March 19, 1929. H. B. ARNOLD 1,705,891

POWER LINE SIGNALING

Filed Feb. 28, 1927 8 Sheets-Sheet 1

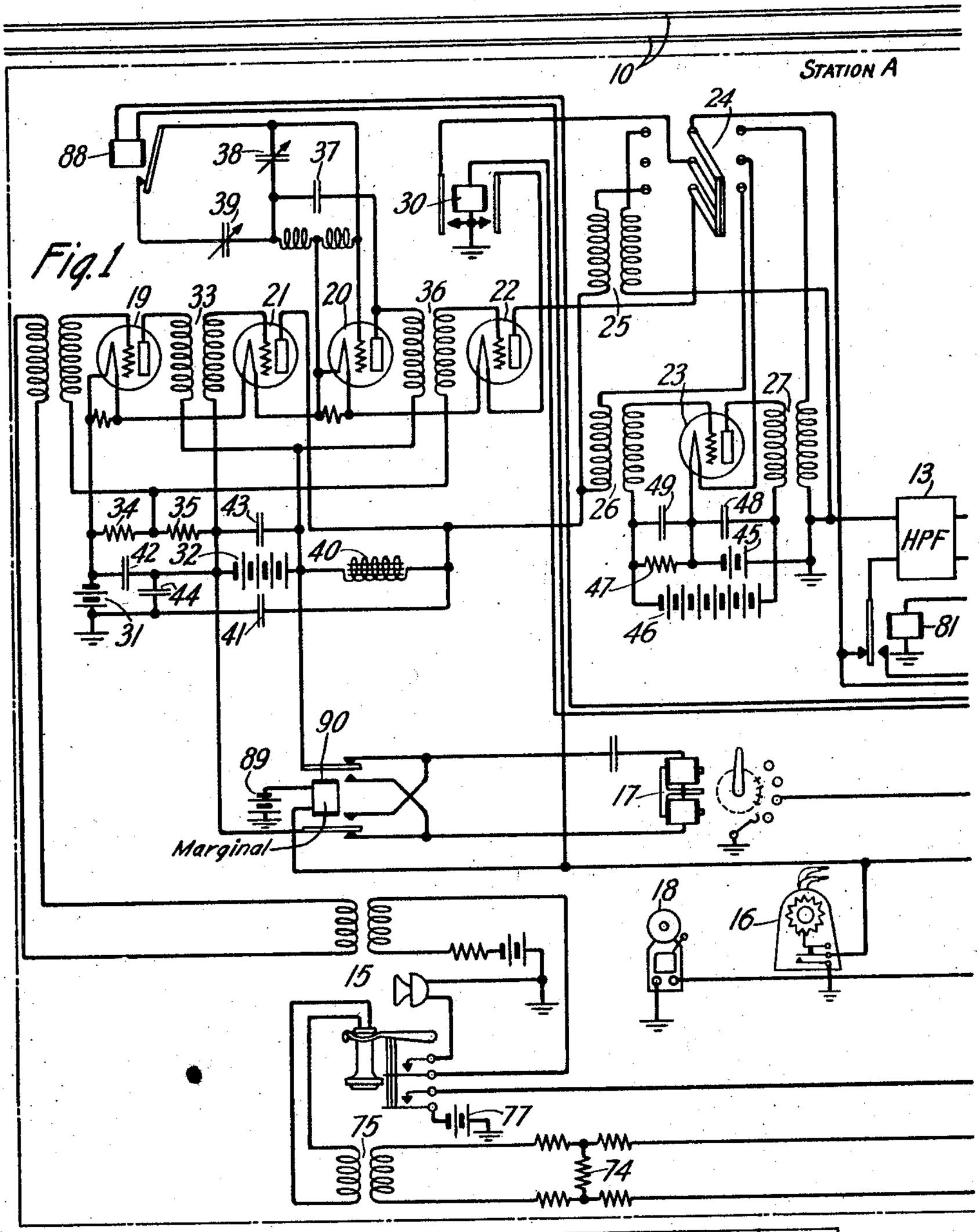

Fig. 9

Fig. 1	Fig. 2	Fig. 3	Fig. 4	Fig. 5	Fig. 6	Fig. 7	Fig. 8

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POWER LINE SIGNALING

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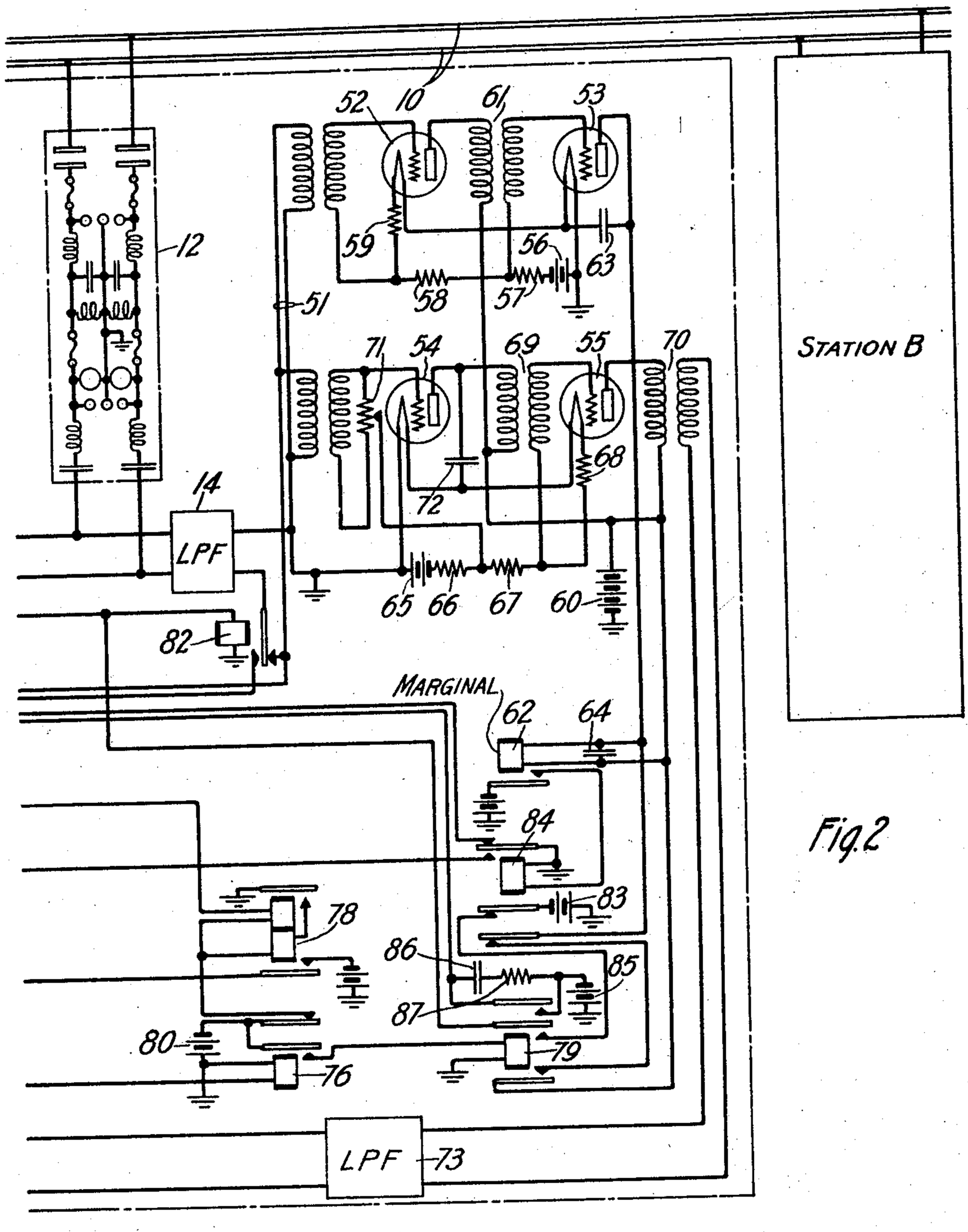

