

Feb. 11, 1930.

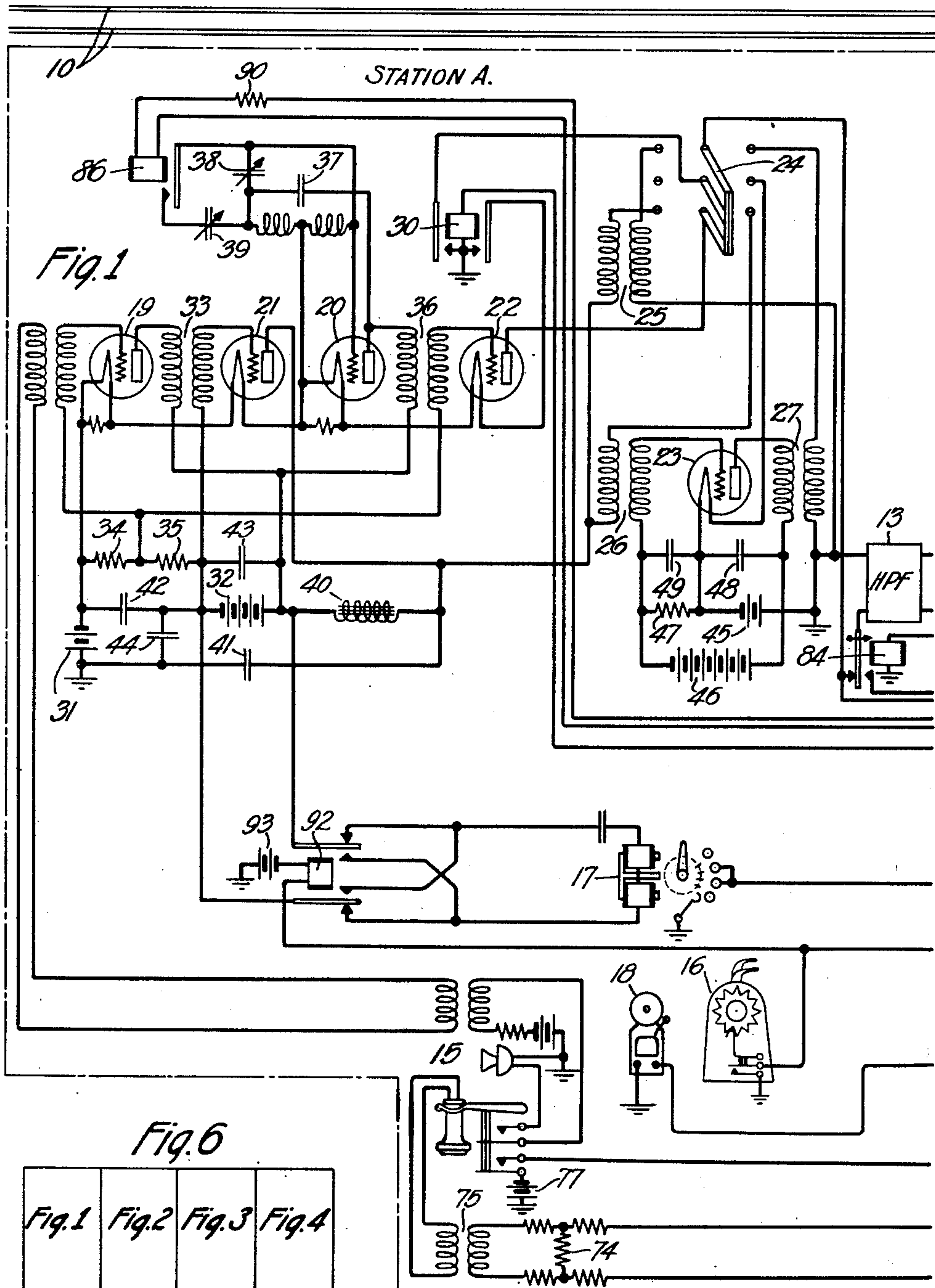
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1,746,808

POWER LINE SIGNALING

Filed Feb. 8, 1927

5 Sheets-Sheet 1



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Feb. 11, 1930.

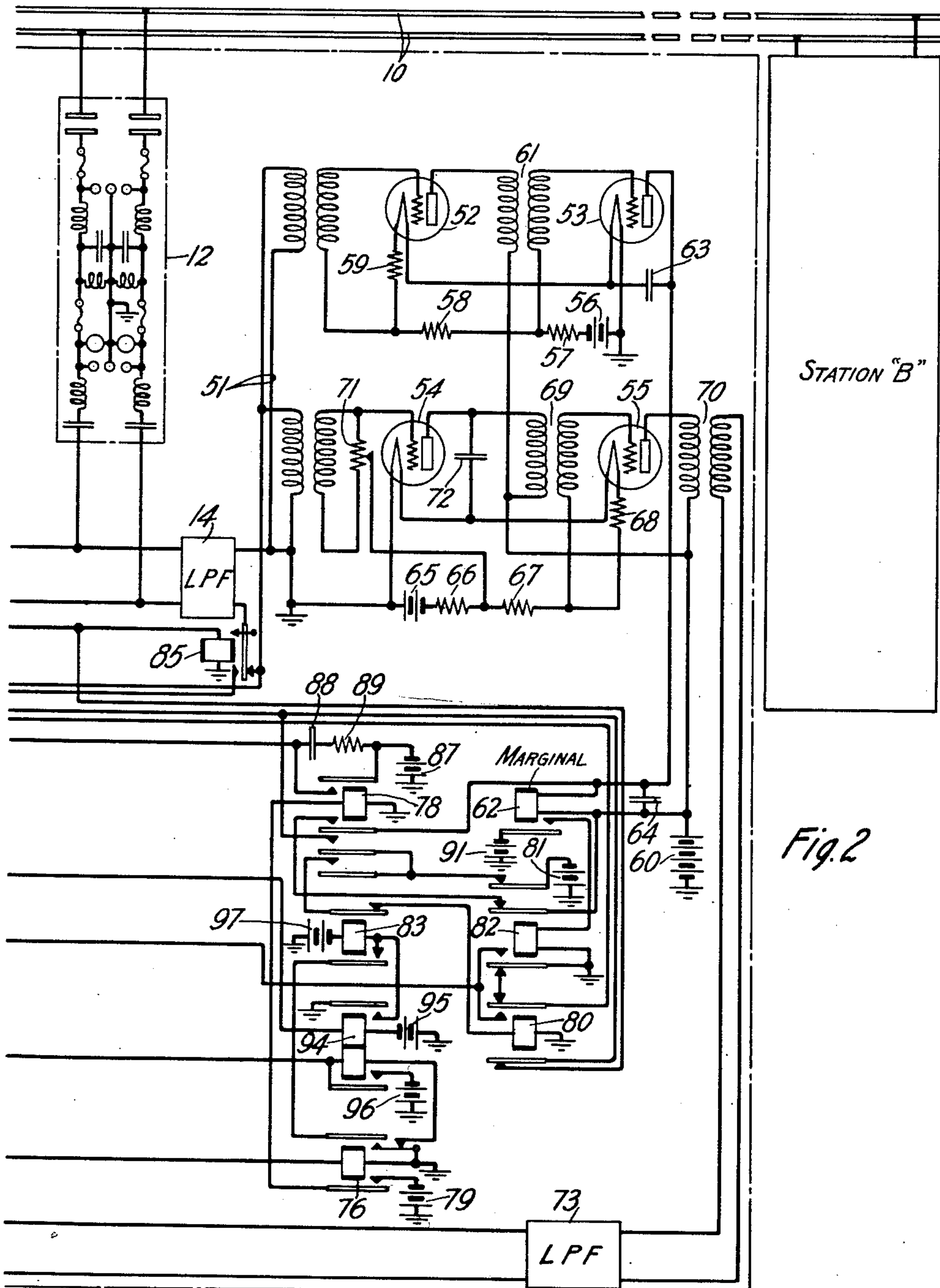
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5 Sheets-Sheet 2



