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WASHINGTON SECTION

BOSTON SECTION

SEATTLE SECTION

SAN FRANCISCO SECTION

THE AVALON-LOS ANGELES RADIO TOLL CIRCUIT*

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Since last summer it has been possible for subscribers served by the Bell Telephone System to call any subscriber at Avalon, Santa Catalina Island, by telephone. This connection makes use of the Avalon-Los Angeles toll circuit with its radio link between Long Beach, on the mainland and Pebbly Beach, Santa Catalina Island, California.

The purpose of this paper is to describe the system employed and the apparatus which makes up the radio link, its installation and some of the features of operation and maintenance. Before discussing the apparatus itself, it may be well to say a word about the location of the circuit, the need for telephone service and the preliminary arrangements.

The Island terminal is located in the city of Avalon on Santa Catalina Island, approximately 30 miles (48 km.) off the coast of Southern California (See Figure 1). The population of the Island is concentrated at Avalon, altho there are a few people at Middle Ranch and others at the Isthmus. Avalon is a well-known summer and winter resort noted for its ideal climate, bathing, big game fishing, and other attractions. A view of the city of Avalon showing the main street is shown in Figure 2. The average yearly permanent population of Avalon is about 1,000, while the population during the summer months is probably between 10,000 and 15,000.

In the past, the only means of communication was the daily steamer to the Island from San Pedro. In 1902 this was supplemented by a radio telegraph service, one of the first commer-

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cial stations in the United States operated by the Pacific Wireless Telegraph Co.[1] This service was maintained with various degrees of satisfaction and duration successively by the United Wireless Telegraph Company, Marconi Wireless Telegraph Company of America, and at the present time† is operated by the United States Naval Radio Service.

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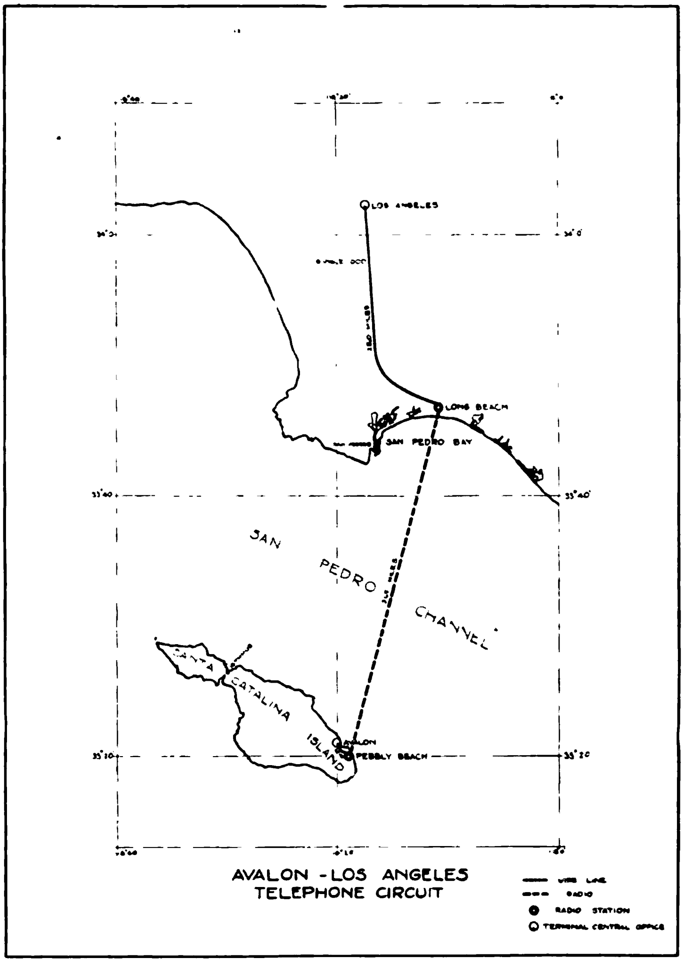

FIGURE 1—Avalon-Los Angeles Telephone Circuit

[1]Marriott, "United States Radio Development," PROCEEDINGS OF THE INSTITUTE OF RADIO ENGINEERS, June, 1917.

† Since the preparation of this paper this service has been discontinued, and all telegraph traffic to and from Avalon is handled by the simultaneous duplex telegraph channel mentioned at the close of this paper.

Avalon was given by a few private circuits including a line to the Isthmus. The need of the transient and permanent population of the Island for a more dependable means of communication between different points on the Island and between the Island and the vicinity of Los Angeles lead to a real demand for telephone service.

FIGURE 2—City of Avalon

Early in May, 1920, it was estimated that it would be practical to establish telephone service to the mainland by making use of a radio telephone connecting link between the wire circuits which would be established on the Island and the existing wire circuits on the mainland. It was believed that such a system could be completed and be in operation by July, 1920.

After these estimates had been carefully considered it was decided to start work immediately on the design and manufacture of the necessary radio and wire terminal equipment, and at the same time to start the installation of the necessary wire facilities at Avalon, the latter to consist of a telephone exchange, pole lines, and subscribers' terminal stations, which portion of the work was cared for by The Pacific Telephone and Telegraph Company.

The actual design and construction of the radio apparatus was started on May 10, 1920. Installation and preliminary tests of this equipment at the sites chosen for the stations were completed so that commercial service was inaugurated on July 16, 1920, 68 days after work was started in New York. On the previous day an official trial was given the complete system for the benefit of the officials of The Pacific Telephone and Telegraph Company, the leading citizens of Avalon and others. Connections were established between Avalon and Los Angeles, San Francisco, Chicago, and New York, so that the people who had gathered were given an opportunity to talk to their friends in these cities. Each circuit included the radio telephone link from the Island to Long Beach, the remainder of the circuits being part of the plant of the Bell system.

Description of System

Any radio telephone circuit which is to form a part of a commercial telephone system not only must be capable of duplex operation, but must allow of ready connections to ordinary two-wire telephone circuits. The duplex requirement was met, in the case of the radio portion of the Avalon-Los Angeles circuit, by the use of different carrier frequencies for transmitting in the two directions. The station at Pebbly Beach transmits a carrier of 750 kilocycles (wave length of 400 m.) and the one at Long Beach a carrier of 638 kilocycles (wave length of 470 m.).

The problem of connecting such a radio link with two-wire telephone circuits at each end is similar to that of providing two-way operation when using one-way repeater elements such as mechanical repeaters or vacuum tubes. The experience acquired with such repeater circuits was directly applicable to this problem. The upper sketch in Figure 3 shows the circuit of the most usual type of two-way telephone repeater. This repeater circuit employs separate elements for amplifying the speech currents in the two directions. These elements are in a four-wire circuit and connection with the two-wire circuits is made thru special output transformers, often called hybrid coils. These transformers, together with their associated lines and networks, form alternating current bridges. The networks are circuits designed to have, as nearly as possible, impedance characteristics identical with the lines thay are to balance. If the balances are perfect, none of the output from either of the repeaters reaches the input circuit of the other repeater, the output current dividing equally between the line and network in each case and inducing no voltage in the input winding. However, if the balance is not perfect, as is always the case in practice, the current flowing into the line is not exactly equal to that flowing into the network and some voltage will be induced in the input coil. This results in a circulating current flowing in the four-wire portion of the circuit thru the two repeater elements. If the transmission loss around this circuit is less than the amplification or gain in the repeaters, "singing" results. The precision with which the networks may

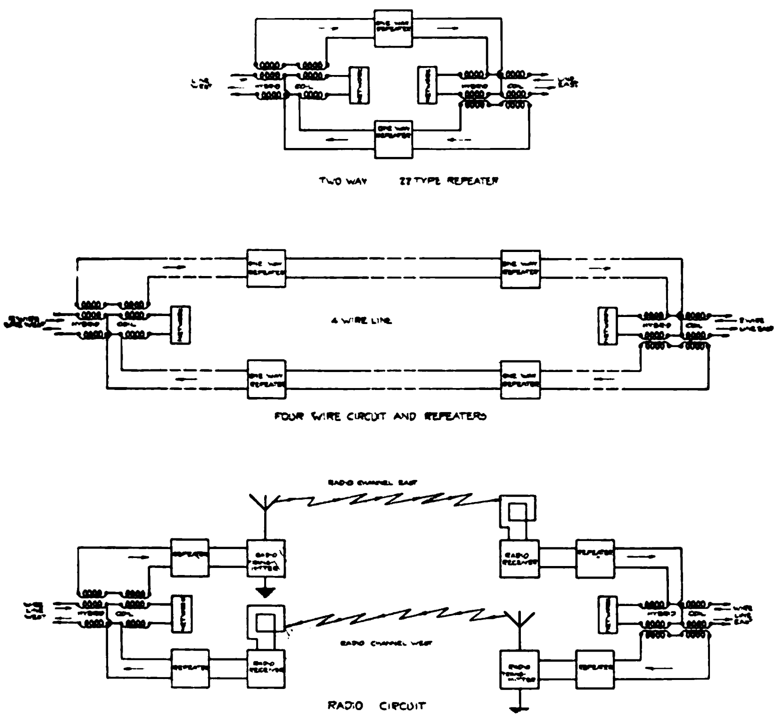

Figure 3—Schematic Diagram of "22" and 4-wire Repeaters and Radio Circuit

be made to balance the connecting lines largely determines the transmission loss around this circuit and in turn limits the amplification which may be obtained with such circuits without "singing." In the commercial operation of repeaters it is necessary to use gains very considerably below the "singing point" in order that speech distortion may be avoided.

The middle sketch in Figure 3 shows the four-wire circuit which is used to a considerable extent in the long-distance cable circuits of the Bell plant. It is to be noted that this circuit is similar to that of the "22 type" repeater shown above, the four-wire portion of the circuit having been expanded and the repeater elements placed at suitable intervals. The balance conditions necessary in this circuit are similar to those in the case of the "22 type" repeater.

The lower circuit in Figure 3 is of a radio telephone system which meets the requirements of duplex operation and terminal connection to two-wire telephone circuits. The similarity to the two repeater circuits described is apparent: the four-wire portion has been replaced by two one-way radio telephone channels. Amplification takes place not only in the repeater in this circuit, but also in the radio transmitter and receiver. In order that this circuit may be stable the total transmission loss in the two radio channels, and from one to the other thru the hybrid coils, must be greater than the total gain in the repeaters and radio equipment. If this condition is not fulfilled the system will "sing" around the two radio channels in a manner exactly similar to the "singing" in the four-wire portion of the repeater circuits. However, if the balance between the networks and their respective lines is accurate enough, it is quite possible to operate such a system with a considerable gain in transmission or amplification between the two connecting wire circuits. Similar types of circuits have already been so thoroly treated[2] that they will not be dealt with further except insofar as special problems related to the Avalon-Los Angeles circuit are discussed.

Circuits

Figure 4 shows schematically the Avalon-Los Angeles circuit consisting of a little more than 1 mile (1.6 km.) of wire line from the Avalon central office to Pebbly Beach, a 31.5 mile (50.4 km.) radio link to Long Beach, and 25 miles (40 km.) additional wire circuit to Los Angeles. This combination wire and radio circuit is operated as a unit providing thru telephone and signaling from Avalon to Los Angeles. At Avalon the circuit may be connected with any subscriber's line and at Los Angeles to any local subscriber's line thru local exchanges or with other long distance lines reaching practically any subscriber in the Bell System.

The general circuit arrangement is indicated in Figure 5 which is a schematic of the Long Beach Station. The heavy lines in this figure show the speech circuit and the light lines the signaling system. For simplicity only the principal connections are shown.

[2]Gherardi and Jewett, "Telephone Repeaters," "Transactions of the American Institute of Electrical Engineers," 1919, page 1322.

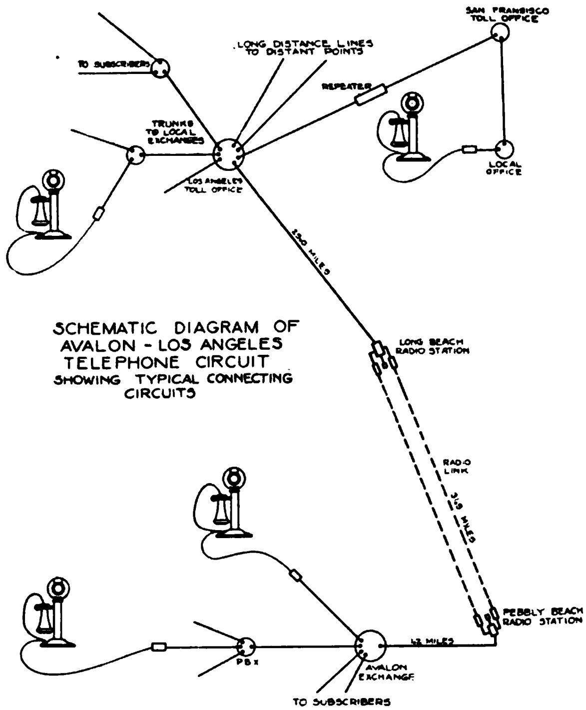

FIGURE 4—Schematic Diagram of Avalon-Los Angeles Telephone Circuit

Speech currents received from the Los Angeles line pass thru the cordless switchboard to the hybrid coil and to the network inducing similar currents in the input winding connected to the send repeater. This repeater amplifies these speech currents and delivers them to a low-pass filter which freely passes the principal speech frequencies of from 200 to 2,000 cycles, but greatly attenuates currents of frequencies higher than 2,200 cycles. Experiments have shown that only the band of frequencies from 200 to 2,000 cycles need be transmitted to deliver commercial quality and readily understandable speech and therefore the use of this filter does not impair to any appreciable extent the quality of transmission. The filter serves two purposes: it prevents interfering currents of frequencies above the necessary speech range from entering the radio transmitter, and it makes the balancing of the line with a suitable network somewhat easier in that the balance must be effective only for frequencies below 2,200 cycles. The output currents from the filter are delivered to the radio transmitter where they are further amplified and employed to modulate the radio frequency carrier current there generated.

The cordless switchboard provides convenient means for testing and monitoring on the circuit and for connecting quickly with another wire line in case of trouble in the wire portion of the circuit. In Figure 6 the hybrid coil, repeaters and signal units are shown as associated with the radio transmitter and receiver. All of this apparatus is mounted in the ends of a flat-top desk which supports the radio receiver and the cordless switchboard. At the rear of this desk is a battery control board providing means for measuring and controlling filament currents as well as protection for both the plate and filament circuits. Alarms are provided which notify the attendant in case any fuse blows. Figure 7 is a photograph of one end of this desk showing the send repeater and the sending unit of the signaling system and Figure 8 a photograph of the battery control board.

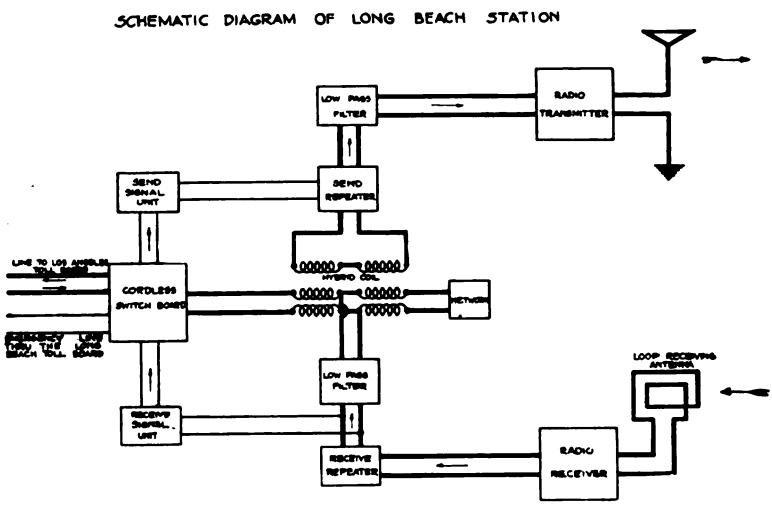

Figure 5—Schematic Diagram of the Long Beach Station

The send repeater (Figure 6) employs two tubes, the first, principally a voltage amplifier, and the second capable of delivering a relatively greater current output. Each of these tubes has the speech input voltage controlled by a potentiometer and by means of these the repeater gain can be adjusted to a suitable value, gains equivalent to more than 40 miles of standard

cable[3] being obtainable. Figure 6 also shows the electrical structure of the low-pass filter, the function of which has already been mentioned.