Fig. 2

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POWER LINE SIGNALING

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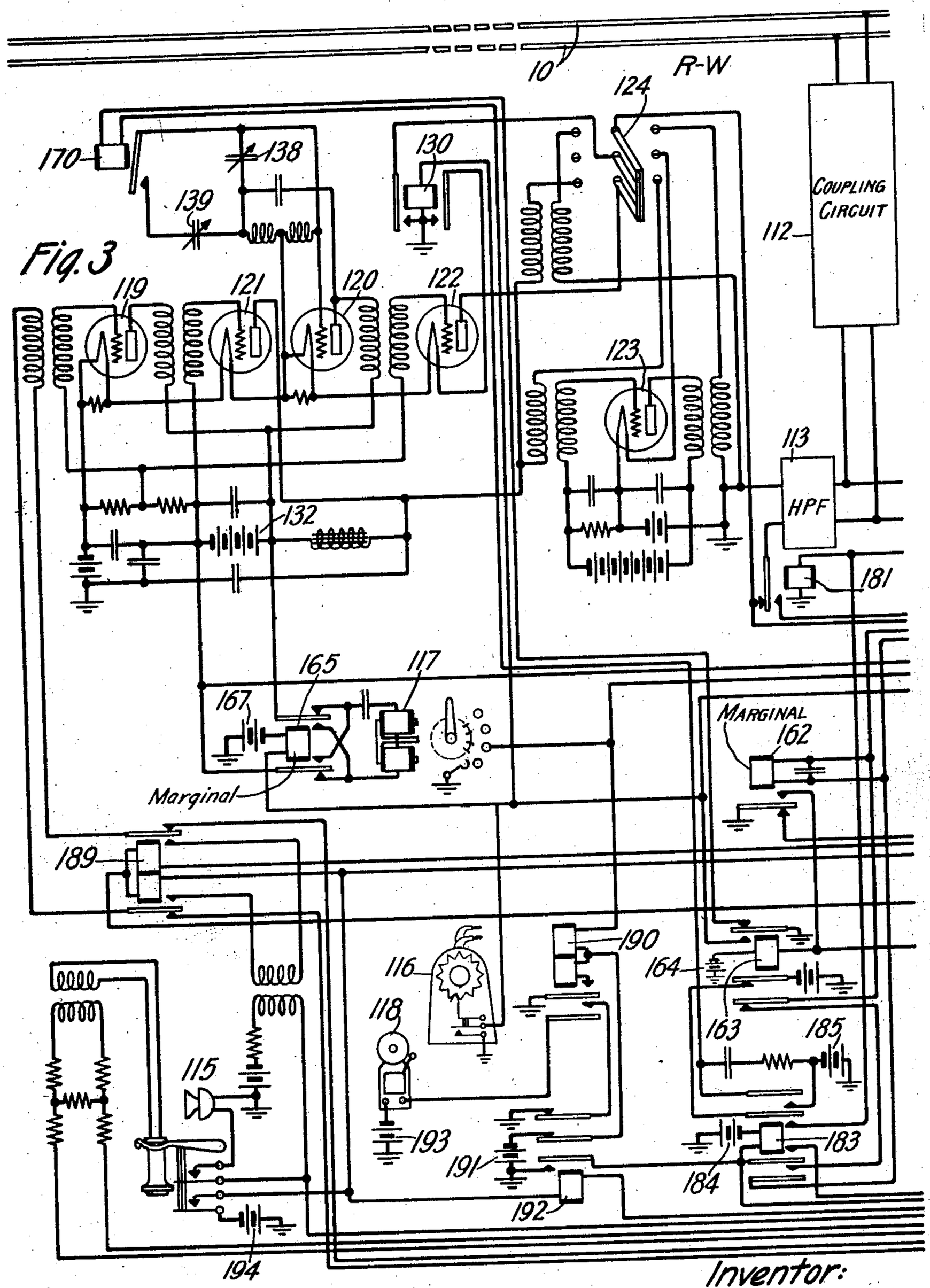
Fig. 3



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POWER LINE SIGNALING

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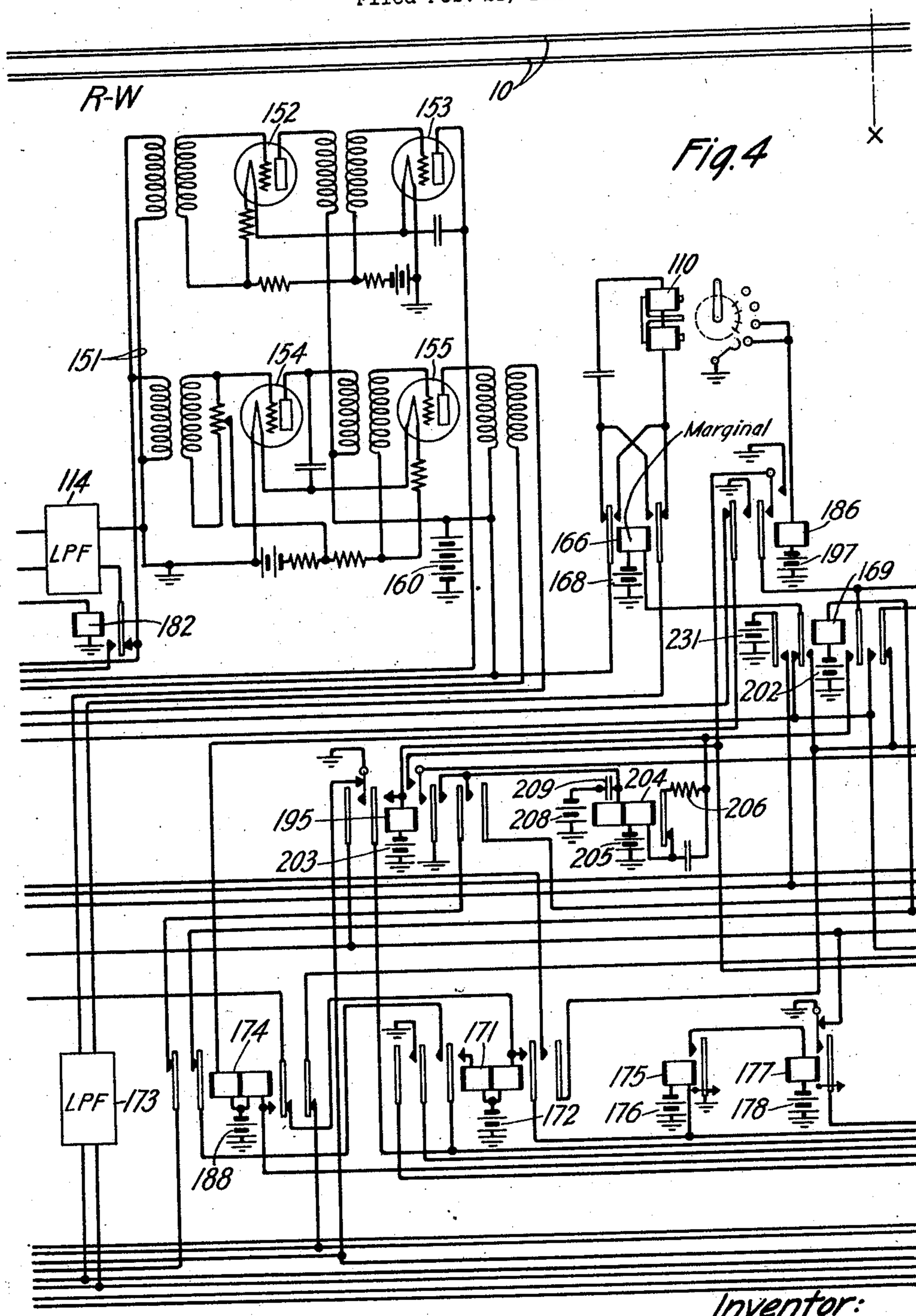

