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Oct. 7, 1930. E. E. CLEMENT 1,777,690

RADIO RELAY DISTRIBUTING SYSTEM

Original Filed Oct. 28, 1924 6 Sheets-Sheet 1

Fig. 1.

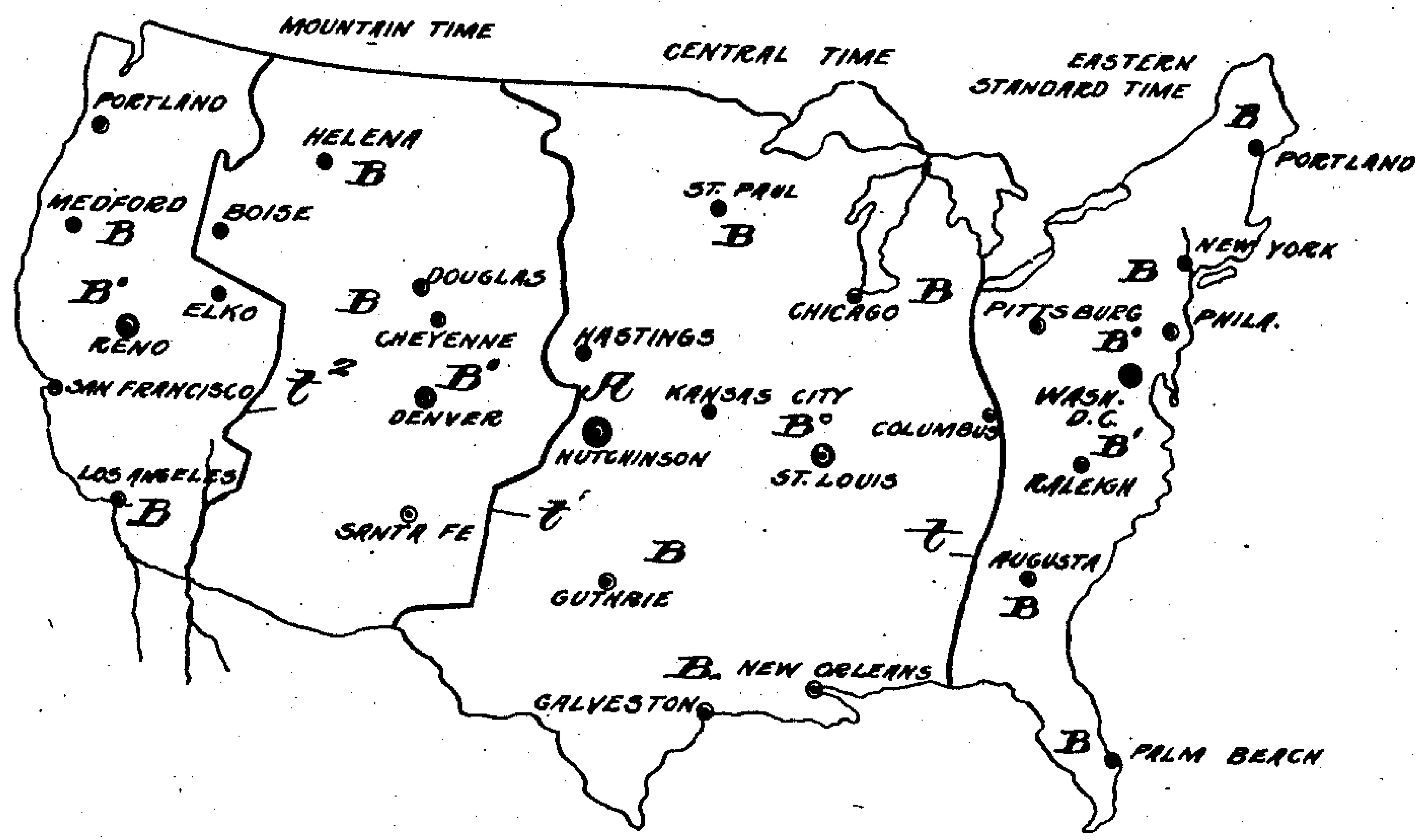
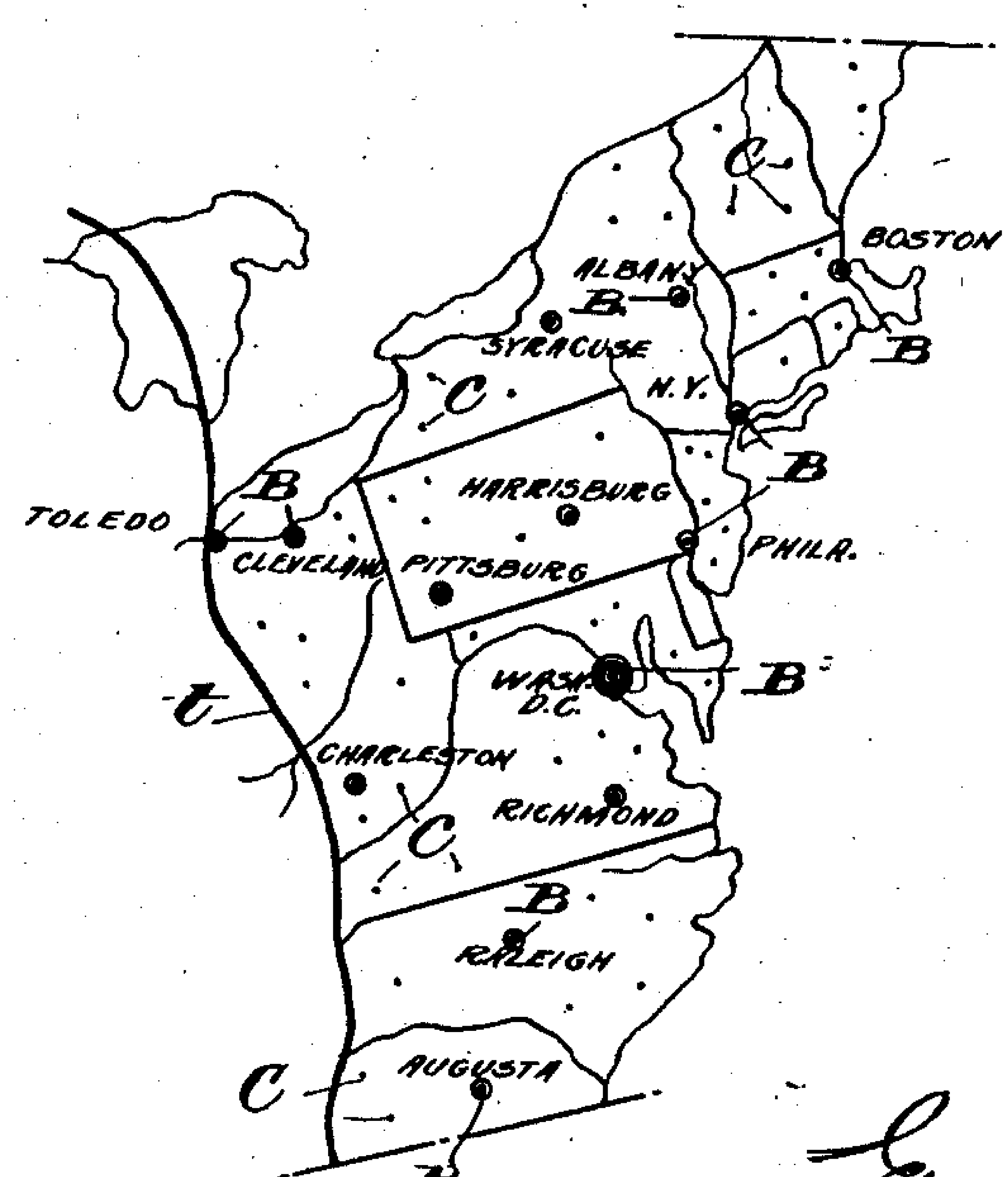


Fig. 2.