FIGURE 7—View of the End of the Repeater Desk

A loop antenna is used for receiving at each of the radio stations of this circuit. These loops are of the solenoidal type, six feet (1.83 m.) square and consist of only four or five turns each. How this loop is associated with the receiving equipment is shown in Figure 6. It was mentioned that the duplex feature of operation was attained by the use of different carrier frequencies for transmission in the two directions. In order to prevent, as far as possible, currents of the transmitting frequencies entering the receiver, an anti-resonant circuit adjusted to have a maximum impedance at the transmitting carrier frequency is included in the loop circuit and forms an effective filter. Figure 9 is a selectivity curve of the receiver showing the attenuation suf-

[3]The "mile of standard cable" is a convenient measure of transmission volume which has found extensive use in telephone engineering.

The transmission equivalent of any circuit or apparatus is equal to the number of miles of standard cable which will cause an attenuation at 800 cycles the same as that experienced by the current in the circuit in question.

Figure 8— Rear View of Desk Showing the Battery Supply Panel

fered by currents outside of the desired transmission band, and Figure 10 is a photograph of the receiver.

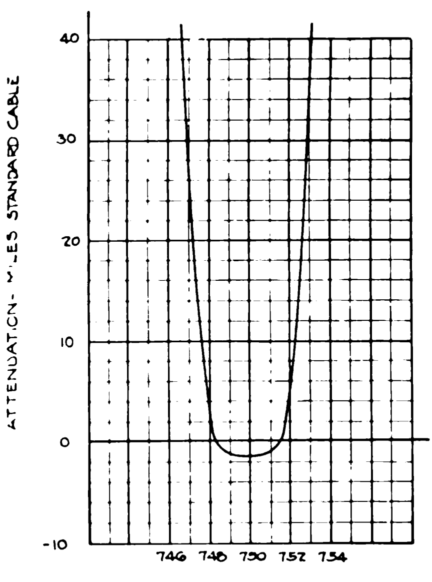

Figure 9 Selectivity Curve of the Radio Receiver

The speech frequency output currents from the radio receiver are amplified by the receive repeater which is similar to the send repeater already described and are delivered to a low-pass filter, the function of which is similar to that of the filter in the transmitting circuit. From the filter the speech currents flow to the hybrid coil, where they divide, half flowing into the network and half into the line. An interesting feature of the receiver is the provision of relays which close a buzzer alarm circuit when the filament of any vacuum tube fails.

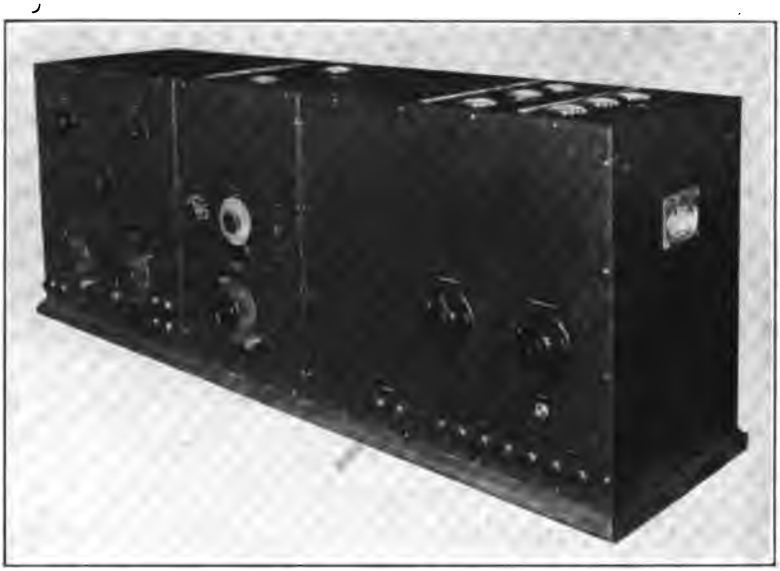

FIGURE 10—Radio Receiver

RADIO TRANSMITTER

The radio transmitter employs a circuit in which the oscillations are generated directly in the antenna circuit (Figure 11). The modulation of the radio carrier frequency is accomplished by the "constant current system"[4] in which both oscillator and modulator tubes, *G*, in this circuit are of 50 watts rating. These tubes are of the coated filament type, having relatively low fila-

[4]Craft and Colpitts, "Radio Telephony," "Transactions of the American Institute of Electrical Engineers," 1919, page 305.
Heising, "Modulation in Radio Telephony," presented before THE INSTITUTE OF RADIO ENGINEERS, December 1, 1920.

ment power consumption and very constant operating characteristics. Figure 12 is a photograph of one of these power tubes.

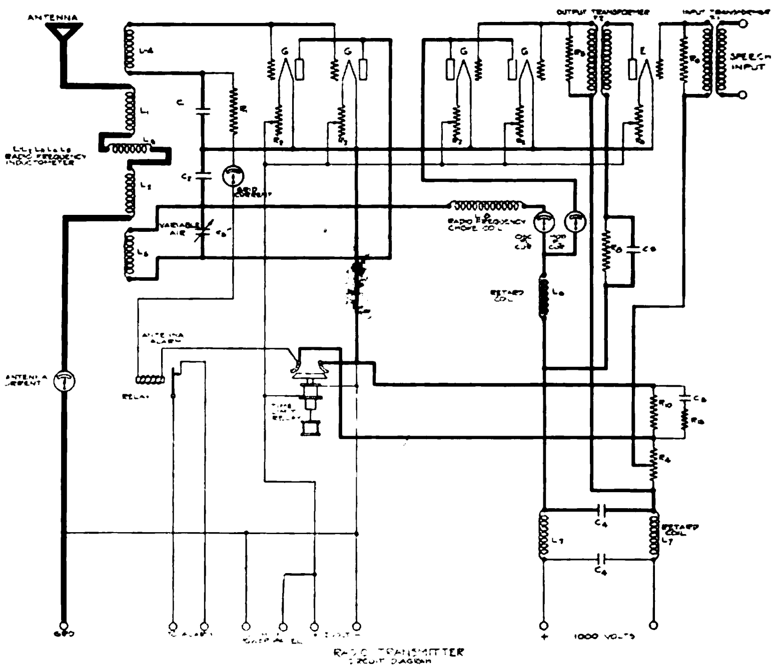

FIGURE 11—Circuit Diagram of the Radio Transmitter

Referring to Figure 11, the speech current is applied to the speech amplifier tube, *E*, thru the input transformer *T*-1. The output of this amplifier is impressed on the grid circuits of the two parallel modulator tubes thru the transformer *T*-2. The action of these modulator tubes is that of an amplifier and their output voltage is impressed on the plate circuits of the two oscillator tubes by means of the reactance L_6, which is common to the modulator and oscillator plate circuits. This modulation of the oscillator plate potential results in speech frequency variation of the amplitude of the antenna current. The frequency of the antenna current when not modulated is nearly that corresponding to the free period of the antenna circuit. It has been frequently shown[5] that a carrier current modulated by a single frequency is actually composed of three components, the carrier frequency and two side frequencies, one of a frequency equal to the sum of the carrier and modulation frequency, and the other of the carrier minus the modulation frequency. This concep-

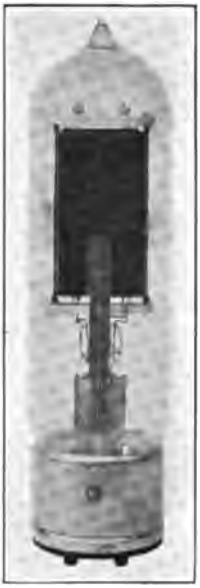

FIGURE 12—View of the 50-watt Tube

tion of the nature of a modulated carrier current is essential to an understanding of the many problems of a radio telephone system. If instead of considering modulating with a single frequency, we consider modulation by the band of voice frequencies from 200 to 2,000 cycles, it is apparent that the result will not be simply two frequencies other than the carrier, but two bands of frequencies, one above and one below the carrier. For example, the Pebbly Beach station transmitting a carrier of 750 kilocycles, when modulated by speech, has the following frequencies present in the antenna circuit:

Carrier—750.0 kilocycles
Upper Side Band—750.2 to 752.0 kilocycles
Lower Side Band—748.0 to 749.8 kilocycles

[6]Craft and Colpitts, previous citation.
Ryan, Tolmie, and Bach, "Multiplex Radio Telegraphy and Telephony," PROCEEDINGS OF THE INSTITUTE OF RADIO ENGINEERS, December, 1920, page 451.

The transmitting antenna satisfactorily passes all of these frequencies as none of them differ as much as 3 per cent. from the resonant frequency and the impedance of this circuit is nearly equal to its resistance over this range.

Figures 13 and 14 are photographs of the radio transmitter and Figures 15 and 16 show the motor generator set and controlling switchboard supplying the plate and filament power for the transmitter. This motor generator set consists of 1,000 and 12 volt direct current generators driven by an induction motor. The filter consisting of the series retard coils L_7 and shunt condensers C_4 (Figure 11), serves the double purpose of protecting the 1,000 volt generator from the radio frequency potentials and smoothing out any commutator ripple or other machine noises which would tend to modulate the radio carrier and result in objectionable noises in the subscriber's instrument.

Two other important details of the radio transmitter circuit, as shown in Figure 11, are the method of obtaining and controlling the required negative grid potentials and the alarm provided to indicate failure of the oscillators. The negative grid potential for the speech amplifier, E, is obtained from the drop in potential in the upper part of the resistance R_4 and that for the modulator tubes from the entire drop in this resistance which carries the space current of all the tubes in the transmitter. A time limit relay is provided which is controlled by the filament circuit and which itself controls an auxiliary negatuve grid potential which results from the drop of potential in R_{10}. This negative potential is relatively large and results in the stopping of oscillations and the reduction of all space currents to a low value. This arrangement insures that the filaments will have reached normal temperature before the auxiliary grid potential is removed and therefore that no excessive space currents can flow during the period when the filaments are heating. If for any reason oscillations cease in the antenna circuit, the oscillator grid current also stops flowing and the relay shown in the oscillator grid circuit releases, actuating an alarm at the cordless switchboard.

Signaling System

Another interesting feature of the installation and one which is important in completing the commercial usefulness of the telephone circuit is that of the signaling system. By means of it the signals are not only passed over the radio telephone system itself, but are automatically relayed at the points of junction with the wire circuits so that the operators at the ends of the

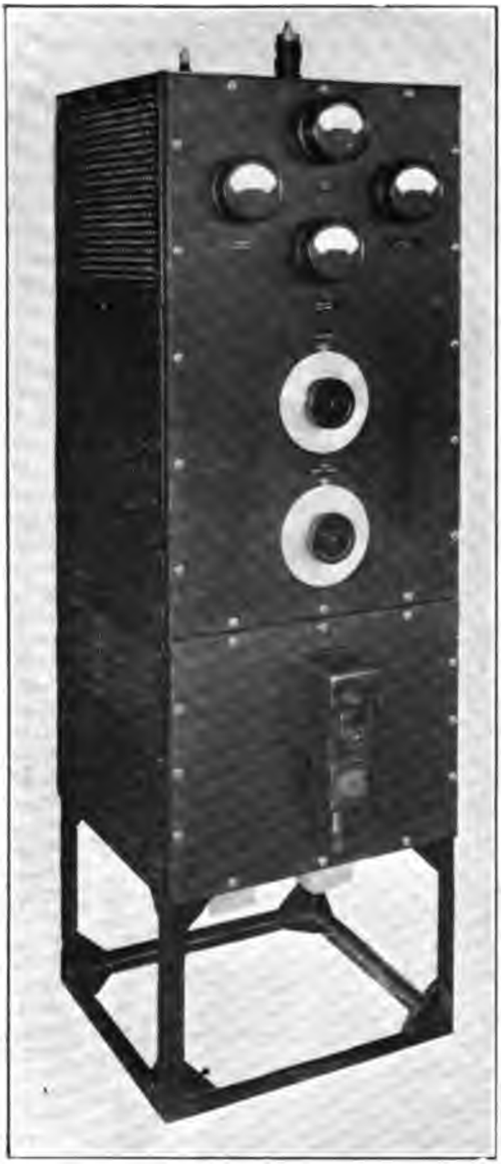

FIGURE 13—Radio Transmitter

FIGURE 14—Radio Transmitter (Rear View)

thru radio-wire toll line may ring down a drop at the distant end of the circuit and operate a visual or audible signal. By means of this system, then, the thru circuit may be operated from the remote land line switchboards in a manner according with standard wire practice.

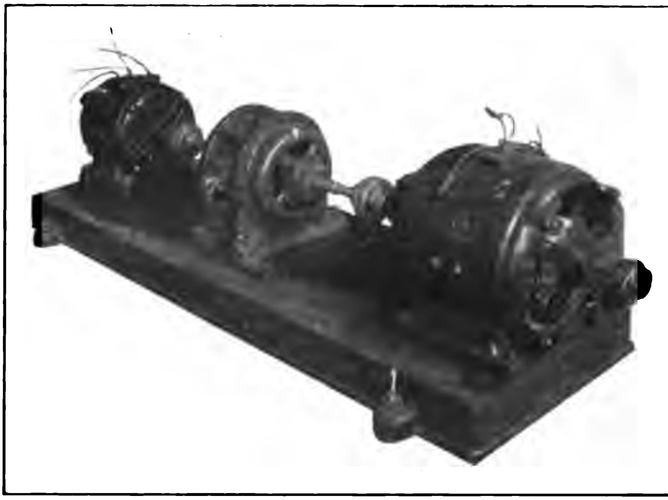

FIGURE 15—Motor Generator

Altho the requirements of the radio portion of the signaling system are somewhat rigid, the system in use has met them very satisfactorily. It has proven to be reliable, reasonably rapid, and free from false operation by interference from speech currents, circuit noises, static, or interference from other radio stations. The system represents an adaptation of a signaling arrangement originally developed for use on long distance wire circuits.

The manner in which the signal system is associated with the telephone and radio circuits is shown in Figure 6. The usual 16-cycle ringing current from the wire line actuates a relay which in turn controls three other relays. These latter relays disconnect the receive signal unit to prevent false signals, connect the output of the send signal unit with the second tube of the send repeater and energize the send signal unit. Upon reception of the signal impulses the relay in the output circuit of the receive signal unit releases and energizes another relay which disconnects the wire line from the hybrid coil and connects it with a source of 16-cycle signaling current. This same relay connects an auxiliary network to the line terminals of the hybrid coil maintaining a balanced condition and preventing "singing" during signaling. With this arrangement it is only necessary for the operator at Avalon to throw the usual ringing key and a light appears on one of the positions of the Los Angeles toll board and in a similar manner Los Angeles can signal Avalon.

FIGURE 16—Power Panel

SELECTION OF STATION SITES

The sites for the radio stations were selected and the antenna and ground systems were designed and installed while the equipment was being built in New York. The mainland end of the link is located at Long Beach, California, first because Long Beach is so located with respect to the Englewood Radio Station and San Pedro Harbor that the directional effect of the loop antenna can be used to discriminate against this station and ship stations in San Pedro Harbor, and second because adequate power and telephone facilities were available at the Long Beach Toll Exchange. Figure 1 shows the location of the radio stations and the wire circuits connecting them to Los Angeles and Avalon. Figure 17 is a photograph of the Long Beach Toll Exchange and Figure 18 is a photograph of the Avalon Exchange.

FIGURE 17—Long Beach Exchange

At Avalon there was no existing telephone plant and only one radio transmitting station, which was located practically at the center of the town on the water front. No site could be found which would at the same time satisfy wire center requirements and be at a reasonable distance from this spark transmitting station. Outside of the city proper, the only level stretch of ground suitable for a radio transmitter and antenna system was found at Pebbly Beach (Figure 19), which is about a mile and a quarter (2 km.) from Avalon.

