to be installed in the New York Harbor during the month of August, 1921.

Word has been received from England and France telling of the advance made with the piloting cable system and of the installation of permanent cable systems in certain harbors of these countries. This news is gratifying inasmuch as it shows the importance of the application of the system and promises a great future for this new aid to navigation It is the opinion of the writer that the piloting cable system will soon take its place with radio telegraphy and the radio compass as one of the chief aids to nagivation.

In concluding the writer desires to state that this work was conducted under the supervision of Commander S. C. Hooper, U. S. N., of the Radio Division, Bureau of Engineering, Navy Department, and that the writer and Expert Radio Aid, H. J. Lang, of the New York Yard, were instrumental in developing the apparatus to its present state.

SUMMARY: The further development of an aural receiver for the piloting cable system of guiding ships into harbors is described. In particular, the choice of a detecting coil of the most desirable number of turns, the proper choice of transformer input impedance and step-up ratio, and the use of audio frequency tuning of the coil circuit are discussed. The design of the latest coil, receiver, and amplifier is given.

FURTHER DISCUSSION ON "PILOTING VESSELS BY ELECTRICALLY ENERGIZED CABLES"*

BY A. CROSSLEY

H. P. Rivers-Moore (by letter):† Mr. Crossley's paper on the "Audio Frequency Piloting System"— known in this country as "Leader Gear"—as published in the PROCEEDINGS for August, 1921, makes no allusion to the distortion of the lines of magnetic force resulting from the conductivity of sea water, and the diagrams given completely ignore this phenomenon and treat the lines as circles about the submerged cable as centre.

In May or June of 1918 I was asked to begin a research on the possibility of using a submerged cable carrying current as a means of navigation, on behalf of a Department of the British Admiralty engaged in experimental work connected chiefly with anti-submarine work. My first experiment was to take a coil about three feet (1 meter) square in a small motor boat and investigate over an existing loop of cable laid at the mouth of a harbor in about four fathoms (7.8 m.) of water and supplied with interrupted direct current of 1.5 amperes at 500 interruptions per second. It was expected that in a wooden boat at least, the maximum strength of signals would always be obtained when the coil was in a plane directed towards the cable. At the first trial I reported that at a distance of upwards of 50 yards from the cable the flux appeared to be perfectly horizontal. I wrote "under the conditions of test in a rocking boat the exact angle for maximum or minimum could not be determined, but within the limits of accuracy obtainable the positions appeared truly vertical and horizontal."

It seemed evident that this result was due to distortion owing to the fact that the magnetic flux was partly in a partial conductor and partly in air and, as a method of approaching the problem theoretically I considered what must happen as the flux was built up round the cable by the increasing current in it. The effect of the conducting medium would be to diminish the rate at which the lines of force would be propagated, but as long as the lines were totally within the medium they would remain as circles. (See Figure 1.) As soon, however, as a line broke surface it would be propagated at normal speed thru the

*PROCEEDINGS OF THE INSTITUTE OF RADIO ENGINEERS, August, 1921, page 273.

†Received by the Editor, October 1, 1921.

air. The resulting distortion is indicated in Figure 1 and shows the sort of angles of the lines of force to be expected near the surface of the water.

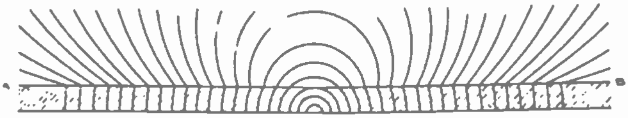


FIGURE 1—Suggested Distribution of Magnetic Field About a Submerged Cable Carrying Alternating Current

To test this theory, I then made a number of experiments in calm weather with wooden boats, using a coil pivoted about a horizontal axis and also capable of rotation about a vertical axis so that the horizontal axis could always be maintained parallel to the cable. A pointer and scale enabled angles to be read with considerable accuracy.

An example of the results obtained is given in Figure 2 which completely bears out the predicted distribution of field. It also indicates the remarkable fact that the original idea that the coil would always give maximum signals when pointing towards the cable is not merely inaccurate but, at quite a short distance from the cable, directly erroneous. The diagram is drawn to scale and the depth is nearly ten yards (9.8 m.). It will be seen that at a distance of only fifteen yards (14.8 m.) on either side of the cable the coil would be horizontal for maximum strength of signals and beyond this would actually point more and more steeply *away from* the cable.

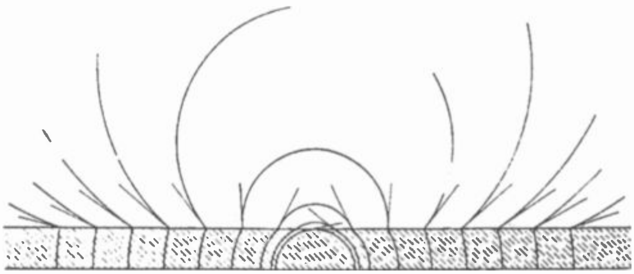


FIGURE 2—Supposed Distribution of Magnetic Field About a Submerged Cable Carrying 3 Amperes at 500 Cyles Per Second, Derived from Determination of the Direction of Field at the Surface Over a Long Cable

Considering now the case of two coils hung vertically on either side of a vessel and neglecting for the moment any screening or distortion due to the ship. The use of this method depends on the assumption that the coil farthest from the cable will give the weakest signals. Early in the course of the experiments and before I had fully recognized the extent of the distortion and its practical effect, I was directing the ship which had laid a special "leader" cable on its return voyage. I had not kept continuous watch but when still out of sight of land and approaching sand banks, I was asked to say which side the cable lay. I compared the signals from two vertical coils rigged port and starboard and said the cable was on the landward side. We made in that direction but signals were shortly lost. I was so sure of my result that I assumed the current had failed and we kept on the same tack hoping to pick up signals later. It was not until we sighted a wreck, piled up on the sands, that we realized we were well out of our proper course and in some danger of running aground. Needless to say the navigating officers had no more use for the cable and I returned nonplussed and discomfited. Later when the results given in the above diagrams had been secured and investigated I saw that if screening did not intervene it was quite possible that in any position beyond the region of vertical field the coil furthest from the cable would actually embrace a greater flux than that nearer to it owing to the fact that the field further out was more horizontal and therefore more favorable to a vertically suspended coil. The further coil would thus give the louder signals.

It appeared, and still appears, to me, that this accident was one which shows the method of two vertical coils to be a somewhat hazardous one. The vessel in question was of steel but the coils were placed above the decks and were evidently not efficiently screened. It is therefore most important that any vessel fitted in this way should be thoroly tested for screening effect and the coils carefully placed, since, apart from screening, the field due to the cable will actually give directly opposite readings to those expected and necessary for correct navigation, except over a narrow area quite close to the cable.

I put forward proposals for avoiding this difficulty. One was to use two triangular coils of few turns and large area rigged somewhat after the manner of a pair of directional radio aerials. These coils should preferably be set at an angle of 45 degrees to the keel line of the ship. Switching from one coil to the other is now equivalent to rotating a coil about a *vertical* axis and the distortion of the field due to the sea water has no effect on the directional results obtained. The coil which is most nearly parallel to the cable is the one which gives loudest signals. If the signals are growing stronger the ship is approaching the cable; if weakening, she is leaving it. When running parallel to the cable, signals are of equal strength in both coils.

Mr. R. H. Marriott, with his demand for simplicity in the receiving apparatus, will probably agree with me in preferring the alternative device which I recommended, namely to use a single horizontal coil, with or without amplifiers. Figure 3 gives general indication of the strength of signals obtained when passing across a leader cable and listening with a horizontal coil. When close over the cable there occurs a maximum, zero, and another maximum in rapid succession. This is an indication very

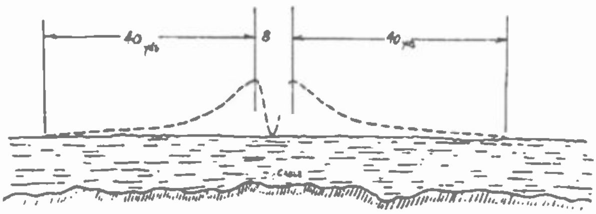


FIGURE 3

easy to observe. My method, therefore, used to be to direct the helmsman to steer in the general direction of the cable. I should then know at once when it was crossed. Knowing also the general lie of the cable and our course by the compass, I should know whether it then lay to port or starboard. I would turn the ship pretty sharply back towards the cable and note when it was crossed again, observing by the length of time that elapsed whether we were still approaching it steeply or gradually. After a few changes of course in lessening degree we should soon be running fairly parallel to the cable. In open water it was not necessary to keep always within touch of it as long as we knew which side it lay. Owing to the horizontal disposition of the field at a distance from the cable it is useful to swing the coil into a vertical position when first searching for the cables in this position the range of detection is much greater.

It is interesting to observe that the distortion at the surface is obtained with a cable laid on the ground. The lower half of the field is retarded by the conductivity of the earth while the upper half radiates out at the normal rate. I have taken angular measurements indicating this, and others showing the extraordinary and practically unpredictable twists in the field owing to the presence of comparatively small masses of iron. This again points to the unreliability of results obtained with pairs of coils placed on board ship unless the screening effects are carefully investigated in each case.

Croydon, Surrey, England, September 17, 1921.

A. Crossley (by letter):* Replying to statements made by Mr. Rivers-Moore, I desire to make the following statements which will clear the mysterious behavior of the two vertical coil collector system observed by him.

First, it may be stated that the writer or his associates have never experienced the contrary results observed by Mr. Rivers-Moore in obtaining the correct location of the cable. The coil nearest the cable always collected maximum power. All persons who were present on board the *Semmes* during the week of October 6, 1920, will bear out the writer in this statement, as it was by means of this pronounced effect that a great many of the persons present actually piloted the *Semmes* over different parts of the course.

A closer inspection of the receiving equipment used by Mr. Rivers-Moore shows that the collector coils used were placed above the deck (unshielded) and in which position the coils would naturally be inoperative with reference to producing marked differences in signal strength. If the coils had been placed over the side of the vessel and sloped outboard at the correct angle the results obtained would be far different than those obtained, as the shielding effect of the vessel would then be brought into play.

The present piloting cable receiving system, described in the PROCEEDINGS OF THE INSTITURE OF RADIO ENGINEERS, volume 10, number 1, is very simple in construction and easy to instal and operate. There are only two switches to operate, one changes the amplifier from the port coil to the starboard coil or vice versa, while the other changes the degree of amplification. In actual practice, the first switch is always used while the second switch is only used for a short while when picking up the cable from seaward. The writer cannot see where the manipulation of a single switch places the apparatus in the complicated class.

The triangular type collector system proposed by Mr. Rivers-Moore may show promising results on wooden or concrete vessels, but most likely would not be practical for use on steel vessels where the electromagnetic field from the cable is distorted by the local structures.

The horizontal coil system is in the same class with the

*Received by the Editor, November 22, 1921.

triangular collector system and cannot be considered for use on steel vessels, see discussion of the tilting coil system in my article (PROCEEDINGS OF THE INSTITUTE OF RADIO ENGINEERS, volume 9, number 4), on page 288, paragraph 7. The horizontal coil can be adapted for aircraft work, by use of which two maximums can be obtained when in the vicinity of the cable, one to the right and the other to the left of the cable. A discussion of a proposed system for aircraft piloting will be shortly disclosed by me, whereby aircraft can use a system similar to the present ship system for entering airports.

In view of the numerous experiments summarized in my article, I did not go into detail and explain the exact nature of the electromagnetic field in water and above water over the cable, as the curve shown in Figure 9 of my article contained sufficient data to satisfy requirements covering the design of the receiving equipment. I stated, however, that Figures 10 and 11 showed the apparent field acting on the collector coils and the practical results obtained verify the statement. Commenting further on this subject it is known that the field around the cable is bound to be distorted to a certain extent due to the counter action of the field from the inner conductor on the field produce by the return current path thru water and the armor of the cable. The amount of distortion is dependent on the size and resistance of the armor and the water return paths.