Fig. 4

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POWER LINE SIGNALING

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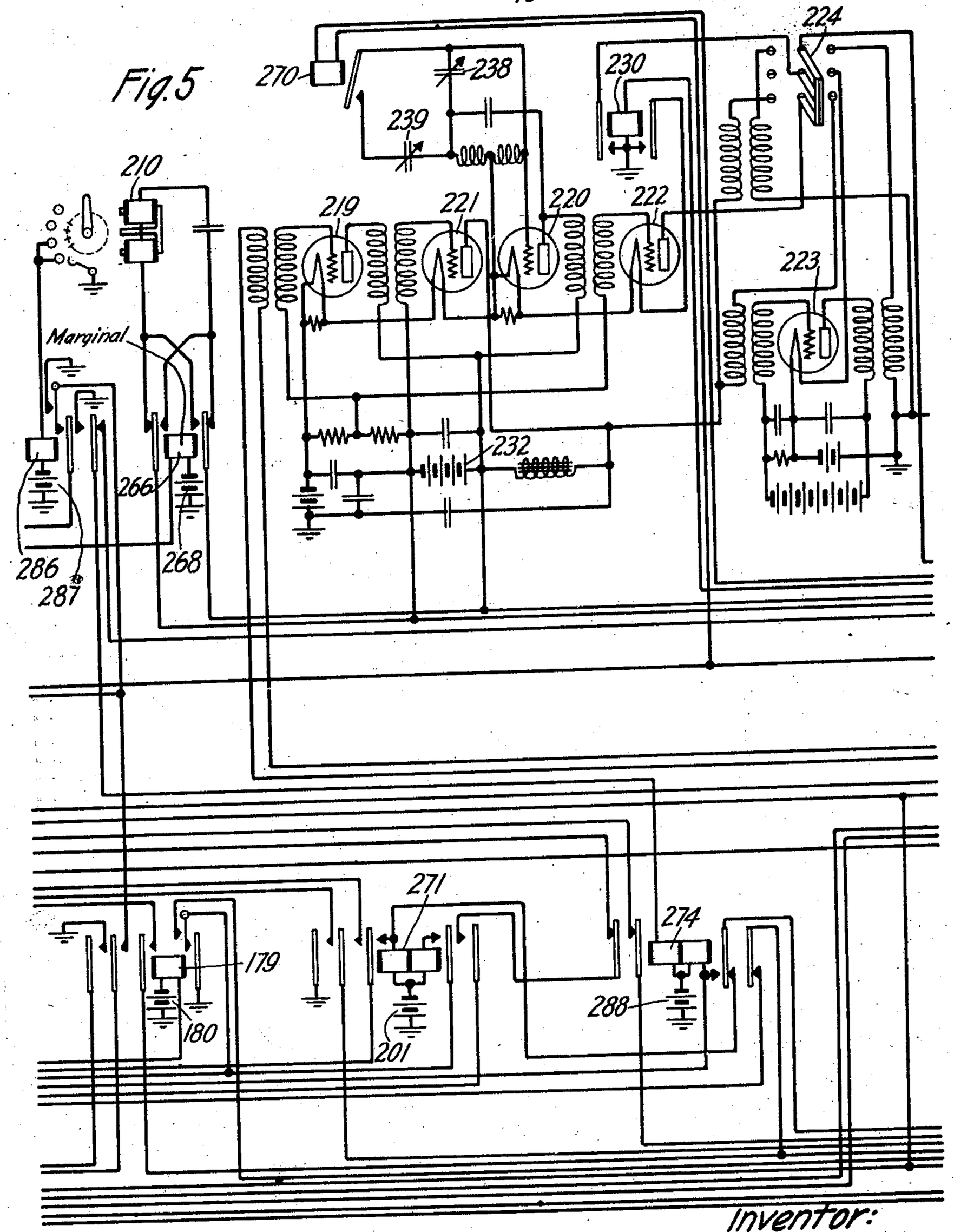
10 R-E

Fig. 5



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POWER LINE SIGNALING

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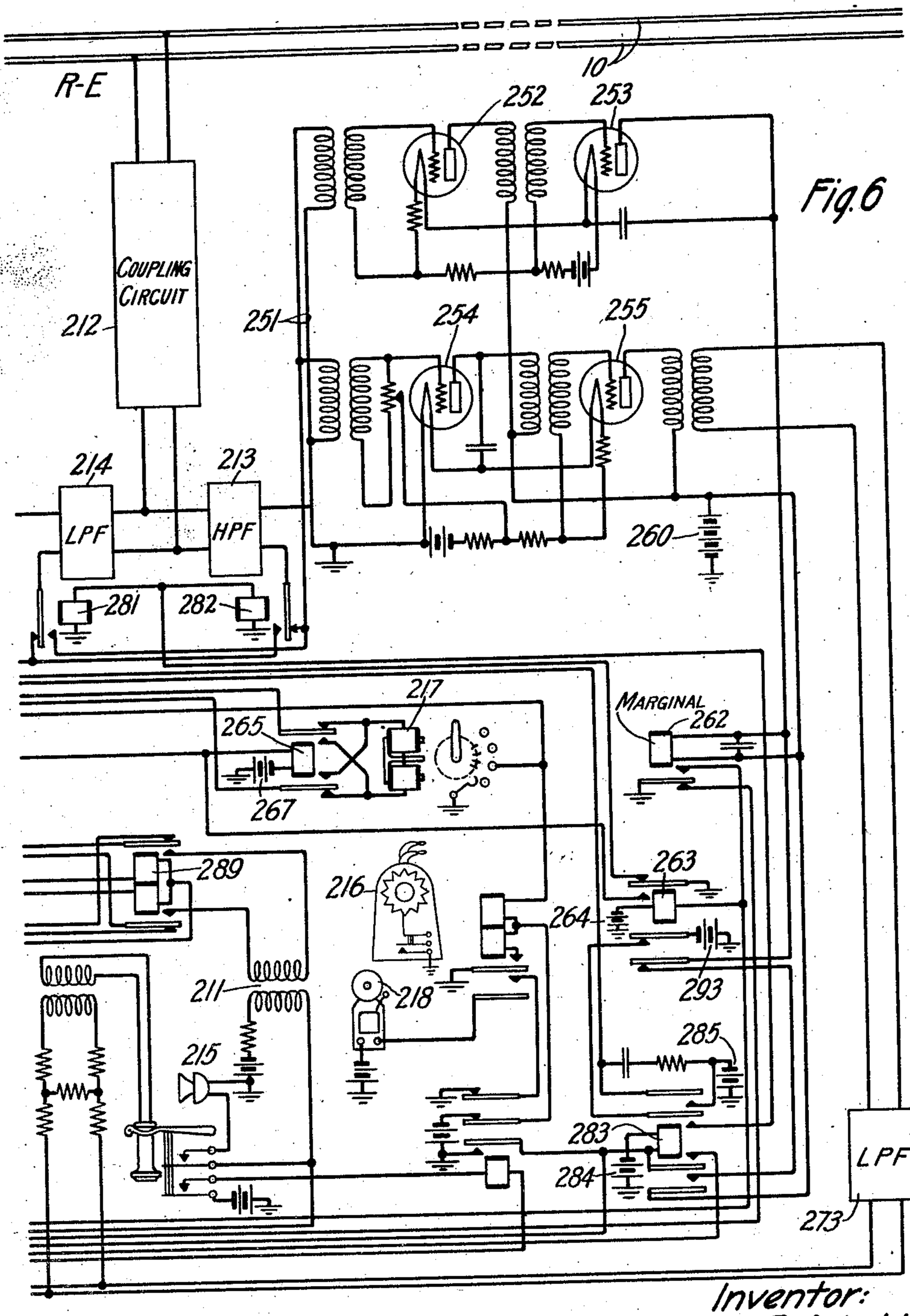

Fig. 6

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POWER LINE SIGNALING

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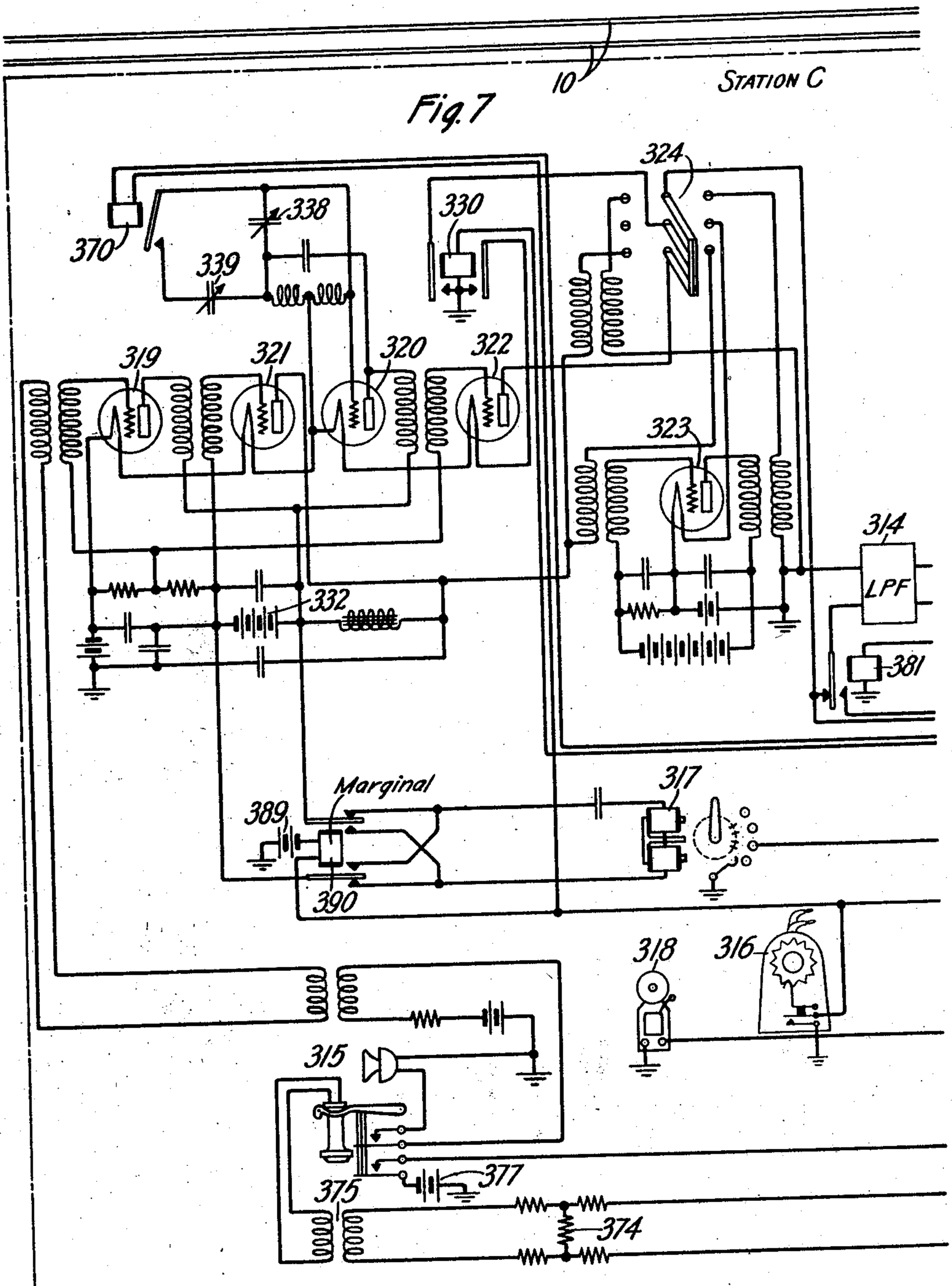
Fig. 7