ANTENNA AND GROUND SYSTEMS

Due to the short time available for construction purposes and further because it was desirable to use, as much as possible, types of construction already standard in telephone practice, the longest telephone poles that it was possible to secure locally are used to support the antenna. These poles are 90 feet (27.4 m.) long and are set on a special concrete and I-beam footing so that advantage is taken of the full height of the masts. Figure 20 shows the special footing supporting the pole which consists of four 8-inch (20.3 cm.) I-beams partly embedded in reinforced concrete. The I-beams are diametrically opposite each other

FIGURE 18—Avalon Exchange

with respect to the pole butt, and enough space is left so that the butt of the pole will fit snugly between them. The beams are then drawn tightly to the pole by bolts passing thru both. This footing is designed to have a bending moment sufficient to support the pole alone in a 90-mile (162 km.) an hour wind. The poles are also guyed in four directions with 7 strands of number 12 B. W. G. galvanized steel messenger cable.* These guys are attached to the pole at a point 15 feet (4.6 m.) from the top to minimize as much as possible the effect of their presence in the field of the antenna. Each guy is broken into three sections by porcelain strain insulators.

The wires of the T type antenna are supported by double cross arms which are bolted to the pole and have in addition a channel iron truss to stiffen the structure. Each antenna wire

*Diameter of number 12 B. W. G. wire = 0.109 inch = 0.277 cm.

FIGURE 19—View of the Pebbly Beach Radio Station

is fastened to a long eye-bolt passing thru both cross-arms and secured with lock nuts. With this type of construction the tension in each individual wire can be regulated without affecting the tension of the other wires. Each wire is insulated from the

FIGURE 20—View of the Special Footing for the Masts

cross-arms by a series of four porcelain strain insulators. Figure 21 shows the details of the insulation and cross-arm construction while Figure 17 shows the completed antenna at Long Beach and Figure 22 the completed antenna at Pebbly Beach. The

FIGURE 21—View of the Transmitter House, Showing the Mast and Antenna Construction

advantages of this rigid type of antenna construction are its strength and constant electrical capacity.

At each station a large area of buried ground conductor is used and in addition every piece of metal in the vicinity of the station is brought to ground potential. At Pebbly Beach, owing to a 16-foot (4.9 m.) layer of small rocks (see Figure 21) an extensive ground system buried a few inches in the rock is installed, which materially reduces the resistance of the antenna circuit.

Figure 22—View of the Antenna System at Pebbly Beach

Installation of System

At the time the apparatus arrived from New York, the Long Beach antenna system was nearly completed and the power and telephone facilities were available. For this reason the apparatus was first installed and tested at Long Beach. The Avalon installation work was started while the houses were but partially completed and the installation of apparatus was practically complete when the antenna, the power, and telephone facilities were available.

The transmitter, power panel, and motor generator at Long Beach are located in the northeast corner of the apparatus room (second floor) of the Toll Exchange. (Figure 23.) The storage batteries for the radio receiver, the charging switchboard, and the charging motor generator are located along the south wall while the radio receiver, repeater, and terminal equipment are located in a small room on the southwest corner of the building. The disposition of the telephone as well as of the radio equipment is approximately shown on the floor plan, Figure 24. Some idea of the proximity of the transmitter, the antenna, and telephone equipment to the receiver can be gained from this figure. The power is supplied from the 220 volt, 3 phase, 50 cycle mains of the Southern California Edison Company, and no auxiliary power supply is available.

At Pebbly Beach the transmitting house is located under the center of the antenna system while the receiving house is one hundred feet (30.5 m.) away on a line perpendicular to the flat top of the antenna. Figure 22 shows the location of the buildings with respect to the antenna system and gives a general idea of the surrounding country.

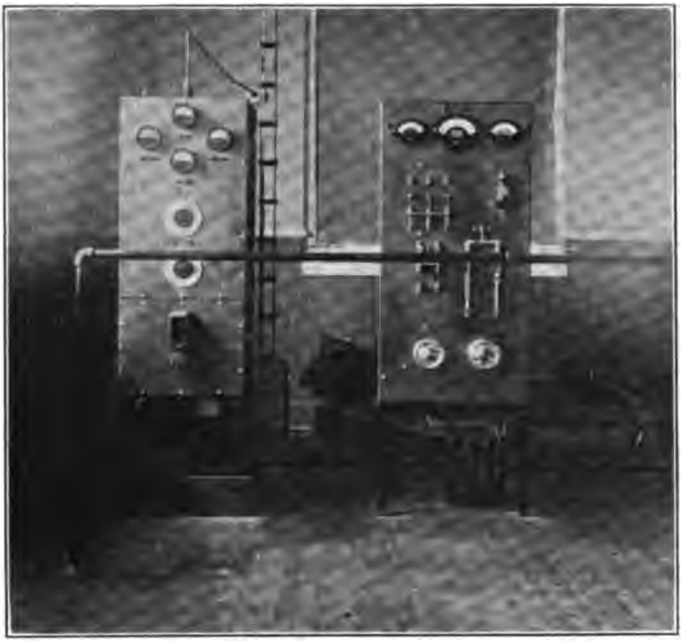

FIGURE 23—View of the Transmitter, Power Panel, and Motor Generator Installed at Long Beach

The radio transmitter power panel and motor generator, as well as the storage batteries for the radio receiver and repeaters, charging panel, and charging motor generator, are located in the transmitting house. The radio receiver, loop antenna, repeaters, signaling and terminal equipment are located in the receiver house. A photograph of the apparatus in the receiving house is shown in Figure 25.

All wiring between the two houses is in underground conduits which have been carefully grounded. The power supply is obtained from the municipal plant at Avalon and the single phase 2,200 volt leads together with three telephone lines are carried

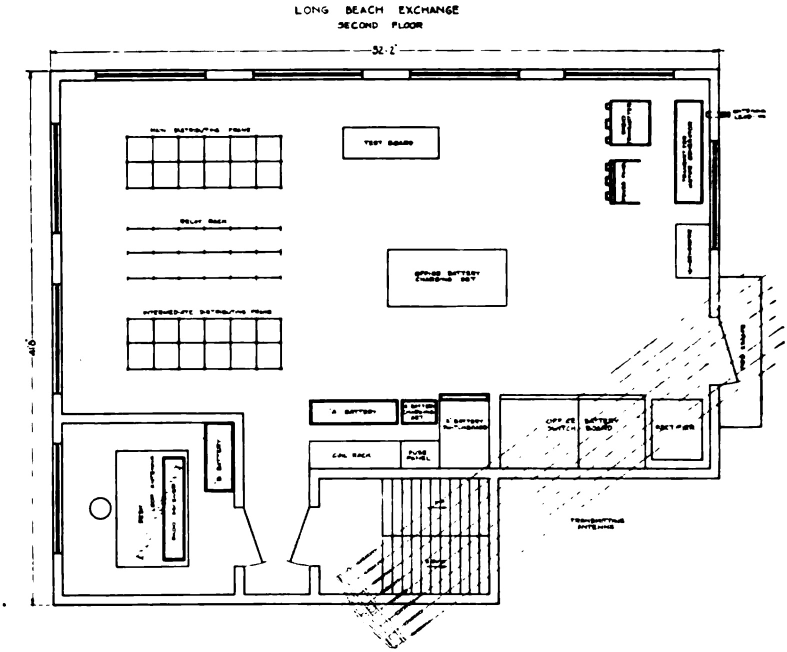

FIGURE 24—Floor Plan of the Long Beach Exchange

on a pole line to a point five hundred feet (153 m.) away from the radio station. The last pole of the line can be seen in Figure 19 to the right of the lower center portion of the photograph. A

FIGURE 25—View of Receiving Equipment at Pebbly Beach


LINE
VARIA
FREQU
OSCIL

conduit to the transmitting house carries the 110-220 volt power leads and a ten pair telephone cable enters the receiving house thru a separate conduit.

Special Problems

The Pebbly Beach-Avalon and Long Beach-Los Angeles lines are so short that the terminations play an important part in their impedance characteristics. For example, the impedance of the line measured at the radio station with the far end open-circuited is materially different than when the far end is closed thru the impedance of a cord circuit and an average subscriber's loop. The lines terminate in jacks at the Avalon and Los Angeles toll boards. The cords used with these lines are specially equipped and never allow the lines to be opened under any switching condition. Figure 26 is a schematic of the circuit between the Pebbly Beach radio station and the Avalon exchange and shows a cord circuit, the dispatch operator's set, and the special circuits to maintain the balance of the line and network.

The network at the Pebbly Beach station is of such an impedance that it balances the line, a cord circuit, and an average subscriber's loop. The special circuit is so arranged that a network which simulates a cord circuit and an average subscriber's loop is always bridged on the line except when the connecting cord is plugged into a subscriber's jack and his receiver is off the hook. The network is controlled by the supervisory relay in the cord circuit and extra contacts on the line jack. A dispatch operator's set is permanently connected to the line and is provided with a high impedance monitoring connection which has little effect on balance or transmission of the circuit. This arrangement maintains the balance with sufficient accuracy to allow the circuit between the wire terminals at Pebbly Beach and the wire line at Long Beach to work at a net gain of more than 5 miles of standard cable.

Excessive cross talk between the transmitter and the receiver is prevented by carefully shielding all of the filament and plate battery leads and providing large by-pass condensers. This prevents such radio frequency currents as may be induced in the filament leads from entering the receiver and producing objectionable cross talk between the sending and receiving channels, which may cause local singing.

Noises due to telephone apparatus in the exchange, such as ringing machines, telephone relays, and so on, are eliminated by shunting each troublesome contact with a condenser and series resistance of the proper electrical constants.

Commutator ripple from the charging generator and a noise due to the intermittent grounding of the radio induction on the charging leads thru the commutator are entirely prevented by connecting a retard coil in series with the charging lead to the battery and draining off the radio frequency induced currents by connecting two condensers across the commutator and grounding the mid-point.

Quality of Service

Since this circuit is the only telephone channel between the Island and the Mainland, it was very heavily over-loaded from the day of opening until the cessation of the summer tourist traffic in the latter part of September. Due to the methods employed, the high grade circuit, and so on, a great deal more traffic is handled over this circuit than is generally handled by a single toll line.

A record of all of the interruptions to service is kept at both of the stations together with the cause of the delay, its duration, and other information. It is interesting to note that altho the circuit was open to commercial service during the worst of the static season, subscribers had but little or no difficulty in using the circuit. Transmitting frequencies of 750 and 638 kilocycles (400 and 470 meters) were chosen for the stations after an extensive survey of the ether, so that the telephone would cause least interference to and be interfered with the least by radio stations in the vicinity. Some trouble was experienced from the Avalon spark station located about one mile from the receiving station at Pebbly Beach. This station employed a transmitting frequency of 1,000 kilocycles (300 meters) while the Pebbly Beach station had its receiving apparatus tuned to receive 638 kilocycles (470 meters). Upon investigation it proved that the logarithmic decrement of the Avalon station greatly exceeded 0.3. When the decrement is kept below 0.2 little or no trouble is experienced from this station.

The circuit, due to the choice of sites, directional characteristics of the loop antennas, and selectivity of the radio receivers, is quite free from interference and it is only occasionally that an interfering spark signal is heard. The harmonics from the Poulsen arcs installed at the Naval Radio Stations at San Diego and Englewood, California, have given rise to some trouble. If the arc harmonic beats with the radio carrier and side frequencies of the radio telephone station at either an audible or nearly audible rate, the quality of the speech over the circuit may be affected materially. This is in effect the same result which obtains when speech signals are received on an ordinary heterodyne receiver when the local oscillator is not adjusted to the same frequency as that of the transmitter. Altho this trouble can be eliminated as soon as it is discovered by shifting the carrier frequency of the radio telephone transmitter a few thousand cycles, it is obvious that in the future, when many stations may be expected to be operating, this difficulty must be eliminated in a more rational manner.

Maintenance

The circuit is in operation sixteen hours per day, which covers the period 6:30 A.M. to 10:30 P.M. The largest items in the maintenance charges of a radio telephone and telegraph system are personnel, tube renewals, and power. The radio attendants play no part in the actual handling of traffic, but look after the maintenance of the equipment in the same way that a wire repeater attendant maintains the repeater equipment. It may be mentioned in this place that it is not necessary frequently to change the adjustments of the tuned circuits of either the transmitter or receiver.

Separate Auxiliary Receiver

A receiver capable of receiving signals on 500 kilocycles (600 meters wave length) is installed at Long Beach. The flagpole on the exchange, which is approximately thirty feet (9.2 m.) from the transmitting antenna, supports a single wire vertical antenna. An anti-resonant circuit tuned to the local transmitter frequency is connected in series with the antenna lead. This receiver using a detector and two-stage amplifier makes it possible to receive signals of all frequencies except a narrow band near the local transmitting frequency of 638 kilocycles.

Transmission Measurements

The transmission equivalent of the circuit from the wire line at Pebbly Beach to the wire line at Long Beach has been studied by employing methods and apparatus in general use in the Bell plant. The apparatus employed was the same as that used when it is desired to measure the equivalent of a wire telephone toll circuit. Figure 27 shows schematically the circuit and apparatus used in making these measurements. At each radio station the wire line was disconnected and the line network replaced by a 600 ohm resistance which insured a balance with the sending and receiving measuring units which were substituted for the lines. At each station a calibrated variable frequency oscillator was provided which delivered a current measured by a thermocouple milliammeter to a 600 ohm network. At Pebbly Beach this network was connected to the line terminals of the hybrid coil. At Long Beach a unit consisting of an amplifier and rectifier with its meter provided means of indicating like strength of measuring current. In addition to this equipment two artificial lines were provided, one having a fixed attenuation and the other being variable. The measurement of the transmission equivalent was made in two operations. In the first of these the oscillator at Long Beach was connected to the indicating unit thru the fixed artificial line and the frequency of the oscillator adjusted to the desired value. The oscillator output current (as indicated by the thermocouple milliammeter) is then adjusted to a suitable value and the potentiometer at the input of the indicating unit adjusted to give a convenient value of rectified current. The second operation consisted of connecting the indicating unit thru the variable artificial line to the line terminals of the hybrid coil and at Pebbly Beach adjusting the oscillator to deliver exactly the same current and the same frequency as the Long Beach oscillator. The variable artificial line was then adjusted until the rectified current in the indicating unit was the same as that obtained during the first operation. It is then apparent that the transmission equivalent of the circuit from the oscillator used to the indicating unit was the same for each operation as similar oscillator outputs delivered equal inputs to the indicating unit. In the first case this circuit was simply the fixed artificial line and in the second it was the radio link plus the variable artificial line. The transmission equivalent of the radio link is therefore the equivalent of the fixed artificial line minus that of the variable artificial line. The apparatus was so arranged that the desired transmission equivalent could be read directly. It is to be noted that in case the equivalent of the variable line exceeds that of the fixed line the transmission equivalent of the circuit is a negative value, indicating a gain in transmission. This was the case with the radio link.

Transmission measurements were made at two different times between the two stations to determine the variation in transmission from hour to hour thruout the twenty-four hours. Figure 28 is a curve showing the results of one of these tests.

The maximum variation from the mean is seen to be only two miles of cable which ordinarily is not noticeable to the average person. Most of this variation, it is believed, was due to variation of voltage at the stations beyond the control of the observers. The transmission between the two radio stations is therefore, practically the same thruout the twenty-four hours of the day, as was to be expected for such a short radio link.

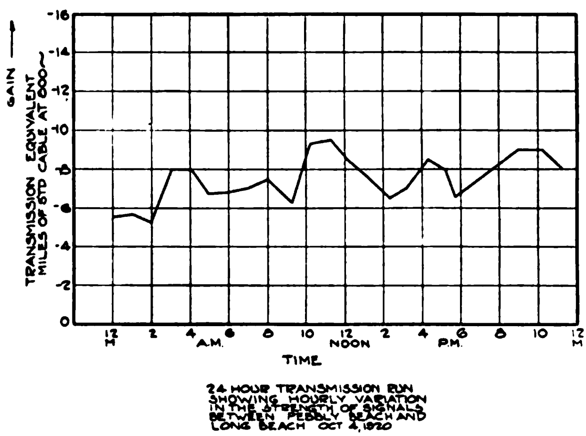

FIGURE 28—24-hour Transmission Run, Showing Hourly Variation in Transmission

FREQUENCY TRANSMISSION CHARACTERISTIC

In order to study quantitatively the ability of the circuit to transmit good quality speech, a frequency transmission charactertic of the circuit was taken. This was accomplished by measuring the equivalent of the circuit in miles of standard cable for several different frequencies between 250 and 2,400 cycles per second. Figure 29 is such a characteristic of the circuit between Pebbly Beach and Long Beach with reception done at Long Beach and shows that the frequency transmission characteristic is reasonably flat.