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RADIO RELAY DISTRIBUTING SYSTEM

Original Filed Oct. 28, 1924 6 Sheets-Sheet 2

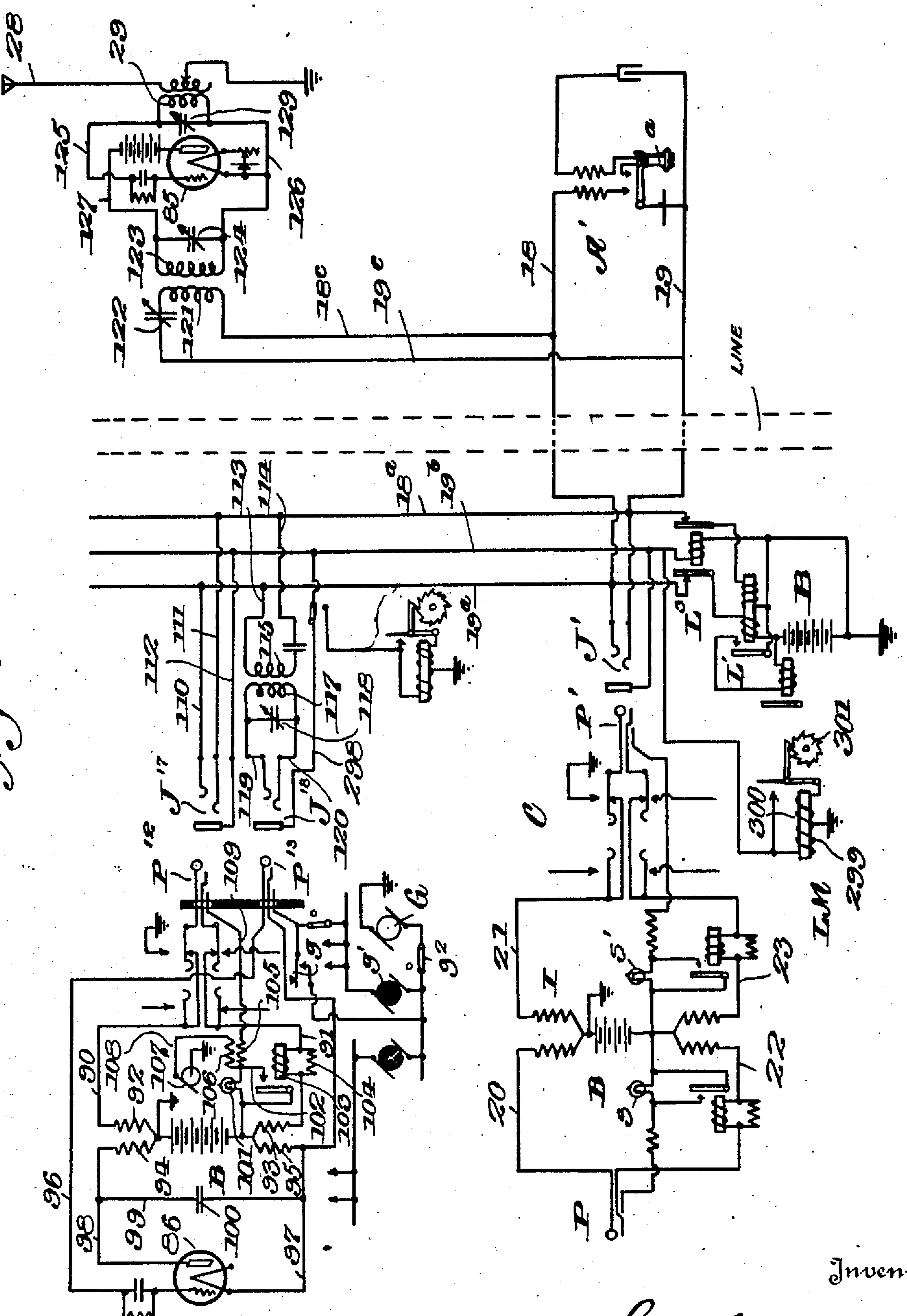

Fig. 3.

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RADIO RELAY DISTRIBUTING SYSTEM

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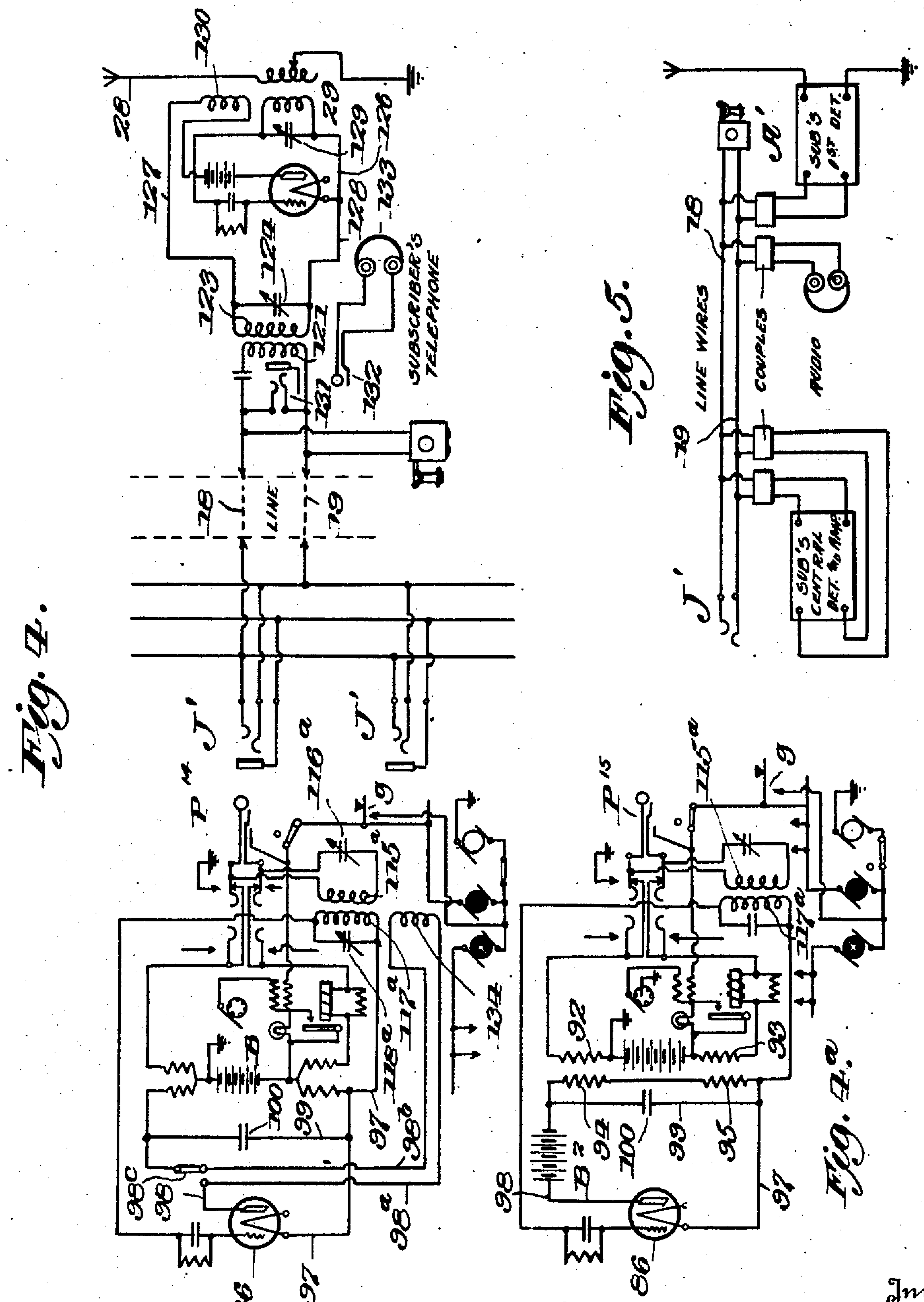