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POWER LINE SIGNALING

Filed Feb. 28, 1927 8 Sheets-Sheet 8

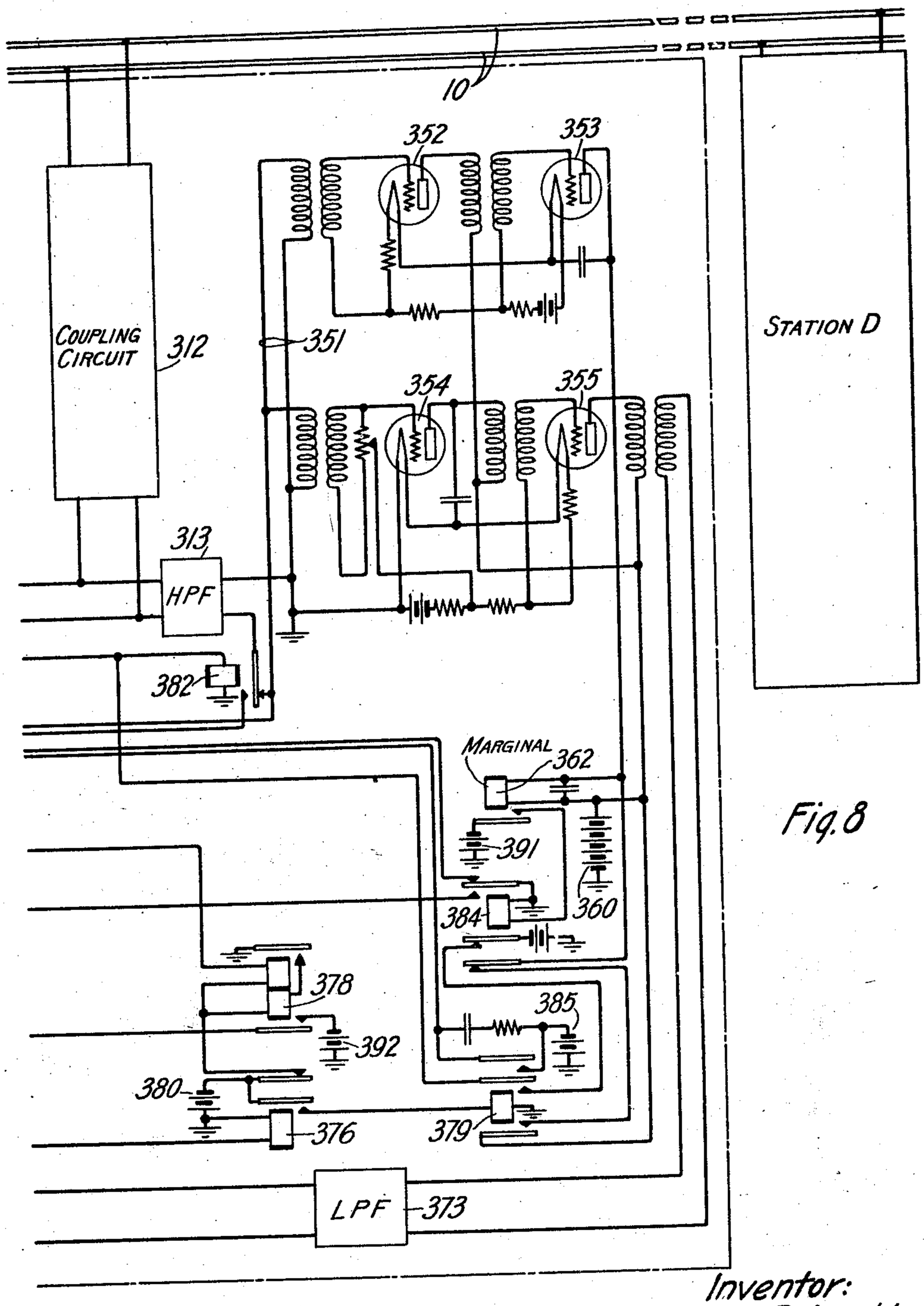

Fig. 8

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Patented Mar. 19, 1929. 1,705,891

UNITED STATES PATENT OFFICE.

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POWER LINE SIGNALING.

Application filed February 28, 1927. Serial No. 171,402.

This invention relates to communication by means of carrier frequency waves, and particularly to communication over composite power current and carrier wave transmission systems employing repeaters.

An object of the invention is to increase the utility and efficiency of power line signaling systems employing repeaters.

A related object of the invention is to establish independent signaling circuits on opposite sides of a repeater in such a system.

Another object of the invention is to apprise stations connected to a signaling circuit on one side of a repeater when a signaling circuit on the opposite side of the repeater is in service.

The invention provides a selectively operated power line signaling system employing a plurality of stations and a repeater, in which any station on the line may freely call and communicate with any other station or the repeater. A feature of the invention is an arrangement for establishing communication between stations located on one side of the repeater without interrupting communication between stations located on the opposite side of the repeater. Another feature of the invention is an arrangement whereby a busy signal is transmitted to warn stations on one side of the repeater when stations on the other side of the repeater are in service.

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

Figs. 1 to 8, inclusive, illustrate diagrammatically a power line signaling system comprising a plurality of stations and a repeater embodying the invention; and

Fig. 9 is a diagram showing the manner in which the several sheets of drawings should be organized.

In the system shown in the drawings, 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 to 6, inclusive, may be employed to repeat calling signals and telephone conversations between the stations either when the power line 10 is a continuous line, or when a discontinuity, such as a voltage transformer or an open power switch, exists at the point X in the power line. In the detailed description, however, it will be assumed that the power line 10 is continuous. 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.

It is to be understood that station B is equipped with apparatus similar in arrangement and function to that shown at station A in Figs. 1 and 2, and that station D is equipped with apparatus similar in arrangement and function to that shown at station C in Figs. 7 and 8.

The repeater station shown in Figs. 3 to 6, inclusive, includes a repeater R—W which receives waves originating at stations A and B on the west or left hand side of the repeater station, and a repeater R—E which receives waves originating at stations C and D on the east or right hand side of the repeater station. The high frequency wave transmitting and receiving circuits employed at the several stations are, in general, similar, and hence such apparatus as is common to all of the stations will be described in detail only in connection with the description of station A.

It is to be understood that the references hereinafter made to the particular bands of frequencies employed are merely for the purpose of illustration, and that the invention is not limited to the use of any particular bands of frequencies. For example, in a typical case, stations A and B at the left of the repeater may be arranged to transmit or receive carrier waves of 80 and 100 kilocycles frequency, and stations D and E at the right of the repeater may be arranged to transmit or receive carrier waves of 70 and 110 kilocycles frequency. On outgoing calls stations A and B may be arranged to transmit at 80 kilocycles and receive at 100 kilocycles, in which case on incoming calls these stations will receive at 80 kilocycles and transmit at 100 kilocycles. Likewise, on outgoing calls stations D and E may be arranged to transmit at 110 kilocycles and receive at 70 kilocycles, in which case on incoming calls these stations will receive at 110 kilocycles and transmit at 70 kilocycles. The repeater R—W, shown in Figs. 3 and 4, is arranged to transmit or receive waves of the frequencies assigned to stations A and B, for example 80 and 100 kilocycles, while repeater

R—E, shown in Figs. 5 and 6, is arranged to transmit or receive waves of the frequencies assigned to stations D and E, for example 70 and 110 kilocycles.