The effect of the filters is clearly shown by the sharp bend of the characteristic at about 2,000 cycles. The lower frequencies in the speech range are responsible for the naturalness of a speaker's voice while the higher frequencies contribute toward the understandability.

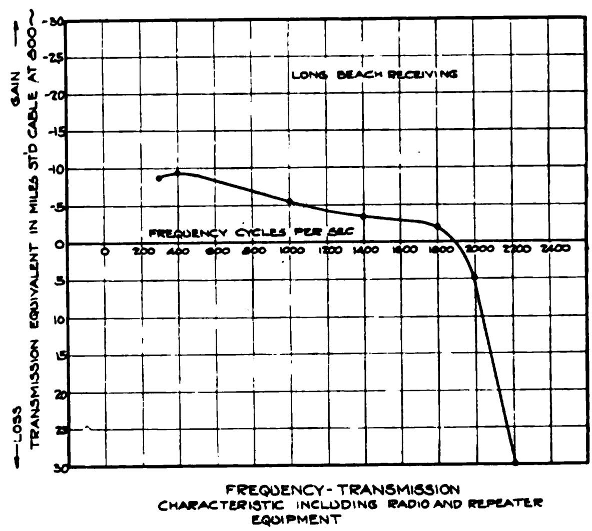

Figure 29—Frequency Transmission Characteristic

General Considerations

The large amount of commercial traffic which the Avalon-Los Angeles Toll Circuit has handled every day since July 16, 1920, is ample proof of the practicability of operating toll circuits containing radio telephone links.

The volume of speech and the quality of transmission are such as to allow of satisfactory connections to the longer telephone circuits of the Bell System. This is quite aptly illustrated by a connection which was established between the steamship *Gloucester* on the Atlantic Ocean and Avalon, Santa Catalina Island. Starting from the ship the following circuits were used:

(a) Steamship *Gloucester* to Deal Beach, New Jersey, via radio.

(b) Deal Beach to New York, via telephone line.

(c) New York to San Francisco, via trans-continental telephone line.

(d) San Francisco to Los Angeles, via telephone line.

(e) Los Angeles to Avalon, thru the Long Beach and Pebbly Beach radio equipments.

Figure 30 is a map showing the route taken by the various sections of the line showing the repeater and radio stations which enabled the conversation to be carried on. The success of such a conversation naturally depends, not only on the transmission over the radio, but over the far greater wire portion of the circuit.

In addition to the telephone facilities described an experimental duplex telegraph channel was installed operating simultaneously with the telephone. This telegraph channel makes

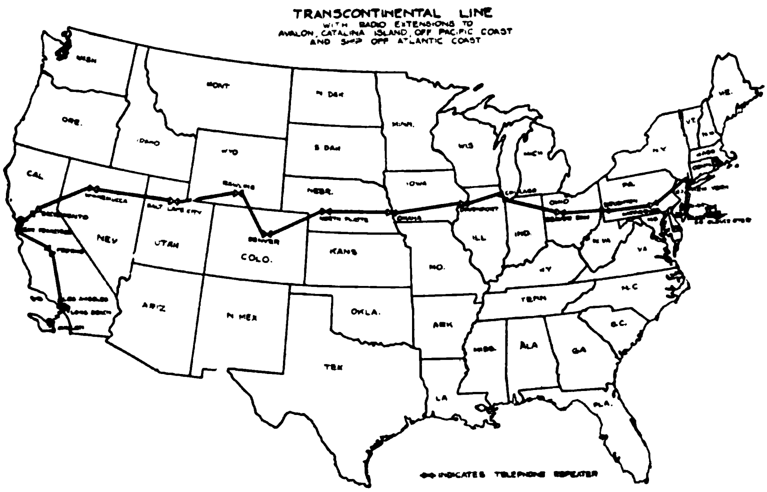

FIGURE 30—Trans-continental Line with Radio Extensions to a Ship and Avalon

use of the ordinary Morse instruments and may form a part of any thru line telegraph circuit. Experimentally, this circuit has been operated in conjunction with existing telegraph circuits to give thru duplex telegraph connection between Avalon and San Francisco, California.

SUMMARY: The communication facilities of Santa Catalina Island are described with special reference to the radio telephone service to the Californian mainland and the mode of connection to the wire telephone networks at the ends of the radio telephone channel. The radio telephone link is full duplex, and is connected thru special two-way repeaters to the telephone system at each end. A simultaneous duplex radio telegraph channel is available. A number of special points are discussed, such as the narrowing, by means of filters, of the side frequency bands due to modulation, the circuits of the transmitter and receiver, automatic alarm systems indicating when any portion of the radio equipment ceases to function, thru signaling system, location, and antenna and ground arrangements. The service rendered is analyzed and the results of transmission measurements are given.

A VISUAL AND PHOTOGRAPHIC DEVICE FOR RECORDING RADIO SIGNALS*

By

Charles A. Hoxie

(General Electric Company, Schenectady, New York)

Altho the instrument here described is, as it stands today in its latest form, particularly adapted to the recording of radio signals at high speed, the recording or high-speed features were not considered when the work was begun. The first model was designed and built to produce a device that would enable the signals to be seen instead of being read by ear in the ordinary way by means of the telephone. The main reason for this development was the fact that in the early attempts to equip airplanes for radio reception, difficulty was experienced in hearing the signals.

It was thought that if the eye could be substituted for the ear, much better results could be obtained, and in order to do this successfully, it was decided that the instrument should possess the following characteristics:

1. It should be sufficiently sensitive to record a signal of a strength equal to that required for ordinary telephone reception.
2. The action should be quick enough to record clearly the dots and dashes when received at a maximum speed of approximately 12 or 15 words per minute.
3. It must operate equally well in any position.
4. It should be of rugged construction.
5. It should not easily be put out of adjustment.
6. It should be selective, so as to pick out and record only the signals desired.
7. It should not respond to impulses such as are caused by atmospheric disturbances (static), tube noises, and so on.

In order to meet all of these requirements it was necessary

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to construct a special type of instrument. The galvanometer, as first constructed, consisted of a thin strip of iron stretched between the poles of two permanent magnets. Coils of wire were placed around the poles of the magnets, the terminals of which led to the receiving set. A small shaft mounted in jewels and free to turn on its axix, carrying a small mirror, was connected by means of a wire to the strip of iron, or vibrator.

When a current due to the receiving signal traversed the coils, the vibrating strip of iron moved to and fro between the poles of the magnet, thereby causing the shaft to rotate thru a very small angle which in turn vibrated the mirror. A beam of light from a lamp having a single straight filament was allowed to fall on this mirror, and an image of the filament, by means of a spherical lens just in front of the mirror, was projected on to a surface of ground glass. When no signals were being recorded, a single light line was visible on the ground glass. When a dot or dash caused the mirror to vibrate, the line would apparently become broad, due to the very rapid vibration of the mirror. The line becoming broad for a short time represented a dot and for a relatively long time, a dash. In this manner signals could be read.

This first galvanometer required a signal that would be considered fairly strong for telephone reception in order to produce a readable deflection. The action was quick enough for speeds up to approximately 30 words per minute. It could be held in any position without interfering with its operation, the small mass of the shaft and mirror being held firmly in position by the connecting wire, to the vibrating reed, the mirror being affected only by the very minute and rapid vibration of the iron strip. This also tended to make the instrument very rugged. It could even be shipped by express without danger of being put out of adjustment. It had a natural period of approximately 1,000 cycles, and was sensitive only when the frequency of the incoming signal accurately corresponded to the natural period of the galvanometer. Two or three per cent above or below this frequency reduced the deflection to zero unless the signal was abnormally strong.

Means were provided for varying this period from about 800 to 1,200 cycles, by putting more or less tension on the vibrating strip. The most important of its characteristics, however, was the fact that it did not respond readily to atmospheric disturbances or to the ordinary tube noises so frequently present in the average type of amplifiers. Figure 1 is a photograph of the first model constructed.

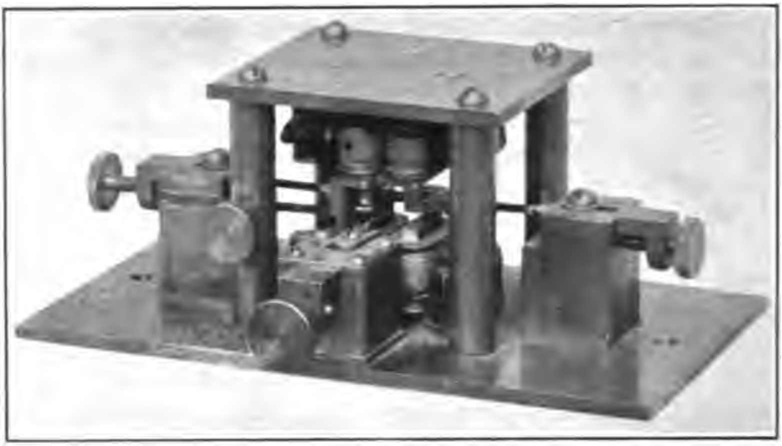


FIGURE 1—First Model of Galvanometer for Visual Reception

A summary of its characteristics show, then, that the requirements regarded as necessary for successful operation, were met, except that in the first and seventh, there was chance for improvement. Taking them in the order given:

1. It was fairly sensitive.
2. The action was sufficiently quick to meet the requirements.
3. It was not affected by position.
4. It was rugged.
5. It was not easily put out of adjustment.
6. It was selective.
7. It did not respond readily to static impulses, and so on.

A second instrument was then built for visual reception, a photograph of which is shown below (See Figure 2). The size of this instrument was approximately 8 inches (20.3 cm.) wide, 6 inches (15.2 cm.) deep, 22 inches (55.9 cm.) long. It could either be held in the arms while reading the signals, or supported otherwise at will. A hood projected over the ground glass, on which the beam of light was projected, in order more easily to see the signals. An enlarged view of this galvanometer is shown in Figure 3. Signals could be easily read by the visual method up to about 15 words per minute, but it was very trying to the eyes to read steadily for any great length of time, and for this reason it was believed to be impractical.

It was then decided to develop an instrument that would photographically record the signals. Within the next year, models of three different types were constructed; and after giving a brief description of these, I shall describe at length a later type of which several have been made and are now in use in various trans-Atlantic receiving stations.

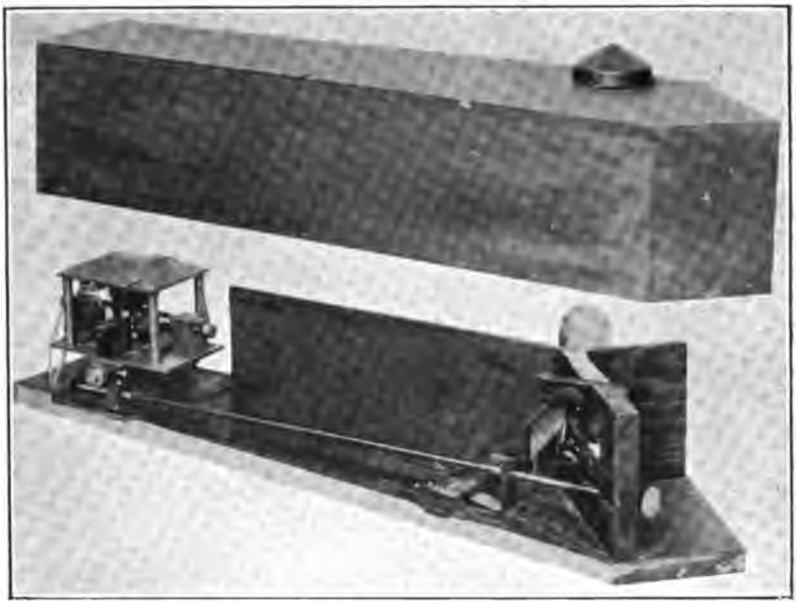


FIGURE 2—Model of Instrument for Visual Reception

The first recorder constructed was designed to receive signals at a speed not greater than 25 words per minute.

The photographic record was obtained by projecting the image of a straight filament lamp from the mirror of the galvanometer onto a cylindrical lens and focused by the same mirror to a small dot of light on a specially prepared sensitized paper tape. When the mirror was set into vibration by the incoming signal, this spot of light moved rapidly back and forth across the tape, its width of vibration depending on the strength of the signal. As the tape was moved across the point of exposure, the rapid vibration of the light resulted in the dots and dashes appearing as solid blocks. Figure 4 is a photograph of the first model constructed for photographically recording radio signals.

By means of a spring motor connected with suitable gears and friction pulleys, the tape was made to move not only past the point of exposure, but thru a tube of developing solution, and then thru a tube containing the fixing bath, from which it passed into the receiving basket.

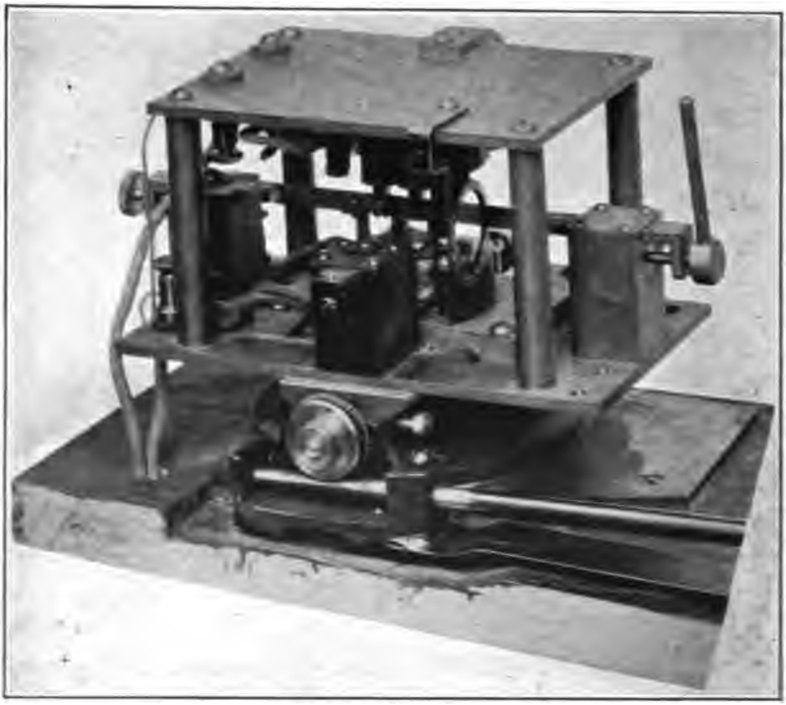


FIGURE 3—Galvanometer Used in Completed Model for Visual Reception

In this model, a second mirror was mounted on the shaft at a slightly different angle from the other, so that an image of the lamp filament could also be projected on a ground glass, thus permitting the operator to adjust the instrument properly and supervise its operation. A pair of telephones were also attached so that it was also possible to hear the signals. Means were provided for using rolls containing 200 feet (61 m.) of tape each, upon which about 2,000 words could be recorded. A special sensitized paper tape was used, which was very sensitive and capable of being developed in less than 1/2 minute, by using a special developing solution.

Figure 5 shows the arrangement of the galvanometer and the lighting system.

Figure 6 is a view of the galvanometer used in this instrument, in which are shown the two mirrors and the adjusting mechanism. In order to show the remarkable selectivity of this instrument the following experiment was made.