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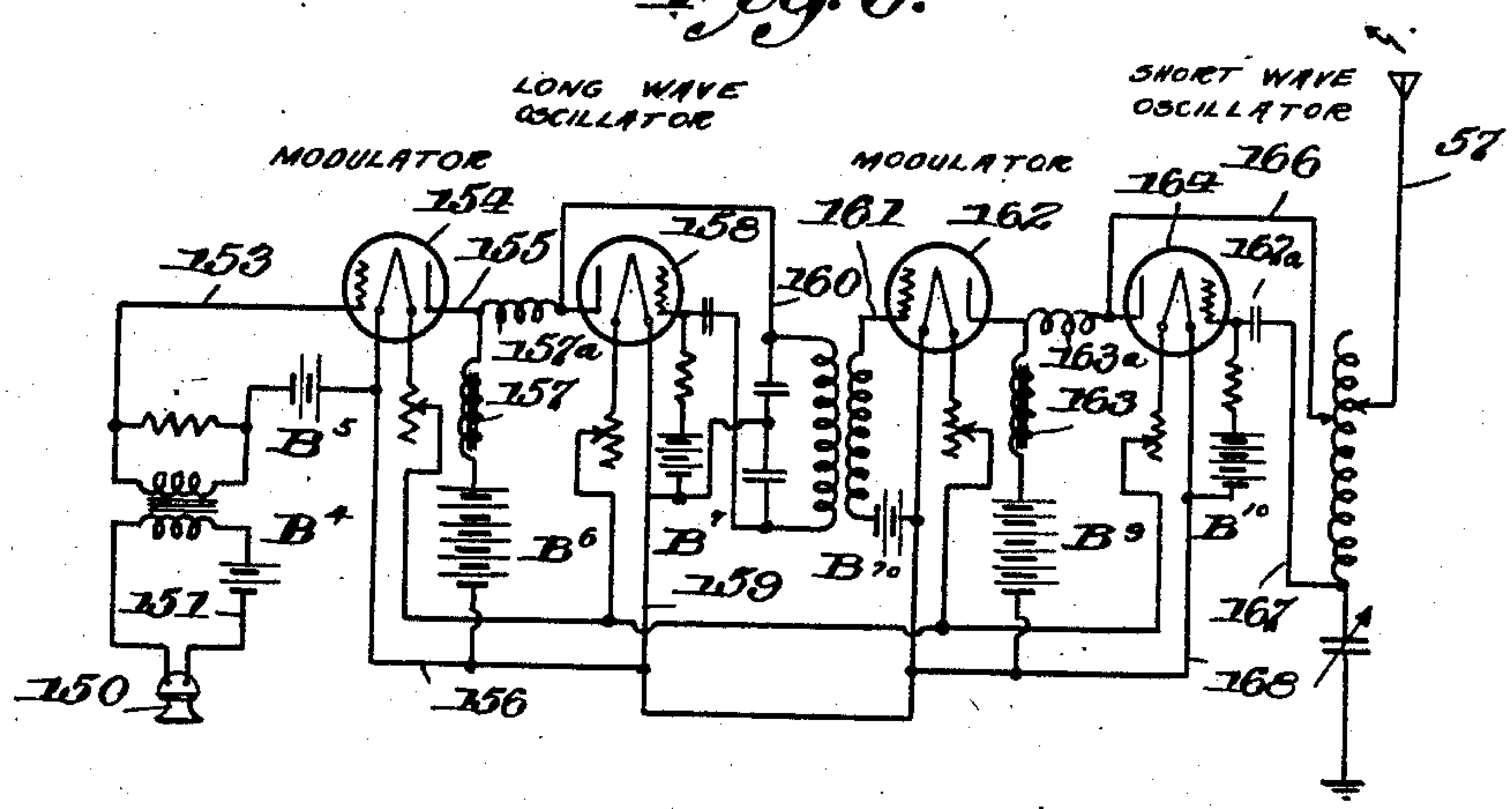
Fig. 6.



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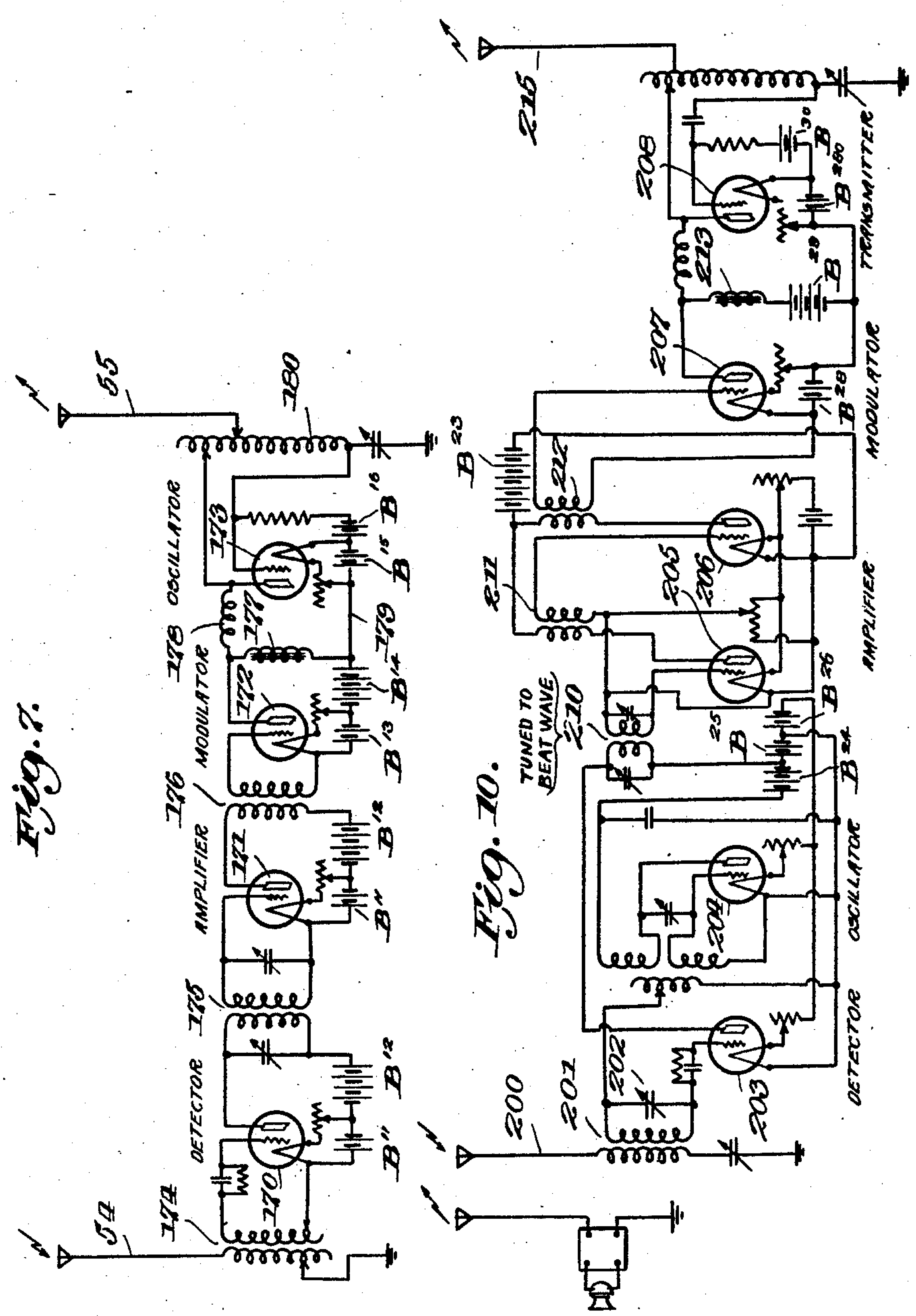
RADIO RELAY DISTRIBUTING SYSTEM