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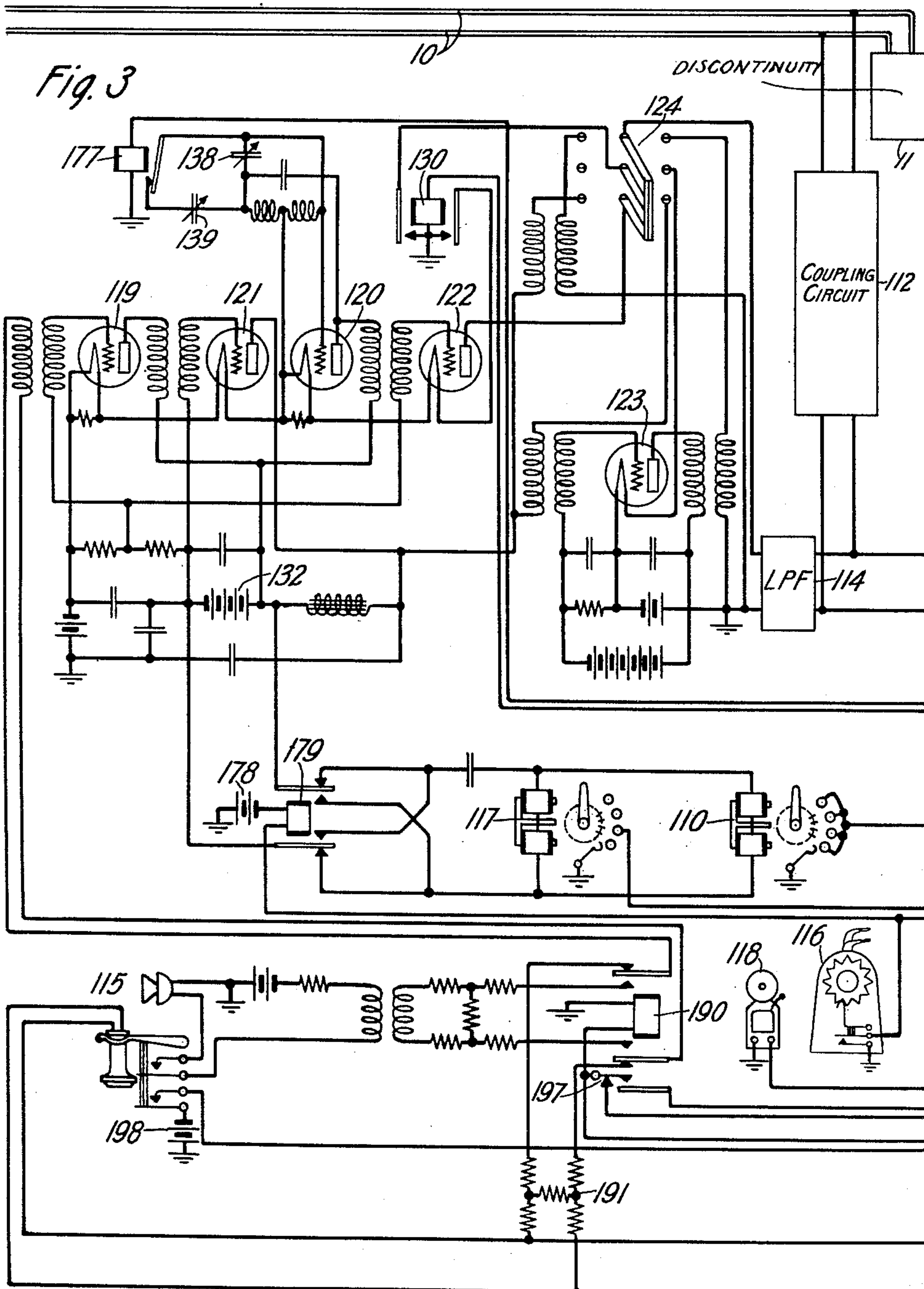
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POWER LINE SIGNALING

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5 Sheets-Sheet 3



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POWER LINE SIGNALING

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5 Sheets-Sheet 4

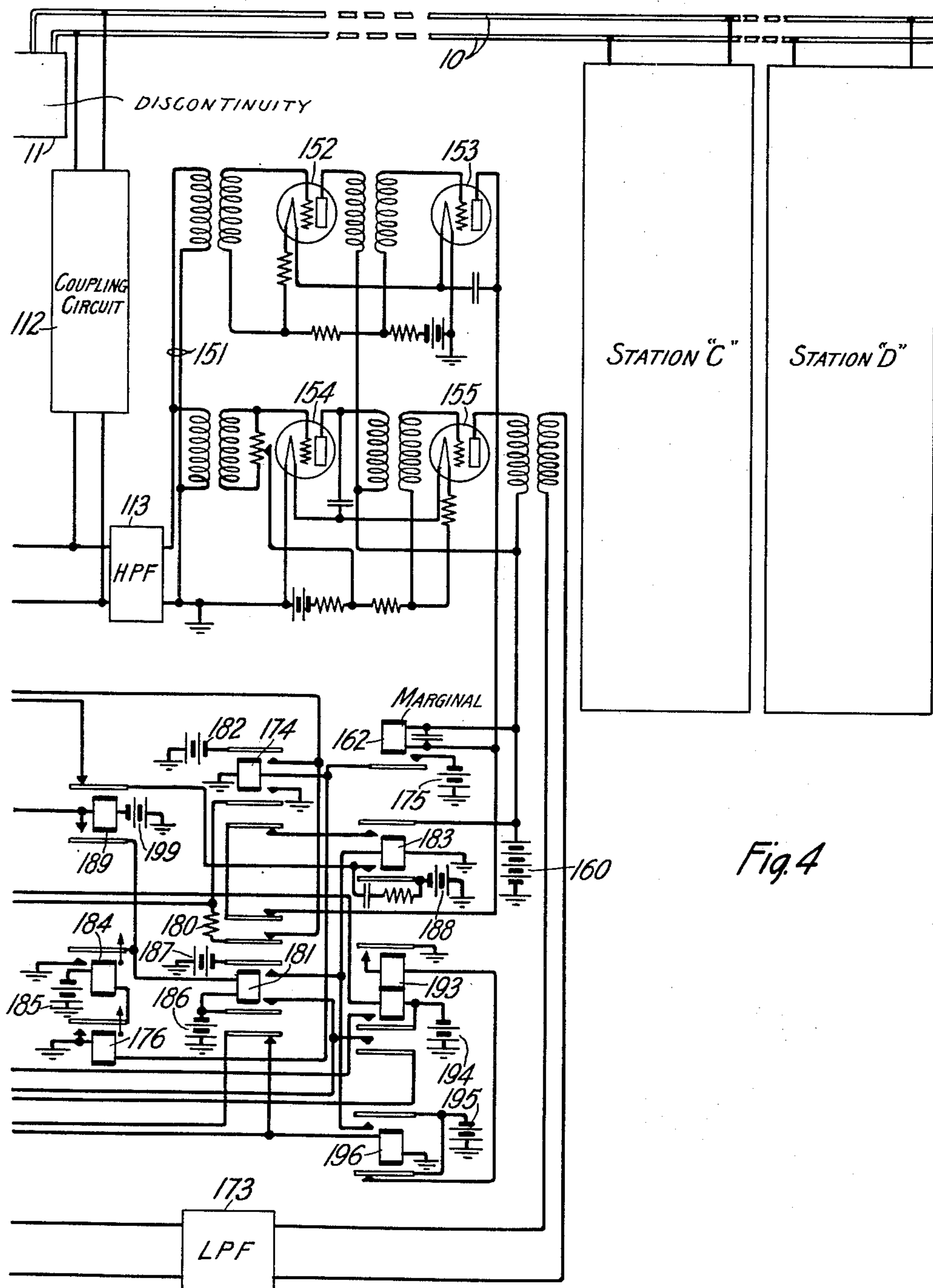


Fig. 4

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POWER LINE SIGNALING

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5 Sheets-Sheet 5

Fig. 5a.

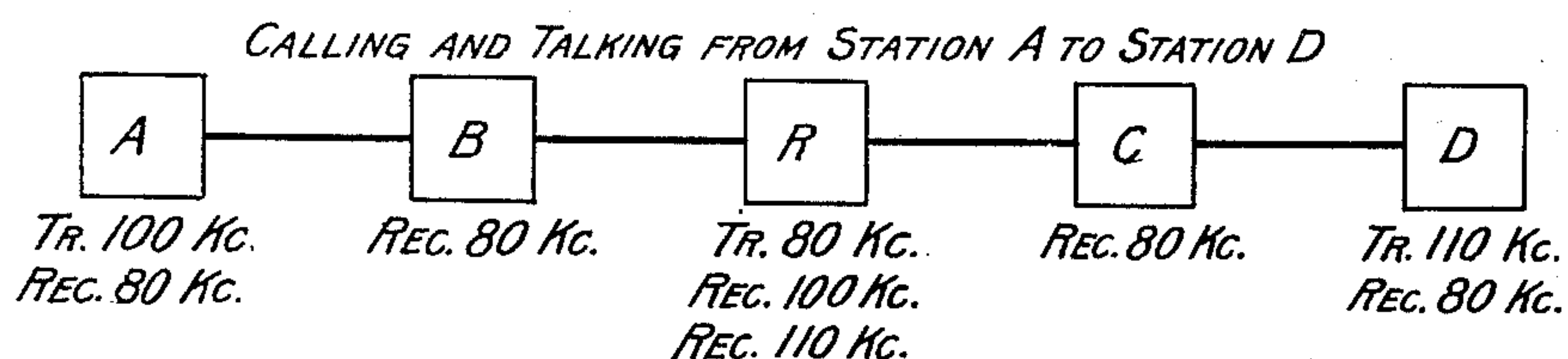


Fig. 5b.