It has been proven as the result of extensive experiments conducted to date, that a large size inner conductor with sufficient insulation and a thin armor is the best type of piloting cable. Any increase in the size of the armor greatly detracts from the strength of the received signal from the cable.

Mr. Rivers-Moore refers to the use of a loop of cable for his experiments. The term "loop" is not understood. Does it refer to a straight cable with water return or the usual circular loop with metallic return. If the latter type of insulation was used during his experiments it is understood why Mr. Rivers-Moore obtained results contrary to our results.

Referring to Figures 1 and 2 of his paper, insufficient data on the type of cable used, also length of cable, together with method of grounding the cable makes it extremely hard for the writer to comment on the experimental results represented by the figures. The use of different size of armoring on cables and the method of grounding the internal conductor materially affect the field resulting from the inner conductor and the return path thru water, earth, and the armor. With the original type of cable shown in my article, it is possible to obtain signals of 10,000 times audibility, while with a cable that is heavily armored the audibility of the received signal is reduced to 500.

In contrast to the results represented in Mr. Rivers-Moore's figures, the writer, when at New London, used a tilting coil and obtained maximum signals from the cable when the plane of the coil pointed directly at the cable and minimum signals when the plane of the coil was 90 degrees to the cable. The water at New London is brackish and most likely was not of the same degree of salinity as the water in which Mr. Rivers-Moore conducted his experiments.

In concluding it is stated that the negative results obtained with the two vertical coil system by Mr. Rivers-Moore is contrary to the results obtained in this country. Reports received by the United States Hydrographic Office from the British Admiralty during the early part of this year show that the British Admiralty are now using the two coil vertical coil system in the same manner that we do, that is, the coils are placed over the side of the vessel. In view of the Admiralty report, the writer assumes that further experimental work conducted by the Admiralty has corrected the usual oversights made during the initial experiments and that they now make use of the important shielding effect of the hull of the vessel.

For further information on recent work conducted by the British Admiralty, the reader may consult an excellent article on this subject which has been written by Mr. J. J. Bennett, in a recent issue of the London "Electrician." In this article, the results obtained by the Admiralty are described as identical with those observed by the writer and reported in my article.

In answer to Mr. G. W. Pickard's discussion on my paper, I desire to state that the two coil system will not be applicable to cement or wooden ships, and recourse will have to be made to a single coil preferably placed in a horizontal position admidships. Such a coil would give two maximums, one on each side of the cable.

The idea of the use of two cables is theoretically correct if plain insulated cables are used, but such type of cables will not stand up under the abrasive action of moving sands and other destructive agents, as will an armored cable.

It is true that numerous combinations in the form of magnetic fields are possible with the system proposed by Mr. Pickard and it is not unreasonable to think that electrical systems which produce certain types of concentrated fields could be used in place of buoys at a later date.

In view of the lengthy discussion which would be necessary in undertaking the discussion of the concentrating effect of the 500 cycle current on the field about the cable, reference should be made to Mr. J. J. Bennett's article on "Leader Cables in Navigation" in the London "Electrician" for August 12, 1921, which very clearly explains this phenomena.

I heartily agree with Mr. Pickard in stating that the art of piloting by means of audio frequency current systems is new, and I predict a wide application of such a system or systems employing supersonic frequencies for all types of mobile bodies.

In answer of Mr. R. H. Marriott's excellent discussion of the piloting cable system, especially his interesting discourse on the troubles to be experienced in introducing and commercializing this new aid to navigation, I wish to congratulate him on his manner of presenting the subject. The Navy Department has gone out of its way to interest pilots and captains of merchant vessels in this system, and in certain cases has loaned apparatus for demonstration purposes; and it is hoped that the outcome of the efforts made to date will lead to greater interest on the part of merchant captains who during peace times can derive the benefits of such a system, to a greater extent than is the case with naval craft.

Mr. Marriott is a pioneer in this art and speaks from experience. The writer fully realizes the great importance of commercializing any new system, especially when it entails an expenditure of a comparatively large sum of money with the thought that no reward is attached to the work involved other than knowing that it will add another aid to the many aids now available to navigators. The great importance of the new system will be appreciated more by navigators of aircraft than navigators of seacraft.

A NEW RECTIFIER*

By

V. Bush and C. G. Smith

(Research Laboratories, American Radio and Research Corporation)

The purpose of this paper is to introduce to the Institute a new form of rectifier. Briefly described, it consists of a pair of electrodes surrounded by a moderate pressure of gas, the conduction between the electrodes being definitely under the control of a magnetic field. The electrodes may both be cold, as thermionic emission is not utilized. The device has no definite current limit, except such as is imposed by the heating due to losses. It is adapted for high voltage purposes. Its life is very long. In our files it is known as the "S-Tube."

In this present paper, only one of the simplest forms of these tubes will be described, and its theory developed; for a complete analysis is very involved. However, such theory as is here presented can be quite accurately checked with an "S-tube" of the type to which it strictly applies.

Gaseous conduction between electrodes in a gas at low pressure is usually considered an erratic and unreliable phenomenon. When such conduction takes place in a glass tube with widely separated electrodes, the phenomenon decidedly earns its undesirable reputation. The development of this rectifier has been the problem of bringing this conduction under control.

Conduction between widely separated electrodes in a gas at low pressure, assuming that the electrodes remain sufficiently cold to bar effects due to thermionic emission or vaporization of the metal, takes place by reason of ionization by collision. There is always in a gas a certain small amount of spontaneous ionization. Under a potential gradient of sufficient magnitude, the number of ions rapidly increases, for the speed attained by the freed electrons becomes sufficient so that upon impact with neutral molecules they knock them apart, producing ions and more electrons. The process is thus cumulative until sufficient

* Presented before the Boston Section of The Institute of Radio Engineers, April 8, 1921. Presented before The Institute of Radio Engineers, New York, October 5, 1921. Received by the Editor, April 15, 1921.

current flows to reduce the potential between the electrodes to a definite value, depending upon many factors.

In order to produce gaseous conduction proper, therefore, two factors are necessary: first, a potential gradient sufficient to produce ionization; and second, sufficient distance between electrodes for collision to take place.

If two electrodes are so situated in a gas that they are nowhere separated by a length of discharge path of the order of magnitude of the mean free path of an electron in the gas used and at the pressure present, and if there is no magnetic field present, then there can be no gaseous conduction proper between such electrodes at any potential difference whatsoever. Ionization by collision cannot become cumulative, for in the great majority of cases a spontaneously freed electron drops into the anode without impacting with a neutral molecule. The space between the electrodes is thus kept swept clear of free electrons and ions. The conduction which takes place due to the spontaneous formation of ions is extremely minute, and is the same sort of conduction as takes place between electrodes in air at atmospheric pressure and at potentials below the point of corona formation, which conduction can be with difficulty detected.

It is, in fact, sufficient to prevent conduction that all lines of electrostatic stress between the electrodes be either short compared to the mean free path of the electron, or else be interrupted by an isolated body capable of accumulating a charge. Very many forms of electrodes may be constructed to utilize this principle, one or two of which will be illustrated in this paper.

The tube of Figure 1 will conduct at a comparatively low potential if filled with, say, hydrogen to a pressure of 0.1 mm., even altho the distance of separation *a* be much less than the mean free path of an electron in hydrogen at this pressure. The conduction will take place along paths such as the one shown dotted.

However, a tube such as shown in Figure 2 will not so conduct; for the only long lines along which an electron may be propelled by the potential difference are interrupted by the glass walls, which will accumulate a charge and reduce the gradient in the gas to a low value.

Such a tube, constructed with properly cleaned electrodes, will not pass a microampere at a potential difference of ten thousand volts. Of course at very high potential gradients, of the order of magnitude of a million volts to the inch, or so, very peculiar effects may be produced; but not gaseous conduction proper.

A tube which insulates by reason of the short path principle may be rendered conducting by the introduction of a magnetic field of proper value, and in a direction perpendicular to the lines of electrostatic stress.

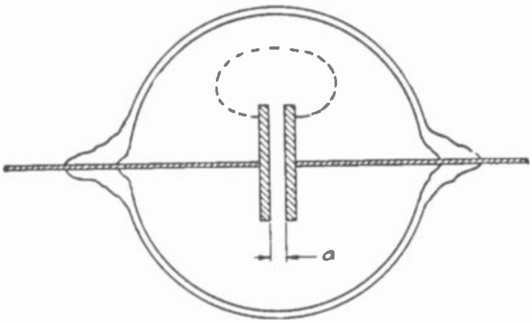


FIGURE 1

When an electron moving in the short distance between two electrodes is acted upon by a magnetic field, its path is curved and thereby lengthened. Moreover, the increase in length of path of an electron starting from the cathode is gradual with increasing magnetic field strength up to a certain value, and then very sudden. This sudden increase occurs when the path curvature is such that the electron completely misses the opposite electrode. The electron paths between plane electrodes for various field strengths are plotted in Figure 3 to render this clear.

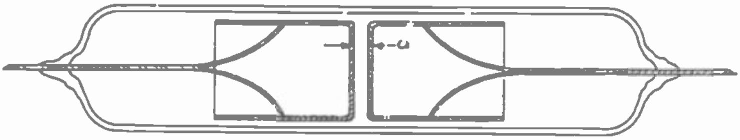


FIGURE 2

The magnetic field strength necessary just to make the electron thus miss the opposite electrode is derived for the plane case in Appendix A. Its value depends upon the potential E between electrodes, their separation a, and the electron ratio of charges to mass m, thus:

$$H = \frac{1}{a}\sqrt{\frac{2Em}{e}} \qquad (1)$$

or, if E is in volts, and a in cm., we may insert the value of e/m and write:

$$H = \frac{3.35\sqrt{E}}{a} \text{ gausses} \tag{2}$$

for the critical field strength.

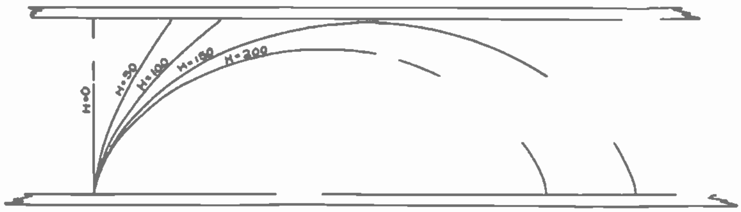


FIGURE 3

Let us now construct a tube such that the distance straight between electrodes is too short to ionize, but such that the path of an electron is just made to miss the opposite electrode is sufficiently long to ionize. Assume a high potential in accordance with the short path principle. Apply a magnetic field to this tube parallel to the electrode surface. Then when this field is increased to the critical value, the tube will very suddenly conduct freely. The electrons fly in long paths and ionize by impact. The positive ions thus formed drop into the cathode and produce secondary emission of electrons from the surface. These new electrons also pursue long paths and ionize, in turn. Since one ion may knock several electrons from the cathode, and each electron may make several ions, the process is cumulative; and the discharge builds up to a point determined by the external circuit.

It may be noted in passing that the critical nature of this phenomenon gives a simple method by which the value of e/m may be checked experimentally.

A rectifier may now be constructed. Construct a short path tube and place it in one of the usual rectifier circuits. Apply to the tube an alternating field and a uni-directional field superposed. Adjust the field such that during one-half cycle it is correct for conduction, and during the next half wave, not. The tube will then rectify completely.

This, however, is not the simplest construction. By using curved electrodes, instead of plane electrodes, a permanent magnet may be used to supply a uni-directional field, and the alternating field dispensed with.

If concentric cylinders are used for electrodes and suitable arrangements made to render the end paths also short, an axial field of proper strength will render the tube conducting. It is shown in Appendix B, however, that the critical field strength is now different for conduction in the two directions. In fact the critical field strengths bear the same ratio as the diameters of the cylinders, that is:

$$\frac{H_h}{H_g} = \frac{g}{h} \tag{3}$$

Thus for conduction with outer cylinder negative, the critical magnetic field is smaller than when the inner is negative.