Original Filed Oct. 28, 1924 6 Sheets-Sheet 5



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RADIO RELAY DISTRIBUTING SYSTEM

Original Filed Oct. 28, 1924 6 Sheets-Sheet 6

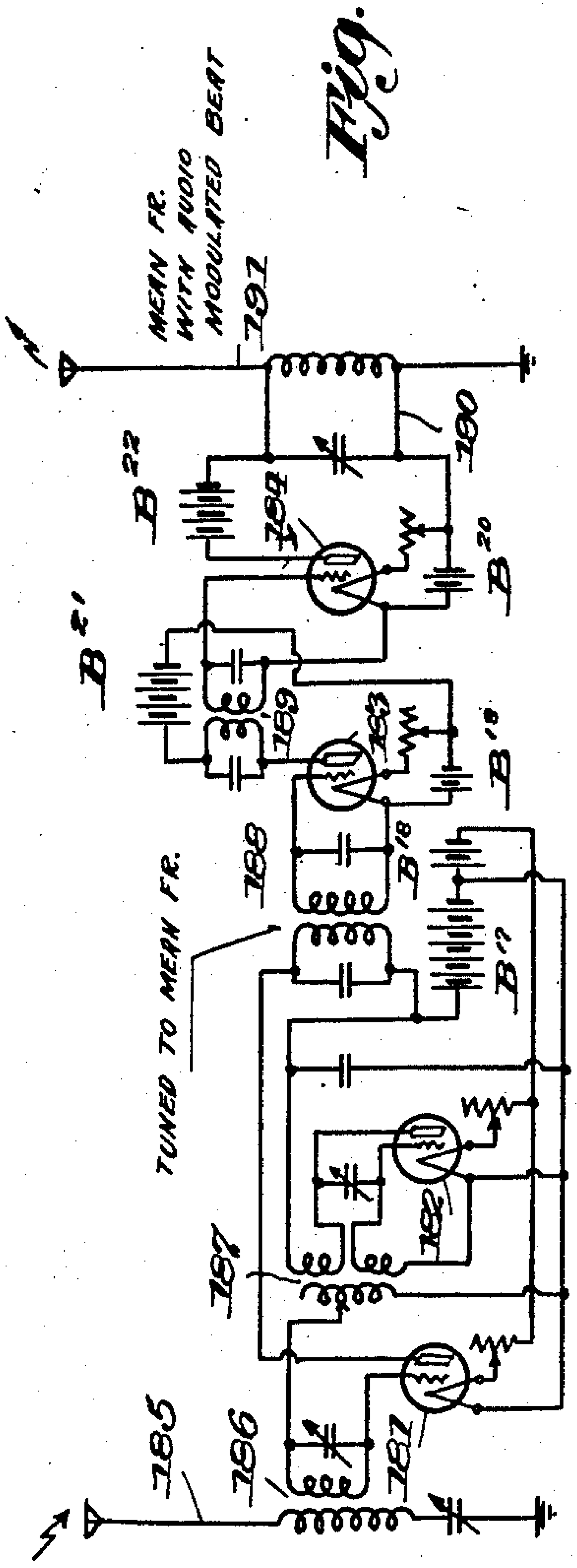

Fig. 8.

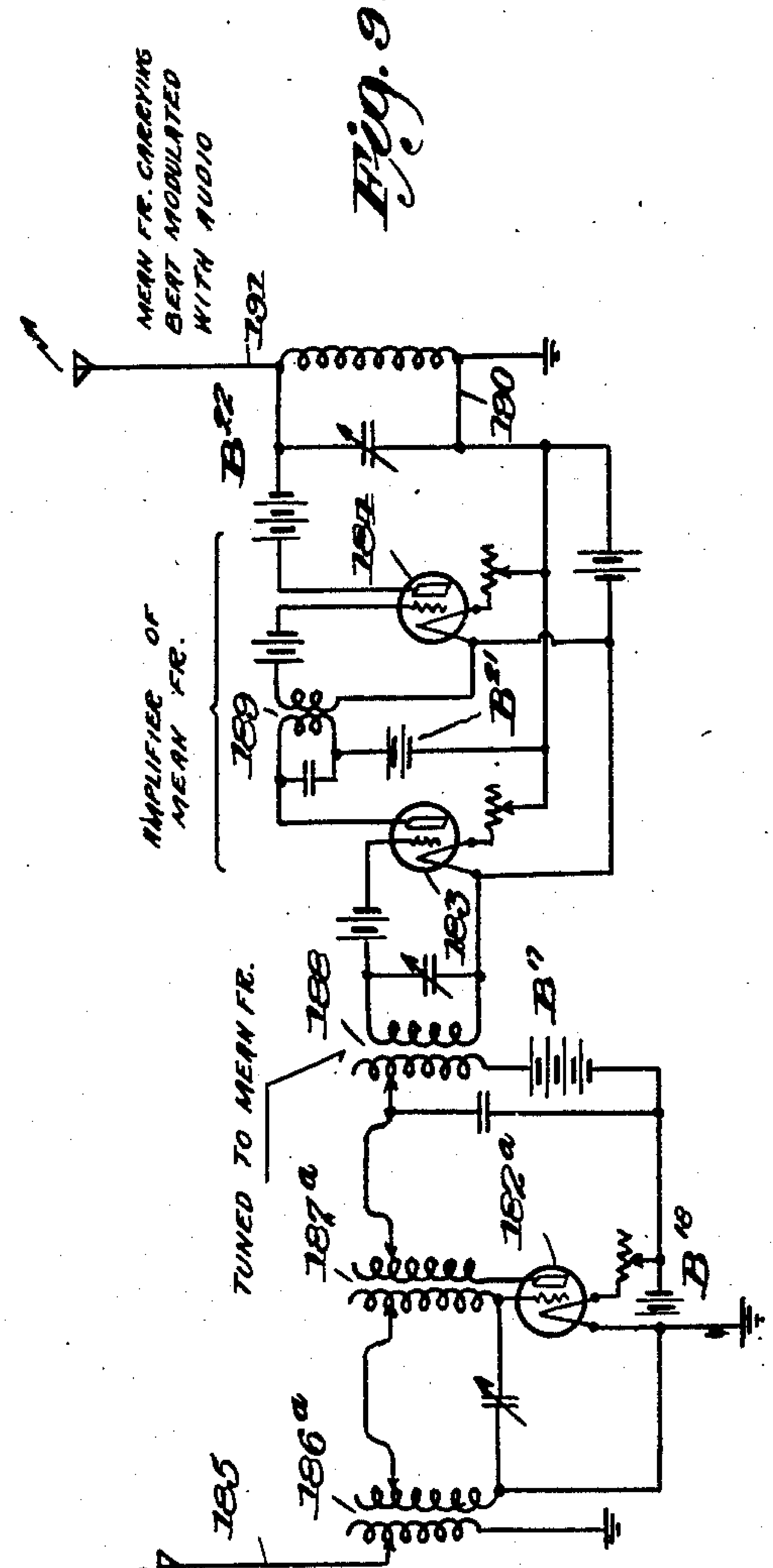

Fig. 9.