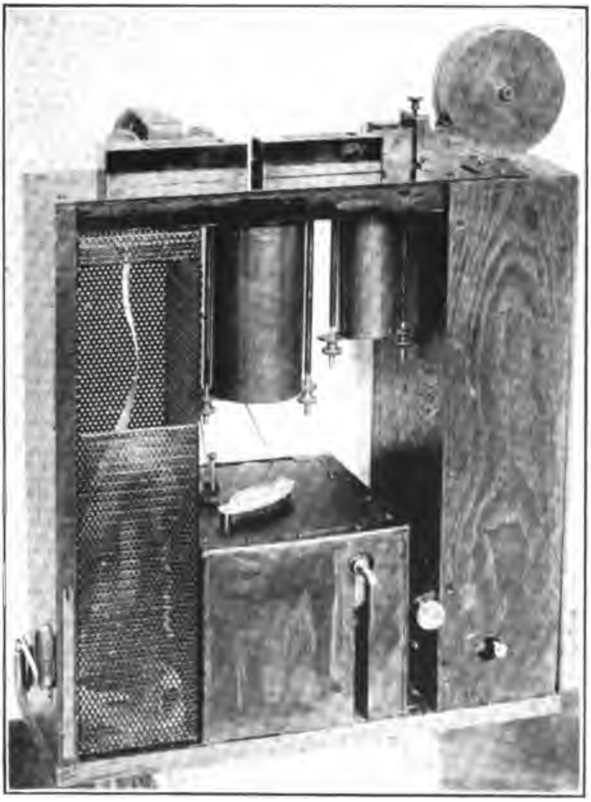


FIGURE 4—Photographic Recording Device for Radio Telegraphic Signals—Front View

Two separate messages were impressed upon the receiving circuit simultaneously from two different sources. One was at an audio frequency of 1,000 cycles and the other at 1,025 cycles. While these messages were coming in, the instrument was first tuned to 1,000 cycles and a portion of one message recorded; it was then tuned to 1,025 cycles and a portion of the other message

Altho the instrument just described was very selective and well adapted to record signals under conditions for which it was designed, it was not suitable for recording the weak signals

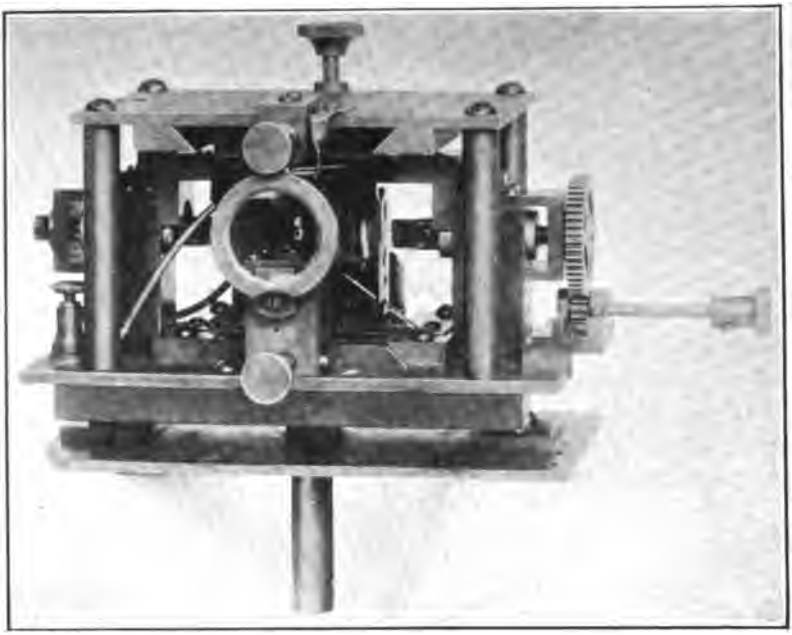


Figure 6—Vibrating Unit Used in Photographic Recording Device for Radio Telegraphic Signals—Front View

coupled with the static ratio that is generally encountered in trans-Atlantic reception. This was made apparent while making a demonstration with the model just described at the Bureau of Standards, Washington, D. C., in the presence of radio experts

Figure 7

of the Army and Navy. At this time messages were successfully recorded from several radio stations, but when an attempt was made to record signals from across the Atlantic it was found that the static interference was sufficient to render a large part of the record unreadable.

Steps were then taken to improve the instrument by making it more sensitive and less affected by static or strays.

In order to make the instrument more sensitive, the small shaft carrying the mirror was re-designed so as to eliminate the lost motion at the terminals of the shaft where they entered the jewels. This was done by constructing a shaft with a knife edge running its entire length, on which the mirror was mounted. This edge fitted into the apex formed by placing two rectangularly shaped jewels at right angles to each other, the shaft being held firmly in this position by the action of a small magnet. The thick side of the shaft was connected to the reed by means of a wire, the vibrations of the reed causing it to rock to and fro. Only one mirror was cemented to the shaft, an extra lamp being provided to produce the other image. Figure 8 shows the details of this construction.

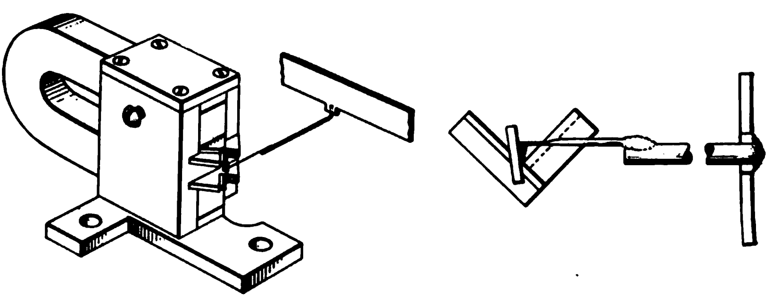


FIGURE 8—Showing Construction of the Vibrating Element

It was found also by changing the coils so as to encompass the vibrating strip instead of being wound around the pole pieces as in the type previously described, that greater sensitivity could be obtained. Figure 9 shows this construction. The galvanometer was placed at double the distance from the sensitized tape, which also produced the effect of increasing its sensitivity two-fold. In fact, the total increase in sensitivity in this model over the first was at least ten times. A signal which can be said to have an audibility of about 40 can be easily recorded.

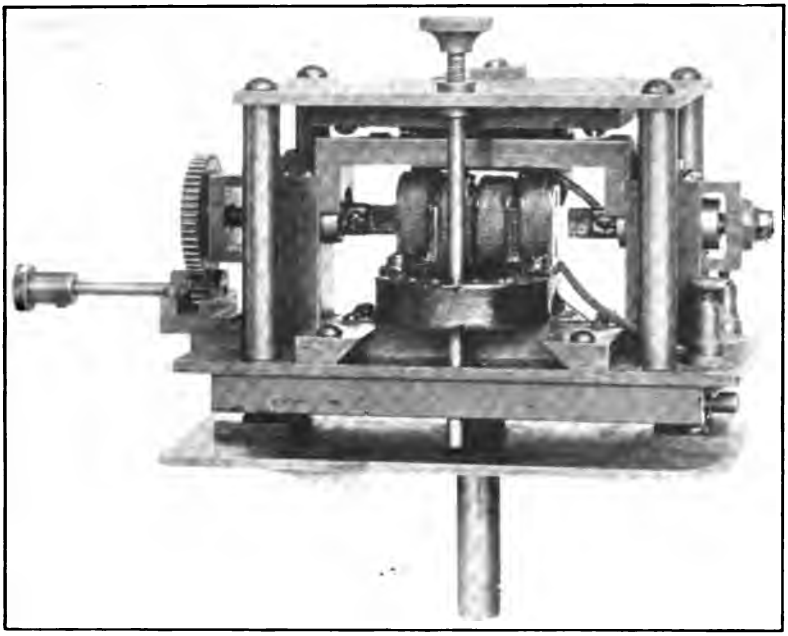


FIGURE 9—Vibrating Unit Used in Photographic Recording Device for Radio Telegraphic Signals—Back View

The problem left unsolved was simply to make the changes necessary to prevent its responding to static or strays and still to be left sensitive to signal impulses.

After reading my discussion on Dr. Austin's paper* in which I submitted several sample records of static made with my recorder, I am afraid I shall have difficulty in persuading the readers of this paper that I was very successful, but I can assure them that altho static conditions can still be such as to render the record unreadable, a considerable improvement was made. As stated before, the galvanometer, when tuned to 1,000 cycles, did not readily respond to static or strays, but it was found by experiment that when the natural period of the vibrator was above 1,500 cycles, the tendency to respond to static impulses was much less. This is very clearly shown in Figure 10. This figure shows signals recorded under exactly the same conditions except that the natural periods of the vibrator is adjusted first to 1,200 cycles, then to 1,500 cycles, and finally to 2,000 cycles.

* PROCEEDINGS OF THE INSTITUTE OF RADIO ENGINEERS, volume 8, number 5, October, 1920, page 408.

The 1,200 record was unreadable because of the interference by static, but no interference whatever can be seen when tuned to 2,000 cycles. It was also found by experiment that less static was recorded if a closed electrical circuit containing inductance and capacitance, commonly called a tone or frequency trap, and accurately tuned to the natural period of the vibrating reed was connected in parallel with the galvanometer. A great deal,

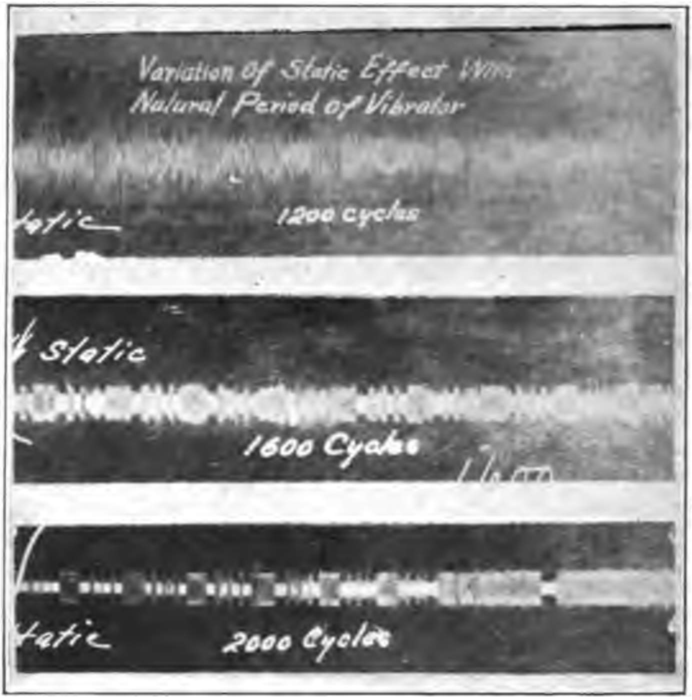


FIGURE 10

however, depended on the construction of the tone trap. It was found that in order to prevent a decrease in signal and otherwise to obtain the best results, the capacitance should not exceed one or two-tenths of a microfarad for a frequency of 2,000, and also that the resistance of the inductance circuit should not be more than 40 ohms.

An instrument embodying these improvements, also designed to record at a maximum speed of about 35 words per minute, was then constructed, a small electric motor being used to pull the tape thru the machine. Figure 11 is a photograph of this model. With this instrument messages were successfully recorded at the then Naval Radio Station of Belmar from Nauen, Germany; Lyons, France; Carnarvon, England; Rome, Italy; San Diego, California; Pearl Harbor, Honolulu; and several other points.

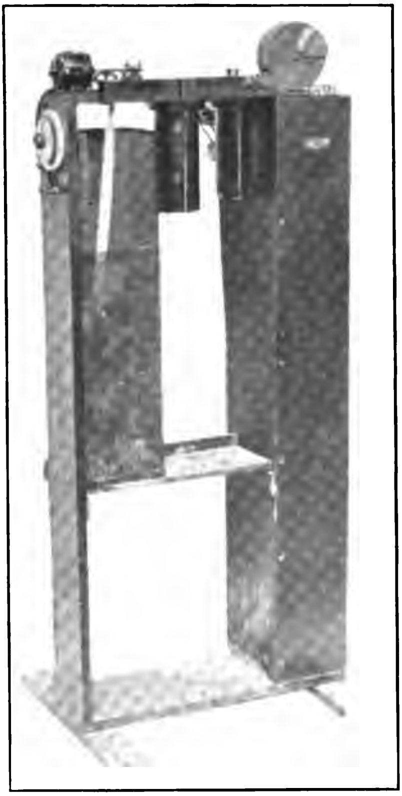


FIGURE 11—Second Model of Photographic Recorder

If my memory serves me right, it was during the year of 1899 that my attention was called to the art of "wireless" telegraphy by reading in the "Scientific American," a description of the first demonstration conducted by Mr. Marconi in this country, when he reported the result of the International Yacht Races off Sandy Hook.

At that time, and for a considerable time afterward, the dots and dashes were recorded on a paper tape. In this respect a similarity exists between Marconi's apparatus and the one here described. It did not, however, meet the present day requirements of speed.

Just why it was not practical to record at a speed greater than 12 or 15 words per minute with the apparatus used by Marconi, was very forcefully impressed upon me during the ensuing year while trying to duplicate the achievement with the limited means at my command. It was very easy to set a bell to ringing or even to adjust the coherer to obtain single taps, but perhaps there are some who can remember how easy it was to record the dots and how hard it was to adjust the system so that a dash did not look like a series of dots. The mere fact that the armature of the recording relay had a considerable mass prevented it from responding to the rapid action of the decohering hammer, and placed a low limit on the speed of reception. A little later the auto-coherer, and electrolytic and crystal detectors came into use making reception possible by telephone and thereby increasing not only the speed of reception, but the range of transmission. Under these conditions from 25 to 30 words per minute could be received. By using later types of keys and automatic devices the speed of transmission again exceeded that of reception, so then it was again a problem for the engineers to design a receiving device to meet the requirements.

In the early days of radio, the main question was not so much the speed at which a station could transmit, as it was the distance to which the messages could be transmitted. Now that we are able to send round the world, if necessary, the principal thing that concerns us is how many words or letters can be transmitted and received accurately per minute.

While in the photographic recorder previously described, the depth of the tubes containing the developer and fixing bath, the tape driving system, and the small candle power of the light used, limited the recording speed of this instrument to about 35 words per minute, the galvanometer itself was capable of recording several hundred words per minute. This feature will be referred to in another part of this paper.

The next model constructed was by far the longest step taken toward the development of a practical machine for commercial use. I will omit a detailed description of this instrument, except to say that it was designed to record at least 200 words per minute, and the tape, besides being simply developed and fixed, was also washed and dried before leaving the machine. The roll contained 1,000 feet (305 m.) instead of 200 feet (61 m.) of tape, thus permitting over 10,000 words to be recorded without re-loading. This model was taken to the Navel Radio Station at Otter Cliffs, Bar Harbor, Maine, in order to test the operation of the instrument when used in actual commercial service and for the purpose of receiving from European stations at high speed. It was soon made very apparent, however, that the words "high speed" did not mean 200 words per minute to the radio operators in Europe; even 100 was considerably beyond their limit. By repeated tests and numerous adjustments of the sending relay, it was found practical for the station at Lyons, France, to transmit at a speed of about 50 words per minute. This was, at least, considerably better than 20, the average speed of ear reception.

During the winter of 1918 and 1919 the traffic from Lyons was quite heavy; and 3,000 to 12,000 words daily, at approximately 50 words per minute, were recorded with this model.

An instrument was then designed for commercial use, of which several were made and are now in use at several trans-Atlantic receiving stations. Figure 12 is a photograph of this instrument.

These machines are capable of recording signals at a maximum speed of 200 words per minute, but during a series of special tests, over a distance of a few miles, satisfactory results were obtained at 250 words per minute. The speed of reception in this case was not limited by the galvanometer action, but by the time necessary for development, fixing, washing, and so on. There are four tubes shown in this figure of about 5 feet (1.53 m.) in length each, the first one at the right containing developer, the next the hypo solution, the third running water, and the last the drying tube. In order for the tape to be sufficiently developed, fixed, washed, and dried, at the maximum speed of reception, it is necessary for it to pass to the bottom of the tube. Figure 13 shows diagrammatically the method of exposure and the manner in which the tape is fed thru the machine. Arrangements are made whereby the pulleys a_1, a_2, a_3, and a_4 can be made to enter the tubes automatically to any desired depth, this depth depending upon the speed at which the signals are being recorded. In order to facilitate the threading of the tape, the traveling pulleys can be raised to the top of the tubes. The driving pulley at (*b*) causes the tape to move across the point of exposure at (*c*); it is then pulled by means of the friction clutch pulley at (*d*) thru the rest of the system. The mirror (*e*) permits the record to be inspected as it leaves the hypo bath. The roller (*f*) removes the surplus water in order to facilitate the drying of the tape. (*d*) is a blower by which air is driven over a heated coil (*l*) up thru the tube, thus drying the paper before entering the basket.