A tube arranged with cylindrical electrodes and supplied with a permanent axial field, intermediate between these two critical values, will then conduct in one direction but not in the other. This gives a very simple rectifier, indeed.

By suitable choice of diameters and field strength, the tube may be so arranged that it conducts in one direction as soon as the potential across the tube rises to a value sufficient to give ionization by collision and secondary emission, that is to one or two hundred volts depending upon the gas and electrode material used. It may also be arranged so that when the potential in the opposite direction rises to this same value, the field will be already too weak for conduction. The tube will not then conduct in the wrong direction for any value of voltage up to that which destroys the insulation or otherwise flashes the tube over.

Certain other benefits may be obtained by the use of non uniform fields; but the consideration of these effects will be re served for later treatment.

A model known as "Type H" is shown in Figure 4, and in Figure 5 as supplied with a permanent magnet and pole pieces for supplying the axial field. A section of this design is also shown in Figure 6.

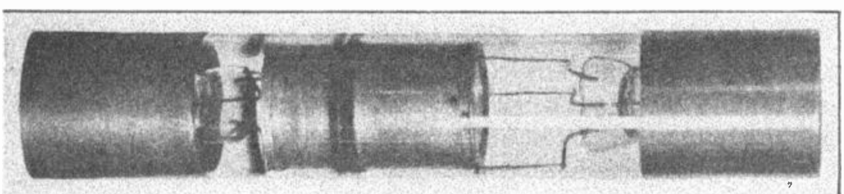


FIGURE 4

The inert, monatomic gases are preferable for filling "S-tubes," because of their lack of chemical action and low potential drop. Using helium and aluminium electrodes, the drop in the tube is in the neighborhood of 150 volts. Under these conditions the disintegration of the electrodes is very slight when operating normally.

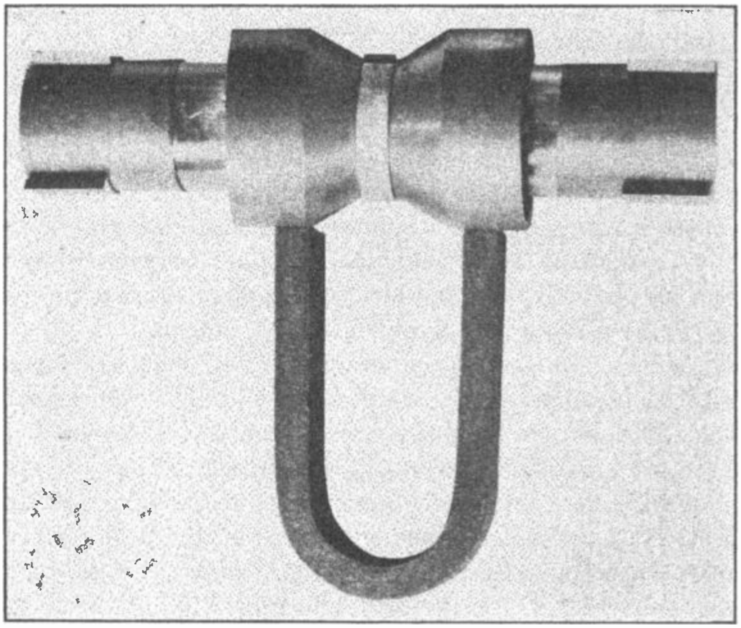


FIGURE 5

Since the cooling of the electrodes occurs largely by reason of the heat conductivity of the working gas, it is unnecessary to run the electrodes very hot in order to dissipate a considerable amount of loss. A tube 7 inches (17.8 cm.) long of the type illustrated above will handle 230 milliamperes continuously with the electrodes well below a red heat. There will then be about 40 watts loss in the tube.

The output depends, of course, on the voltage being rectified. At 4,000 volts a current of 250 milliamperes represents an output of 1 kilowatt. Several amperes may be passed thru such a tube for a short interval.

The voltage current characteristic of a tube depends largely upon its design. With the arrangement shown above the voltage drop will rise about 10 per cent. from no load to full load.

The wave form of potential delivered by a rectifier depends, of course, upon the circuit in which it is used. The "S-tube" is a complete rectifier, as no appreciable current passes in the reverse direction. A practically constant drop of 150 to 200 volts is inherent in this particular design. By using polyphase connections, or condenser and inductance combinations, the ripple in the delivered voltage may be reduced.

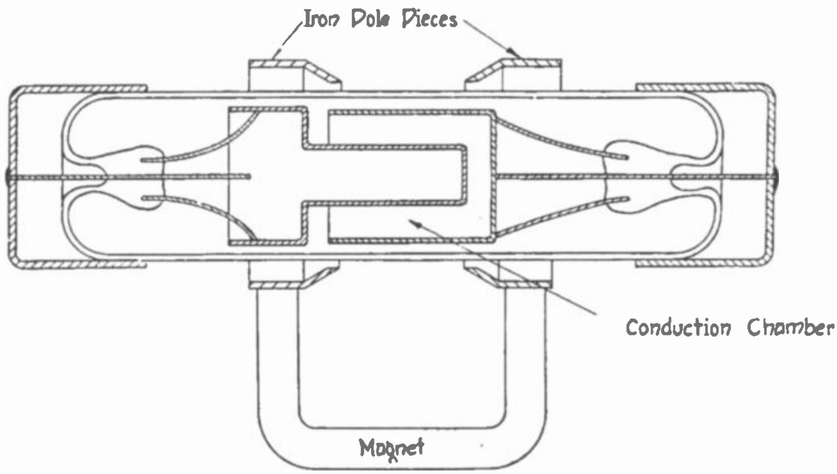


FIGURE 6

As a rugged, long-lived, relatively inexpensive rectifier there will probably be many uses to which the "S-tube" can be put. In particular, it should serve as a convenient source of direct current for use in thermionic tube radio transmitting sets, particularly for high powers. It should make also a convenient piece of laboratory apparatus.

This paper is necessarily limited in its treatment to merely an introduction of the device. The authors will very much welcome any suggestions as to ways in which it will be possible to make this new instrument of greatest service to the practice of radio telegraphy and telephony

Medford Hillside, Massachusetts,
April 8, 1921.

APPENDIX A

The Critical Field Strength for Plane Electrodes

The value of the critical field in this case may be found as follows:

Let e = charge on electron
m = mass of electron
X = voltage gradient
H = field strength

Then, referring to Figure 7, we have—

$$m\frac{d^2 y}{d t^2} = e X - H e\frac{d x}{dt}$$

$$m\frac{d^2 x}{dt^2} = H e\frac{d y}{d t}$$

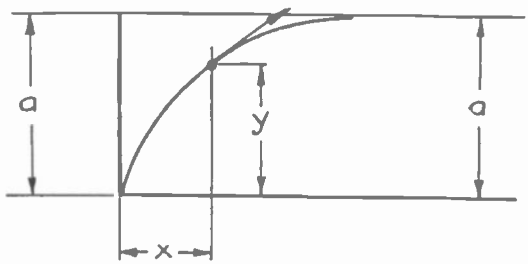


Figure 7

These equations can readily be shown to be those of a cycloid.[1]

Integrating the second equation—

$$m\frac{d x}{dt} = H e y + C$$

Now when $y=0$, $\frac{d x}{dt}=0$, and hence $C=0$,

$$\text{so that } m\frac{d x}{dt} - H e y$$

We are interested, however, in the field strength which will make the path of the electron tangent to the opposite electrode.

If v is the velocity of the electron, we have by the conservation of energy

$$\frac{m v^2}{2} = e X y$$

[1] See Thompson, "Conduction of Electricity Thru Gases."

$$\text{so that } v=\sqrt{\frac{2eXy}{m}}$$

Now for the path to be tangent, we must have—

$$\frac{dx}{dt}=v$$

$$\text{or } \frac{Hey}{m}=\sqrt{\frac{2eXy}{m}}$$

and, for tangency also, $y=a$, which gives—

$$H=\frac{\sqrt{2}\sqrt{Xa}}{a\sqrt{\frac{e}{m}}}$$

Or, if the potential across the plates is written

$$E=Xa$$

the necessary field strength is

$$H=\frac{\sqrt{2E}}{a\sqrt{\frac{e}{m}}}$$

Inserting the value of e/m, and reducing to practical units—

$$H=\frac{3.35\sqrt{E}}{a}$$

where H is in gausses
E is in volts
a is in cm.

Thus if $a=0.25$ cm.
$E=400$ volts

we obtain $H=\dfrac{(3.35)}{0.25}\sqrt{400}=268$ gausses

as the necessary field strength.

APPENDIX B

Critical Field Strength for Cylindrical Electrodes

We shall consider first the path of an electron which leaves the inner cylinder, which is considered negative.

Referring to Figure 8, and using the same notation as before—our two equations now become—

$$m\frac{d^2y}{dt^2}=Xe\frac{y}{\rho}+He\frac{dx}{dt}$$

$$m\frac{d^2x}{dt^2}=Xe\frac{x}{\rho}-He\frac{dy}{dt}$$

From these two equations, eliminating X

$$m\left\{x\frac{d^2 y}{d t^2}-y\frac{d^2 x}{d t^2}\right\}=H e\left\{x\frac{d x}{dt}+y\frac{d y}{dt}\right\}$$

or integrating—

$$x\frac{d y}{d t}-y\frac{d x}{d t}=\frac{H e}{2m}(x^2+y^2+C)$$

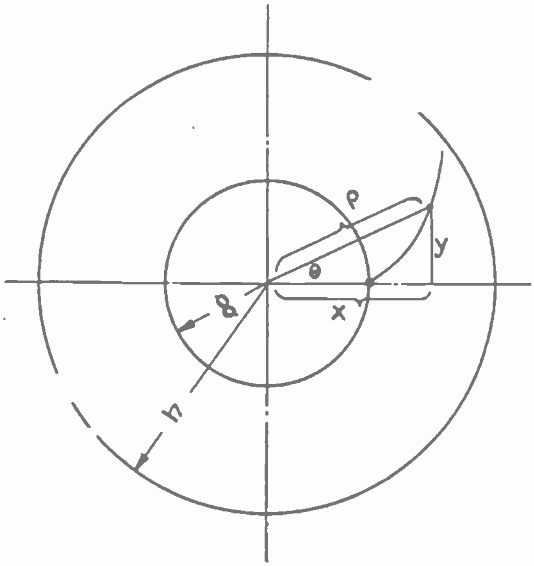


FIGURE 8

and from $$y=0,\ \frac{d y}{dt}=0, x=g$$

we have $$C=-g^2$$

so that $$x\frac{d y}{dt}-y\frac{d x}{dt}=\frac{H e}{2 m}(\rho^2-g^2)$$

or, in polar co-ordinates entirely—

$$\rho^2\frac{d \theta}{dt}=\frac{H e}{2 m}(\rho^2-g^2)$$

$$\frac{d \theta}{dt}=\frac{H e}{2 m}\cdot\frac{\rho^2-g^2}{\rho^2}$$

For an electron to just reach the other electrode, we have—

$$\frac{m v^2}{2}=e E$$

but here also $$v=h\frac{d \theta}{dt}$$

which, inserted, give for the necessary field,

$$H_g=\sqrt{\frac{2\,m\,E}{e}}\left(\frac{2\,h}{h^2-g^2}\right)$$

An exactly similar derivation gives for the critical field strength when the outer cylinder is negative—

$$H_h=\sqrt{\frac{2\,m\,E}{e}}\,\frac{2\,g}{h^2-g^2}$$

and dividing we have—

$$\frac{H_h}{H_g}=\frac{h}{g}$$

which equation has been verified many times experimentally.