The following description of station A will be followed by a description of the repeater station and a consideration of the method of communicating between the several stations.

Station A.

The 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 a copending application of W. V. Wolfe, Serial No. 664,147, filed September 22, 1923, permitting the transfer of high frequency waves between the apparatus and the power line with safety to the apparatus and 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 switch-hook. 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 incoming impulses for controlling the operation of a bell or other signaling device 18. 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 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 resistance 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.

The incoming channel extends from the power line 10, through the coupling circuit 12, to the 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 of 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 transformer 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 by-pass 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.

As pointed out above, the repeater shown in Figs. 3 to 6, inclusive, comprises a repeater R—W and a repeater R—E. The repeaters R—W and R—E each include transmitting and receiving apparatus similar to that provided at the stations, the apparatus at these repeaters being connected by means of relay circuits. The repeater thus resembles two stations plus the necessary connecting circuits, and, therefore, may be termed a "two terminal repeater". The portion of the apparatus at the repeater which has been referred to as the repeater R—W is connected to the power line 10 by means of a coupling circuit 112, and the portion of the apparatus referred to as repeater R—E is connected to the power line by means of a coupling circuit 212. These coupling circuits are similar to the coupling circuit 12 employed at station A.

On incoming calls the repeater R—W receives on the lower carrier frequency of 80 kilocycles per second and transmits on the higher carrier frequency of 100 kilocycles per second and hence, as pointed out above, is arranged to receive calls only from stations A and B. On incoming calls the repeater R—E receives on the higher carrier frequency of 110 kilocycles per second and transmits on the lower carrier frequency of 70 kilocycles per second so that this repeater, as pointed out above, can receive calls only from stations C and D. When the repeaters R—W and R—E are being used to repeat calls from station A or B to station C or D both repeaters transmit on their respective higher frequencies and receive on their respective lower frequencies. However, when the repeaters R—W and R—E are being used to repeat calls from station C or D to station A or B both repeaters transmit on their respective lower frequencies and receive on their respective higher frequencies. With this arrangement the waves transmitted from either repeater cannot feed back into the receiving channel of the other repeater. At the repeater R—W the high pass filter 113 is normally connected to the outgoing channel and the low pass filter 114 is normally connected to the incoming channel, while at the repeater R—E the high pass filter 213 is normally connected to the incoming channel and the low pass filter 214 is normally connected to the outgoing chanel.

Telephone communication between the repeater and either of the stations A or B 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 operation at either station A or B. A selector 117 associated with the receiving channel is operated according to a predetermined combination of impulses when either station A or B calls the repater. This selector controls the operation of the bell or other signaling device 118.

Telephone communication between the repeater and either station C or D is effected by means of an operator's telephone set 215 comprising a receiver which is connected to the incoming channel of the repeater R—E, and a transmitter which is arranged to be connected to the outgoing channel of the repeater R—E as hereinafter described. The selector key 216 is employed to transmit calling signals for calling the operator at station C or D. The selector 217 associated with the receiving channel of the repeater R—E is operated according to a predetermined code of impulses when either station C or D calls the repeater. This selector controls the operation of the bell or other signaling device 218 which, if desired, may have a tone different from that of the bell 118 in order to

apprise the operator at the repeater as to which telephone set to use in answering the call.

According to a feature of the invention, the portion of the system on each side of the repeater will function independently of the rest of the system. For example, communication may be established between stations A and B, or between station A or B and the repeater R—W, even though a conversation is in progress between stations C and D, or between the repeater R—E and station C or D. Under such conditions, if communication has been established between stations C and D, for example, it is desirable to transmit a busy signal to station A or B if the operator at either of these stations attempts to call either station C or D. According to the invention, if the operator at station A actuates his transmitting key 16 to call either station C or D when these two stations are busy, the operator at station A will receive a busy tone apprising him that the called station is busy. The busy tone, however, will not be applied to the line if the operator at station A calls either station B or the repeater R—W under the conditions just mentioned.

The transmission of the busy signal in a proper case is controlled by means including the auxiliary selectors 110 and 210 associated with the repeaters R—W and R—E, respectively. These selectors normally function to energize the filament circuits of the outgoing channels at the repeater. The selector 110, for example, is arranged to be operated on a normal call to station A or B, closing one of its associated contacts to control the operation of apparatus at the repeater. The selector 210 is arranged to close one of its contacts on a normal call to station C or D and serves also to establish the proper circuit at the repeater. If a station, such as C or D, on one side of the repeater attempts to call a station, such as A or B, on the other side of the repeater when stations A and B or station A or B and the repeater R—W are in service, the selector 110 and other apparatus will function to apply a busy tone to the line. The selector 210 will function in a similar manner when the conditions are reversed, that is, when a station at the left of the repeater attempts to call any station which is already in service at the right of the repeater.

The outgoing and incoming channels at the repeaters R—W and R—E 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. Furthermore, since the outgoing and incoming channels at the repeaters R—W and R—E are alike, reference will be made at this point only to the channels of the repeater R—W. 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 condenser 138 which is permanently connected in the oscillator circuit determines the higher carrier frequency of 100 kilocycles per second, and the addition of condenser 139 in parallel determines the lower carrier frequency of 80 kilocycles per second.

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 station.

In describing the operation of the system the method of calling and talking through the repeater station from station A to station C will first be considered.

The operator at station A, in initiating a call to station C 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 76, in operating opens its upper contact, thereby opening an energizing circuit of the relay 78. Relay 79 is now energized over a circuit extending from grounded battery 80, through the lower armature and contact of relay 76, winding of relay 79, to ground. Relay 79 in closing its lowermost contact short-circuits relay 62 so that this relay cannot be energized in response to the carrier waves subsequently to be received. Relay 79 in closing its second upper contact completes an energizing circuit for the filter controlling relays 81 and 82, which may be traced from grounded battery 83, through the first lower armature and contact of relay 84, second upper contact and armature of relay 79, windings of relays 81 and 82 in parallel, to ground. The operation of relay 81 serves to disconnect the high pass filter 13 from the outgoing channel and connect it to the incoming channel, and the operation of relay 82 serves to disconnect the low pass filter 14 from the incoming channel and connect it to the outgoing channel.

The relay 79 in closing its uppermost contact causes the operation of relay 30 over a circuit extending from grounded battery 85, through the uppermost contact and armature of relay 79, winding of relay 30, to ground.

The condenser 86 and resistance 87 serve to protect the upper contact of relay 79 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 filament circuits were traced above in the description of the terminal apparatus. As shown in the drawing, the relay 88, which controls the connection of condenser 39 in the circuit of the oscillator 20, is energized over a circuit extending from grounded battery 89, through the winding of a marginal pole changing relay 90, winding of relay 88, uppermost back contact and armature of relay 84, to ground, the current flowing in this circuit, however, being insufficient to operate the pole changing relay 90. Since the relay 88 is energized the condenser 39 is connected in the oscillatory circuit of the oscillator 20 and hence the oscillator 20 produces carrier waves of 80 kilocycles frequency. The carrier waves of 80 kilocycles frequency, generated by the oscillator 20, are transmitted through the low-pass filter 14 and coupling circuit 12 to the power line 10.

The repeater R—W is normally arranged to receive carrier waves of 80 kilocycles frequency. Accordingly, the carrier waves of 80 kilocycles frequency transmitted from station A pass through the coupling circuit 112 at the repeater, and are selectively passed by the low pass filter 114 to the common collecting circuit 151. Carrier waves of this frequency will also pass into the receiving channel at station B which, like the receiving channel at station A normally has its low pass filter connected to the receiving channel. The carrier waves received in the circuit 151 at the repeater R—W 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 energization of relay 163 over a circuit extending from grounded battery 164, through the winding of relay 163, front contact and armature of relay 162, to ground.

The operation of relay 163 causes the energization of the marginal pole changing relays 165 and 166. The energizing circuit of relay 165 extends from grounded battery 167, through the winding of relay 165, uppermost front contact and armature of relay 163, to ground. The energizing circuit of relay 166 extends from grounded battery 168, through the winding of relay 166, second left hand armature and back contact of relay 169, uppermost front contact and armature of relay 163, to ground. The operation of relays 165 and 166 causes an impulse of current from the source 132 to be supplied to the electromagnets of selectors 110 and 117. These 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.

It will be noted that relay 170 is normally energized over a circuit extending from grounded battery 167, through the winding of marginal relay 165, winding of relay 170, uppermost back contact and armature of relay 163, to ground. Now, upon the operation of relay 163, the energizing circuit of relay 170 is opened at the uppermost back contact of relay 163, but the deenergization of relay 170 performs no useful function at this time.