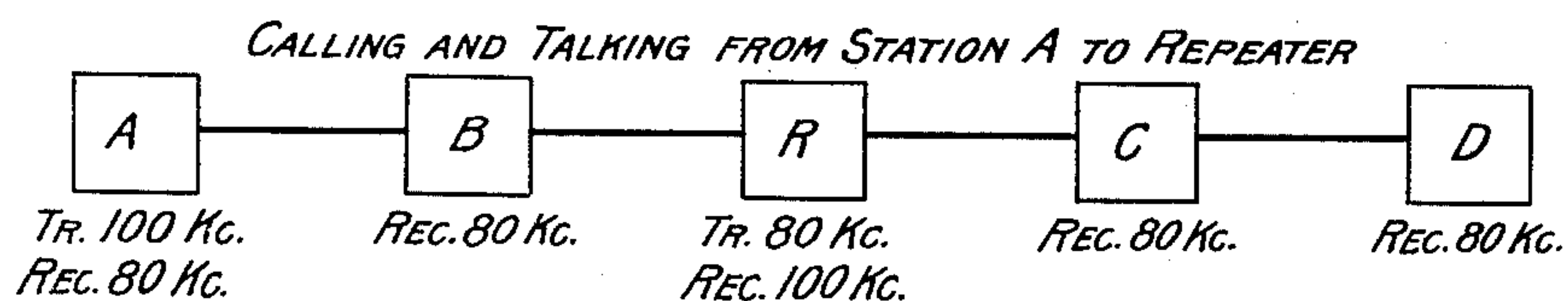


Fig. 5c.

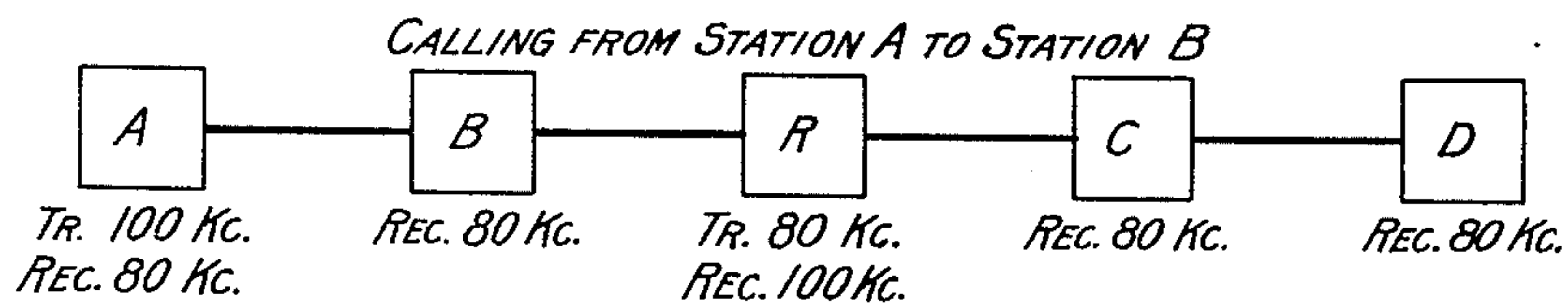
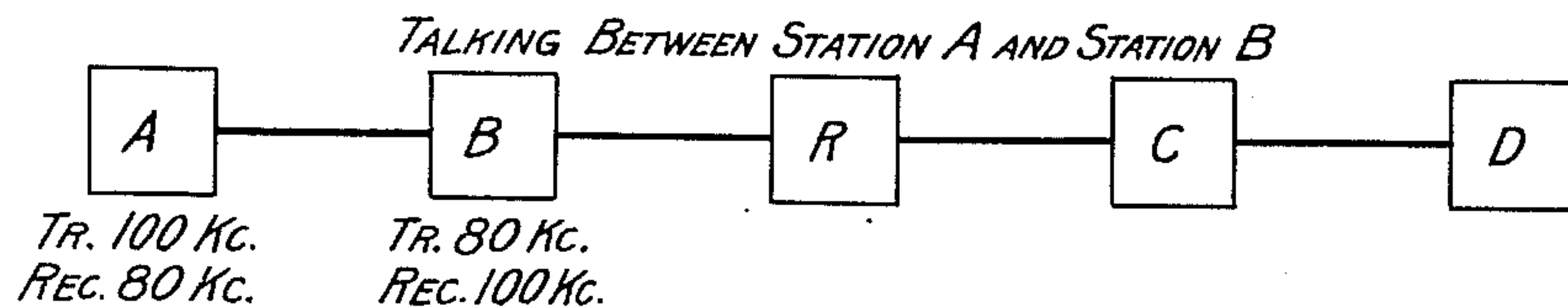


Fig. 5d



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UNITED STATES PATENT OFFICE

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POWER-LINE SIGNALING

Application filed February 8, 1927. Serial No. 166,664.

This invention relates to communication by means of high frequency waves and particularly to communication over power lines by superimposing the high frequency waves upon the power currents traversing the power line.

An object of the invention is to repeat such high frequency waves between a plurality of terminal stations located on both sides of a power transformed or other discontinuity in the power line.

Another object of the invention is to simplify the operation and maintenance of composite power current and carrier wave transmission systems employing repeaters.

The invention provides a power line signaling system including a repeater which is particularly useful for repeating calling signals and telephone conversations past a discontinuity in the power line, such as a voltage transformer or an open power switch. The repeater may also be employed to repeat signals between two or more distant carrier terminals on a continuous line, or to connect the carrier circuits of two separate power lines at a common point.

In my copending application, Serial No. 664,147, filed September 22, 1923, there is disclosed a carrier wave signaling system for telephoning over high voltage power lines with safety to the operators and the signaling apparatus. In that system, any of a plurality of stations connected to the power line may freely call and converse with any other station on the line. Calling is accomplished, for example, by transmitting impulses on the lower of two carrier frequencies, a selector at the called station responding to a predetermined code of impulses. Each station is provided with a high pass and a low pass filter for passing waves of one frequency and suppressing waves of the other frequency. The high pass filter at each station is normally connected to the outgoing channel and the low pass filter is normally connected to the incoming channel. A relay arrangement is employed to interchange the filters with respect to the incoming and outgoing channels whereby the station originating a call trans-

mits on the lower of the two frequencies and receives on the higher frequency.

In a particular embodiment of the present invention, two or more stations are connected to the power line on each side of a repeater. Communication between the stations resolves into three separate situations, namely, communication between stations on the same side of the repeater, communication between any station and the repeater, and communication between stations on opposite sides of the repeater. A feature of the invention resides in utilizing only three different carrier frequencies to effect communication in all of these situations. For example, the stations on one side of the repeater may be arranged to transmit and receive waves of 80 and 100 kilocycles frequency, while the stations on the opposite side of the repeater may be arranged to transmit and receive waves of 80 and 110 kilocycles frequency. The repeater is arranged to receive waves of either 100 or 110 kilocycles frequency and to transmit waves of 80 kilocycles frequency. When communication is effected between two stations on the same side of the repeater the calling station transmits at high frequency and receives at low frequency and the called station transmits at low frequency and receives at high frequency. When communication is effected between a station and the repeater, the station transmits at high frequency and receives at low frequency and the repeater transmits at low frequency and receives at high frequency. When communication is effected between two stations on opposite sides of the repeater the calling station transmits at high frequency and receives at low frequency and the called station transmits at high frequency and receives at low frequency.

The repeater is provided with two selectors, one of which is operated according to a predetermined code of impulses of alternating polarity when any station calls the repeater. The other selector at the repeater is operated whenever one station calls another station located on the same side of the repeater. The operation of the second selector in this manner serves to disconnect the repeater from the talking circuit so that thereafter the call-

ing and called stations on the same side of the repeater may converse directly without using the repeater. In order to operate the second selector at the repeater in a proper case two code signals are assigned to a selector at each station. One code signal is used when a station is called by another station on the same side of the repeater, and the other code signal is used when the same station is called by the repeater or any other station located on the opposite side of the repeater. By means of this arrangement the auxiliary selector at the repeater is selectively operated only when the calling and the called stations are located on the same side of the repeater.

The various features of the invention will be described in detail in connection with the accompanying drawings, in which:

Figs. 1 to 4, inclusive, illustrate diagrammatically a power line signaling system comprising a plurality of stations and a repeater embodying the invention;

Figs. 5^a to 5^d, inclusive, are schematic views illustrating the method of utilizing three different carrier frequencies for effecting communication between the different stations; and

Fig. 6 is a diagram showing the manner in which Figs. 1 to 4 should be organized.

In the system shown in Figs. 1 to 4, inclusive, a plurality of stations and a repeater are arranged for communication over a high voltage transmission line 10. By "high voltage transmission line" is to be understood any system or network of conductors for the electrical transmission of power over which it is possible to transmit high frequency waves.