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Patented Oct. 7, 1930

1,777,690

UNITED STATES PATENT OFFICE

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RADIO RELAY DISTRIBUTING SYSTEM

Original application filed October 28, 1924, Serial No. 746,358. Patent No. 1,672,372, dated June 5, 1928. Divided and this application filed August 1, 1925. Serial No. 47,546.

The present application is a division of my copending application, Serial No. 746,358, filed October 28, 1924, Patent No. 1,672,372, June 5, 1928. The invention relates to systems of radio broadcast distribution, has for its object the provision of such a system in which the broadcasted matter may be relayed through one or several relay stations without loss in quality and to selected subscribers' receiving stations under local centralized supervision and control of the reception, or of both relay transmission and reception.

A further object of the invention is to provide a system of broadcast distribution in which the necessary receiving apparatus is simplified both in structure and operation by the provision of receiving devices having complementary parts at the receiving stations and at a centralized station common to a group of receiving stations thereby reducing the amount of apparatus necessary at the receiving station and placing an important portion thereof at the central station for supervision and control by expert operators.

A further object of the invention is to provide a system of radio distribution and reception in which the receiving apparatus is situated partly at receiving stations and partly at a central station common to a group of receiving stations, the parts at the central station being arranged to be interchangeably associated with the parts at the different receiving stations.

Various other objects of my invention will be apparent from a perusal of the following specification and the drawings accompanying the same.

My invention is illustrated in the accompanying drawings, in which:

Fig. 1 is a geographical diagram of the area of the United States divided with respect to standard time, showing stations positioned to form part of a typical distributing system embodying this invention.

Fig. 2 is an enlarged geographical diagram of a portion of Fig. 1 showing subdivision of distribution in localized or districted areas.

Fig. 3 is a diagram showing the subscriber's double detector receiving set divided into two single demodulating units, one located at the subscriber's station and the other located at the central office, the first detector being at the subscriber's station and sending long waves through the subscriber's line to the second detector at central, which sends back audio waves to the subscriber's telephone.

Fig. 4 is a diagram showing a modification of the circuit of Fig. 3, in which regeneration is added, at the subscriber's station, and the intermediate wave line coupling at central is included in the cord circuit.

Fig. 4ª is a diagram of a further modification showing the said cord circuit provided with the same elements as in Fig. 4 except the battery which is in two units, one for talking and telephone signaling, and the other for the detector tube plate circuit.

Fig. 5 is a schematic diagram showing the relation of units of any type connected up to perform the functions of the circuits shown in Figs. 3, 4 and 4ª.

Fig. 6 is a circuit diagram of double modulating apparatus.

Fig. 7 is a circuit diagram of relay apparatus for stations B or C.

Fig. 8 is a circuit diagram showing means primarily intended for A and B stations, but which may be located also at C stations, for picking up any single modulated carrier wave which it is desired to put out in the system, and changing this into a double modulated wave by heterodyning, amplifying, and transmitting the modulated intermediate frequency carrier or beat, on a short carrier wave whose frequency is the mean of the frequencies of the original carrier and the heterodyning oscillator waves.

Fig. 9 is a circuit diagram similar to Fig. 8 showing a modified form of apparatus that may be used in Fig. 8, employing the autodyne principle for receiving instead of a double tube heterodyne circuit.

Fig. 10 is a circuit diagram showing equipment supposed to be located at the A, B, and C stations, for receiving on any single modulated carrier wave, heterodyning and detecting the same and modulating the beat taken therefrom on to the standard frequency short carrier wave of the next succeeding order of stations. If located at station A, the beat would be modulated and transmitted on the B frequency, and if located at a station B, transmission would then be on standard carrier wave C.

Referring to the drawings, and particularly to Fig. 1, this is a diagram of the United States of America, divided by lines t, t' and t^2 into four divisions marked respectively "Eastern standard time," "Central time," "Mountain time," and "Pacific coast time." It happens that the town of Hutchinson, Kansas, is within fifty miles of the geographical center of the United States and hence I have shown this town with three rings around it, and the letter A, indicating the location either of the headquarters or master station of the entire system. In each division there is one station with two rings around it, and marked B°. These are the head or master district stations of the several divisions, which under certain conditions serve as relay stations between the A stations and the other B stations for their respective divisions. Other stations are shown in each division with one ring each, and marked B. These are district stations, and receive either directly from the A stations or on occasion by relaying from the head or master B stations in their respective divisions. This illustrates the general manner of distribution, and will be referred to hereinafter.

Fig. 2 shows on an enlarged scale a portion of the Eastern standard time division, which may be regarded as one or more districts, as it contains a number of district stations B. The main function of this figure is to show the relation between the district station and the local or regional distributing centers C. It is to be noted that Washington, D. C., is the head or master B station in the eastern division, while other towns from Boston to Augusta are shown in Fig. 2 with one ring as ordinary distributing centers each serving a number (which in practice would be very considerable) of outlying local or regional exchange centers marked C. Around each of these local stations or centers C are grouped subscribers.

In Fig. 1, I have shown eight district stations B in the eastern division, ten in the central division, and six each in the Mountain and Pacific coast divisions, or a total of thirty. This of course is illustrative only and not to be taken as final either in positioning or numerical selection. As a matter of fact if the area of the United States be divided up into substantially equal districts, approximately one hundred district stations B would be a convenient number, but it is doubtful whether the traffic would require this many district stations at first. In Fig. 2, I have shown a larger number of stations in part of the same territory, or B stations, and have related a considerable number of C stations thereto. The location of these is a matter of choice, and they may or may not be associated with local telephone exchanges, as convenience and traffic conditions may demand.

For the purposes of a basic description herein of the system as a whole, in the simplest form, I shall assume that each of the three orders of stations, B, C, and D, is allotted a single carrier wave frequency for receiving, which is common to all the stations of the same order, and that say ten intermediate or long wave frequencies may be modulated thereon, each intermediate frequency being in turn modulated at audio frequencies intended for distribution. At certain times these ten intermediate frequencies may all be used at the master station A and broadcasted on the B carrier wave to all the B stations, which in turn will demodulate the initial carrier, amplify and reimpose the same intermediate frequencies and modulations on the common C carrier wave and so relay them to all the C stations, which in turn will demodulate the carrier waves received by them and reimpose the same upon the common carrier wave allotted to all the D or subscribers' stations. At other times there may be only one or two or even none of the intermediate frequencies in use by station A and at such times the unused intermediate frequencies may be allotted to different B stations or even to C stations for local or district broadcasting. In the first instance, it will be observed that the original modulations on all the intermediate frequencies are simply passed along by relaying until they reach the subscribers, who receive them in the original package, so to speak, so that it is entirely possible to say truthfully to the subscribers that they receive and actually hear the original audio modulations, with equal efficiency from all points, foreign or domestic; and this in spite of the simplicity of their instruments.

Fig. 2 shows geographically the method of distribution in the district or B areas and the relation in general between B and C stations.

Referring to Fig. 3, the subscriber's station A' is equipped with a radiophone receiving device including an antenna circuit 28, tuned as usual, and coupled by means of coils 29 to the input side or grid circuit 125—126 of the detector tube 85. The input circuit may be tuned by means of condenser 129, but it is to be understood that this condenser and also the tuning elements in the antenna circuit may be adjusted once for all if the subscribers all work on a constant frequency, as hereinbefore set forth. The plate circuit 127—128 of the tube 85 includes one winding 123 of a tuned filter coupler, the other side of which 121 is connected to extensions 18^c and 19^c of the subscriber's telephone line circuit 18—19. The coil 123 is shunted by a condenser 124, and the capacity and inductance are so adjusted that the short circuit thus formed is resonant to the intermediate frequency waves imposed on the short carrier waves reaching the subscriber's instrument through the antenna 28. The variable condenser 122 is included in series with the coil 121, because of the line connection, tuning of the line being accomplished at both ends as will presently appear.