The relay 162, in operating, completes an energizing circuit for relay 171, from grounded battery 172, through the right hand winding of relay 171, inner right hand back contact and armature of relay 174, front contact and armature of relay 162, to ground. The operation of relay 171 establishes an energizing circuit for the slow releasing relay 175, which extends from grounded battery 176, through the winding of relay 175, inner right hand armature and contact of relay 171, inner right hand back contact and armature of relay 174, front contact and armature of relay 162, to ground. The slow releasing relay 177 is thereupon energized over a circuit extending from grounded battery 178, through the winding of relay 177, contact and armature of relay 175, to ground. The operation of relay 177 causes the energization of relay 179 over a circuit extending from grounded battery 180, through the winding of relay 179, armature and front contact of relay 177, to ground.

The operation of relay 171, as described above, also establishes an energizing circuit for relay 283 of the repeater R—E at the repeater, which may be traced from grounded battery 284, through the winding of relay 283, right hand armature and contact of relay 274, outer left hand armature and contact of relay 171, to ground. The operation of relay 283 causes the energization of relay 230 over a circuit extending from grounded battery 285, through the uppermost contact and armature of relay 283, winding of relay 230, to ground. The energization of relay 230 causes filament heating current to be supplied to all the space discharge tubes in the outgoing channel of the repeater R—E, including the auxiliary amplifying tube 223 if this tube is in service. The filament circuits are similar to the corresponding circuits previously described at station A. It will be noted that the relay 270, which controls the connection of the condenser 239 in the circuit of the oscillator 220, is energized over a cir-

cuit extending from grounded battery 268 through the windings of the marginal pole changing relay 266, outer right hand armature and back contact of relay 169, winding of relay 270, uppermost back contact and armature of relay 263, to ground. Relay 270 is also energized over a circuit extending from grounded battery 267, winding of relay 265, winding of relay 270, uppermost back contact and armature of relay 263 to ground. Since the relay 270 is energized, the condenser 239 is disconnected from the oscillatory circuit of the oscillator 220, and hence carrier waves of 110 kilocycles frequency are generated by the oscillator 220. Carrier waves of this frequency ordinarily would not pass to the power line since the low pass filter 214, which is normally connected to the outgoing channel of the repeater R—E, will not pass waves of this frequency. However, the operation of relay 283 in the manner described above completes an energizing circuit for the relays 281 and 282 which control the connection of the high pass and low pass filters to the outgoing and incoming channels. This energizing circuit extends from grounded battery 293, through the first lower armature and contact of relay 263, the upper armature and contact of relay 283, windings of relays 281 and 282 in parallel, to ground. The operation of relay 281 disconnects the low pass filter 214 from the outgoing channel and connects it to the incoming channel, and the operation of relay 282 disconnects the high pass filter 213 from the incoming channel and connects it to the outgoing channel. The carrier waves of 110 kilocycles frequency, generated by the oscillator 220, therefore pass through the high pass filter 213 and coupling circuit 212 to the power line 10.

The station C is normally arranged to receive carrier waves of 110 kilocycles frequency, high pass filter 313 thereat normally being connected to the incoming channel. Accordingly, the carrier waves of 110 kilocycles frequency relayed from the repeater station, pass through the coupling circuit 312 at station C, and are selectively passed by the high pass filter 313 to the common collecting circuit 351. Carrier waves of this frequency, of course, also pass into the receiving channel at station D. The carrier waves received in the circuit 351 at station C are amplified by the amplifier 352 and rectified by the rectifier 353, the rectified waves causing the operation of relay 362. The operation of relay 362 causes the operation of relay 384 over a circuit extending from grounded battery 391, through the armature and contact of relay 362, winding of relay 384, to ground. Relay 384 in attracting its lowermost armature opens a short-circuit path around the relay 362 so that the relay 362 will not be short-circuited when relay 379 is subsequently operated. Relay 384 in attracting its first lower armature opens the energizing circuit of the filter controlling relays 381 and 382 so that these relays will not be operated upon the subsequent operation of relay 379. Accordingly, since the relays 381 and 382 remain deenergized, the low pass filter 314 remains connected to the outgoing channel and the high pass filter 313 remains connected to the incoming channel. The relay 384 in opening its uppermost back contact, opens the energizing circuit of relay 370, thereby connecting the condenser 339 in the oscillatory circuit of the oscillator 320. Furthermore, the relay 384 closes its uppermost front contact, establishing an energizing circuit for the pole changing relay 390 from grounded battery 389, through the winding of relay 390, uppermost front contact and armature of relay 384, to ground. The operation of relay 390 causes an impulse of current from the source 332 to be supplied to the electromagnet of selector 317. The selector will thereupon advance one step but will immediately fall back to the starting position.

The sequence of operations described above took place when the operator at station A removed his receiver from the switchhook, and prior to the actuation of the selector key 16. The operator at station A now actuates the selector key 16 which is set to transmit the proper combination of impulses for calling station C. The operation of selector key 16 short-circuits the relay 88 each time a tooth of the selector key closes the key contact, thus alternately deenergizing and energizing the relay 88. The alternate deenergization and energization of relay 88 in response to these impulses causes the condenser 39 to be placed alternately out of and into the oscillatory circuit of the oscillator 20. During the operation of the selector key 16, the frequency generated by the oscillator 20 is thus changed back and forth from the low carrier frequency of 80 kilocycles per second to the high carrier frequency of 100 kilocycles per second, and vice versa. However, the high carrier frequency is not transmitted to the power line inasmuch as the low pass filter 13, which is now connected between the outgoing channel and the power line, is designed to pass only the low carrier frequency and to suppress the high carrier frequency. The groups of impulses of the low carrier frequency of 80 kilocycles per second are thus transmitted to and impressed upon the power line.

The operation of the selector key 16 also completes an energizing circuit for the pole changing relay 90, from grounded battery 89, through the winding of relay 90, closed contact of selector key 16, to ground. The energization of relay 90 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 key 16 is opened relay

90 releases, which causes an impulse of current of opposite sign through the electromagnet of selector 17. The selector thus advances step by step in response to the transmitted impulses. The operation of relay 90 and the selector 17 at this time performs no useful function, but is usually provided for in systems of this general type so that relay 90 may also be used to relay calling impulses to a substation, not shown in the drawing, if this feature should be found desirable.

The lower frequency impulses of 80 kilocycles per second which are transmitted over the power line pass through the coupling circuit 112 at the repeater, and thence through low-pass filter 114 to the common collecting circuit 151, amplifier 152 and rectifier 153. These impulses, of course, also pass into the receiving channel at station B. Each time the relay 162 is deenergized in response to the incoming impulses, the relay 270 of the repeater R—E is short-circuited through the outer right hand armature and contact of relay 171 and the back contact and armature of relay 162. That is, the alternate deenergization and energization of the relay 162, in response to the received calling impulses, causes the alternate deenergization and energization of the relay 270, causing the condenser 239 to be placed alternately into and out of the oscillatory circuit of the oscillator 220. The calling impulses received by the repeater R—W thus cause the frequency generated by the oscillator 220 of the repeater R—E to be changed back and forth from the high carrier frequency of 110 kilocycles per second to the low carrier frequency of 70 kilocycles per second. The low carrier frequency of 70 kilocycles per second, of course, is not transmitted to the power line inasmuch as the high-pass filter 213, which is now connected between the outgoing channel of the repeater R—E and the power line, is designed to pass only the high carrier frequency and to suppress the low carrier frequency. Groups of impulses of 110 kilocycles per second, corresponding in number and arrangement to the groups of impulses transmitted from station A, are thus transmitted to and impressed upon the power line by the repeater R—E.

The alternate deenergization and energization of relay 162, as described above, causes the alternate deenergization and energization of relay 163 which, in operation, causes the alternate deenergization and energization of the pole changing relay 165 of the repeater R—W. The relay 165, in operating, causes the selector 117 to advance step by step in the manner previously described. The relays 175 and 177, being slow releasing relays, remain operated during the relaying of the impulses by the repeater, the relay 177 maintaining the relay 179 energized. The relay 171 is therefore locked up during the relaying of the impulses, through a circuit extending from grounded battery 172, through the left-hand winding and innermost left-hand contact and armature of relay 171, right hand front contact and armature of relay 179, to ground. It is necessary to maintain the relay 171 energized at this time since the energizing circuit of the relay 270 of the repeater R—E, which is alternately short-circuited during the relaying of the impulses, extends through the outer right hand armature and contact of the relay 171.