FIGURE 12—Visual and Photographic Receiving Device—Front View

Figure 14 is a diagrammatic view of the way in which the traveling pulleys are moved up or down in the tubes and also the method by which their depth is automatically determined.

Referring again to Figure 12, these four pulleys are clearly seen at the top of the instrument. The control relays are shown near the drying tube. The driving motor is shown just above the roll holder. The speed of this motor can be controlled by the rheostat located on the power panel below. Besides this control, arrangements are provided for three speeds by means of suitable gears—the control lever being shown at the top and near the right of the instrument. This permits the tape feed

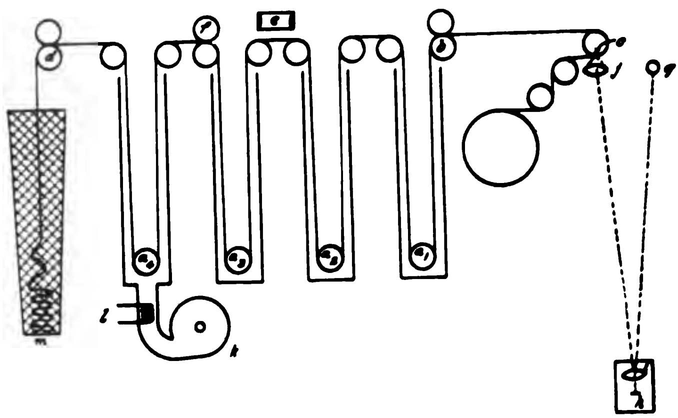


FIGURE 13—Showing Diagrammatically How Tape Is Fed Thru Machine

to be regulated so that the proper amount of space is given to each letter whether recording at normal rate or at the maximum speed of reception. Rolls of tape having a standard length of 1,000 feet (305 m.) are used, the holder being located just below the motor. An indicating device is provided to show the amount of tape in the holder. On the radio panel, located at the upper right hand corner, is located a condenser which is in parallel with the oscillator condenser and is for the purpose of controlling the audio frequency necessary for the proper operation of the galvanometer, the standard frequency adopted being 2,000 cycles. On this panel a telegraph key also is located by which any desired notation may be made on the edge of the tape, thru which the beam of light is projected on to its edge, resulting in dots or dashes, depending upon the operation of the key. An example of this will be shown later. On this panel are also located the binding posts to which a telephone is connected in order that the signal being recorded may also be heard.

As before described, the vibration of the galvanometer may be noted by means of an image of a light filament projected on to a panel of ground glass. The opening thru which this line of light is observed is located at the upper extreme right hand corner of the picture. Not only does this give the operator an opportunity to note the character of the signals being recorded, but it also enables him to make the proper adjustments as to frequency, position on tape, and so on.

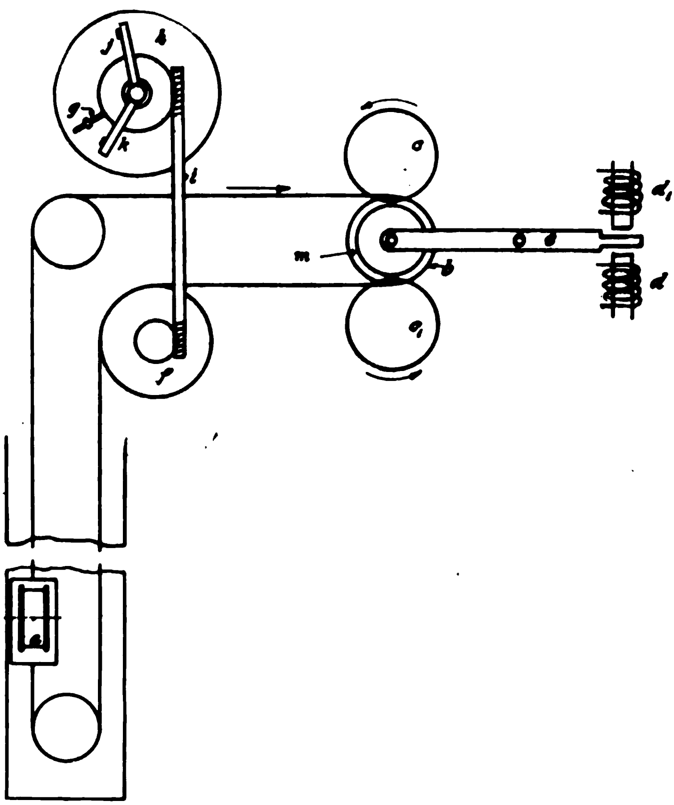


FIGURE 14—Diagram of Depth Control System

Figure 15 is a rear view of the instrument. In this picture, the glass gauges are shown by means of which the height of the solution in the tubes is indicated. The portion at the top, showing the controlling magnets and other gear, is protected by a suitable covering case, when the machine is in operation.

Figure 16 is a diagram showing the relative position of the reading and observation lamp and the galvanometer. The galvanometer as finally designed and built was considerably more massive than the former types. This made it less liable to get out of adjustment, and in general more stable and less sensitive to extraneous vibrations. Figure 17 is a photograph of the instrument as it appears when in use. It is protected with a dust-proof covering case. The high rate of speed at

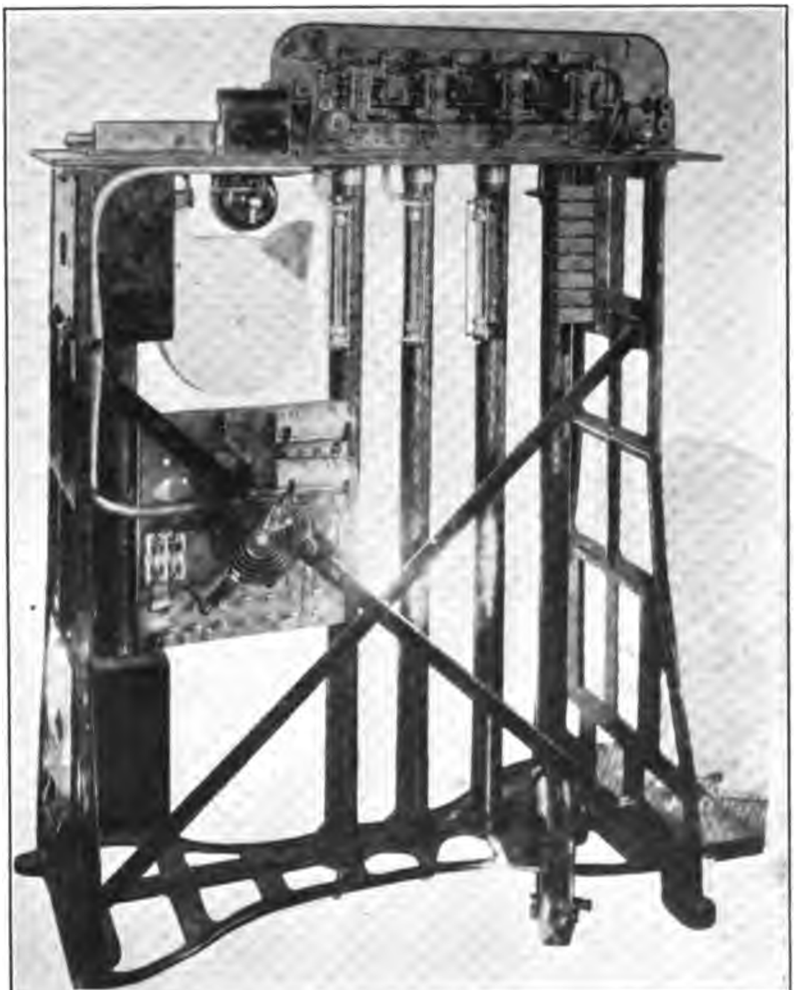


FIGURE 15—Visual and Photographic Receiving Device—Back V ew

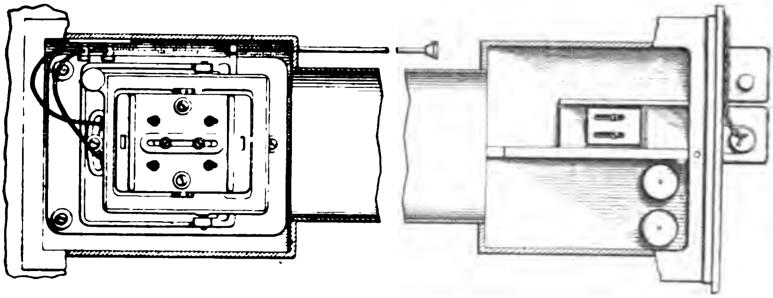


FIGURE 16—Diagram Showing Relation Between Lighting System and Galvanometer

which the galvanometer is capable of recording is perhaps the most spectacular feature of the instrument, even tho it may not be the most important. Laboratory tests have shown that it will record successfully as high as 600 words per minute. In fact, even higher speeds have been obtained. It is somewhat

FIGURE 17—Galvanometer for Visual and Photographic Recorder (Asse ed View)

interesting to note the action of the galvanometer when recording 100 words per minute (see Figure 18). In order to check the speed at which these signals are received, the following calculations can be made: 50 units equal an average word at 5 letters in the Continental Code. A dot equals one unit at 100 words per minute. 5,000 units equal 1 minute, or 83.4 units per second.

The galvanometer reed vibrates at 2,000 cycles per minute.

2,000 divided by 83.4 equals 24, and if we should take the trouble to count the vibrations in the dots here shown, we would find them equal to 24.

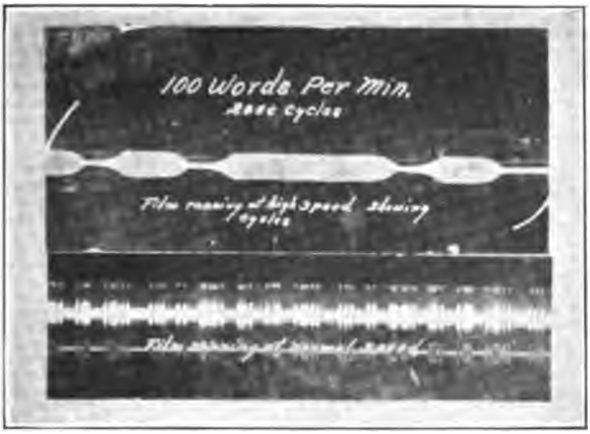


FIGURE 18

The principal item of interest connected with this picture however, is the fact that only 4 cycles are necessary for the signal to reach full amplitude. This means that the speed of the incoming signal can be increased to 500 words per minute and still be perfectly recorded. The lower line shows the signals as they appear on the tape in the regular way. Figure 19 shows high speed signals from 300 to 600 words per minute. It is

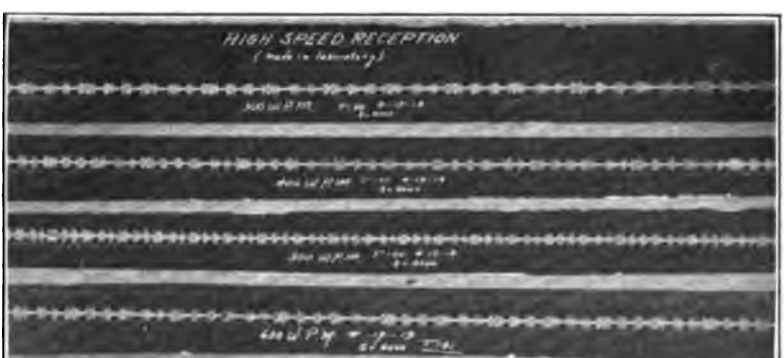


FIGURE 19

needless to say that these signals were produced in the laboratory within a few feet of the machine, but serve to show that the instrument would record satisfactorily at these speeds. Figure 20 shows records made by actual radio signals sent at high speed.

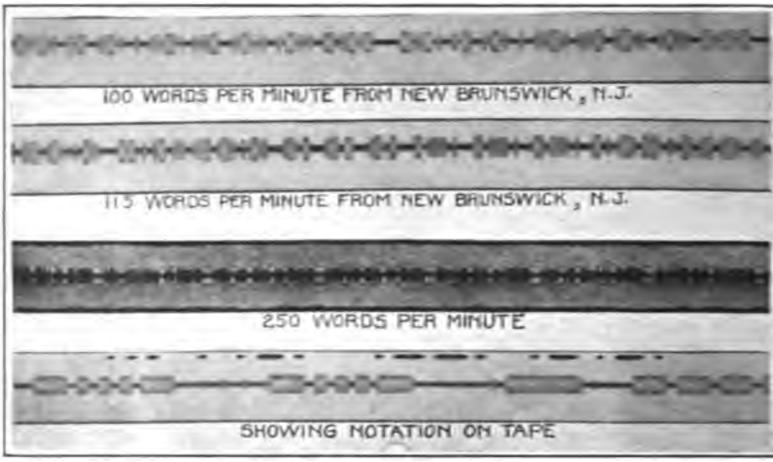


FIGURE 20

The two first records made were transmitted by the Alexanderson alternator from New Brunswick, New Jersey at 100 and 115 words per minute, respectively, and recorded in the General Electric Company's Laboratory at Schenectady, New York. The third record shown was also recorded in the laboratory from a small power station about three miles away (5 km.) at 250 words per minute. The lower record is made simply to show the appearance of the notations on the edge of the tape, made by means of the key on the radio panel of the machine as previously described.

One of these instruments has been in use in the Navel Radio Station at Otter Cliffs, Bar Harbor, Maine, for the past three years. During one of my visits within the past year or so, more than 100,000 letters or the equivalent of 20,000 five-letter words were recorded from Norway within a period of twelve hours at an average rate of 60 words per minute.

The lower portion of Figure 21 is a photograph of a piece of the record taken that day.

All the messages taken during the entire run were complete,

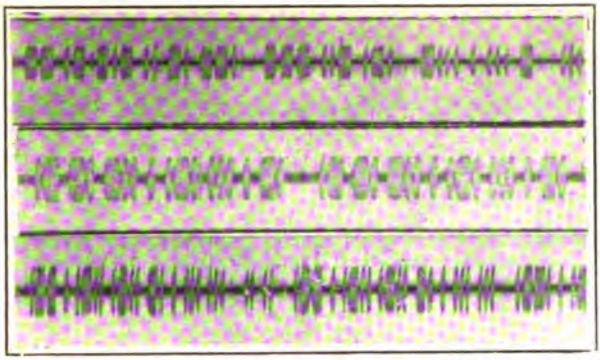


FIGURE 21—Signals Recorded By Visual and Photographic Recorder

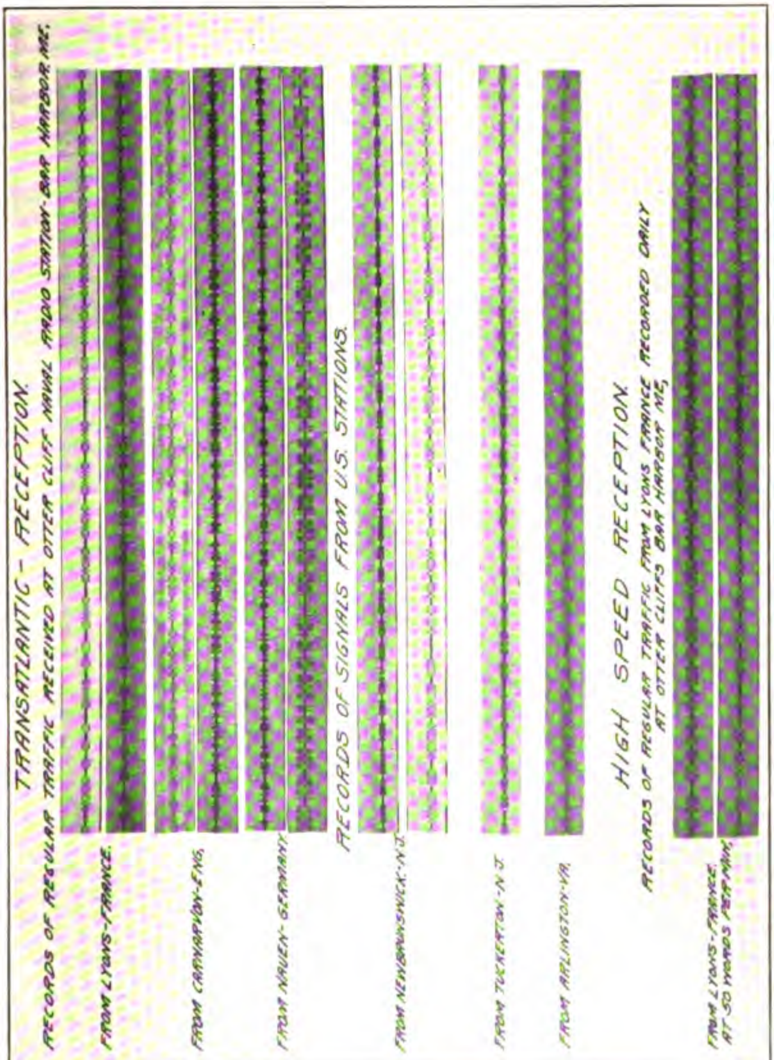


FIGURE 22—Exhibition Record of Radio Signal Records

and no repeats were necessary. The upper record in the figure is a part of a message from Nauen, Germany. Figure 22 is a photograph of several records made at the Otter Cliffs Station.