The repeater, shown in Figs. 3 and 4, serves to repeat calling signals and telephone conversations past a discontinuity in the power line 10, such as a voltage transformer or open power switch 11. Stations A and B are connected to the power line at the left of the repeater, and stations C and D are connected to the power line at the right of the repeater.

Each station is equipped with terminal apparatus similar in arrangement and function to that shown at station A in Figs. 1 and 2. The following description of station A, which is also representative of the other stations, will be followed by a description of the repeater and a consideration of the method of communicating between the several stations.

Station A

The terminal apparatus at station A comprises an outgoing channel and an incoming channel which are connected to the power line 10 by means of a coupling circuit 12. This coupling circuit may be of the type disclosed in my copending application, mentioned above, permitting the transfer of high frequency waves between the terminal ap-

paratus and the power line without danger to the apparatus or the operator.

High pass and low pass filters 13 and 14 are connected to the coupling circuit 12 and are arranged to be included alternatively in either the outgoing channel or the incoming channel by means of apparatus hereinafter described. These filters, and the other filters employed in the system, may be designed in accordance with the principles set forth in U. S. Patent No. 1,227,113 to G. A. Campbell, issued May 22, 1917.

Telephone communication with a distant station is effected by means of an operator's telephone set 15 comprising a receiver which is connected to the incoming channel, and a transmitter which is arranged to be connected to the outgoing channel when the receiver is removed from the switchhook. A selector key 16 controls the transmission of calling signals to the distant stations in a manner hereinafter described. This key may be of any suitable type such as the master impulse transmitting device disclosed in U. S. Patent No. 1,354,814 to J. C. Field, issued October 5, 1920, which may be adjusted to transmit the proper code or combination of impulses for calling any station on the line. A selector 17 associated with the receiving channel responds to either of two different groups of incoming impulses for controlling the operation of a bell or other signalling device 18. One of the two groups of impulses is used by station B when the operator at station B desires to call station A. The other group of impulses is used by the repeater or by stations C and D, which are connected to the power line on the right of the repeater, when the operator at any of these stations desires to call station A. The selector 17 may be of the type disclosed in U. S. Patent No. 1,343,256 to J. C. Field, issued June 15, 1920.

The outgoing channel includes (1) an amplifying tube 19 for amplifying the outgoing speech currents; (2) an oscillator 20 designed to produce waves at two different high frequencies, for example, 80 and 100 kilocycles per second; (3) a constant current modulator including the tube 21 and associated circuits whereby the outgoing high frequency waves are modulated in accordance with speech; (4) an amplifying tube 22 whereby the waves produced by the oscillator 20 are amplified to sufficiently high power for transmission under normal conditions; (5) an auxiliary amplifier 23 and its associated circuit connections which may be connected into circuit to increase the power amplification for transmission under abnormal conditions as, for example, when a section of the line is down; and (6) a switch 24 which when thrown to the left connects the output circuit of amplifier 22 to filter 13 or 14 through transformer 25, and when thrown to the right connects the output circuit of

The incoming channel extends from the power line 10, through the coupling circuit 12, to high pass or low pass filter 13 or 14, and includes, in addition to these elements, (1) a common collecting circuit 51 for receiving unmodulated carrier waves, carrier waves interrupted in accordance with the calling impulses, and the side bands representing the carrier waves modulated in accordance with speech; (2) an amplifier 52 for amplifying the received calling impulses; (3) a rectifier 53 for rectifying the amplified calling impulses; (4) a demodulator 54 for combining the received carrier and side bands to reproduce the speech currents; and (5) an amplifier 55 for amplifying the speech currents.

The amplifying and rectifying tubes 52 and 53 are supplied with filament heating current through a circuit extending from the negative side of battery 56, through resistances 57, 58 and 59, the filaments of the tubes, to the positive side of battery 56. Space current is supplied to the amplifying tube 52 through a circuit extending from grounded battery 60, through the primary winding of transformer 61, the plate, discharge path and grounded filament of tube 52. Space current is supplied to the rectifying tube 53 through a circuit extending from grounded battery 60, through the winding or relay 62, the plate, discharge path and grounded filament of tube 53. The grid of the amplifying tube 52 is made negative with respect to the negative end of its filament due to the drop in potential produced by the filament current in resistance 59. The grid of the rectifying tube 53 is made negative with respect to the negative end of its filament due to the drop in potential produced by the filament current in resistances 58 and 59 and the filament of the amplifying tube 52. The relay 62 is a marginal relay and is not operated by the small current normally flowing in the anode-cathode circuit of the rectifying tube 53 when no calling impulses are received. The characteristics of the tube 53 and its associated circuits are such that the received calling impulses of carrier frequency are rectified and caused to operate the relay 62. The operation of this relay causes the stepping up of the selector 17 as hereinafter more fully described. The condenser 63 by-passes the alternating current in the output circuit of the tube 53. The condenser 64 by-passes alternating currents around the winding of relay 62.

The demodulating and amplifying tubes 54 and 55 are supplied with filament heating current through a circuit extending from the negative side of battery 65, through resistances 66, 67 and 68, the filaments of the tubes, to the positive side of battery 65. Space current is supplied to the tube 54 over a circuit extending from grounded battery 60, through the primary winding of transform-

er 69, the plate, discharge path and grounded filament of tube 54. Space current is supplied to the tube 55 over a circuit extending from grounded battery 60, through the primary winding of transformer 70, the plate, discharge path and grounded filament of tube 55. The grid of the tube 54 is made negative with respect to the negative end of its filament due to the drop in potential produced by the filament current in resistances 67 and 68 and the filament of the tube 55. The grid of the tube 55 is made negative with respect to the negative end of its filament due to the drop in potential produced by the filament current in resistance 68. A gain control potentiometer 71 is included in the input circuit of the demodulator tube 54. A condenser 72 in the output circuit of tube 54 serves to bypass the high frequency carrier waves. The speech frequency waves in the output circuit of the demodulator 54 are amplified by the amplifier 55 and transmitted through transformer 70, low pass filter 73, resistance network 74, and transformer 75 to the receiver of the operator's telephone set 15. The low pass filter 73 is designed to pass waves comprised within the speech frequency range and to suppress waves of other frequencies.

Repeater

The repeater, shown in Figs. 3 and 4, comprises an outgoing channel and an incoming channel which are connected to the power line 10 on both sides of the voltage transformer or open power switch 11 by means of coupling circuits 112. These coupling circuits are similar to the coupling circuit 12 employed at terminal station A. Since the repeater is to receive only waves of 100 and 110 kilocycles frequency and to transmit only waves of 80 kilocycles frequency, the high pass filter 113 is permanently connected to the incoming channel and the low pass filter 114 is permanently connected to the outgoing channel.

Telephone communication with a distant terminal station is effected by means of an operator's telephone set 115 comprising a receiver which is connected to the incoming channel, and a transmitter which is arranged to be connected to the outgoing channel in a manner hereinafter described. A selector key 116 is employed to transmit calling signals when the operator at the repeater desires to communicate with the operator at any station. A selector 117 associated with the receiving channel is operated according to a predetermined code of impulses when any station calls the repeater. This selector controls the operation of the bell or other signaling device 118. An auxiliary selector 110, having its windings connected in parallel with the windings of selector 117, is arranged to close a contact whenever one station calls another station located on the same side of the repeater. The closure of such contact

amplifier 22 to the input circuit of auxiliary amplifier 23 through transformer 26, and connects the output circuit of auxiliary amplifier 23 to filter 13 or 14 through transformer 27.

It will first be assumed that line conditions are normal and that the auxiliary amplifier 23 is not to be used, in which case the switch 24 is closed in the left position. Filament heating current is supplied to the tubes 19, 20, 21 and 22 under the control of a heavy duty relay 30 having a high inductance winding which is adapted to be energized in a manner hereinafter described. The filament heating circuit extends from grounded battery 31, through the filaments of the tubes, right hand armature and contact of relay 30, to ground. Space current is supplied to the tube 19 through a circuit extending from the positive side of battery 32, through the primary winding of transformer 33, the plate, discharge path and filament of tube 19, resistances 34 and 35, to the negative side of battery 32. The current flowing in this circuit produces a drop in potential across the resistance 34 which causes a negative biasing potential to be impressed upon the grid of tube 19. The oscillator tube 20 is supplied with space current through a circuit extending from the positive side of battery 32, through the primary winding of transformer 36, the plate, discharge path and filament of tube 20, filaments of tubes 21 and 19, resistances 34 and 35, to the negative side of battery 32. A blocking condenser 37 prevents the plate potential from being applied to the grid of the oscillator tube 20. A condenser 38 which is permanently connected in the oscillator circuit determines the higher carrier frequency of 100 kilocycles per second, and the addition of condenser 39 in parallel determines the lower carrier frequency of 80 kilocycles per second. The transformer 36 couples the output circuit of oscillator 20 to the amplifier 22 whereby the carrier waves are amplified before being impressed upon the power line.