SUMMARY: The authors describe a new type of cold electrode power rectifier tube utilizing gaseous conduction, and based on the following principles:

No considerable gaseous conduction occurs between coaxial cylindrical electrodes separated by less than the mean free path of the electrons.

An axial magnetic field (perpendicular to the electric force) will cause the electrons to pursue a longer path, and thus permit considerable conduction provided the magnetic field intensity exceeds a critical value.

The critical value of the magnetic field required for producing conduction is greater for conduction from the inner to the outer electrode than in the reverse direction (that is, there are two critical values).

By choosing a magnetic field intensity intermediate between the two critical values, unilateral conductivity results.

Tubes constructed on this basis are described, and their performance given. The approximate mathematical theory of their action is derived.

POLYPHASE RECTIFICATION*

By

Hudson R. Searing and Mark H. Redmond

The problem of high potential supply for vacuum tube work becomes quite important when large tubes, requiring high voltage, are used. Single-phase alternating current can be rectified, but the resultant direct current is pulsating and seriously distorts the voice when used on a radiophone set, as shown in Figure 1.

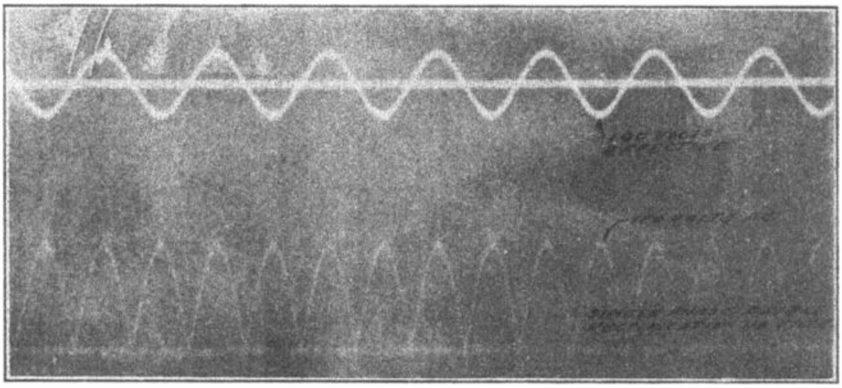


Figure 1

This distortion can be reduced by means of filters (Figure 2), but condensers of large size and high voltage insulation are expensive and bulky.

Experiments were made to determine whether the filters could be dispensed with by using polyphase supply and rectifying each phase. Using three-phase supply with transformers arranged in delta-to-star, and three rectifying tubes, it is possible to secure an output much more desirable than that produced by single-phase operation. The circuit used is shown in Figure 3.

The transformers are connected delta to the supply line and star on the secondary side. Each secondary line is connected

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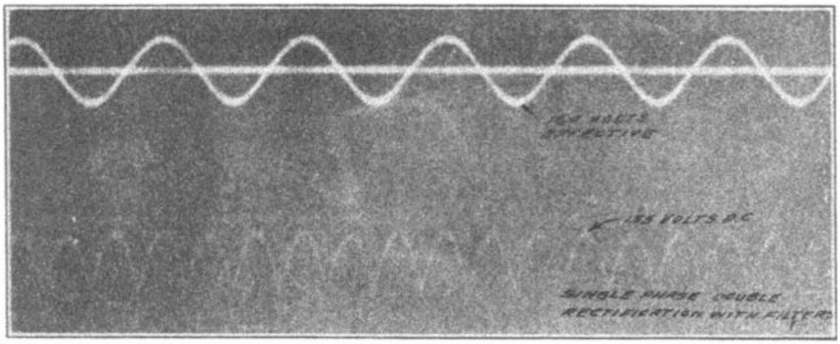

FIGURE 2

to the plate of the rectifier tube, the output being taken from the filament circuit and the neutral of the star connection. The resultant voltage is the envelope of the three-phase waves and

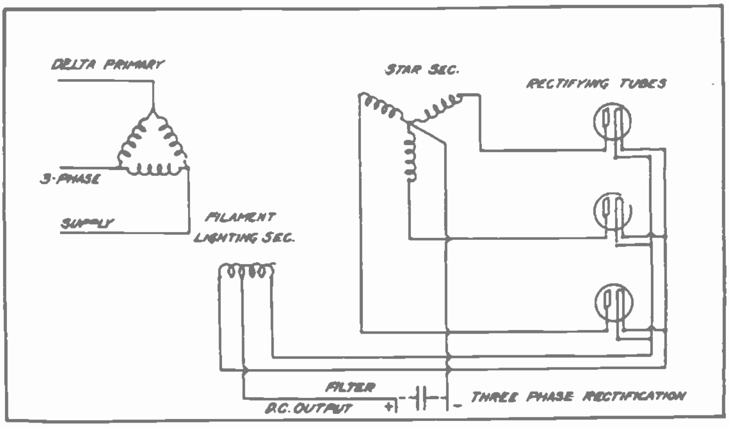

FIGURE 3

consist approximately of an 85 per cent component of direct current plus 15 per cent alternating current of three times the original frequency, and is illustrated in Figure 4. This may be used in radiophone work without serious distortion, but operation is improved by the addition of a filter (Figure 5).

Using six-phase alternating current obtained from a three phase supply line by the use of transformers connected delta-to star, an output closely approximating commutated direct cur rent is obtained. This voltage can be used for radiophone work without filters with practically no distortion. The circuit is given in Figure 6, while the resulting direct currents, with and without filters, are shown in Figures 7 and 8.

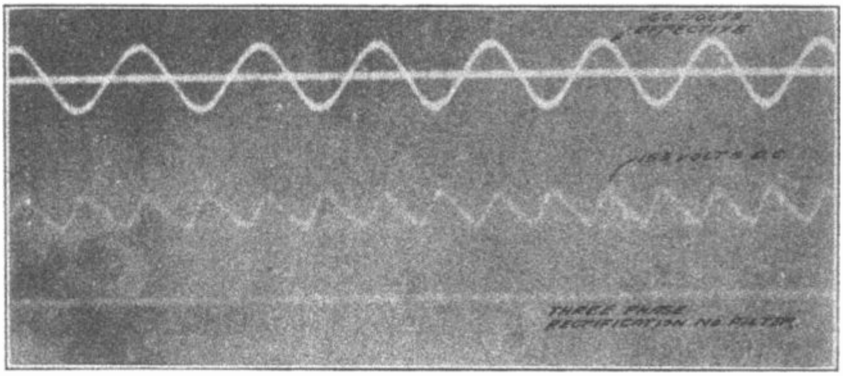

FIGURE 4

In our experiments, Western Electric Company's VT-2 tubes were used, the grid and plate circuits being connected together. When used in this manner, the internal impedance is about 500 ohms. *A* simple filter consisting of a condenser of 3 microfarads capacity connected across the line was used in the case of those oscillograms marked "with filters."

A polyphase oscillating circuit was tried in which the three- or six-phase voltage was applied to vacuum tubes which were coupled to an oscillating circuit. It was found that more tubes were required for a given output than would have been necessary for rectifier and separate oscillator operation. Furthermore,

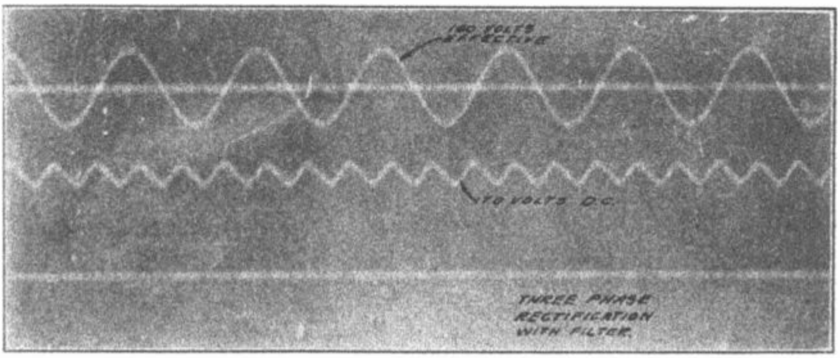

FIGURE 5

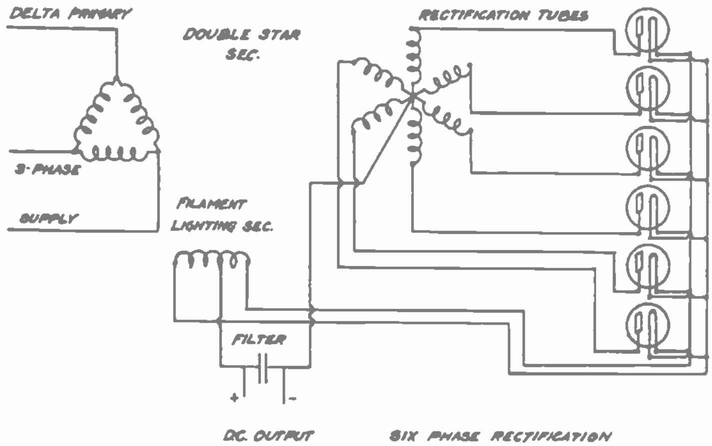

FIGURE 6

modulation by the Heising method was very distorted and unsatisfactory.

At first glance, it would appear that the triple frequency ripple in the three-phase rectified wave would serve as a means to modulate for telegraphy. On account of the limited amplitude of this ripple, such modulation is not sufficient.

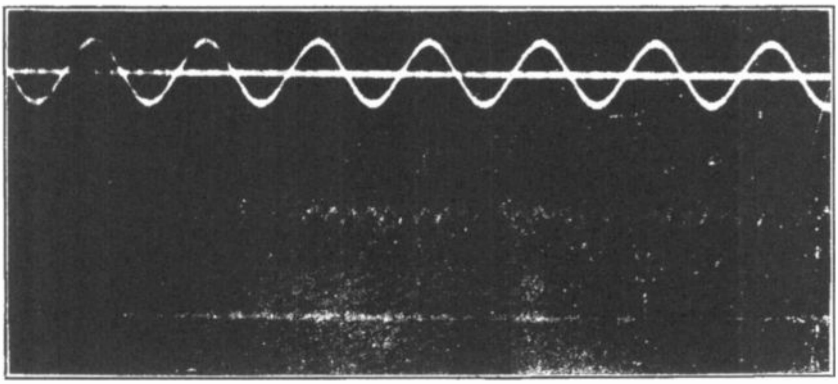

FIGURE 7

The oscillograms were taken in the Research Laboratory of the General Motors Corporation, Delco Section, thru the assistance of Mr. J. H. Hunt, Research Engineer. They show the voltage of one phase and the output. An oscillogram of single-phase rectification is given for comparison.

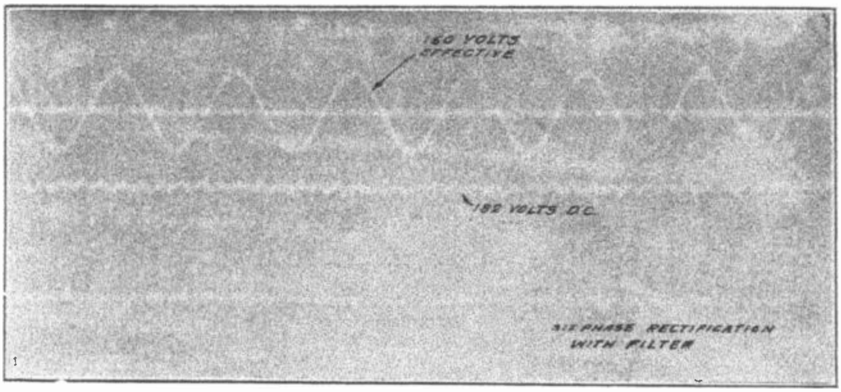

FIGURE 8

SUMMARY: The use of three-phase and six-phase rectified alternating current for feeding the plate circuits of vacuum tube oscillators in radiophone work is described with circuit diagrams and oscillograms of the resulting currents.