At the central office, the line wires 18—19 are connected to any desired number of answering and multiple jacks typified by the single jack J′, and is provided with extensions 18^a—19^a passing to the radio department or radio switchboard R in the upper part of the figure. The telephone jacks are intended to be interconnected with other jacks for telephonic purposes through a standard cord circuit 20—21, 22—23, having terminal plugs P—P′, and bridged by a common talking and signaling battery B, feeding through the two halves of repeating coil I and also feeding through a ring on each plug and test thimble on each jack to the cut off relay circuit 19^b, so that whenever a plug is in a jack of the line 18—19, circuit from battery to the cut off relay L^8 will be completed and the line relay L′ with its connection to the main battery B will be cut off and removed entirely from the line. In this cut off portion of the cord circuit are inserted supervisory lamp signals, *s*—*s*′, adapted to be shunted by contacts controlled by supervisory relays included in the conductors 22—23, respectively. These relays respond to current in the subscriber's lines when they are interconnected, and the lamps light when the subscribers hang up their receivers.

On the radio switchboard R, the same line is provided with jacks typified by jacks J^{17}—J^{18}. As shown, these are in pairs, for convenience only, and to avoid putting a large number of contacts in one jack. The upper jack J^{17} is a duplicate of the telephone jack J′, and has its contacts connected in parallel to the same conductors, respectively. Jack J^{18} is a radio jack pure and simple, and is connected to the same line wires 18^a—19^a through a tuned filter coupler composed of coils 115 and 117 and condensers 116 and 118. The elements 115 and 116 are employed in conjunction with the elements 121—122 at the subscriber's station to tune the line circuit to resonance at the frequency of the long waves sent forward as demodulated by the subscriber. The elements 116—117 at central are included in this figure between the line and the jack because by this means the tuning of the line can be made constant and adjusted once for all. The cord circuit adapted to cooperate with these twin jacks has corresponding twin plugs P^{12}—P^{13} preferably connected mechanically so they can be inserted and removed from the jacks at the same time. The plug P^{12} is the terminal of a standard talking circuit 90—91, with battery B bridged across it through coils 92—93, and provided with supervisory lamp 101, the controlling shunt therefor 102, the supervisory relay 103 and the talking shunt therefor 104, also with special test coil 106 supplied with a radio tone test through wire 108 from the commutator 107. When this plug is inserted in the jack J^{17} the cut off relay L^8 of the telephone line is pulled up and the line cleared of all telephone switchboard connection, for radio use.

The plug P^{13} forms the terminal of a radio detector circuit, the tip and sleeve of the plug being connected through conductors 96—97 with the grid and the filament respectively of the detector tube 86. The plate circuit 97—98 of this tube is connected to the outside terminals of coils 94—95 which with the bridged coil 92—93 form the usual repeating coil connection between two ends of the standard bridged battery cord circuit. The battery B bridged between the windings 94—95, has its positive terminal connected to the plate through coil 94 and wire 98, and the conductors 97—98 are bridged by a conductor 99 containing a by-pass condenser 100.

The result of this arrangement is as follows: The subscriber calls for radio service by moving his switchhook at station A′, up and down rapidly. This flashes the line lamp before the telephone operator, who transfers the line over an order trunk to the radio operator, who thereupon inserts the twin plugs P^{12}—P^{13} into the jacks J^{17}—J^{18}. This pulls up the cut off relay L^8, clears the line through from the substation to the cord circuit 90—91, 96—97, and thereupon, assuming that the subscriber has closed his filament circuit at the substation, radio waves received on his antenna 28 are demodulated, and their long wave or intermediate frequency component, carrying the audio modulations, is transmitted to line through the filter coupler 121—123. From line it passes through the filter coupler 115—117 and through the wires 96—97 to the grid circuit of the tube 86. The varying potentials thus produced in the grid circuit of the tube are reproduced in current changes in the circuit 97—95—B—94—98. The superaudio frequency waves are absorbed by the circuit 99 and the condenser 100, and pure audio frequency waves are propagated through the repeating coil 94—95—92—93, into the telephone line circuit, through the plug P^{12}, the jack J^{17}, multiple wires 18^a—19^a, and line circuit 18—19. At the subscriber's station these audio waves may be received on his ordinary telephone receiver *a*, or upon any special form of receiver desired.

Referring now to Fig. 4, I have shown therein a modification of the circuit of Fig. 3, in which the following features are introduced: First, I provide a feed back coil or tickler 130 at the subscriber's station; a special receiving telephone 133 with a terminal plug 132 adapted to be inserted in the jack 131 bridged across the telephone line outside of the filter coupler 121—123; and lastly I have removed the central office filter coupler 115—117 from its position between the line and the jack J^{13} as in Fig. 3 and instead thereof have located this coupler in a bridge of the cord circuit 96—97, thus doing away with the twin plug P^{13} and its connections. This also reduces the number of couplers required, and most important of all enables the complete radio cord circuit to be used with any ordinary telephone jack, since the terminal plug P^{14} is an ordinary telephone terminal plug. For the reason stated, I have designated both jacks in this figure by the letter J′, the lower one being at the telephone switchboard and the upper one at the radio switchboard. Both may be used interchangeably, or an ordinary telephone switchboard may be used for radio purposes without any change other than adding the filter coupler, the detector tube, and other connections to an ordinary standard answering plug cord. This interchangeability of the parts, makes it possible to give radio service on any telephone switchboard, using the same operators if desired, for both services. It also makes it possible to lengthen the life of a telephone switchboard, by rewiring the cords and converting it into a radio switchboard.

In Fig. 4, the antenna circuit 28 and the coupler 29 are the same as before; the grid circuit is 125—126, the plate circuit 127—128 includes a tickler coil 130, and the other parts have been referred to. At the central station the plug P^{14} is connected as in Fig. 3 to the repeating coil, battery, supervisory lamp, controlling relay therefor, tone test, etc. The coil 115^a of the central office filter coupler is bridged across the terminals of the plug, with its tuning condenser 116^a. The twin member of the filter coupler 117^a, with its shunting tuning condenser 118^a, is bridged through conductors 96—97 across the grid circuit terminals of the tube 86. The plate circuit 97—98 is connected to the repeating coil in the cord, and in this case also includes a tickler coil 134, which may be cut in and out of the plate circuit at will by means of a switch 98^c. This coil 134 feeds back into the grid circuit waves at intermediate frequency, as received over the line, and is intended to give a higher ratio of amplification in the audio current returned to the subscriber than would be possible without it. It should be noted however, that instead of thus using the regenerative principle, I contemplate employing radio and audio amplification in one or more stages of each, inserted between the detector tube 86 and the plug P^{14} or P^{15}. (Fig. 4.)