The carrier waves in the anode-cathode circuit of the amplifying tube 22 are modulated according to the "constant current" method of modulation disclosed in a copending application of R. A. Heising, Serial No. 525,906, filed December 30, 1921. The modulating tube 21 has its plate connected to the plate of the amplifying tube 22 through the primary winding of transformer 25. Space current is supplied to these tubes from the battery 32 through a retard coil 40. The drop in potential across the resistances 34 and 35 due to the current flowing therein causes a negative biasing potential to be impressed upon the grid of the tube 21. The drop in potential across the resistance 34 which is connected between the filament and grid of the amplifying tube 22 causes a negative

biasing potential to be impressed upon the grid of this tube. The retard coil 40 offers a high impedance to the speech and carrier currents and hence there will be no change in current through this coil. Speech variations which are impressed upon the grid of the modulating tube 21, however, produce variations in the impedance of the anode-cathode circuit of this tube. The condenser 41 serves to by-pass the carrier current around the retard coil 40, but offers an impedance such that changes in the impedance of the anode-cathode circuit of the modulating tube 21 produce corresponding changes in the carrier current flowing in the anode-cathode circuit of the amplifying tube 22. As a result of this action the carrier waves flowing in the output circuit of the amplifying tube 22 are modulated in accordance with the speech variations which are impressed upon the grid of the modulating tube 21. Both the upper and lower side bands produced by modulation are impressed upon the power line along with a component of carrier frequency. The condenser 42 serves to by-pass speech frequency currents in the output circuit of tube 19 around resistances 34 and 35. Condenser 43 by-passes alternating currents around the plate battery 32, and condenser 44 by-passes alternating currents around the filament battery 31.

If line conditions are bad owing, for example, to a section of the line being down, the switch 24 is moved from the normal left position to the right position. The plates of the modulating and amplifying tubes 21 and 22 are then connected together through the primary winding of transformer 26 instead of through the primary winding of transformer 25. The production and modulation of the carrier waves, however, is accomplished in the manner described above. Filament heating current is supplied to the auxiliary amplifying tube 23 over a circuit extending from grounded battery 45, through the filament of tube 23, switch 24, left hand armature and contact of relay 30, to ground. Space current is supplied to the tube 23 over a circuit extending from the positive side of battery 46, through the primary winding of transformer 27, the plate, discharge path and filament of tube 23, resistance 47 to the negative side of battery 46. The current flowing in this circuit produces a drop in potential across the resistance 47 which causes a negative biasing potential to be impressed upon the grid of the tube 23. The condensers 48 and 49 serve to by-pass alternating currents around battery 46 and resistance 47, respectively. When the auxiliary amplifier 23 is connected in circuit, the amplified carrier and side band waves are transmitted through transformer 27, filter 13 or 14, as the case may be, and coupling circuit 12 to the power line 10.

serves to disconnect the repeater from the talking circuit, as hereinafter described, so that thereafter the calling and called stations on the same side of the repeater may converse directly without using the repeater. The selector 110 is therefore provided with four contacts, one for each station in the system, each of these contacts corresponding in its code setting to one of the selector contacts at a station. As pointed out above, one group of impulses is used when any station is being called by another station on the same side of the repeater, and another group of impulses is used when the same station is being called by the repeater or any other station located on the opposite side of the repeater. Station B, in calling station A, for example, transmits a predetermined group of impulses which not only cause the selector 17 at station A to close one of its contacts, but also cause the selector 110 at the repeater to close its corresponding contact, whereby the repeater is subsequently disconnected from the talking circuit. Either of stations C or D, in calling station A, however, transmits a different group of impulses which cause the selector 17 at station A to close its second contact but do not cause the selector 110 at the repeater to close a contact, and hence the repeater remains in service to repeat the two-way conversation between station A and station C or D, as the case may be. It will thus be seen that the selector 110 at the repeater is selectively operated only when the calling and the called stations are located on the same side of the repeater.

The outgoing and incoming channels at the repeater are similar to the corresponding channels at station A and, therefore, will not be described in detail except so far as it is considered necessary to understand the operation of the system. The outgoing channel includes a speech frequency amplifier 119, an oscillator 120, a modulator 121, an amplifier 122, and an auxiliary amplifier 123 which may be connected to or disconnected from the circuit by means of switch 124. The condensers 138 and 139, which are normally connected in parallel in the oscillator circuit, determine the carrier frequency of 80 kilocycles per second assigned to the outgoing channel. The intermittent disconnection of condenser 139 from the circuit in accordance with groups of impulses permits corresponding groups of impulses of 80 kilocycles frequency to be transmitted through the low pass filter 114 to the line.

The incoming channel includes an amplifier 152 for amplifying the received calling impulses, a rectifier 153 for rectifying these impulses, a demodulator 154 for demodulating the received speech modulated carrier waves, and an amplifier 155 for amplifying the speech currents. It will be noted that space current from the source 160 is supplied

to the rectifier tube 153 through the winding of relay 162. This relay is marginal, like the relay 62 at station A, and is operated only in response to the rectified current flowing in the anode-cathode circuit of the rectifier tube 153.

Calling and talking through repeater

In describing the operation of the system the method of calling and talking through the repeater from station A to station D will first be considered. The arrangement of the carrier frequencies transmitted and received by the different stations in this situation is illustrated in Fig. 5^a.

The operator at station A, in initiating a call to station D, removes his receiver from the switchhook, thereby operating relay 76 over a circuit extending from grounded battery 77, through the lower contact of the switchhook, winding of relay 76, to ground. Relay 78 is thereupon energized over a circuit extending from grounded battery 79, through the lower contact and armature of relay 76, winding of relay 78, to ground. The operation of relay 78 establishes an energizing circuit for relay 80, which may be traced from grounded battery 81, through the uppermost armature and contact of relay 82, lowermost armature and contact of relay 78, upper armature and contact of relay 83, winding of relay 80, to ground. Relay 80, in operating, opens its lower contact, thereby preventing relays 84 and 85 from being energized through the lower middle contact and armature of relay 78. The relays 84 and 85 control the connections of the high pass filter 13 and the low pass filter 14, and by maintaining these relays deenergized, the high pass filter 13 remains connected to the outgoing channel and the low pass filter 14 remains connected to the incoming channel, as shown in the drawing. The relay 80, in operating, also closes its upper contact, thereby preparing a circuit to be closed through the relay 86 and the transmitting key 16 when the transmitting key 16 is subsequently operated. The relay 78, in operating, also short-circuits the relay 62 through the first lower armature and contact of relay 78 and the second upper contact and armature of relay 82, preventing the subsequent operation of relay 62. The operation of relay 78 also causes the operation of relay 30 over a circuit which extends from grounded battery 87, through the uppermost armature and contact of relay 78, winding of relay 30, to ground. The condenser 88 and resistance 89 serve to protect the upper contact of relay 78 against sparking due to the high inductance of the winding of relay 30. The energization of relay 30 causes filament heating current to be supplied to all the space discharge tubes in the outgoing channel, including the auxiliary amplifying tube 23 if this tube is in service. The fila-

ment circuits were traced above in the description of the terminal apparatus. Carrier waves of 100 kilocycles frequency, generated by the oscillator 20, are transmitted through the high pass filter 13 and coupling circuit 12 to the power line 10.

The repeater, as pointed out above, is arranged to receive carrier waves of either 100 or 110 kilocycles frequency, and to transmit carrier waves of 80 kilocycles frequency. Accordingly, the carrier waves of 100 kilocycles frequency transmitted from station A pass through the left hand coupling circuit 112 at the repeater, and are selectively passed by the high pass filter 113 to the common collecting circuit 151. Carrier waves of this frequency, however, will not pass into the receiving channel at station B which, like the receiving channel at station A, is normally arranged to receive only waves of 80 kilocycles frequency. The carrier waves received in the circuit 151 at the repeater are amplified by the amplifier 152 and rectified by the rectifier 153, the rectified waves causing the operation of relay 162. The operation of relay 162 causes the operation of relay 174 over a circuit extending from grounded battery 175, through the contact and armature of relay 162, winding of relay 174, to ground. Slow releasing relay 176 is also operated over a circuit extending from grounded battery 175, through the contact and armature of relay 162, winding of relay 176, to ground. The relay 177 which controls the connection of the condenser 139 to the circuit of the oscillator 120 is normally energized over a circuit extending from grounded battery 178, through the winding of pole changing relay 179, resistance 180, upper middle armature and contact of relay 181, winding of relay 177, to ground, the current flowing in this circuit, however, being insufficient to operate the relay 179. The operation of relay 174 completes another energizing circuit for the relay 177, which extends from grounded battery 182, through the uppermost armature and contact of relay 174, winding of relay 177, to ground. The operation of relay 174 also causes the operation of relay 179 over a circuit extending from grounded battery 178, through the winding of relay 179, middle armature and contact of relay 174, to ground.