NOTES ON THE THEORY OF MODULATION*

By

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It is a well-known fact that in carrier wave[1] transmission it is necessary to provide for the efficient transmission and reception not only of the carrier frequency itself but also for a band of frequencies of width depending on the frequency and character of the signal itself. This necessity is becoming more and more a serious consideration as the severity of wave length regulation and the necessity of sharp selective tuning are increased. In view of these facts a great deal of inventive thought has been devoted to the problem of narrowing the band of transmission frequencies. Some of the schemes which are directed to this end are very ingenious; all, however, are believed to involve a fundamental fallacy. It is the purpose of this note to discuss briefly the general problem of modulation and to analyze the more ingenious and plausible schemes which have been advanced to solve this problem.

A pure modulated wave may be mathematically defined by the expression

$$f(t)\, A \cos \omega t \qquad (1)$$

Here $f(t)$ is the low frequency signal, $\omega/2\pi$ is the carrier frequency and A is an amplitude factor which fixes the magnitude of the transmitted wave.

The pure modulated wave is often defined in words as "a carrier wave of constant frequency whose amplitude is proportional to the signal wave." Properly interpreted this definition is correct; however, the inference which is sometimes made, that the *resultant wave* is of constant frequency is erroneous, as may easily be shown.

*Received by the Editor, January 6, 1922.

[1]It is to be understood that the term carrier wave is employed in its generic sense to cover radio as well as carrier wave wire transmission in both of which the carrier wave plays the same role.

[2]See "Carrier Wave Telephony and Telegraphy," by Colpitts and Blackwell, "Journal of the American Institute of Electrical Engineers," April, 1921

Let the signal wave $f(t)$ be represented, as we assume in telephone theory, by a plurality of sinusoidal terms, thus

$$f(t) = \sum_{1}^{m} a_j cos(p_j t + \theta_j) \qquad (2)$$

Substitution in (1) gives for the pure modulated wave:

$$\begin{aligned} &\frac{1}{2}A \sum_{1}^{m} a_j\, cos\,[(\omega - p_j)\, t - \theta_j] \\ &+ \frac{1}{2}A \sum_{1}^{m} a_j\, cos\,[(\omega + p_j)\, t + \theta_j] \end{aligned} \qquad (3)$$

It follows at once that the frequencies transmitted lie between $(\omega + p_m)/2\pi$ and $(\omega - p_m)/2\pi$; that is the width of the bandis $2\,p_m/2\pi$. For example let us take a carrier wave of 100,000 cycles per second, and modulate this wave with telephone signals which we shall assume contain frequencies up to 2,500 cycles per second. The pure modulated wave then contains frequencies lying between 102,500 and 97,500 cycles per second and a band of 5,000 cycles must be transmitted.

It has, however, been known for several years[2] that it is not necessary to transmit the pure modulated wave which contains a band of frequencies of twice the signal wave range of frequencies and that theoretically perfect transmission can be had by transmitting only one "side band" and suppressing the other. This may be explained as follows: Referring to the expression (3) for the pure modulated wave, suppose that all frequencies below[3] that of the carrier $\omega/2\pi$ are filtered out so that the transmitted wave is

$$\frac{1}{2}A \sum a_j\, cos\,(\omega + p_j)\, t + \theta_j \qquad (4)$$

Let the receiving stations be provided with a local generator of frequency $\omega/2\pi$ which is combined in the demodulator with the received wave. If the locally generated wave is represented by $B\, cos\, \omega t$, the demodulated wave is

$$\frac{1}{2}A\, B\, cos\, \omega t \sum a_j\, cos\,(\omega + p_j)\, t + \theta_j$$

which is equivalent to

[3]A precisely similar argument holds if all the frequencies *above* the carrier frequency $\omega 2\pi$ are suppressed.

$$\frac{1}{4} A B \sum a_j \cos (p_j t + \theta_j)$$

$$+ \frac{1}{4} A B \sum a_j \cos (2 \omega + p_j) t + \theta_j$$

The first expression is simply the signal wave $f(t)$ multiplied by the factor $\frac{1}{4} A B$ while the second expression is of double radio frequency which is entirely suppressed in the audio frequeney circuits.

In the system of modulation discussed above it will be observed that the *amplitude* of the carrier wave is varied by and in accordance with the low frequencies signal wave and that this process inherently requires the transmission of a band of frequencies at least equal to the range of essential frequencies in the signal itself.[4] In order to eliminate this necessity which is inherent in all actual systems of modulation it has been proposed a number of times to employ an apparently radically different system of modulation which may be termed *frequency* modulation as distinguished from *amplitude* modulation, in the belief that the former system makes possible the transmission of signals by a narrower range of transmitted frequencies. This belief is erroneous; the suggestion is, however, quite ingenious, and the reasoning on which the supposed advantage is based is very plausible, and indeed requires some mathematical analysis before its incorrectness can be satisfactorily established. The system of *frequency* modulation will now be explained and analyzed in terms of the specific physical system in which the idea was first called to the attention of the writer.

Suppose that we have an ideal non-dissipative oscillation circuit of inductance L and capacity C. Such a circuit is of course ideal and unrealizable, but the analysis of the actual vacuum tube oscillator, as regards frequency modulation, may be safely based on a consideration of the ideal circuit. This circuit when once energized, will continue to oscillate at frequency $\omega/2\pi$ when $\omega = 1/\sqrt{LC}$. Now suppose that the capacity (or inductance) is varied in accordance with an audio frequency signal. For the present we shall simplify the discussion by assuming that the signal is a pure tone of frequency $p/2\pi$, and that the instantaneous value of the capacity is $C_o(1 - 2h \sin pt)$ where h is an amplitude factor proportional to the signal intensity. We

[4]It should be noted that after either "side band" is suppressed, the resulting wave does not fall within the definition of a pure modulated wave of equation (1).

shall later consider the general case where the signal is represented by $f(t)$. Assuming that h is small compared with unity we can write

$$\omega = \frac{1}{\sqrt{LC}} = \frac{1}{\sqrt{LC_o}}(1+h \sin pt)$$
$$= \omega_o(1+h \sin pt)$$

From the foregoing reasoning it has frequently been concluded that the oscillation circuit generates a continuously varying frequency of instantaneous value

$$\frac{\omega_o}{2\pi}(1+h \sin pt)$$

so that the generated frequency varies between the limits $\omega_o(1-h)/2\pi$ and $\omega_o(1+h)/2\pi$. According to this theory, if $2h\omega_o$ is made less than p the range of frequencies transmitted $2h\omega_o/2\pi$ will be smaller than $p/2\pi$, which is the minimum range required in *amplitude* modulation.

The foregoing gives, very briefly, the essential reasoning underlying the idea of *frequency* modulations. We shall now analyze the scheme more closely: The differential equation of the circuit may be written as

$$L\frac{d^2I}{dt^2} + \frac{1}{C}I = 0$$

$$\frac{d^2I}{dt^2} + \frac{1}{LC_o}(1+2h \sin pt)I = 0 \qquad (5)$$

$$\frac{d^2I}{dt^2} + \omega^2 I = 0$$

Now if ω is treated as a constant, a particular solution is

$$I = A \cos \omega t$$

If we now substitute for ω the expression

$$\frac{1}{\sqrt{LC_o}}(1+h \sin pt) = \omega_o(1+h \sin pt)$$

we get

$$I = A \cos[\omega_o(1+h \sin pt)t] \qquad (6)$$

which is interpreted as representing a wave of instantaneous frequency

$$\frac{\omega_o}{2\pi}(1+h \sin pt)$$

Both the solution of the equation and the interpretation of this solution are incorrect. Equation (5) by a simple transformation of variables is reducible to the form

$$\frac{d^2 I}{d x^2}+(a+16 q \cos x)I=0$$

which is the canonical form of Mathieu's Equation (see Whittaker and Watson, "Modern Analysis," page 402), and it is easily shown from the theory of this equation that the solution of (5) is *the real part of*

$$e^{i\omega_o t}\sum_{\infty}^{+\infty} a_n e^{inpt} \tag{7}$$

Consequently the solution is a series of the form

$$\sum_{-\infty}^{+\infty} b_n \cos\left[(\omega_o+n p)\, t+\theta_n\right] \tag{8}$$

The frequencies present in the wave form an infinite series spaced at the interval $p/2\pi$ of the signal frequency. They may be tabulated as

	ω_o	
ω_o+p		ω_o-p
ω_o+2p		ω_o-2p
ω_o+3p		ω_o-3p
ω_o+np		ω_o-np

It follows at once that *the transmission of the signal by frequency modulation requires the transmission of a band of frequencies* at least $2p/2\pi$ *in width*; that is *a band of width equal to twice that of the signal itself*.

If the solution (7) is substituted in the differential equation (5), we get the following system of difference equations for the determination of the constants.

$$-i\,(2\,np\,\omega_o+n^2 p^2)\, a_n+h\,\omega_o^2(a_{n-1}-a_{n+1})=0 \tag{9}$$

In the practically important case where p is so small compared with ω_o that np may be neglected in comparison with ω_o, this is satisfied by

$$A_n=(i)^{-n} J_n\,(h\,\omega_o/p) \tag{10}$$

where $J_n\,(h\,\omega_o/p)$ is the Bessel function of order n and argument $h\,\omega_o/p$. In this case the series sums up to

$$I=A \cos\left(\omega_o t-\frac{h\,\omega_o}{p} \cos pt\right) \tag{11}$$

The ratio of the term of frequency $({}_o\omega+p)$ to the fundamental of frequency ω_o is $J_1(h\,\omega_o/p)/J_o(h\,\omega_o/p)$, which in case $h\,\omega_o/p$ is less than unity is approximately equal to $h\,\omega/2\,p$. This system of modulation, therefore, discriminates against high frequencies and therefore inherently introduces distortion.

In analyzing this system of frequency modulation consideration has been limited to the case of a signal consisting of a pure tone of frequency $p/2\,\pi$. In the more general case where the signal must be represented by an arbitrary $f(t)$, as is the case in telephonic transmission, a general solution can only be gotten when $f(t)$ is periodic and analyzable into a Fourier series. In this case the differential equation of the problem is reducible to Hill's equation (Whittaker and Watson, "Modern Analysis," page 406), and the theory of this equation shows that the frequencies present in the wave are exactly the same as those given above if $p/2\,\pi$ is the fundamental frequency of $f(t)$.

However if we introduce the approximations indicated by physical considerations, a much simpler and more instructive approximate solution is obtainable without analyzing $f(t)$. Let the instantaneous capacity be represented by $C_o(1-2h\,f(t))$; then assuming $2h\,f(t)$ small compared with unity the differential equation of the problem is

$$\frac{d^2 I}{dt^2}+\omega_o^2\,(1+2\,h\,f(t))\,I=0$$

Assuming that the solution is the real part of $e^{i\omega_o t}\phi(t)$ and sub stituting in the differential equation we get

$$i\,2\,\omega_o\phi'(t)+\phi''(t)+2\,h\,\omega_o^2 f(t)\,\phi(t)=0.$$

Now if $f(t)$ is a relatively slowly varying function compared with the carrier wave, the term $\phi''(t)$ may be neglected and we get

$$\phi(t)=A\,e^{i\,\omega_o h\int f(t)\,dt}$$

whence

$$I=A\cos\left[\omega_o\,(t+h\textstyle\int f(t)\,dt)\right] \tag{12}$$

If $\omega_o h\int f(t)\,dt$ is small compared with unity, as it would be in practice, this gives approximately

$$I=A\cos\omega_o t-\omega_o h A\textstyle\int f(t)\,dt\sin\omega_o t$$

The second term is a modulated wave, but the amplitude instead of being proportional to the signal wave is proportional to its integral. Consequently this type of modulation inherently distorts without any compensating advantages whatsoever.