In Figure 23 is shown the way in which the recorder is ordinarily connected to the receiving system. The correct pitch or note is obtained by varying the heterodyne or local oscillator until the maximum amplitude of vibration is obtained.

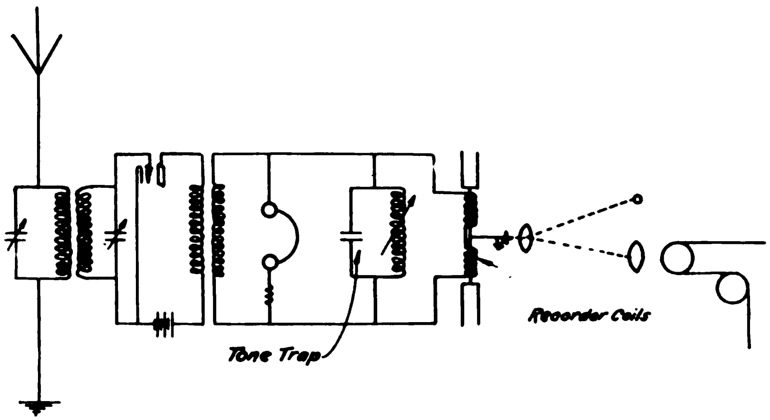


FIGURE 23—Diagram Showing Manner in Which Recorder Is Connected to the Receiving System

SUMMARY: The development of a visual and photographic recorder of the tuned vibrator type is described. The most recent forms of the instrument, together with its receiving speed possibilities and behavior toward stray disturbances, are discussed.

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

ISSUED AUGUST 23, 1921—OCTOBER 25, 1921

By
JOHN B. BRADY
(PATENT LAWYER, OURAY BUILDING, WASHINGTON, D. C.)

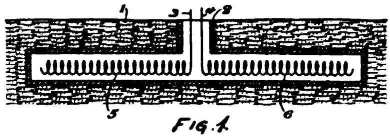
The object of this section in the PROCEEDINGS OF THE INSTITUTE OF RADIO ENGINEERS is to make available in convenient form for research engineers and others interested, brief information on radio patents which are issued each week by the Patent Office. The rapid developments in this art emphasize the importance of radio research engineers being familiar with patent literature, to eliminate, as far as possible, the duplication of effort in research. It is not the purpose of this section to explain radio inventions fully, but merely to indicate the general nature of the patents in order that those of particular interest to individuals concerned with certain problems may be selected, and complete copies of the patents obtained for study. Copies of the patents may be secured at ten cents each by communicating with the Commissioner of Patents, Washington, D. C.

1,387,885—William R. Davis, of Minneapolis, Minnesota, issued August 16, 1921, filed March 9, 1918. Assigned to The William Hood Dunwoody Industrial Institute.

RADIO SIGNALING APPARATUS for the teaching of radio signals to students in a classroom. The equipment comprises an inductor which is rotatably driven adjacent to a plurality of magnets connected in separate transmitter and receiver circuits for use by individual students or groups of students. By varying the speed of the inductor, different frequencies of signals may be obtained to assimilate the conditions in radio reception.

1,388,336—Earl C. Hanson, of Washington, District of Columbia, filed February 25, 1919, issued August 23, 1921.

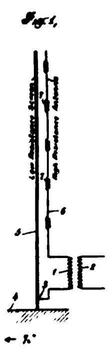
*Received by the Editor, November 7, 1921. While great care has been taken in the preparation of these Digests, THE INSTITUTE OF RADIO ENGINEERS assumes no responsibility for their correctness or completeness, or for possible omissions of particular patents.—EDITOR.



NUMBER 1,388,336—Underground and Submarine Antenna

UNDERGROUND AND SUBMARINE ANTENNA, wherein the antennas are formed by a pair of extended inductances connected to radio signaling apparatus. The inductances are buried horizontally in the earth and have their ends electrically free.

1,388,441—Michael I. Pupin, of Norfolk, Connecticut, and Edwin H. Armstrong, of Yonkers, New York, filed October 1, 1915, renewed January 14, 1921, issued August 23, 1921.



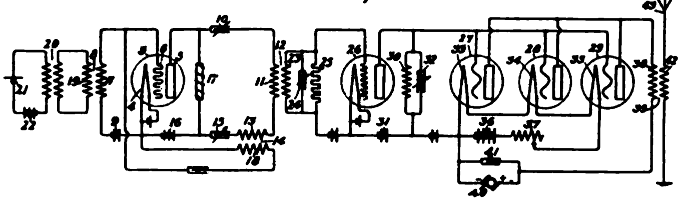
NUMBER 1,388,441—Multiple Antenna for Electrical Wave Transmission

MULTIPLE ANTENNA FOR ELECTRICAL WAVE TRANSMISSION, screened against the disturbing effects of electrical impulses of short duration. A receiving antenna, of such high resistance as to screen the system effectively against disturbing electromagnetic waves impressed upon the conductor, is employed in inductive relation with a low resistance antenna which serves as a screen protecting the high resistance antenna against electromagnetic pulses of short duration.

1,388,450—Edwin H. Colpitts, of East Orange, and Harold De Forest Arnold, of Maplewood, New Jersey, Assigned to Western Electric Company, filed September 3, 1915, renewed January 13, 1921, issued August 23, 1921.

TRANSMISSION OF INTELLIGENCE by radio telephony. Radio

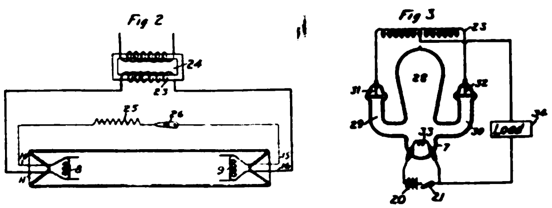
Fig. 1



NUMBER 1,388,450—Transmission of Intelligence

frequency oscillations of feeble amplitude are generated at the transmitter and these feeble oscillations modulated while in their feeble state. These feeble modulated oscillations are then amplified both in voltage and amperage to sufficient power for effective trsnsmission.

1,388,793—Wilfred T. Birdsall, of Montclair, New Jersey, filed January 5, 1917, issued August 23, 1921. Assigned to Westinghouse Lamp Company.

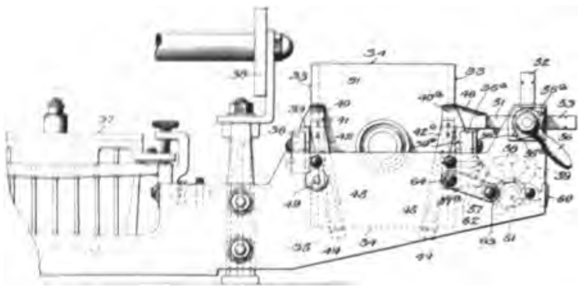


NUMBER 1,388,793—Vacuum Type Converter

VACUUM TYPE CONVERTER, wherein the discharge is not dependent upon an auxiliary heating current thru a filamentary cathode as is the case with the heated filament construction of the Fleming rectifier and the De Forest tube. The discharge is maintained by virtue of electron emission and operates in the absence of auxiliary means for maintaining one or more electrodes at an electron emitting temperature. The apparatus comprises two filamentary electrodes, means for supplying either a direct or alternating current across the electrodes and means for initially passing a heating current thru each of the electrodes until they are brought to an electron-emitting temperature. Having raised the electrodes to this temperature a bi-lateral current flow is established between them and this current flow maintains the electrodes at an electron-emitting temperature, the initial heating means being disconnected from the electrodes. Another feature of the apparatus is the provision of electrostatic shields, 22 upon the electrodes which prevent the localization of discharge upon restricted portions of the surfaces of either of the electrodes. Figure 3 shows the connections for delivering rectified energy to the load 31 from an alternating current supply 23.

1,388,834 Fritz Lowenstein, of Brooklyn, New Yok, filed January 19, 1918, issued August 23, 1921.

Fig. 1.



NUMBER 1,388,834 Spark-Gap Apparatus

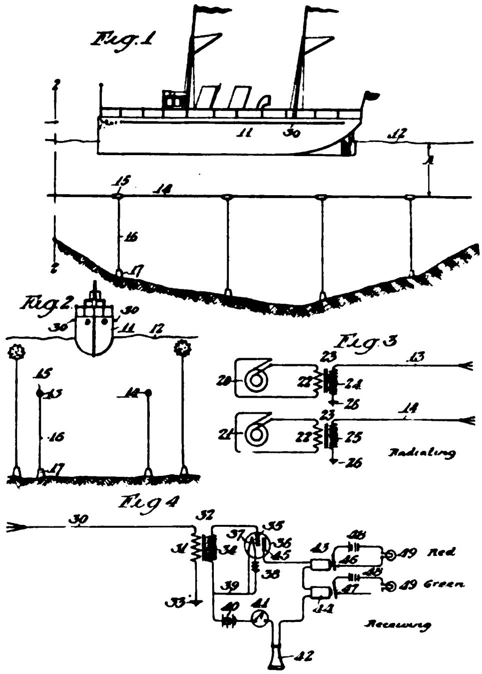
SPARK-GAP APPARATUS for use with quenched spark radio transmitters. The quenched gap is carried in a rack associated with the wave changer and condensers. The quenched gap unit comprises a pair of electrode members insulated from each other and having co-operating circular annular sparking surfaces disposed in parallel, closely spaced relation in combination with a bolt extending within the inner peripheries of said sparking surfaces, the bolt threading into one of said members and extending thru the other of said members but insulated therefrom and arranged to clamp the same in sparking position with the first-mentioned electrode.

1,388,936 Horace St. John de Aula Donisthrope, of London, England, filed April 28, 1920, issued August 30, 1921.

RADIO TELEGRAPHIC AND TELEPHONIC APPARATUS for portable operation. The receiver is made compact by its construction in the form of hinged sections similar to a book, with inductances in the opposite leaves. The apparatus includes a crystal detector, a condenser, telephone terminals and aerial and earth terminals. The inductances have their coupling varied by a change in the angular relationship of the hinged parts.

1,388,940 Earl C. Hanson, of Los Angeles, California, filed

June 4, 1918, issued to August 30, 1921. Assigned to Title Insurance and Trust Company.

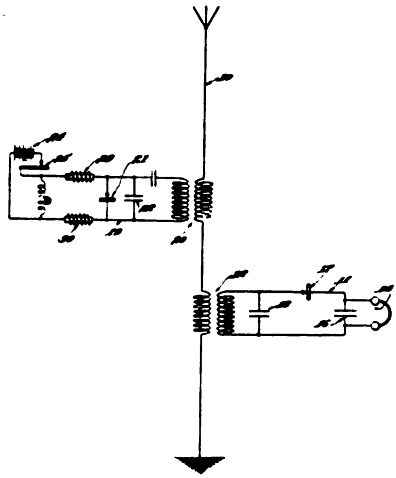


NUMBER 1,388,949—Audio Frequency "Wireless" for Fog Signaling System

AUDIO FREQUENCY "WIRELESS" FOG SIGNAL SYSTEM for the piloting of vessels into and out of port in fog or darkness. The apparatus is installed upon shipboard to enable navigation thru tortuous channels or harbors by visible or audible signals not dependent upon lighthouses or buoys. The system includes a cable laid in the channel way and energized from an audio frequency source. The apparatus on shipboard comprises a collector of the field of force emanating from the cable, a vacuum tube amplifier associated with said collector and means for observing the received energy. The patent describes both port and starboard visible signal lamps operated by the received energy and also telephone receivers operated by the amplified energy. The patent illustrates the position of a cable for piloting vessels in safety thru a mine field.

1,389,026—Vannevar Bush, of Chelsea, Massachusetts, filed

May 19, 1920, issued August 30, 1921. Assigned to American Radio and Research Corporation.



NUMBER 1,389,026—Radio Receiving System

RADIO RECEIVING SYSTEM for the reception of sustained oscillations which are broken up or modulated into groups at an audible frequency by periodically varying the resistance of the receiving circuit at audible frequency.

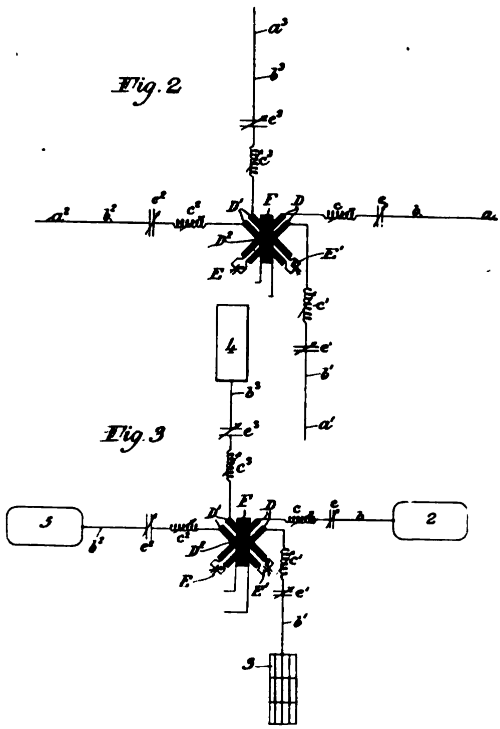
1,389,255—Leslie R. McDonald, of Montreal, Quebec, Canada, filed May 16, 1917, issued August 30, 1921. Assigned to William J. O'Leary, of Montreal, Quebec, Canada.

RADIO FREQUENCY ELECTRICAL OSCILLATION APPARATUS, comprising a construction of a combined capacity and inductance by which radio frequency energy is transferred from an oscillating circuit to a working circuit. Both the primary and secondary of the inductive coupling are open so that the coupling affords a large proportion of the capacity of the oscillation circuit.

1,389,351—Charles Howard Harvey, of London, England, filed May 7, 1918, issued August 30, 1921. Assigned to General Electric Company, Ltd., London, England.

MEANS FOR SUPPORTING ELECTRODES IN IONIC TUBES, comprising a spring mounting for the cathode. The vacuum tube casing is provided with a tubular socket of glass fixed within the vessel with a shoulder at the outer end of the socket. An anchor wire having a knob at its end passes slidably thru said socket and is engaged by the shoulder. The anchor wire is secured to a spring and the spring in turn supports the heated cathode.

1,389,800—Roy Alexander Weagant, of New York, N. Y., filed February 1, 1918, issued September 6, 1921. Assigned to Radio Corporation of America.



NUMBER 1,389,800—Radio Signaling Apparatus

RADIO SIGNALING APPARATUS at a radio receiving station having a plurality of separated antennas tuned to the same frequency and adapted to receive horizontally propagated waves in a plurality of directions. Figures 2 and 3 show the antennas in the form of extended wires and plates or networks with means connected in the antenna circuits for the elimination of static disturbances.

1,390,288—John Hays Hammond, Jr., of Gloucester, Massachusetts, filed July 24, 1913, renewed January 24, 1921, issued September 13, 1921.