The operation of relay 179 causes an impulse of current from the source 132 to be supplied to the electromagnets of selectors 110 and 117. The selectors will thereupon advance one step but will immediately fall back to the starting position. If either of these selectors happens accidentally to be held in an advanced position before the call is initiated, this single pulse will cause it to advance another step to a position from which it will promptly fall back to the normal starting position before the operator at station A actuates his calling key 16. The relay 174

in attracting its lowermost armature opens a shunt path around the relay 162 which would otherwise be closed upon the operation of relay 183, and would extend from grounded battery 160, through the upper armature and contact of relay 183, lowermost contact and armature of relay 174, and uppermost armature and contact of relay 181. The opening of this shunt path allows the relay 162 to remain in the anode-cathode circuit of the rectifier tube 153, responsive to impulses subsequently received from the power line.

The relay 176, in operating, completes an energizing circuit for slow releasing relay 184, which extends from grounded battery 185, through the winding of relay 184, armature and contact of relay 176, to ground. The operation of slow releasing relay 184 causes the energization of relay 181 over a circuit extending from grounded battery 186, through the winding of relay 181, armature and contact of relay 184, to ground. The relay 181 in opening its uppermost contact opens the shunt path around the relay 162 which was traced above. By opening its second upper contact the relay 181 opens the energizing circuit of relay 177 which extends through resistance 180, the relay 177, however, remaining energized over the circuit previously traced from grounded battery 182 through the uppermost armature of relay 174. The relay 181 also closes its third upper contact, establishing an energizing circuit for relay 183, which extends from grounded battery 187, through the third upper armature and contact of relay 181, winding of relay 183, to ground. At its lowermost contact the relay 181 opens a circuit through the relay 190 so that this relay will remain deenergized even if the operator at the repeater removes his receiver from the switchhook. The operation of relay 183 establishes an energizing circuit for relay 130, which may be traced from grounded battery 188, through the lower armature and contact of relay 183, upper armature and contact of relay 189, winding of relay 130, to ground. The operation of relay 130 causes filament heating current to be supplied to all the space discharge tubes in the outgoing channel, including the auxiliary amplifying tube 123 if this tube is in service. Carrier waves of 80 kilocycles frequency generated by the oscillator 120 are thereupon transmitted through low pass filter 114 and coupling circuits 112 to both sections of the power line 10. These carrier waves of 80 kilocycles frequency are received by all the stations, and are rectified at stations B, C and D and caused to operate the relay thereat which corresponds to relay 62 at station A. The relay 62 at station A, however, does not operate since it is short-circuited as described above. The operation of such relay at stations B, C and D, however,

causes the selector at each of these stations to advance one step from which advanced position it will fall back to the starting position.

5 The sequence of operations described above took place when the operator at station A removed his receiver from the switchhook. The operator at station A now actuates the selector key 16 which is set to transmit the
10 proper combination of impulses for calling station D. The operation of selector key 16 causes the relay 86 to operate each time a tooth of the selector key closes the key contact. The energizing circuit of the relay 86
15 may be traced from ground, through the closed contact of selector key 16, upper contact and armature of relay 80, winding of relay 86, resistance 90, second lower contact and armature of relay 78, uppermost contact
20 and armature of relay 82, to grounded battery 81. The alternate energization and deenergization of relay 86 in response to these impulses causes the condenser 39 to be placed alternately into and out of the oscillator circuit. During the operation of the selector
25 key, the frequency generated by the oscillator 20 is thus changed back and forth from the high carrier frequency of 100 kilocycles per second to the low carrier frequency of
30 80 kilocycles per second, and vice versa. However, the low carrier frequency is not transmitted to the power line inasmuch as the high pass filter 13, which is connected between the outgoing channel and the power
35 line, is designed to pass only the high carrier frequency and to suppress the low carrier frequency. The groups of impulses of the high carrier frequency of 100 kilocycles per second are thus transmitted to and impressed
40 upon the power line. The operation of the selector key 16 also completes an energizing circuit for the pole changing relay 92, from grounded battery 93, through the winding of relay 92, closed contact of selector key 16, to
45 ground. The energization of relay 92 causes an impulse of current from the battery 32 to be supplied to the electromagnet of selector 17 which causes the selector to advance one step. When the contact of the selector
50 key is opened the relay 92 releases, which causes an impulse of current of opposite sign through the electromagnet of selector 17. The operation of relay 92 and the selector 17 at this time performs no useful function, but
55 is usually provided for in systems of this general type so that relay 92 may also be used to relay calling impulses to a sub-station, not shown in the drawing, if this feature should be found desirable.

60 The high frequency impulses which are transmitted over the power line pass through the left hand coupling circuit 112 at the repeater, and thence through high pass filter 113 to the common collecting circuit 151, amplifier 152 and rectifier 153. The rectified

impulses in the output circuit of the rectifier 153 cause the alternate deenergization and energization of relay 162, thus alternately opening and closing the energizing circuit of relay 174 which, in turn, causes the relay
70 177 to release and operate, alternately placing the condenser 139 out of and into the circuit of oscillator 120. As a result of this action groups of impulses of 80 kilocycles frequency, corresponding in number and arrangement to
75 the impulses transmitted from station A, are transmitted through low pass filter 114, coupling circuit 112, to both sections of the power line. The relay 174, in opening and closing its first lower contact, alternately opens and
80 closes the energizing circuit of relay 178, thereby causing selectors 110 and 117 to advance step by step. The relays 176 and 184 at the repeater are made slow releasing in order to maintain the relay 181 energized
85 during the calling operation, thus maintaining the closure of the filament circuit of the tubes in the outgoing channel. The relay 190, being unoperated, maintains the closure between the incoming and outgoing repeater
90 channels through which the speech currents are to be transmitted.

The calling impulses of 80 kilocycles frequency which are relayed from the repeater cause the selectors at stations B, C and D to
95 step up, but only the selector at station D closes the proper contact. The selectors at the repeater and the other stations fall back to the starting position. The operation at station D may be followed by referring to the
100 corresponding apparatus at station A, shown in Figs. 1 and 2. The alternate energization and deenergization of relay 62 at station D in response to the received impulses causes the alternate energization and deenergiza-
105 tion of relay 82, the circuit of relay 82 extending from grounded battery 91, through the armature and contact of relay 62, winding of relay 82 to ground. The intermittent operation of relay 82 by relay 62 causes the
110 intermittent operation of the pole changing relay 92 over a circuit extending from grounded battery 93, through the winding of relay 92, lowermost front contact and armature of relay 82 to ground, until the selector
115 17 closes its contact which corresponds to the transmitted code of impulses. Relay 82 in attracting its uppermost armature opens an energizing circuit of relay 80, and in attracting its second upper armature opens the
120 shunt path around the relay 62. When the selector 17 at station D stops at the proper contact, the relay 94 is energized over a circuit extending from grounded battery 95, through the upper winding of relay 94, closed
125 contact of selector 17, to ground. Relay 94 is thereupon locked up through a circuit extending from grounded battery 96, through the lower contact, armature and winding of relay 94, closed contact of relay 76, to ground.
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It will be noted that the contact of selector key 16 at the calling station A is opened at the conclusion of the dialing, that is, this contact is opened after the last tooth has passed the contact arm of the selector key, and as a result carrier waves of 100 kilocycles frequency continue to flow from the outgoing channel at station A to the power line.⁵ Carrier waves of 80 kilocycles frequency are therefore impressed upon the power line from the outgoing channel at the repeater at the conclusion of the dialing operation. The carrier waves of 80 kilocycles frequency which are thus received at station D maintain the relays 62 and 82 energized during the subsequent communication between stations A and D. The final operation of relay 82 causes an additional impulse through the pole changing relay 92 which causes the selector 17 to advance another step from which advanced position it falls back to the starting position.

The bell 18 at station D is energized over a circuit extending from grounded battery 96, through the lower contact and armature of relay 94, electromagnet of bell 18, to ground. Relay 83 is also energized over a circuit extending from grounded battery 97, through the winding of relay 83, upper contact and armature of relay 94, to ground. The relay 83 in attracting its upper armature opens the energizing circuit of relay 80 so that this relay cannot be operated at this time. However, even though relay 80 is de-energized in this manner, the relays 84 and 85 which control the connections of the filters 13 and 14 will not be operated because their energizing circuits are now open at the uppermost contact of relay 82. When the operator at station D responds to the call by lifting his receiver from the switchhook, the relay 76 is operated over a circuit extending from grounded battery 77, through the lower contact of the switchhook, winding of relay 76, to ground. Relay 76 establishes an energizing circuit for relay 78 which extends from grounded battery 79, through the lower contact and armature of relay 76, winding of relay 78, to ground. The operation of relay 78 causes the operation of relay 30 which lights the filaments of the space discharge tubes in the outgoing channel at station D, causing carrier waves of 110 kilocycles frequency to be impressed upon the power line. Relay 76 in attracting its upper armature completes a second energizing circuit for relay 83 from grounded battery 97, through the winding, contact and lower armature of relay 83, upper armature and contact of relay 76 to ground. The locking circuit of relay 94 is thereupon broken at the upper break contact of relay 76, thus breaking the energizing circuit of the bell 18.