The foregoing solutions, tho unquestionably mathematically correct, are somewhat difficult to reconcile with our physical intuitions, and our physical concepts of such "variable frequency" mechanisms as, for example, the siren. Upon closer analysis it is seen, however that the difficulty arises in connection with what we mean by frequency, and can be cleared up satisfactorily, it is believed, by the following generalized concept and definition of frequency.

Suppose we have a function $sin\,(\Omega\,(t))$ where $\Omega\,(t)$ is any specified function of time: Its derivative with respect to time is $\Omega'\,(t)\,cos\,\Omega(t)$ where $\Omega'\,(t) = d/dt\Omega(t)$. We define the *generalized frequency* of such a function as equal to $\frac{1}{2\pi}\Omega'\,(t)$. This definition, while formally arbitrary, has considerable physical significance, and is believed to be a useful concept. In the case where $\Omega(t) = \omega t$ it agrees with the usual definition of frequency $\omega/2\pi$. Furthermore, if we apply this definition to formulas (11) and (12) the *generalized frequencies* are respectively $\omega_o\,(1 + h\,sin\,pt)$ and $\omega_o\,(1 + h\,f\,(t))$, which agree with our physical intuitions. It agrees also with the fact that in the case of the siren the mathematical analysis of which differs in no essential way from that of the "variable frequency" oscillator just discussed, the *generalized frequency*, as defined above, corresponds with the "instantaneous frequency" which the ear apperceives. This may be shown as follows:

In the neighborhood of time $t = \tau$, $\Omega\,(t)$ may be expanded as

$$\Omega\,(t) = \Omega\,(\tau) + \frac{t-\tau}{1\,!}\,\Omega'\,(\tau) + \frac{(t-\tau)^2}{2\,!}\,\Omega''\,(\tau) + \cdots$$

Now the function $sin\,[\Omega\,(t)]$ alternates when the function $\Omega\,(t)$ changes by the amount π; or otherwise stated, the interval between zeros corresponds to the time intervals during which $\Omega\,(t)$ changes by the amount π. From the foregoing expansion this interval is approximately $\pi/\Omega'\,(t)$ in the neighborhood of the time $t = \tau$. That is to say, *the rate of alternation of the function* $sin\,[\Omega\,(t)]$ is approximately *the same at any time t, as that of the function $sin\,\omega t$, where $\omega = \Omega'\,(t)$.* In this sense and this sense only do "variable frequency mechanisms" generate a continously varying frequency over the range of frequencies corresponding to the extreme values of $\Omega'\,(t)$.

Exactly the same conclusions are reached by the analysis of another theoretically possible scheme of frequency modulation which suggests itself. This is to vary the speed of a radio frequency alternator in accordance with the signal so that its instantaneous angular velocity is representable by

$$\omega(1+hf(t))$$

A superficial consideration of this scheme would lead to the erroneous conclusion that the frequency generated is

$\frac{\omega}{2\pi}(1+hf(t))$ and for a sinusoidal signal varies between

$\frac{\omega}{2\pi}(1-h)$ and $\frac{\omega}{2\pi}(1+h)$. *A* mathematical analysis shows, however, that it differs in no essential way from the arrangement analyzed above and that the frequency band which must be transmitted is at least equal to that required in *amplitude* modulation.

The foregoing discussion is immediately applicable to the analysis of the system of continuous wave radio telegraphy which employs the so-called "spacing wave." In its essentials this system merely employs "frequency modulation" instead of "amplitude modulation" in the sense employed above and formula (12) is directly applicable. It follows therefore at best, as regards the necessary range of frequencies, the "spacing wave" system is inferior to that in which the dot and dash correspond to modulation of amplitude of a constant frequency carrier. Superiority, however, has been claimed for the former on the alleged ground that, since "the amplitude is constant," transient disturbances are minimized. This claim is seen to be quite invalid when the real significance of "frequency modulation" is analyzed, and no such superiority exists.

SUMMARY: The transmission system of "frequency modulation" (transmission by variation of the frequency of the radiated wave) is mathematically analyzed, and the width of the band of frequencies occupied by this method of transmission at a given speed is compared with the width of the corresponding band for transmission by amplitude variation. It is proved that the frequency modulation system using a spacing or compensating wave is inferior to the amplitude variation system both as to the width of the frequency band occupied and as to distortion of signal wave form.

DIGEST OF UNITED STATES PATENTS RELATING TO RADIO TELEGRAPHY AND TELEPHONY*

ISSUED NOVEMBER 1, 1921–DECEMBER 27, 1921

BY

JOHN B. BRADY

(PATENT LAWYER, OURAY BUILDING, WASHINGTON, D. C.)

1,395,378—Richard H. Wilson, of Newark, New Jersey and John P. Schafer, of Richmond Hill, New York, filed September 29, 1919, issued November 1, 1921. Assigned to Western Electric Company.

SECRET SIGNALING. This patent shows a radio telephone secret signaling system. The transmitter comprises two branch circuits and separate modulators coupled thereto. The microphone circuit is coupled to filter circuits which transmit freely only a limited range of the essential voice frequencies. For example, one filter may transmit frequencies between 500 and about 900, while the other filter will transmit frequencies between 900 and about 1,500. Separate carrier wave frequencies may be employed from separate generators modulated in accordance with the separate modulators actuated by the frequencies transmitted through the filters. At the receiving station branch circuits are employed to combine the component frequencies forming the signal wave. An outsider in attempting to pick up the conversation would tune his receiving set to the frequency of one or the other of the transmitted carrier waves, but would obtain only unintelligible sounds from either wave alone.

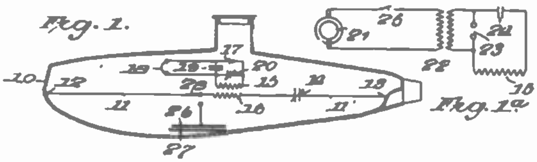
1,395,390—Lewis M. Clement, of Newark, New Jersey, issued November 1, 1921, filed September 30, 1918. Assigned to Western Electric Company.

OSCILLATION-GENERATING SYSTEM. The object of this invention is to provide a vacuum transmitter with means for varying the frequency of the oscillator and simultaneously to automatically

*Received by the Editor, January 5, 1922. The purpose and scope of this section of the PROCEEDINGS have been given in previous issues, and will not be repeated herein.

provide the proper plate coupling and feed-back coupling for any particular frequency at which the oscillator is set to operate. A number of different wave lengths are made available, and the operator can switch from one to the other instantly. No adjustment need be made other than a single movement of a single switch.

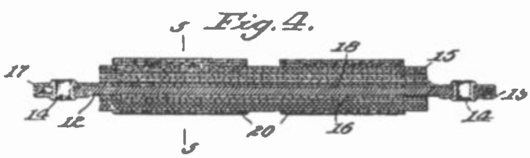
1,395,454—James Harris Rogers, of Hayattsville, Maryland, filed March 9, 1920, renewed September 12, 1921, issued November 1, 1921.



NUMBER 1,395,454—Radio Signaling System

RADIO SIGNALING SYSTEM. This patent shows an antenna for a submarine vessel having a metallic hull comprising conductors extending longitudinally and entirely inclosed by the hull and electrically connected at their ends to the metallic walls of the hull. The radio signaling apparatus is inductively coupled to this antenna system. A modification of the system shows a loop antenna contained entirely within the metallic hull of the submarine.

1,395,931—Charles F. Smith and William H. Smith, of Brooklyn, New York, filed May 17, 1920, issued November 1, 1921.

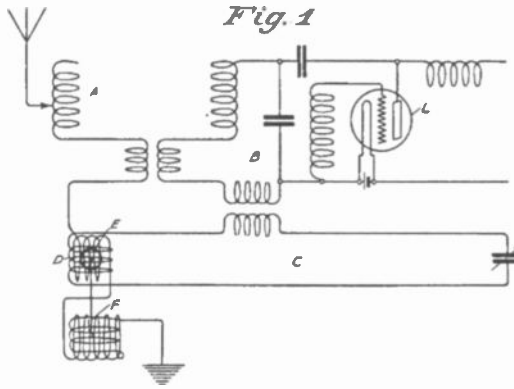


NUMBER 1,395,931—Electric Condenser

ELECTRIC CONDENSER. An electric condenser unit is shown in this patent comprising a base or body of thin board and a wrapping of dielectric and metallic foil encircling the fiber board. The sheets of metal foil are smaller in size than the sheets of dielectric and the stack is folded around the fiber board and the leads brought out to eyelet terminals on the ends of the board.

A number of units may be associated in parallel by building up a structure with bolts passing thru the eyelet terminals.

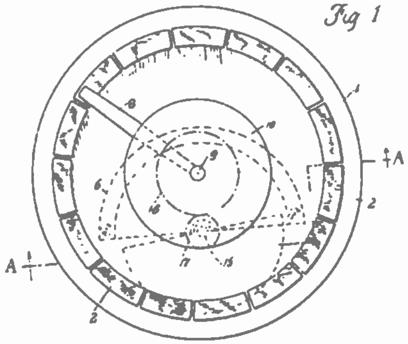
1,395,987—Henry Joseph Round, of London, England, filed March 24, 1921, issued November 1, 1921. Assigned to Radio Corporation of America.



NUMBER 1,395,987—"Wireless" Signaling Apparatus

"WIRELESS" SIGNALING APPARATUS. The object of this invention is to provide means whereby the wave length of a radio transmitter may be kept constant automatically. The antenna circuit and the closed oscillator circuit of the transmitter are combined with a small rotating field motor comprising two windings. One winding is connected in the closed circuit and the other winding in the antenna circuit or in any circuit whose period varies with that of the antenna. When the antenna is exactly in tune with the closed circuit there will be no rotating field produced by the two windings at right angles; but if the antenna increases its wave length, the phase of the antenna current will tend to produce a rotating field in one direction whereas if the antenna decreases its wave length the rotating field will be in the other direction. The rotation of the shaft of the armature of the rotating field motor controls a variometer, a variable condenser, or other means for varying the period of the antenna. Thus when the antenna increases its wave length the variometer decreases it until there is no longer any rotating field and vice versa, so that the wave length of the antenna is kept practically constant. The system is intended for all types of sets such as a vacuum tube transmitter, an alternator, or an arc transmitter.

1,396,030—William Dubilier, of New York, N. Y., filed July 25, 1917, renewed February 2, 1921, issued November 8, 1921.



NUMBER 1,396,030—Variable Condenser

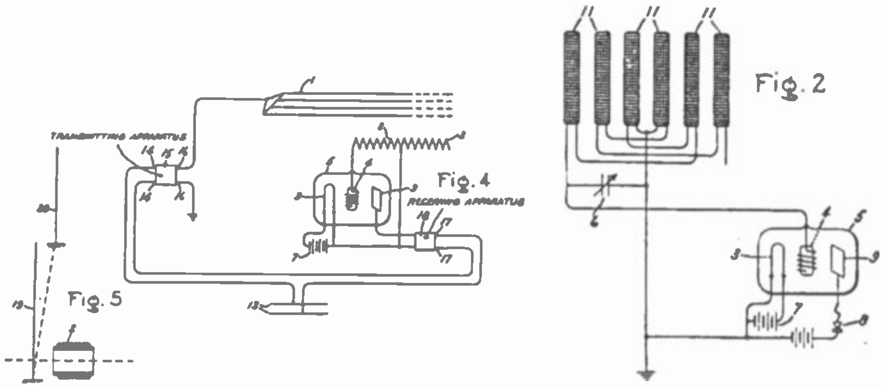
VARIABLE CONDENSER. A variable condenser is shown in this patent comprising a number of fixed condenser units connected to contacts, a switch for cutting in the units, and variable condenser having a maximum capacity substantially equal to the common difference between the capacities of the fixed condenser units. Intermediate capacities between the fixed capacities are thereby obtained by manipulating the variable condenser while the errors due to changes in the variable condenser are minimized.

1,396,491—R. L. Williams, of Newton, Massachusetts, filed June 24, 1919, issued November 8, 1921. Assigned to Submarine Signal Company.