The calling impulses of 110 kilocycles frequency, which are relayed from the repeater, are received by the stations C and D. These impulses cause the selectors at stations C and D to step up, but only the selector at station C closes the proper contact. The impulses which are received at station C cause the alternate deenergization and energization of relay 362 which, in turn, causes the alternate deenergization and energization of relay 384. The intermittent operation of relay 384 by relay 362 causes the intermittent operation of the pole changing relay 390, causing the selector 317 to advance step-by-step until it closes its contact corresponding to the transmitted combination of impulses. When the selector 317 at station C stops at the proper contact, the relay 378 is energized over a circuit extending from grounded battery 380, through the uppermost armature and contact of relay 376, upper winding of relay 378, closed contact of selector 317, to ground. The relay 378 is thereupon locked up through a circuit extending from grounded battery 380, through the upper armature and contact of relay 376, lower winding and upper contact and armature of relay 378, to ground. The bell 318 at station C is now energized over a circuit extending from grounded battery 392, through the lower contact and armature of relay 378, electromagnet of bell 318 to ground.

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 80 kilocycles frequency continue to flow from the outgoing channel at station A to the power line. Carrier waves of 110 kilocycles frequency are therefore impressed upon the power line from the outgoing channel of repeater R—E at the conclusion of the dialing operation. The carrier waves of 110 kilocycles frequency which are thus received at station C maintain the relays 362 and 384 energized during the subsequent communication between stations A and C. The final operation of relay 384 causes an additional impulse through the pole changing relay 390 which causes the selector 317 to advance another step from which advanced position it falls back to the starting position.

The calling impulses received at the repeater station in the manner described above, cause the intermittent operation of relays 165, 166, 265 and 266, thus causing selectors 117, 110, 217 and 210 to advance step-by-step along with the selectors at the other stations. The selectors 117 and 217, of course, are arranged to respond only to their own particular combinations of impulses, and hence these selectors do not close their contacts in response to the combination of impulses assigned to station C but promptly fall back to the starting position before the conclusion of the impulses. The selector 110 also falls back to the starting position since this selector is operated only on calls to stations A and B. The combination of impulses transmitted from station A to station C, however, not only causes the selector 317 at station C to close its associated contact but also causes the selector 210 at the repeater R—W to close one of its contacts. This is due to the fact that, as pointed out above, one of the contacts of selector 210 corresponds in its code setting to the combination of impulses assigned to the selector 317 at station C. When the selector 210 at the repeater R—E closes its associated contact corresponding to the code setting of the selector 317 at station C, relay 286 is energized over a circuit extending from grounded battery 287, through the winding of relay 286, closed contact of selector 210, to ground. Relay 274 is thereupon operated over a circuit extending from grounded battery 288, through the left hand winding of relay 274, right hand armature and front contact of relay 286, to ground. The operation of relay 274, however, performs no useful function at this time. The operation of relay 286 also causes the energization of relay 183 over a circuit extending from grounded battery 184, through the winding of relay 183, middle left hand armature and contact of relay 179, left hand front contacts of relay 286 to ground. A holding circuit for the relay 183 is thereupon established from grounded battery 184, through the winding, first lower armature and contact of relay 183, left hand armature and contact of relay 179 to ground, so that relay 183 remains energized even after relay 286 is deenergized when the selector 210 falls back to the starting position. The operation of relay 183 establishes an energizing circuit for relay 130, from grounded battery 185, through the uppermost contact and armature of relay 183, winding of relay 130, to ground. The operation of relay 130 serves to light the filaments of the space discharge tubes in the outgoing channel of repeater R—W. Since the condenser 139 is disconnected from the oscillatory circuit of the oscillator 120 carrier waves of 100 kilocycles frequency are generated by this oscillator and transmitted through the high-pass filter 113 and coupling circuit 112 to the power line.

When the operator at station C, upon hearing the bell, responds to the call by lifting his receiver from the switchhook, the relay 376 is energized over a circuit extending from grounded battery 377, through the lower contact of the switchhook, winding of relay 376, to ground. Relay 376 in attracting its upper armature opens the holding circuit of relay 378, thereby deenergizing this relay and the bell 318. The relay 379 is energized over a circuit extending from grounded battery 380, through the lower armature and contact of relay 376, winding of relay 379, to ground. The relay 330 is thereupon energized over a circuit which may be traced from grounded battery 385, through the uppermost contact and armature of relay 379, winding of relay 330, to ground. The operation of relay 330 causes the lighting of the filaments of the space discharge tubes in the outgoing channel at station C. Since the energizing circuit of relay 370 is now broken at the uppermost back contact of relay 384, the condenser 339 is connected in the oscillatory circuit of the oscillator 320, and carrier waves of 70 kilocycles frequency generated by this oscillator are transmitted through the low-pass filter 314 and coupling circuit 312 to the power line.

The operators at stations A and C may now carry on a conversation over the power line. Speech modulated carrier waves of 80 kilocycles frequency impressed upon the power line at station A pass through the coupling circuit 112 at the repeater R—W and thence through the low-pass filter 114 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, back contacts and armatures of relay 289, to the input circuit of the speech frequency amplifier 219. The speech currents which are thus supplied to the outgoing channel of repeater R—E are caused to modulate the carrier waves of 110 kilocycles frequency produced by the oscillator 220, and the modulated carrier waves are transmitted over the power line to station C. A portion of the waves received at the repeater R—W is rectified to maintain relay 162 energized. The speech modulated carrier waves of 110 kilocycles frequency received at station C are demodulated in the usual manner and the speech frequency components of demodulation pass through the low-pass filter 373, resistance network 374 and transformer 375 to the receiver of the operator's telephone set 315. Similarly, the speech modulated carrier

waves of 70 kilocycles frequency impressed upon the power line at station C are transmitted to the repeater R—E where they are demodulated in the usual manner, the speech frequency components of demodulation passing through the low-pass filter 273, the back contacts and armatures of relay 189, to the input circuit of the speech frequency amplifier 119. The speech currents which are thus supplied to the outgoing channel of repeater R—W are caused to modulate the carrier waves of 100 kilocycles frequency produced by the oscillator 120, and the modulated carrier waves are transmitted over the power line to station A where they are received in the manner described above at station C.

On a call through the repeater such as that described above, the receivers associated with the operators' telephone sets 115 and 215 at the repeater are connected across their respective receiving circuits, and hence provide a busy indication to the attendant at the repeater which he may observe by lifting his receiver without closing the switchhook contacts. If, however, the operator at the repeater should close the switchhook contacts in raising his receiver, there will be no interference to the call because the operating paths of relays 189 and 289, which maintain the closure betwen the incoming and outgoing repeater channels, are open at the upper back contact of relay 177. Upon the completion of the conversation, the operators at stations A and C will replace their receivers upon the switchhooks, causing the system to return to the normal condition shown in the drawings.

Calling and talking to repeater.

When the operator at station A desires to call and converse with the operator at the repeater, he proceeds in the manner employed in calling station C 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 other selectors throughout the system falling back to the starting position. The operation of selector 117 causes the energization of relays 174 and 190. The energizing circuit of relay 174 extends from grounded battery 188, through the left hand winding of relay 174, left hand armature and back contact of relay 186, closed contact of selector 117, to ground. The energizing circuit of relay 190 may be traced from grounded battery 191, through the middle contact and armature of relay 192, upper winding of relay 190, closed contact of selector 117, to ground. A holding circuit is thereupon established from grounded battery 191, through the middle contact and armature of relay 192, lower winding and first lower contact and armature of relay 190, to ground, so that relay 190 remains energized even though the selector 117 falls back to the starting position. The bell 118 is now energized over a circuit extending from grounded battery 193, through the electromagnet of bell 118, lowermost armature and contact of relay 190, uppermost armature and contact of relay 192, to ground. The relay 174 remains operated during the communication between station A and the repeater, preparing a circuit for the transmission of the busy signal in case station C or D should attempt to call station A or B while the transmission circuit at the left of the repeater is in service. The holding circuit of relay 174 extends from grounded battery 188, through the right hand winding and inner front contact of relay 174, front contact of relay 162, to ground. The transmission of the busy signal is described hereinafter in connection with a call from station A to station B, and hence will not be discussed further at this point.