As pointed out above, the circuits at station D are now arranged to transmit carrier waves

of 110 kilocycles frequency and to receive carrier waves of 80 kilocycles frequency. Speech modulated carrier waves of 100 kilocycles frequency impressed upon the power line at station A pass through the left hand coupling circuit 112 at the repeater, and thence through high pass filter 113 to the common collecting circuit 151. These waves are combined in the demodulator 154 with the unmodulated carrier component which is also transmitted over the line. The low frequency components of demodulation appearing in the output of the demodulator 154 are amplified by the amplifier 155 and transmitted through low pass filter 173, resistance network 191, back contacts and armatures of relay 190, to the input circuit of speech frequency amplifier 119. The speech currents which are thus supplied to the outgoing repeater channel are caused to modulate the carrier waves of 80 kilocycles frequency produced by the oscillator 120, and the modulated carrier waves are transmitted over the power line to station D. A portion of the waves received at the repeater is rectified to maintain relay 162 energized. Similarly, the speech modulated carrier waves of 110 kilocycles frequency impressed upon the power line at station D are transmitted to the repeater where they are converted into speech modulated carrier waves of 80 kilocycles frequency which are transmitted to station A. At station A these waves are demodulated in the demodulator 54 and the low frequency components of demodulation, after being amplified by amplifier 55, pass through low pass filter 73, resistance network 74 and transformer 75 to the receiver of the operator's telephone set 15. Upon the completion of the conversation, the operators at stations A and D will replace their receivers upon the switchhooks, causing the system to return to the normal condition shown in the drawings. On a call through the repeater, such as that described above, the receiver associated with the operator's telephone set 115 is connected to the talking circuit so that the operator at the repeater may determine when the line is busy. If, however, the operator at the repeater should dial under this condition, the dialing will be ineffective, since the circuit extending from the selector key 116 to the relay 177 is open at the second upper armature and contact of relay 181.

Calling and talking to repeater

When the operator at station A desires to call and converse with the repeater, he proceeds in the manner employed in calling station D except that the selector key 16 must first be adjusted to transmit the particular code of impulses which will cause the selector 117 at the repeater to close its associated contact. When such a call has been initiated at station A, the operation of the apparatus at

station A and the repeater is the same as that previously described up to the stepping up of the selectors in response to the calling impulses. Only the selector 117 at the repeater stops on the proper contact, the selector 110 and the selectors at the several stations falling back to the starting position. The operation of selector 117 causes the energization of relay 193 over a circuit extending from grounded battery 194, through the lower winding of relay 193, closed contact of selector 117, to ground. A holding circuit for relay 193 is established from grounded battery 195, through the lower armature and contact of relay 196, upper winding and uppermost contact and armature of relay 193, to ground. An energizing circuit for the bell 118 is established from grounded battery 194, through the first lower armature and contact of relay 193, electromagnet of bell 118, to ground. The carrier waves received from the power line at the conclusion of the calling impulses cause the selector 117 to advance a final step from which advanced position it falls back to the starting point. The relay 190 is energized over a circuit extending from grounded battery 186, through the first lower armature and contact of relay 181, which was energized in the manner previously described, lowermost contact and armature of relay 193, contact 197 of relay 190, winding of relay 190, to ground. The energizing circuit of relay 190 is thereupon established from grounded battery 186, through the first lower armature and contact of relay 181, lowermost armature and contact of relay 190, winding of relay 190, to ground, so that relay 190 will remain energized even though relay 193 becomes deenergized when the operator removes his receiver from the switchhook. The operation of relay 190 opens the connection between the incoming and outgoing channels of the repeater and connects the local transmitting circuit of the operator's telephone set 115 to the input circuit of the speech frequency amplifier 119. When the operator removes the receiver from the switchhook, the local circuit of the operator's transmitter is closed, and the relay 196 is energized over a circuit extending from grounded battery 198, through the lower contact of the switchhook, winding of relay 196, to ground. Relay 196 in opening its lower contact breaks the holding circuit of relay 193, thereby deenergizing the bell 118. A second energizing circuit is established for the relay 183 from grounded battery 195, through the upper armature and contact of relay 196, winding of relay 183 to ground, which, however, performs no useful function at this time since the relay 183 is already energized over a circuit previously traced through the third upper armature and contact of relay 181. The circuit from grounded battery 195 through relay 183, however, is the circuit which is established for

operating the relay 183 to energize the filaments of the space discharge tubes in the outgoing channel when a call is initiated at the repeater. The operators at station A and the repeater may now converse, station A transmitting at 100 kilocycles and receiving at 80 kilocycles, and the repeater transmitting at 80 kilocycles and receiving at 100 kilocycles, as indicated in Fig. 5^b.

Calling and talking to station on same side of repeater

When the operator at station A desires to call and converse with station B, he proceeds in the manner employed in calling either station D or the repeater, except that the selector key 16 must first be adjusted to transmit the particular code of impulses which will cause the selector 17 at station B to close its associated contact. When such a call has been initiated at station A, the operation of the apparatus at station A and the repeater is the same as that previously described up to the stepping up of the selectors in response to the calling impulses. The combination of impulses transmitted in this case, however, not only causes the selector at station B to close its associated contact, but also causes the selector 110 at the repeater to close one of its four contacts. This is due to the fact that, as pointed out above, one of the contacts of selector 110 corresponds to the code employed by the operator at station A to call station B.

The operation of the apparatus at station B is the same as that previously described in connection with station D up to the completion of the dialing. In other words, the calling impulses relayed to station B by the repeater, cause the operation of relays 62, 82 and 92. When the selector 17 at station B closes the proper contact, the relay 94 is operated in the manner described above, thereby energizing the bell 18, and also operating relay 83. Although the selector 17 at station B falls back to its starting position the bell 18 continues to ring until the operator at station B removes his receiver from the switchhook, since relay 94 is locked up in the manner previously described. When the operator at station B removes his receiver from the switchhook, the relay 76 is energized, thereby energizing relay 78 over the circuit previously traced from grounded battery 79, through the lower contact and armature of relay 76, winding of relay 78, to ground. The operation of relay 78 causes the energization of relay 30 which lights the filaments of the space discharge tubes in the outgoing channel. During the transmission of the calling impulses station A, which originates the call, transmits at 100 kilocycles and the repeater receives at 100 kilocycles and transmits at 80 kilocycles, while all of the other stations re-

ceive the interrupted 80 kilocycle waves, as illustrated in Fig. 5^a.

When the selector 110 at the repeater closes its associated contact corresponding to the code setting of the selector 17 at station B, relay 189 is operated over a circuit extending from grounded battery 199, through the winding of relay 189, closed contact of selector 110, to ground. Although the selector 110 falls back to the starting position, the relay 189 remains energized over a holding circuit extending from grounded battery 199, through the winding, lower contact and armature of relay 189, upper armature and contact of relay 184, to ground. The relay 189, in attracting its upper armature, opens the energizing circuit of relay 130, thereby disconnecting battery from the filaments of the space discharge tubes in the outgoing channel at the repeater. The carrier waves of 80 kilocycles frequently thereupon cease to flow to the power line from the repeater, and hence relay 62 at station B is deenergized. When relay 62 at station B releases its armature the relay 82 is deenergized. The filter controlling relays 84 and 85 are thereupon energized over a circuit extending from grounded battery 81, through the uppermost armature and contact of relay 82, second lower armature and contact of relay 78, lower armature and contact of relay 80, windings of relays 84 and 85 in parallel, to ground. The operation of relay 84 serves to disconnect the high pass filter 13 from the outgoing channel and connect it to the incoming channel, and the operation of relay 85 serves to disconnect the low pass filter 14 from the incoming channel and connect it to the outgoing channel. The relay 86 at station B is now energized over a circuit extending from grounded battery 81, through the uppermost armature and contact of relay 82, second lower contact of relay 78, resistance 90, winding of relay 86, upper armature and back contact of relay 80, lower back contact and armature of relay 82, to ground. Since relay 86 is energized the condenser 39 is connected in the circuit of the oscillator 20, and hence carrier waves of 80 kilocycles frequency are transmitted through low pass filter 14 and coupling circuit 12 to the power line 10. The speech modulated carrier waves of 100 kilocycles frequency which are impressed upon the power line at station A pass through the coupling circuit 12 at station B and are selectively passed by the high pass filter 13 to the common collecting circuit 51, and are then demodulated in the demodulator 54. The low frequency components of demodulation appearing in the output circuit of the demodulator 54 are amplified by the amplifier 55 and passed through transformer 70, low pass filter 73, resistance network 74 and transformer 75 to the receiver of the operator's telephone set 15. Although a portion of the carrier

waves received at station B are rectified by the rectifier 53, the relay 62 will not operate since the winding of this relay is short-circuited through the first lower armature and contact of relay 78 and the second upper contact and armature of relay 82. The operators at stations A and B may thus converse directly without using the repeater, station A transmitting at 100 kilocycles, and receiving at 80 kilocycles, and station B transmitting at 80 kilocycles and receiving at 100 kilocycles, as indicated in Fig. 5^a.