DEVICE FOR ESTIMATING DISTANCES. This patent shows a combination radio system and submarine sound signal system wherein a radio transmitter is operated to give a single signal simultaneously with the operation of a submarine sound signal. The operator at the receiving station gets the single instantaneous radio signal and later hears the first blow of the submarine signal and by measuring the time between the receipt of the radio signal and the first blow of the submarine signal can calculate the distance from the transmitting station.

1,396,571—Alfred N. Goldsmith and Julius Weinberger, of New York, N. Y., filed September 13, 1918, issued November 8, 1921. Assigned to General Electric Company.

RADIO RECEIVING SYSTEM. The object of this invention is to provide a receiving system which is adapted to be used in close proximity to a transmitting system and which is capable of receiving signals from a distant station at the same time that signals are being sent from the transmitting station. In the diagrams, the transmitting antenna is indicated by 1, and 2 is the coil employed for reception. This coil is connected to the cathode 3, and grid 4 of an electron discharge amplifier 5. A tuning condenser 6 may be used for tuning the receiving circuit to the frequency of the signals to be received. The plate cir-



NUMBER 1,396,571—Radio Receiving System

cuit of the amplifier 5 comprises the cathode 3 of the amplifier, a local source of current 7, a wave responsive device 8, and the anode 9 of the amplifier. The grid 4 is connected to one end of the coil 2 and the cathode 3 is connected to the junction point of the two halves of the coil. This point is connected to earth. The mode of operation of this system may be explained as follows: The exposure of the two halves of coil 2 may be represented by condensers between the antenna and the coil. It will be apparent that, for currents flowing thru these condensers and the two halves of coil 2 to ground, the magnetic field of the two halves are in opposition and the two halves of coil 2 act as inductances in parallel. The inductance of the coil for such currents then is $\frac{L-M}{2}$ where L is the inductance of each half of the coil and M is the mutual inductance between the two halves. If M is made equal or very nearly equal to L, then the coil becomes a non-inductive path to ground for capacitively induced currents; consequently no potential difference can build up across its terminals and no interference will result in the receiving set from the local antenna.

1,396,745—Arthur Haddock, of East Orange, New Jersey, filed May 19, 1919, issued November 15, 1921. Assigned to Western Electric Company, Inc.

VACUUM TUBE CIRCUITS. This patent relates to a multistage amplifier. Switching means are provided for varying the number of effective tubes between the input and output circuit of the amplifier and also for regulating the potential between the incoming line and one of the tubes. The object of the circuit is to vary the amplification to any desired degree between the input circuit and the output circuit.

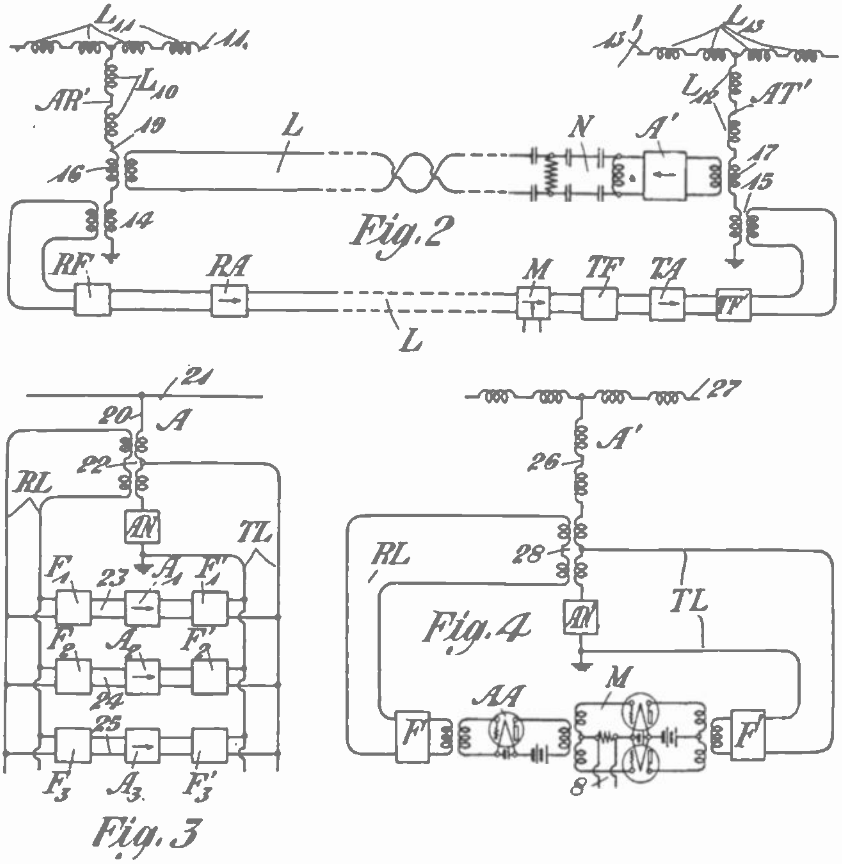
1,396,786—E. O. Scriven, of New York, N. Y., filed November 6, 1916, issued November 15, 1921. Assigned to Western Electric Company, Inc.

SYSTEM FOR TRANSMISSION OF INTELLIGENCE. This invention relates to a radio telephone system wherein signals are transmitted or received by means of a high frequency carrier wave modulated in accordance with the signals. The circuit embodies the combination of two vacuum oscillators which serve as a source of high frequency carrier wave oscillations, the impedanee of which combination is varied according to the low frequency signals to be trasnmitted. At the receiver a vacuum tube containing two grids, two plates, with common filament is employed. The circuit may be arranged for either high frequeney carrier wave reception or modulated high frequency wave reception, in which latter case the tube serves as a homodyne generator, that is, it should produce oscillations of the same frequency as the incoming high frequency oscillations. If the incoming waves are not modulated the vacuum tube gen erator should be a heterodyne generator, that is, it should gen erate oscillations of a frequency different from that of the incoming carrier waves to produce a frequency within the limits of audition.

1,396,897—Phillips Thomas, of Edgewood Park, Pennsylvania, filed October 8, 1917, issued November 15, 1921. Assigned to Westinghouse Electric and Manufacturing Company.

CONDENSER. This patent shows a construction of condenser having means for filing the space which remains at the edges of the conducting foils in condensers constructed in the usual manner. A U-shaped strip of dielectric material is cut to fit closely around the margin of a conducting foil, the strip being substantially of the same thickness as the foil. The conducting sheets assembled with the U-shaped strips are stacked with intermediate sheets with one side of the conducting sheet extending to form the terminals of the condenser.

1,397,093—Lloyd Espenschied, of Hollis, New York, filed September 27, 1919, issued November 15, 1921. Assigned to American Telephone and Telegraph Company.

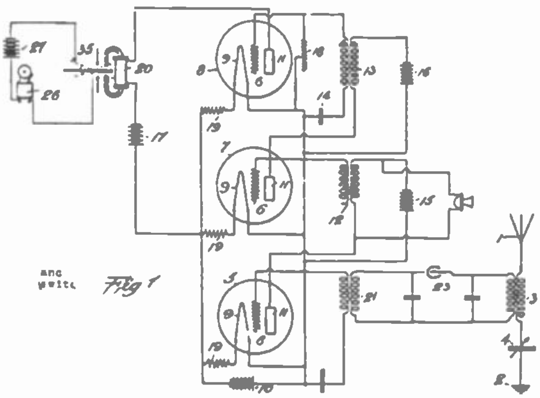


Number 1,397,093—Radio Repeating System

Radio Repeating System. This invention relates to radio repeating stations and apparatus for amplifying at intermediate points the signals transmitted between two terminal stations.

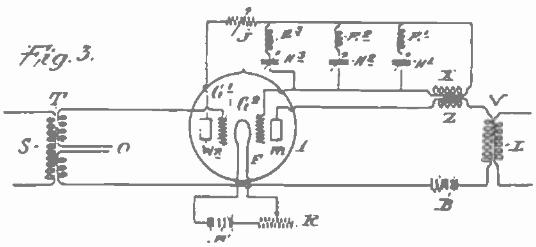
1,397,432—Charles V. Logwood, of New York, N. Y., filed June 16, 1917, issued November 15, 1921.

Signaling System. This patent relates to a radio transmitting and receiving vacuum tube apparatus with means for automatically switching from transmitting to receiving.



NUMBER 1,397,432—Signaling System

1,397,575—L. De Forest, of New York, N. Y., filed April 9, 1915, issued November 22, 1921. Assigned to De Forest Radio Telephone and Telegraph Company.



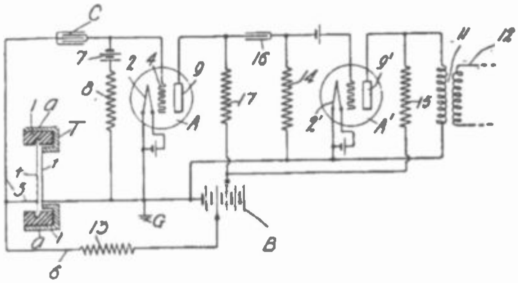
NUMBER 1,397,575—Selective Audion Amplifier

SELECTIVE AUDION AMPLIFIER. This patent describes a vacuum tube amplifier having in its output circuit a plurality of oscillating circuits associated therewith to amplify impressed currents of certain input frequencies to a greater degree than impressed currents of other frequencies.

1,397,862—Albert L. Fitch, of East Orange, New Jersey, filed November 26, 1917, renewed December 26, 1918, issued November 22, 1921. Assigned to Western Electric Company, Inc.

TRANSMISSION SYSTEM. This invention relates to a radio telephone modulating circuit employing a condenser transmitter connected to a vacuum tube amplifier and using a single battery both in the output circuit of the amplifier, and as a means for polarizing the transmitter. In the usual operation of a vacuum tube amplifier circuit with condenser telephone employing a single battery as described, the filament is usually grounded and accidental grounding of the condenser transmitter case causes either the battery or the condenser transmitter to be short-circuited and thus interferes with the operation. The present

Fig. 2.

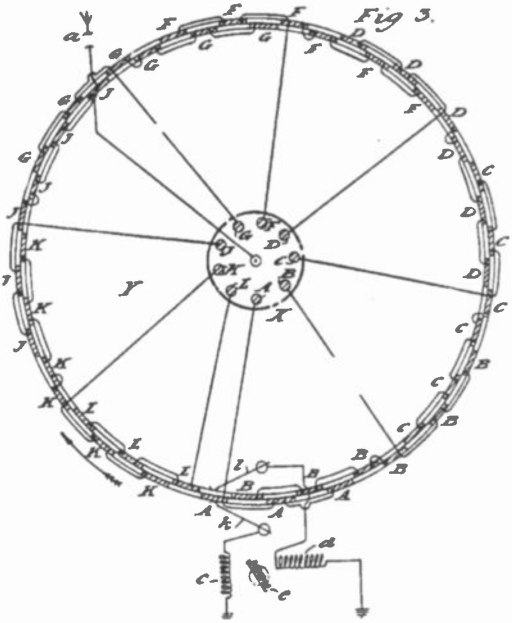


NUMBER 1,397,862—Transmission System

invention remedies this defect by connecting the battery to perform both the functions of charging the condenser transmitter and furnishing current to the output circuit in the amplifier circuit such that one electrode of the condenser transmitter is always grounded and the other electrode is arranged to make grounding substantially impossible. The source of electromotive force is common to both the circuits thru the condenser transmitter and the output circuit of the vacuum tube amplifier as shown in the diagram.

1,398,848—James Erskine-Murray and James Robinson, of Biggin Hill, England, filed March 30, 1920, issued November 29, 1921.