SYSTEM FOR CONTROLLING MOVING BODIES BY RADIO ENERGY having at the transmitter means for emitting different frequencies and at the receiver a plurality of circuits respectively responding to the different frequencies. A commutator apparatus is arranged intermittently and automatically to connect the detector to any one of the receiving circuits and means synchronized with the commutator apparatus are provided for connecting the desired control circuits with the detector circuit.

1,390,883—Theodore W. Case, of Scipio, New York, filed April 5, 1918, issued September 13, 1921.

RADIANT-ENERGY DETECTING AND TRANSLATING DEVICE, embodying a normally oscillating circuit for indicating very slight changes in resistance in a predetermined circuit resulting from variations of intensity of light rays to which resistance is exposed.

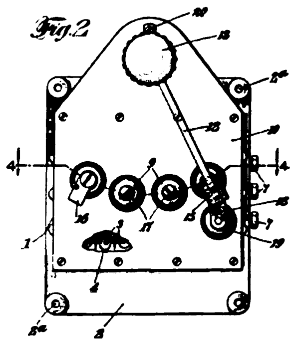
1,391,671—Horace St. John de Aula Donisthrope, of London, England, filed March 23, 1921, patented September 27, 1921.

THERMIONIC VALVE FOR USE IN RADIO TELEGRAPHY AND TELEPHONY, having hollow hemispherical plate and grid electrodes inverted over a looped filament. The advantages claimed for this arrangement are that the cathode stream is more uniformly distributed than when the ordinary plate type of electrode is employed and consequently disintegration is more uniformly distributed thereby increasing the life of the valve; and the arrangement also serves to damp down or eliminate microphonic disturbances or noises.

1,391,672—William Dubilier, of New York, N. Y., filed August 1, 1918, patented September 27, 1921.

ELECTRICAL CONDENSER, constructed of rectangular plates having one dimension substantially greater than the other and interleaved with larger rectangular insulating sheets of greater length than width. The novelty in this condenser lies in the construction of the stack. The side edge portions of the longer dimension of the condenser plates project alternately beyond the two longer sides of the dielectric sheets, the similarly projecting edge portions of the plates being connected together thruout their whole length to constitute the terminals for the condenser. The terminals are thus constructed to provide the shortest mean heat conduction path and the path of lowest mean resistance to the exterior of the condenser.

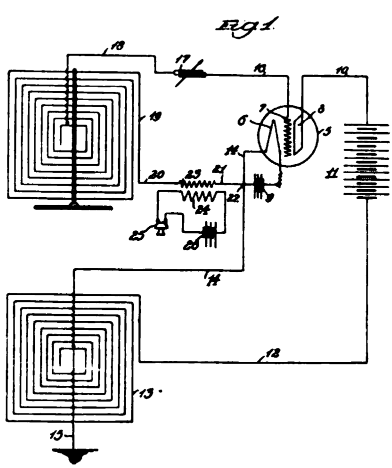
1,391,673—William. Dubilier, of New York, N. Y., filed March 7, 1919, renewed March 5, 1921, patented September 27, 1921. Assigned to Dubilier Condenser Company, Inc.



NUMBER 1,391,673—Antenna Shortening Device

ANTENNA SHORTENING DEVICE, comprising a plurality of condenser sections connected in series and tapped to different terminal posts arranged on a casing containing the condenser sections. A switch arm is provided movable over the terminal posts to connect in circuit the respective condenser sections in series with an antenna system to shorten the wave length to the desired value. A short-circuiting contact is provided whereby the series condenser may be entirely cut out of the antenna circuit.

1,391,855—Henry K. Sandell, of Chicago, Illinois, filed November 28, 1919, patented September 27, 1921. Assigned to Herbert S. Mills, of Chicago, Illinois.



NUMBER 1,391,855—Radio Transmitting System

Radio Transmitting System, employing a vacuum tube oscillator circuit having a loop antenna series connected in the input circuit of the oscillator and rotatably mounted and another loop antenna in series with the output circuit of the oscillator and arranged in proximity to the first mentioned loop. In the circuit illustrated in the patent the oscillator is modulated by a telephone transmitter connected in the input circuit.

1,393,018—Peter Cooper Hewitt, of Ringwood Manor, New Jersey, filed March 9, 1916, issued October 11, 1921.

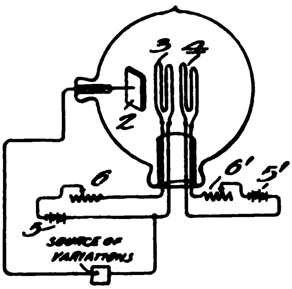


Fig. 3.

Number 1,393,018—Relay

Relay, comprising an evacuated vessel having an anode and a cathode therein, a battery connection for heating the cathode, a conducting member acting as a screen enclosed within the container and adjacent to the anode and means for heating the conducting member to a temperature having any desired relation to the temperature of the heated cathode. The tube is intended for amplifying electrical currents or translating variations and when used in such connection either the cathode or the screen may serve as the grid and the temperature of each may be controlled in such manner as to pass the desired amount of current in either direction.

1,393,077—William C. Brinton, Jr., of Kennett Square, Pennsylvania, filed October 8, 1918, issued October 11, 1921. Assigned mesne assignments to Philbrin Corporation.

Electrical Condenser, comprising layers of conducting material and layers of fibrous dielectric material of different degrees of hardness and compressibility, the harder and less compressible layers being of greater weight than the softer and more compressible layers. The entire condenser is enclosed in a tight-gripping casing compressing the layers in inter-relation.

1,393,594—William C. White, of Schenectady, New York, issued October 11, 1921, filed June 3, 1918. Assigned to General Electric Company.

Fig. 1.

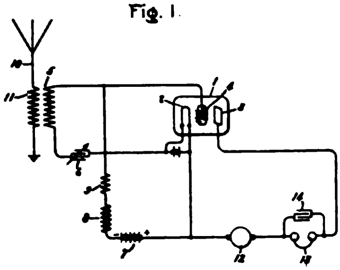
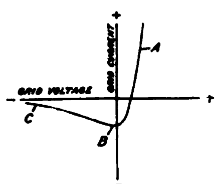


Fig. 2.



NUMBER 1,393,594—Means for Producing Radio Frequency Oscillations

MEANS FOR PRODUCING RADIO FREQUENCY OSCILLATIONS independently of any coupling between the grid and plate circuits of the vacuum tube oscillator. Under certain conditions in vacuum tube oscillator circuits, the current in the grid circuit may have a dropping characteristic, that is, as the voltage impressed upon the grid increases, the current in the grid circuit will decrease. With the proper conditions for operations, a circuit having current characteristics of the type described, may be so organized that oscillations will be produced therein, the essential condition for the production of oscillations being that the circuit shall contain capacity and inductance and that the resistance of the circuit shall be less than:

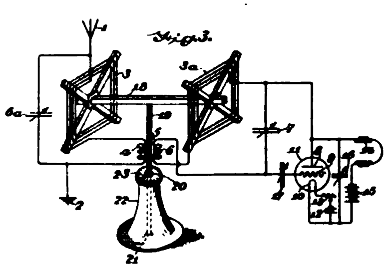
$$2\sqrt{\frac{L}{C}}$$

where L represents the inductance and C the capacity of the circuit. A resonant grid circuit is provided including a source of potential and adjusted so that the current in the grid will vary inversely as the applied potential over a given operating range of negative potential, the source of potential connected to the grid circuit being of such value that the normal potential of the grid is within the operating range, whereby oscillations will be produced in the grid circuit independently of any coupling between the grid and plate circuits.

1,393,602—E. A. Bayles and H. Higham, of Helsby, England, filed December 22, 1919, issued October 11, 1921. Assigned one-third to Ernest Richard Royston, Liverpool, England.

ELECTRICAL CONDENSER, comprising a plurality of condenser units, each unit made up of a series of spaced longitudinally aligned tubular condensers electrically connected and supported in removable racks within an oil container. The individual condensers are composed of coiled or folded laminas of paper and metal enclosed within cylindrical casings adapted to be threaded upon a vertically positioned frame carried on the removable rack submerged in the tank of oil.

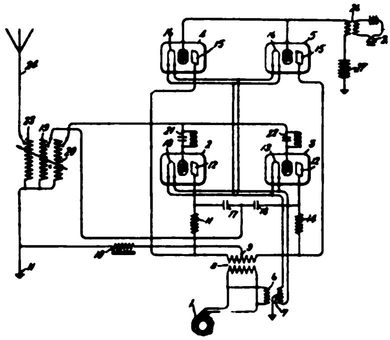
1,394,026—Lloyd M. Knoll, Philadelphia, Pennsylvania. Assigned one-fourth to Thomas Appleby, filed April 2, 1920, patented October 18, 1921.



NUMBER 1,394,026—Radio System

RADIO SYSTEM for the location of the actual direction of a transmitting station as an improvement over systems which merely indicate the course of the signals, but do not differentiate between the true and converse directions. The system comprises the combination of an antenna circuit with a pair of rectangular loop collectors rotatably mounted and adapted to have their mutual coupling varied and connected in circuit as indicated in Figure 3.

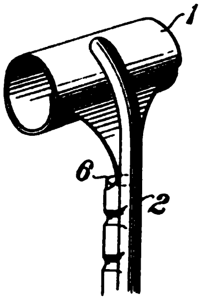
1,394,056—William C. White, of Schenectady, New York. Assigned to General Electric Company. Filed July 3, 1920, patented October 18, 1921.



NUMBER 1,394,056—Signaling System

SIGNALING SYSTEM, employing a vacuum tube oscillator and modulator. A source of alternating current of low frequency 1 is provided for supplying energy for the operation of the electron discharge oscillators 2 and 3 and the modulators 4 and 5. Current for heating the filaments of the oscillators and modulators is also derived from the source 1, being supplied to the filaments by means of the transformer 6, the middle point 7 of which is preferably grounded. Current for the operation of the oscillators and modulators is supplied to the plate circuits by means of the transformer 8, the secondary of transformer 8 being oppositely connected to the plate circuits of the oscillators 2 and 3 as well as to the plate circuit of the modulator 4 and 5. The plate circuits of the oscillators and modulators are all completed by a connection from the middle point 9 of the secondary of the transformer 8 thru a reactance 10 to ground 11.

1,394,090—Cassius Eugene Hiatt and William Joseph Davis, of London, England, filed May 19, 1919, patented October 18, 1921.

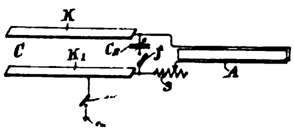


NUMBER 1,394,090—Valve of Radio Transmission Systems

Valve of Radio Transmission Systems, having a construction of plate which provides a high thermal conductivity between the plate and its support and which at the same time is of inexpensive manufacture. In the usual forms of vacuum tubes the plate is connected by electric welding to the upper end of a metal rod or post which at its other end is embedded in the glass support or stem, together with the electrical lead or conductor to which it is connected and which in turn passes to a terminal post of the tube. The electric welding process is usually carried out in an atmosphere of hydrogen in order to prevent oxidation and during the process the electrode absorbs the hydrogen and is therefore not gas-free. In the present construction the plate comprises a spirally-wound portion having an integral extension embedded in the glass support within the bulb, the extension supporting the anode and serving for the connection to the electrical lead and providing a path of high thermal conductivity in addition to its rigid supporting qualities.

1,394,560—Frederick A. Kolster, of Washington, District of Columbia, filed November 27, 1916, patented October 25, 1921.

FIG. 8.



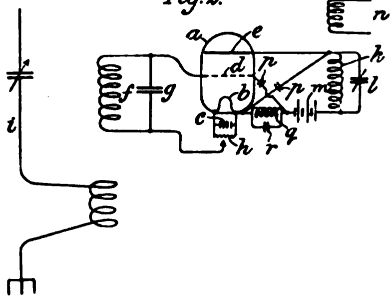
Number 1,394,560—Apparatus for Transmitting Radiant Energy

Apparatus for Transmitting Radiant Energy, comprising a closed radiating circuit including a coil inductance and a capacity made up of large separated areas and serving with the inductance as radiating elements. The circuit is placed in oscillation by coupling a source of either damped or sustained energy to the system modulated in accordance with the signals.

1,394,600—George Maurice Wright, of London, England. Assigned to Radio Corporation of American. Filed June 8, 1916, patented October 25, 1921.

Radio Telegraph Receiver, having a circuit for the reduction of noises due to atmospherics. The natural resistance of the antenna may be made of such a value as to damp the atmospherics while the effective resistance is reduced by the interaction of the incoming and outgoing circuits of a vacuum tube connected between the antenna system and the receiver. The filament of the vacuum tube is heated so slightly as to produce only very small magnification and to all practical degree no magnification of the signals, but sufficient to neutralize the antenna resistance for the weaker amplitudes of signals and yet render effective the resistance for the larger amplitudes of atmospherics.

Fig. 2.



NUMBER 1,394,600—Radio Telegraph Receiver

VOLUME 9 FEBRUARY, 1921 NUMBER 1

PROCEEDINGS of The Institute of Radio Engineers

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ALFRED N. GOLDSMITH, Ph.D.

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Medal and Diploma Received at World's Columbian Exposition Chicago, 1893

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INSULATION "MADE IN AMERICA"

Louis Steinberger's Patents

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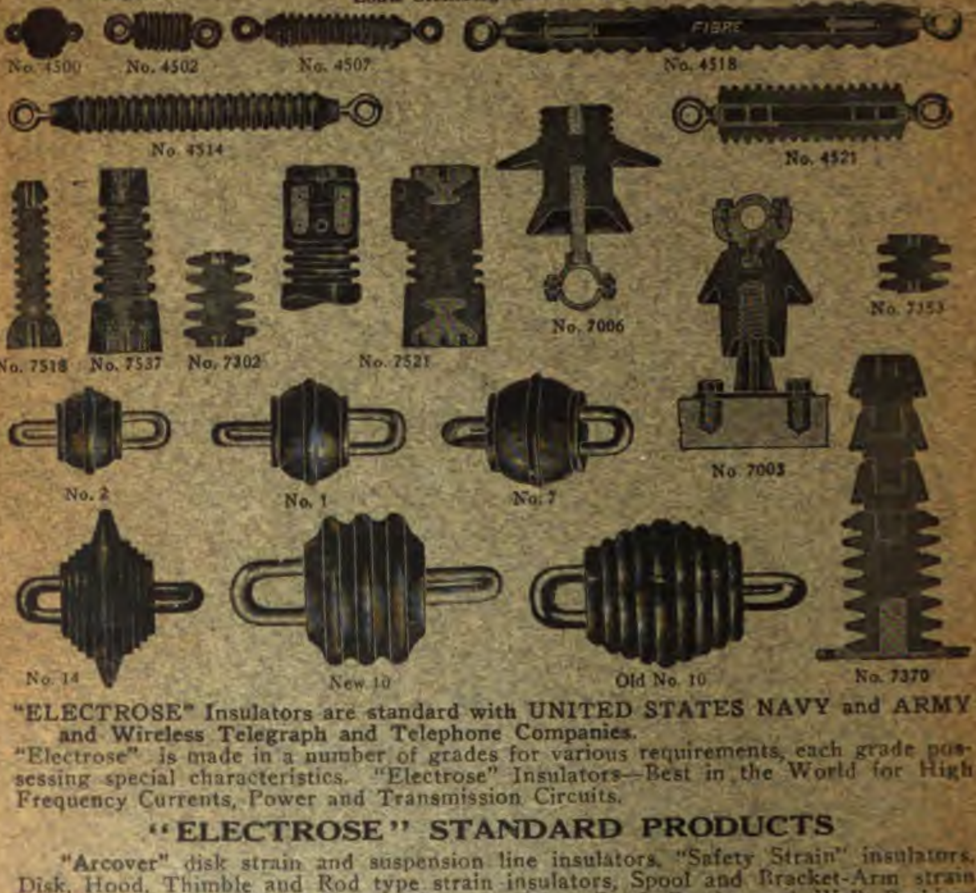

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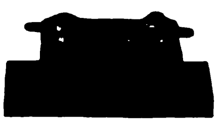

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VOLUME 9 DECEMBER, 1921 NUMBER 6

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of
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