In Fig. 4^a I have shown a modification of the cord circuit in Fig. 4, which consists in providing a separate battery B^2 for the plate circuit 97—98 of the tube. This battery is located next to the plate, and the by-pass condenser 100 is bridged across the terminals of the repeating coils 94—95. This approaches more nearly to the common or standard method of connecting circuits than the bridge circuit of Figs. 3–4, and while probably not more efficient, is a little more flexible, as it permits the voltage of the B^2 battery to be varied at will, without reference to the voltage of the battery B which according to telephone practice is constant at about 22 volts. Thus, if amplifier tubes are used between the tube 86 and the coils 94—95, a separate plate battery would be required for the amplifiers, giving a higher voltage according to common practice. The operation of Figs. 4–4^a is as follows: The subscriber may call as before and in response to his call the radio operator gives him a cord circuit with terminal plug P^{14} or P^{15}, whereupon his unit through the detector tube 85 demodulates the short wave carrier received on antenna circuit 28, and sends the intermediate or long wave modulation thereof through the line wires to central, where it passes to the jack J′ and the plug P^{14} and is repeated by the tuned filter coupler 115^a—117^a into the grid circuit 96—97 of the tube 86. Through this tube, and any amplifying tubes which may be employed, the audio modulations are first detected and then amplified and sent back through the repeating coil to the plug P^{14} and the jack J′ to the subscriber's line. At the subscriber's station they are received either on his regular telephone receiver, or on the special telephone 133 which typifies any kind of receiver which it may be found expedient and desirable to employ.

I contemplate dividing the cord circuits shown in Figs. 3, 4, 4^a, in classes, the first class being like those shown herein, without any amplification; the second class having sufficient audio amplification or radio amplification, or both, to insure good operation of the subscriber's table talker; and those of higher classes having more amplification, serving for the operation of loud speakers giving varying volumes of sound. Thus it may be stated that a No. 1 cord circuit would be as shown, with only one detector tube and the subscriber would therefore receive his audio message on a head telephone or on his ordinary telephone receiver held to his ear; with a No. 2 set at central there would be one stage of audio amplification sufficient at the subscriber's station for a table talker which would not annoy the neighbors; a No. 3 set would have sufficient amplification to actuate a reasonably loud speaker, while a No. 4 set might be so equipped as to fill a hall. For different classes of service as thus outlined, the subscriber should be charged different rates, as in long distance telephone service. It is very necessary that there be metering upon which to base the charges, since the service is a time service and not a message service. For this purpose I contemplate including in each cord a distinctive type of meter actuator which will operate the subscriber's line meter, which may be his telephone meter or a separate meter as desired, a number of times per hour determined by the class of service he is receiving. Thus the No. 1 cord circuit may be connected to a commutator that closes the line meter circuit once every hour; No. 2 may have a meter actuator that works twice every hour; No. 3 may have an actuator that works three times in the hour; while No. 4 may have its actuator work every ten or twelve minutes. The reason for selecting these time divisions is that the average charge per message for telephone service is about five cents. At five cents per hour, and averaging three hours service per day, a subscriber's radio bill would be $4.50 per month. This is fairly comparable to the earnings of an average residence telephone for the same period, on a message rate basis. The fractions of time could not be cut below a five cent value, unless a separate radio meter be provided for each line and it is desired to avoid this expense, as well as the upkeep of one hundred per cent of additional meters. In prior copending applications, Serial No. 581,831, filed August 14, 1922, and Serial No. 583,566, filed August 22, 1922, I have shown and described metering systems which are suitable for use with the system of circuits herein disclosed, I have disclosed and shall claim the adaptation of these metering circuits to the present system.

It should be particularly noted, that a subscriber, (which term is meant to include any user) may not keep his radiophone in service a full hour, a pertinent example being that of a man who desires to obtain a baseball score or other special information. A special provision should be made for registering such service, as it involves all the elements of expense to the operating company which would be included in a much longer connection. For this purpose the operator may have a push button g connecting the actuating generator G direct to the meter circuit through the plug P^{13}, as shown in one form in Fig. 3, together with the automatic actuating means for the meter, comprising the commutator g' which at stated intervals connects the generator G to the wire 297 leading to the third contact on the plug P^{13}, which when the plug is inserted in jack J^{18} completes the circuit from wire 297 through wire 298 to the cut off relay wire 19^b, thence to the high winding 299 of the meter LM. In Fig. 3, the meter is shown as the ordinary standard telephone line meter, which would thus serve a double purpose, registering both the telephone calls and also the time of radiophone use in terms of telephone call units or telephone message units. Such a meter by reason of the high resistance in its winding 299 will not respond to the battery current which energizes the cut off relay L^3, but when the operator connects a generator as G producing current of higher voltage, then the meter magnet becomes sufficiently energized to attract its armature and close the circuit of its low winding 300, the rush of current through the low winding producing strong and certain actuation of the meter counting device 301.

By thus having the operator always press the keys g immediately after making a radiophone connection, there will always be made a base charge of one telephone message unit for the connection. If it should happen that the commutator closes the actuating circuit immediately afterward, the meter would register two units for the first hour of use. If it should happen that the subscriber hangs up in fifteen minutes the line would still bear the charge of two units for one hour. On the other hand, if the connection was made immediately after the commutator had closed the metering circuit, then no additional charge would be made for an hour, and if the subscriber should hang up within less than an hour, he would have only the one charge against the line. In any event, the charge would be safe to the company and fair to the subscriber as all public service corporations make a service charge if the measured rate charged is below a minimum amount. A commutator individual to each cord started when the cord is connected would of course register individual time use only.

Referring to Fig. 5, this is a schematic diagram showing without detail the layout of the subscriber's line instruments and the central office radio connection just described and illustrated in Figs. 3, 4, and 4^a. Line wires shown at 18—19 extend from the subscriber's station A′ to the central office where they terminate on a jack J′. As the units of the apparatus are marked with legends specific description is unnecessary. The principal point is that no physical connection with the telephone line is made at either end except through a tuned filter coupler passing only superaudio frequencies.

Fig. 6 illustrates an arrangement of apparatus and circuits for producing double modulation of a primary or short carrier wave, that is to say, to modulate a relatively long wave carrier, and then modulate this long wave upon a relatively short wave carrier which may conveniently be radiated in the usual fashion. Means for receiving and demodulating such double modulated waves have been described in connection with Figs. 3, 4 and 4^a. In Fig. 6, 150 is a microphone transmitter in a local circuit 151 supplied with energy by battery B^4 and containing the primary winding of an induction coil 152, the secondary of which is connected in the grid circuit 153 of the modulator tube 154, said circuit containing a battery B^5. The plate circuit 155—156 of the tube 154 is bridged by the power battery B^6 and choke coils 157, and is connected through radio jack coil 157^a, to the plate of the long wave oscillator tube 158. The grid circuit of the tube 158 contains a battery B^7, is differentially connected to one coil of the coupler 161, which in turn has a wire connection 160 back to the plate circuit. The coupler 161 is tuned on its input side to the long wave frequency supplied by the tube 158, and its secondary winding is connected to the grid circuit of a second modulator tube 162, containing a battery B^{70}. The plate circuit of the tube 162 is bridged by power battery B^9 and choke coil 163, and is connected through the radio choke coil 163^a to the plate of the short wave oscillator tube 164. The grid circuit of this tube 164 contains a battery B^{10} and is connected through a condenser 167^a and wire 167 to the antenna circuit, which is also connected back to the plate circuit through wire 166. The antenna circuit 57 is thus supplied with short wave oscillations modulated by the tube 162 with long wave oscillations which in turn have been modulated by the tube 154 with audio modulations due to the primary modulator or microphone transmitter 150. It should be noted that this circuit is an adaptation of the Heising modulator circuit in common use, and it is not claimed herein, being shown for example on page 682 of the work on "Principles of radio communication" by J. H. Morecroft, published by John Wiley & Sons, New York, 1921. The use of this apparatus however in combination with other elements to produce the results stated, and the adaptation of the circuit in question to the purposes of this system, are novel and will be claimed herein.