"WIRELESS" RECEIVING AND TRANSMITTING APPARATUS. This patent shows a radio transmitting and receiving system wherein a receiving station determines its bearing relatively to the transmitting station. The transmitting apparatus employs a plurality of antennas arranged in different directions. The receiving station employs an antenna having branch circuits to ground which are alternately connected in the antenna circuit. Two identical coils *c* and *d* are included in the branch circuits and arranged at an angle with each other. An adjustable receiving inductance *e* is coupled with the two circuits and adjusted for comparison of the received signals which permits a bearing to be obtained on the distant transmitting station on minimum signals.



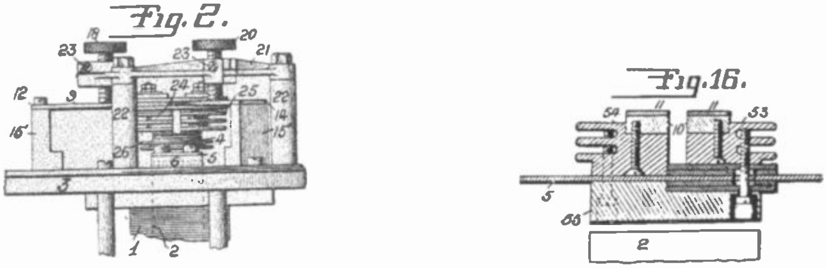
NUMBER 1,398,848—"Wireless" Receiving and Transmitting Apparatus

Re 15,241—Albert Pruessman, of East Orange, New Jersey, application for reissue filed June 14, 1920, reissued November 29, 1921. Assigned to Western Electric Company.

CONDENSER AND METHOD OF MAKING THE SAME. This patent relates to a method of treating a condenser which is impregnated in the presence of heat, which consists in applying pressure to the impregnated condenser as it cools and then removing the pressure, reheating the condenser to a temperature of not less less than 120 degrees F. for a period of not less than three hours without pressure applied thereto.

1,399,005—G. B. Crouse, of Brooklyn, New York, filed June 14, 1918, issued December 6, 1921. Assigned to The Sperry Gyroscope Company.

SPARK-GAP. This invention relates to a spark-gap construction for a buzzer transmitter, operated from a direct current source. The spark-gap construction comprises a vibratory electrode, a portion thereof being magnetic material whereby the electrode may be vibrated by energizing an adjacent electromagnet. A plurality of insulated electrodes are arranged to be normally bridged across the vibratory electrode. Signals are produced upon closing of a key, causing vibratory action of the spark-gap electrode.



NUMBER 1,399,005—Spark-Gap

1,399,251—Emory Leon Chaffee, of Belmont, Massachusetts, filed July 31, 1917, renewed April 21, 1921, issued December 6, 1921.

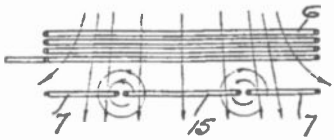
MEANS FOR CHANGING THE INTENSITY OF SIGNALS IN RADIO-DYNAMIC RECEIVING SYSTEMS. This patent shows a circuit for the reduction of the intensity of strong signals in radio-dynamic control work without reducing the intensity of weak signals. The object of the invention is to reduce interference in radio-dynamic control circuits from nearby transmitters and from static.

1,399,254—John Hays Hammond, Jr., of Gloucester, Massachusetts, filed June 30, 1917, renewed April 20, 1921, issued December 6, 1921.

SYSTEM OF RADIO-DYNAMIC CONTROL. This patent shows a radio transmitter control circuit for use in a system of radio-dynamic control for torpedoes and the like. The transmitter includes two sets, one being intended to transmit different wave lengths thru any desired variable range to disturb the enemy, and other being provided with a plurality of control circuits, whereby the frequency transmitter may be changed over a series of wave lengths to control the distant object.

1,399,945—Harold F. Elliott, of Palo Alto, California, filed July 24, 1920, issued December 13, 1921. Assigned to Augustus Taylor.

FIG. 3.



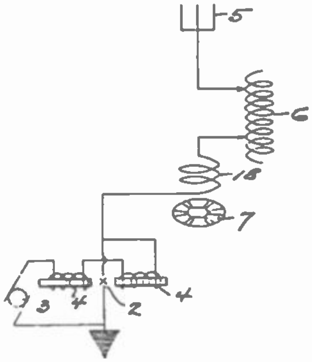


FIG. 5.

NUMBER 1,399,945—Radio Telegraphy

RADIO TELEGRAPHY. This patent relates to a high power arc signaling system in which the signals are produced by a variation in wave length of the radiated wave. The antenna inductance is changed to produce the signals by the closing of a plurality of pairs of contacts in a system of loops inductively associated with the antenna inductance. The shorting inductance includes a plurality of separate loop circuits concentric with the axis of the antenna inductance and each opened and closed simultaneously by a pair of contacts electromagnetically controlled by a signaling key.

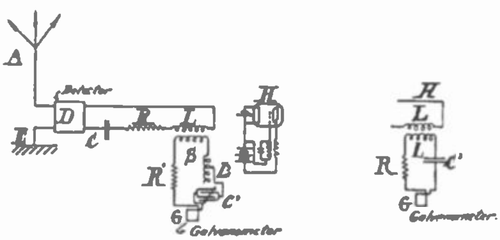
1,400,235—John H. Payne, Jr., of Schenectady, New York, filed September 14, 1916, issued December 13, 1921. Assigned to General Electric Company.

METHOD OF AND MEANS FOR PRODUCING ALTERNATING CURRENTS. This patent shows a vacuum tube circuit for the production of alternating currents. The coupling between the grid and the plate circuits is provided by condensers. Inductances in the grid and plate circuits and the capacities therein are preferably so chosen that radio frequency oscillations will be set up in the circuit which includes these inductances and capacities. The frequency of these oscillations may be varied by changing the position of the plates of a condenser shunting the grid and plate circuits. The inductances and condensers in associated circuits are so proportioned that the circuit including these inductances and capacities will be resonant to a different and preferably an audible frequency, and the frequency of the alternating currents generated in this circuit may be varied by varying the capacity therein.

1,400,847—Ernst F. W. Alexanderson, of Schenectady, New York, filed December 31, 1918, issued December 20, 1921. Assigned to General Electric Company.

System of Radio Communication. This patent shows a speed regulating mechanism for a radio frequency alternator employed at the transmitter in a radio system. The radio frequency alternator shown in the drawings is driven by a three-phase electric motor supplied with power from a distribution system, and a regulator relay is employed to control the power delivered to the shaft of the alternator. The regulator comprises a tuned circuit energized by current derived from the high frequency alternator. A rectifier is associated with the tuned circuit and delivers rectified current to the relay for controlling the power to the motor. Various means are described for amplifying the variations of energy acting upon the regulator relay whereby great sensitivity is obtained to maintain constant the speed of the alternator.

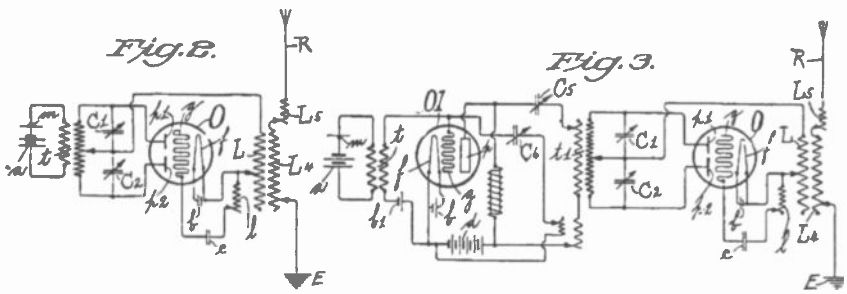
1,400,517—André Eugene Blondel, of Paris, France, filed April 26, 1919, issued December 20, 1921.



Number 1,400,517—Recording Apparatus for Radiotelegraphic Signals

Recording Apparatus for Radiotelegraphic Signals. This patent shows a galvanometer or oscillograph which is adjusted to resonance with an alternating current of any given frequency. The circuit employed includes a receiving antenna system, a detector and a vibrating galvanometer connected in a low resistance tuned circuit. The galvanometer winding may operate the usual mirror for oscillograph reception.

1,400,591—Cornelius D. Ehret, of Philadelphia, Pennsylvania, filed March 12, 1919, issued December 20, 1921.

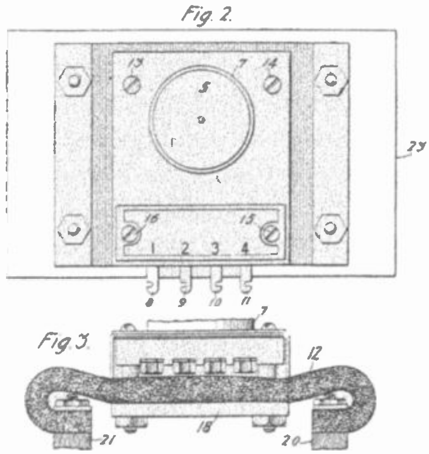


NUMBER 1,400,591—Electrical Wave Transmission

ELECTRICAL WAVE TRANSMISSION. This invention relates to the transmission of radio telephone signals wherein high frequency oscillations are not existent or produced except when the microphone is actuated. The oscillator employed in the system includes a pair of anode circuits, a heated cathode, and a grid circuit. An amplifier may be inserted between the microphone circuit and the oscillator and between the oscillator and the antenna radiating system. In the operation of the system, Figure 3, modulating energy is impressed by transformer t_1 upon the anode circuits of the oscillator *O* with the result that all of the frequencies of positive polarity are converted by one of the anode circuits while all of the frequencies of negative polarity are converted by the other of the anode circuits. Thus, there are directly produced, by conversion of the amplified telephonic energy, high frequency oscillation varying in amplitude in accordance with speech waves. The telephonic energy is the only energy supplied to the plate or anode circuits as distinguished from systems wherein a battery supplies the anode circuit and wherein only the telephonic energy is employed merely to vary the potential of the grid of the oscillator.

1,401,121—Roy M. Allen, of East Orange, New Jersey, filed May 24, 1918, issued December 27, 1921. Assigned to Western Electric Company, Inc.

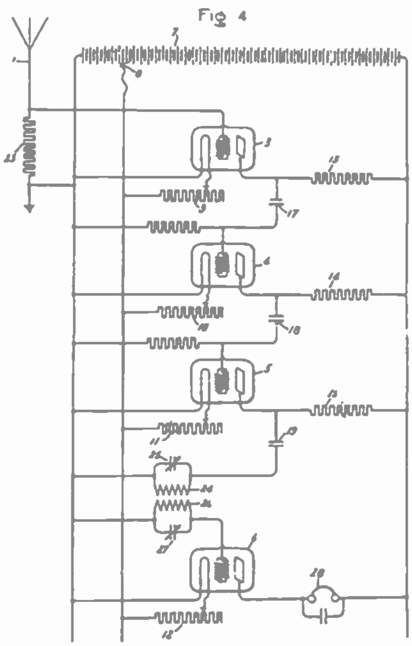
MOUNTING FOR VACUUM TUBES. This invention relates to a



NUMBER 1,401,121—Mounting for Vacuum-Tubes

resilient support for vacuum tubes to reduce the effect of an external vibration upon the structure of the tube.

1,401,644—Chester W. Rice, of Schenectady, New York, filed July 31, 1917, issued December 27, 1921. Assigned to General Electric Company.



NUMBER 1,401,644—Method of and Apparatus for Amplification of Small Currents

Method of and Apparatus for Amplification of Small Currents. The amplifier shown in this patent employs a plurality of vacuum tubes in which all of the plate circuits are supplied with current from a common source and a high resistance is applied to the grid circuit of the first amplifier of the series and the current in the plate circuit of that amplifier is varied proportionally. As a result there will be a variation in potential difference between the cathode and anode of the amplifier and this variable potential is applied to the grid circuit of the second amplifier. The variable potential between cathode and anode of the second amplifier is in turn applied to the grid circuit of the third amplifier and so on thruout the series. The plate circuit of the last amplifier includes a telephone receiver or other device for detecting the received signals.