The invention is capable of other modifications and adaptations not specifically described but included within the scope of the appended claims.

What is claimed is:

1. A transmission system comprising two line sections adapted for the simultaneous transmission of power currents and signaling waves, and means for repeating said signaling waves with a change in the frequency thereof between said line sections.
2. A transmission system comprising two line sections adapted for the simultaneous transmission of power currents and signaling waves, and a common path for repeating said signaling waves with a change in a characteristic thereof in both directions between said line sections.
3. A transmission system comprising a power line including a signaling channel for superimposing signaling waves upon the power currents, means in said power line forming a break in said signaling channel, and a path including an amplifier for repeating said waves with a change in the frequency thereof around the break in said signaling channel.
4. A transmission system comprising a power line including a signaling channel for superimposing signaling waves upon the power currents, means in said power line forming a break in said signaling channel, and a unilateral repeating path for repeating said signaling waves around the break in the signaling channel with a change in the frequency thereof.
5. A transmission system comprising a signaling station, a repeating station, a line connecting said stations, and a second signaling station on said line between said two first mentioned stations and means at said repeating stations for repeating signals transmitted from one of said signaling stations back over the line to the other with a change in a characteristic thereof.
6. A transmission system comprising two line sections adapted for the simultaneous transmission of power currents and signaling waves, a plurality of stations associated with at least one of said sections, and means between said line sections for repeating signaling waves with a change in the frequency thereof from one station to another.

7. A transmission system comprising two line sections adapted for the simultaneous transmission of power currents and signals, and means comprising a repeater station connecting said line sections and responsive to signals transmitted over one line section to repeat said signals at a different frequency to the same line section.

8. A transmission system comprising two line sections adapted for the simultaneous transmission of power currents and signaling waves, and means responsive to signaling waves transmitted over either line section to repeat said waves to both line sections.

9. A transmission system comprising two line sections adapted for the simultaneous transmission of power currents and signaling waves, a discontinuity with respect to signaling waves between said line sections, and means responsive to signaling waves transmitted over one line section for impressing signaling waves of different frequency around said discontinuity upon the other line section.

10. A transmission system comprising two line sections over which signaling waves are transmitted, a discontinuity with respect to signaling waves between said line sections, and means responsive to signaling waves transmitted over either line section for impressing signaling waves of different frequency upon both of said line sections.

11. A transmission system comprising two line sections adapted for the transmission of carrier waves modulated in accordance with signals, and means associated with said line sections for repeating said signals to both line sections as modulations of carrier waves of another frequency.

12. A transmission system comprising two line sections, stations connected to each line section, a repeater connecting said line sections, a calling system including a selector at each station responsive to properly arranged groups of impulses of alternating polarity, means at one or more stations for transmitting groups of carrier frequency waves from which said impulses may be derived, and means at said repeater for converting said groups of waves into corresponding waves of different frequency.

13. A transmission system comprising two line sections over which low frequency power waves and high frequency signaling waves are transmitted, stations connected to said line sections, a discontinuity with respect to signaling waves between said line sections, a repeater for repeating signaling waves between said line sections, means at said stations for transmitting and receiving selective calling signals, and means comprising a selector at said repeater responsive to certain of said calling signals to render said repeater inoperative.

14. A transmission system comprising two

line sections over which low frequency power waves and high frequency signaling waves are transmitted, a discontinuity with respect to signaling waves between said line sections, stations connected to said line sections, a repeater including a channel for repeating signaling waves only in both directions between said line sections, means at said stations for transmitting and receiving selective calling signals, and means comprising a selector at said repeater responsive to certain of said calling signals to disable said repeater channel.

15. A transmission system comprising two line sections over which low frequency power waves and high frequency signaling waves are transmitted, a discontinuity with respect to signaling waves between said line sections, stations connected to said line sections, a repeater including a channel for repeating signaling waves between said line sections, means at said stations for transmitting and receiving selective calling signals, and means comprising a selector at the repeater station for disabling said repeater channel in response to calling signals originated at a station connected to the same line section as the called station.

16. A transmission system comprising two line sections over which low frequency power waves and high frequency signaling waves are transmitted, a discontinuity with respect to signaling waves between said line sections, stations connected to said line sections, a repeater including a channel for repeating signaling waves between said line sections, a calling system including a selector at each station responsive to properly arranged groups of impulses of alternating polarity, and means comprising a selector at said repeater responsive to a group of impulses, also actuating certain of said station selectors, to disable said repeater channel.

17. A transmission system comprising two line sections over which signaling waves are transmitted, stations connected to said line sections, a repeater including a channel for repeating signaling waves between said line sections, a calling system including a selector at the repeater and each of said stations responsive to properly arranged groups of impulses of alternating polarity, and a second selector at said repeater responsive to certain groups of impulses to disable said repeater channel.

18. A transmission system comprising two line sections over which signaling waves are transmitted, stations connected to said line sections, a repeater including a channel for repeating signaling waves between said line sections, a calling system including a selector at the repeater and each of said stations responsive to properly arranged groups of impulses of alternating polarity, and a second selector at said repeater responsive to groups

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of impulses originated at one of said stations connected to the same line section as the called station to disable said repeater channel.

19. A transmission system comprising two line sections over which signaling waves are transmitted, stations connected to said line sections, a repeater including a channel for repeating signaling waves between said line sections, a calling system including a selector at each of said stations responsive to a group of impulses of alternating polarity transmitted from stations connected to one line section and responsive to another group of impulses of alternating polarity transmitted from stations connected to the other line section, a selector at said repeater responsive to groups of impulses transmitted from a station connected to the same line section as the called station, and means controlled by said last mentioned selector for disabling said repeater channel.

20. A transmission system comprising two line sections over which signaling waves are transmitted, stations connected to each line section, a repeater connecting said line sections, means at one or more of said stations connected to one line section for transmitting carrier waves modulated in accordance with signals, means at one or more of said stations connected to the other line section for transmitting carrier waves of different frequency modulated in accordance with signals, and means at said repeater for retransmitting said signals as modulations of carrier waves of another frequency.

21. A transmission system comprising two line sections over which signaling waves are transmitted, stations connected to said line sections, a repeater connecting said line sections, means at one or more of said stations connected to one line section for transmitting carrier waves modulated in accordance with signals, means at one or more of said stations connected to the other line section for transmitting carrier waves of different frequency modulated in accordance with signals, means at said repeater for detecting the signal modulated waves received from both line sections, and means for retransmitting said signals to both line sections as modulations of carrier waves of another frequency.

22. A transmission system comprising two line sections over which signaling waves are transmitted, stations connected to each line section, a repeater connecting said line sections, means at stations connected to one line section to transmit and receive signaling waves comprised within either of two bands of frequencies, means at stations connected to the other line section to transmit and receive signaling waves comprised within one of said bands of frequencies and a third band of frequencies, and means at said repeater to transmit signaling waves comprised within the band of frequencies receivable by all said

stations and to receive signaling waves comprised within the other bands of frequencies transmitted by said stations.

23. A transmission system comprising two line sections over which signaling waves are transmitted, stations connected to each line section, a repeater connecting said line sections, means at stations connected to one line section to transmit and receive signaling waves comprised within either of two bands of frequencies, means at stations connected to the other line section to transmit and receive signaling waves comprised within one of said bands of frequencies and a third band of frequencies, a channel at said repeater for transmitting signaling waves comprised within the band of frequencies receivable by all said stations and to receive signaling waves comprised within the other bands of frequencies transmitted by said stations, and means responsive to properly arranged groups of signaling impulses of alternating polarity to disable said repeater channel whereby stations connected to the same line section may thereafter communicate without actuating said repeater.

24. A transmission system comprising two line sections over which signaling waves are transmitted, stations connected to each line section, a repeater connecting said line sections, means at stations connected to one line section to transmit and receive signaling waves comprised within either of two bands of frequencies, means at stations connected to the other line section to transmit and receive signaling waves comprised within one of said bands of frequencies and a third band of frequencies, a channel at said repeater for transmitting signaling waves comprised within the band of frequencies receivable by all said stations and for receiving signaling waves comprised within the other bands of frequencies transmitted by said stations, a calling system including a selector at the repeater and each station responsive to properly arranged groups of signaling impulses of alternating polarity transmitted over said line sections as modulations of carrier waves comprised within said frequency bands, and a second selector at said repeater responsive to groups of such impulses originated at a station connected to the same line section as the called station for disabling said repeater channel.

In witness whereof, I hereunto subscribe my name this 3rd day of February, A. D. 1927.

WALLACE V. WOLFE.