The apparatus of Fig. 7 is intended to receive a double modulated carrier wave such as that radiated from the antenna in Fig. 6, demodulate the same and reimpose the long wave or intermediate frequency, with its modulations, upon another short wave carrier which is the carrier wave allotted to stations C or the subscribers' stations D, according as to whether the apparatus is situated at a B or a C station, respectively. The purpose of this is to transmit from the point of origin to the point of destination the same intermediate long wave carrier with the same audio modulations intact and merely passed along by relaying from station to station on short carrier waves.

The apparatus and circuits of Fig. 7 is the same at both the B and C stations except that the transmitted or short primary carrier waves are different to enable reception and transmission to be effected at different wave lengths or frequencies.

Referring to Fig. 7 in detail, 54 is the receiving antenna coupled at 174 to the grid circuit of the detector 170, whose plate circuit is connected through a tuned filter coupler 175 to the grid circuit of the amplifier tube 171, whose plate circuit is connected through the transformer 176 to the grid circuit of the modulator tube 172, which in turn has the usual Heising connections 178—179 to the circuit of the oscillator tube 173; the radio choke coil 178, the power battery B^{14} and the magnetic choke coil 177 being arranged as usual. The grid and plate of the oscillator tube 173 are connected to the antenna inductance coil 180, which with the usual tuning condenser 180^a is included in the antenna circuit 55. Filament batteries B^{11}, B^{13}, and B^{15}, and plate batteries B^{12} and B^{16} are located as usual. As thus described, the assemblage constitutes a relay set which will take in the modulated long waves on a short wave carrier, and retransmit them on a carrier of different frequency, without demodulating or disturbing the modulations of the intermediate or long wave.

Another arrangement of apparatus and circuits for performing functions similar to that of the arrangement of Fig. 7, that is to relay on a different carrier frequency carrying the same audio modulations, is shown in Figs. 8 and 9. Referring to Fig. 8, 185 is the receiving antenna with coupler 186 connecting it to the detector tube 181 which has a triple coil oscillator coupler 187, 182 being the oscillator for producing local heterodyning waves. The detector circuit and the oscillator circuit are connected to the tuned filter coupler 188, the output side of which is connected to the grid circuit of the amplifier tube 183, the plate circuit of which is in turn connected through a tuned radio frequency transformer to the grid circuit of the amplifying tube 184, the plate circuit of which goes to the antenna 191. B^{17} is the plate battery of the oscillator and the first tube 181, which, while I have called it a detector because it occupies that position, may be regarded rather as an amplifying tube, since it is worked by preference on the straight portion of the characteristic tube curve, for purposes which will appear. The battery B^{18} and battery B^{20} are filament batteries for the tubes 183—184 respectively, while B^{21} and B^{22} are the plate batteries for the same. The antenna circuit radiates at a frequency determined by the tuning of the circuit 190, and it is to be observed that with this arrangement the radiated frequency is not the beat wave between the incoming wave from antenna 185 and the frequency produced by the oscillator 182, but a frequency lower than any of said other carrier waves, and radiating the same.

5. The method of radio relaying which consists in receiving a singly modulated carrier wave, transforming the same without demodulation into a doubly modulated carrier wave in the form of a high frequency carrier wave modulated with a carrier having a frequency several times lower than that of said single modulated carrier wave and in turn modulated with the signal wave, amplifying and radiating said doubly modulated wave.

In testimony whereof I hereunto affix my signature.

EDWARD E. CLEMENT.

is the mean frequency between these two, and also that the filter coupler 188 is tuned to this frequency. See "Principles of radio communication" by J. H. Morecroft, page 636, published by John Wiley & Sons, Inc., New York, 1921. In these respects, the apparatus of Fig. 8 is very different from an ordinary superheterodyne set, which invariably makes use of the beat wave. In this case the beat wave is not taken off, but appears as an envelope on the mean frequency which is the carrier wave produced, amplified and radiated by the machine from the antenna 191. In other words, by heterodyning and then amplifying and radiating the wave carrying the original modulations, I produce what is really a double modulated carrier wave, since the mean frequency wave has an envelope corresponding exactly to the wave or beat frequency between the original carrier and the heterodyning oscillator waves.

Referring to Fig. 9, the apparatus therein is a modification of what is shown in Fig. 8 but using autodyne receiving tube 182 instead of two tubes shown in Fig. 8. In this case the tube 182 is said to oscillate at the heterodyning frequency, while the circuit 186^a—187^a is tuned to the frequency of the incoming carrier wave. A resultant or mean frequency wave is produced, carrying the original modulations, and having an envelope of the frequency of the beat. This wave is propagated through the coupler 188 into the grid circuit of the tube 183, which is the first amplifier tube, and from thereon the operation is the same as described of Fig. 8.

Referring now to Fig. 10, this is a further arrangement of apparatus and circuits for receiving on any short wave length and relaying by double modulation. The receiving antenna 200 is connected through coupler 201 to the grid circuit of the first detector 203, the input circuit being tuned by means of a variable condenser 202 as usual. The plate circuit of the detector 203 is connected to the tuned filter coupler 210, and the grid or input circuit is coupled through a triple coil coupler to the oscillator 204. The other side of the filter coupler 210 is connected to the grid circuit of the amplifying tube 205, the plate circuit of which goes to the transformer 211, the secondary of which is connected to the grid circuit of the amplifier tube 206, whose plate circuit is in turn connected to the transformer 212, the secondary of which feeds the grid circuit of the modulator tube 207, which is connected in a Heising transmission circuit including the oscillator tube 208, and the radiating circuit 215. The plate circuit of the oscillator tube 207 has the usual power battery B^{29} and choke coil 213, while the oscillating circuit of the tube 208 includes the resistance coil 214 and the tuning elements of the antenna circuit. Battery B^{25} is the plate battery of the tube 203, battery B^{26} is the filament battery, common to the tubes 203—204, and battery B^{24} taken with the battery B^{25} in series constitutes the plate battery of the oscillator tube 204. B^{27} is the filament battery of the amplifier tubes, B^{23} is the high voltage plate battery of the same, B^{29} is the power battery of the modulator oscillator circuit while battery B^{30} is a grid battery for the oscillator tube 208. B^{28} is the filament battery for the same tube.

This arrangement of Fig. 10 is the same as the ordinary supheterodyne circuit up to the tube 207. According to usual practice this tube would be a second detector and would be followed by one or more stages of audio amplification. In the present case, this tube is a modulator, which takes the beat waves passed through the tuned filter coupler 210, and amplified in the tubes 205—206, and imposes them on the high frequency carrier current generated by the tube 208 and radiated from the antenna 215. This shows another method of taking a single modulated incoming wave and by heterodyning and remodulating, sending out the same audio modulations unchanged on a different carrier wave. The waves radiated from the antenna 215 also require receiving instruments capable of double demodulation.

What I claim is:

1. A radio relay apparatus for relaying singly modulated carrier waves comprising means to receive a modulated carrier wave, means to combine therewith a second wave within the range of beating frequencies to produce a composite double modulated carrier wave of a third frequency bearing the beat frequency modulated with the original signal modulations, and means for amplifying and radiating said third frequency wave.

2. The radio relay apparatus described in claim 1 with a filter coupler following the combining means and tuned to the third frequency.

3. The method of radio relaying which comprises the following steps: receiving a singly modulated carrier wave, then combining a second wave of beating frequency with the same to produce a third or intermediate or mean frequency wave bearing an envelope corresponding to the beat, also bearing thereon the original low frequency signal modulation, then amplifying said intermediate wave with its envelope and modulation and radiating the same at said third or intermediate frequency.

4. The method of relaying radio signals which consists in receiving a singly modulated carrier wave, combining therewith a second wave to produce thereby a doubly modulated carrier consisting of a third frequency intermediate that of said first and second waves and modulated with a carrier having