When the operator at the repeater removes the receiver of the telephone set 115 from the switchhook, the local circuit of the operator's transmitter is closed, and the relays 192, 189 and 289 are operated. The energizing circuit of relay 192 may be traced from grounded battery 194, through the lower contact of the switchhook, winding of relay 192, left hand back contact of relay 195, to ground. Inasmuch as relay 174 is energized, the energizing circuit of relay 171 is broken at the inner right hand armature of relay 174, and hence relays 175, 177 and 179 are deenergized. Relay 189 is therefore energized over a circuit extending from grounded battery 194 through the lower contact of the switchhook, lower winding of relay 189, back contact of relay 177, to ground. Relay 289 is energized over a circuit extending from grounded battery 194, through the lower contact of the switchhook, lower winding of relay 289, back contact of relay 177, to ground. The operation of relay 189 opens the connection between the incoming channel of the repeater R—E and the outgoing channel of the repeater R—W, and connects the local transmitting circuit of the operator's telephone set 115 to the input circuit of the speech frequency amplifier 119. The operators at station A and the repeater may now converse, station A transmitting at 80 kilocycles and receiving at 100 kilocycles, and the repeater R—W transmitting at 100 kilocycles and receiving at 80 kilocycles. It will be noted that the operation of the relay 289 connects the transmitter of the operator's telephone set 215 to the input circuit of the speech frequency amplifier 219 of the repeater

R—E, so that the repeater R—E is free to receive a call from station C or D while the call between station A and the repeater R—W is in progress. If such a call is received by the repeater R—E when the operator at the repeater is engaged in conversation with the operator at station A he may, of course, answer the second call at his convenience. Furthermore, during the communication between station A and the repeater, station C may freely call and converse with station D, or vice versa, without in any way interfering with the conversation in progress between station A and the repeater.

Calling and talking to station on same side of repeater.

The operation of the system on a call from station A to station B will now be described. Following this description, the method of transmitting the busy signal will be considered.

The operator at station A proceeds to call station B in the manner employed in calling either station C or the repeater, except that the selector key 16 must first be adjusted to transmit the particular combination of impulses which will cause the selector at station B, corresponding to the selector 17 at station A, 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 carrier impulses of 80 kilocycles frequency impressed upon the power line at station A also enter the receiving channel at station B which is normally arranged to receive carrier waves of 80 kilocycles frequency. These impulses cause the selector at station B to close its associated contact, operating the bell at station B in a manner similar to that previously described in connection with the operation at station C.

The carrier waves of 80 kilocycles frequency also enter the receiving channel of repeater R—W, causing the operation of relay 162. The operation of relay 162 causes the energization of relays 163 and 171 as previously described. The operation of relay 171 establishes an energizing circuit for relay 175, relays 177 and 179, in turn, also being operated. The operation of relay 171 also energizes the relay 283 of repeater R—E, whereby carrier waves of 110 kilocycles frequency are impressed upon the power line by the repeater R—E for transmission to stations C and D. The intermittent operation of relay 162 in response to the calling impulses received at repeater R—W causes the stepping up of the selectors at the repeater, and also causes the calling impulses to be relayed to stations C and D in the manner previously described. Since the combination of impulses assigned to station B has been transmitted, the selector 110 at the repeater R—W closes one of its associated contacts upon the completion of the calling impulses. The relay 186 is thereupon energized over a circuit extending from grounded battery 197, through the winding of relay 186, the closed contact of the selector 110, to ground. The operation of relay 186 establishes an energizing circuit for relay 174, from grounded battery 188, through the left hand winding of relay 174, left hand armature and front contact of relay 186, to ground. A holding circuit is thereupon established for the relay 174, from grounded battery 188, through the right hand winding and inner right hand front contact and armature of relay 174, front contact and armature of relay 162, to ground. The relay 174, in operating, opens its inner right hand back contact, thereby opening the energizing circuit of relay 171. Relay 171 is thereupon deenergized, in turn releasing relays 175, 177 and 179. Accordingly, the common relay equipment at the repeater and the transmitting and receiving apparatus of the repeater R—E, are restored to normal with the exception of relay 174 which remains operated to control the transmission of the busy signal, should occasion require. When the operator at station B, hearing the bell, responds to the call by lifting his receiver from the switchhook, the connection between stations A and B is completed and the operators at these stations may now converse.

During the communication between stations A and B, the stations C and D may communicate with each other or with the repeater R—E. Under such condition, assume that the operator at station D initiates a call to station C. The operation of the apparatus at station D is similar to that previously described in connection with station A. When the operator at station D lifts his receiver from the switchhook, carrier waves of 110 kilocycles frequency are impressed upon the power line. These waves pass into the receiving channels of station C and repeater R—E. The waves which are received at the repeater R—E cause the operation of relay 262 which, in turn, causes the operation of relays 263 and 271. When the operator at station D actuates his selector key, the carrier waves which are impressed upon the power line are interrupted to transmit the calling impulses. These impulses cause the selectors at station C and the repeater to advance step-by-step. The selector 317 at station C thereupon closes its associated contact, energizing relay 378 through the circuit extending from grounded battery 380 through the uppermost armature and contact of relay 376, upper winding of relay 378, the closed contact of selector 317, to ground. The operation of relay 271 at the repeater R—E

performs no useful function at this time. The selector 210 at the repeater R—E also closes one of its associated contacts, operating relay 286, which, in turn, establishes an energizing circuit for relay 274. The operation of relay 274, however, performs no useful function at this time. Although relay 170 at the repeater R—W is alternately deenergized and energized during the transmission of the calling impulses, such transmission of impulses will have no effect upon the call in progress between stations A and B, since the relay 62 at station A is short-circuited and the relay 62 at station B is already energized by the carrier current transmitted from station A. When the operator at station C, hearing the bell, responds to the call by lifting his receiver from the switchhook, the talking circuit between stations C and D is completed, and the operators at these stations may converse without interfering with the call which is simultaneously in progress on the other side of the repeater.

If the operator at station C, for example, originates a call to station A at a time when the stations A and B are in service as described above, a busy signal will be transmitted to station C. Under such condition, assume that the operator at station C initiates a call to station A. The carrier waves of 110 kilocycles frequency which are impressed upon the power line at station C enter the receiving channel of repeater R—E, causing the operation of relay 262. Relay 271 is thereupon energized over a circuit extending from grounded battery 201, through the left hand winding of relay 271, inner right hand back contact and armature of relay 274, front contact of relay 262, to ground. Relay 175 is thereupon energized over a circuit extending from grounded battery 176, through the winding of relay 175, innermost left hand armature and contact of relay 271, inner right hand back contact and armature of relay 274, front contact and armature of relay 262, to ground. The operation of relay 175 causes the operation of relay 177 which, in turn, operates relay 179. A holding circuit is thereupon established for relay 271, from grounded battery 201, through the right hand winding and inner right hand contact and armature of relay 271, right hand contact and armature of relay 179, to ground. Since the relay 174 is operated, an energizing circuit is established for relay 169, which may be traced from grounded battery 202, through the winding of relay 169, left hand contact and armature of relay 274, right hand contact and armature of relay 271, inner right hand front contact and armature of relay 174, front contact and armature of relay 162, which relay is energized due to the carrier waves being received from station A, to ground. The function of relay 169 is to transfer the selectors normally associated with the repeater R—W to the repeater R—E. Accordingly, when the operator at station C transmits the proper combination of impulses for calling station A, the selector 110 closes one of its contacts, thereby energizing relay 186. It was pointed out above that the selector 110 is provided with two contacts which correspond, respectively, to the code settings of the selectors at stations A and B. The operation of relay 186 establishes an energizing circuit for relay 195, which extends from grounded battery 203, through the winding of relay 195, innermost right hand contact and armature of relay 169, right hand armature and right hand front contacts of relay 186, to ground. Relay 283 at the repeater R—E is thereupon energized over a circuit extending from grounded battery 284, through the winding of relay 283, innermost left hand armature and contact of relay 179, innermost right hand front contacts and armature of relay 195, to ground. The operation of relay 283 causes the operation of relay 230, thereby energizing the filaments of the space discharge tubes in the outgoing channel of repeater R—E. The relay 263 is now energized over a circuit extending from grounded battery 264, through the winding of relay 263, front contact and armature of relay 262, to ground. The uppermost back contact of relay 263 is therefore opened and hence relay 270, which controls the connection of condenser 239 in the oscillatory circuit of the oscillator 220, is deenergized. Since the condenser 239 is connected in the oscillatory circuit of the oscillator 220, carrier waves of 70 kilocycles frequency are generated at the repeater R—E and transmitted through the low-pass filter 214 and the coupling circuit 212 to the power line.

The operation of relay 195 also establishes an energizing circuit for the tone producing relay 204, extending from grounded battery 205, through the right hand winding, contact and armature of relay 204, resistance 206, inner left hand contact and armature of relay 195, right hand front contact and armature of relay 179, to ground. When the relay 204 attracts its armature, the energizing circuit through its right hand winding is broken, thereby deenergizing this relay and again closing its back contact and again energizing this relay. The intermittent operation of relay 204 causes the intermittent interruption of the current through its right hand or primary winding, thereby causing a tone to be induced in its left hand or secondary winding. The secondary circuit of relay 204 includes, in addition to the secondary winding of the relay, a battery 208 and a condenser 209, and may be tuned to produce a tone of, for example, 150 cycles per second. The tone produced by relay 204 is transmitted through the outer right hand contact and armature of relay 195, inner left hand contact

and armature of relay 274, and the primary winding of transformer 211. It will be noted that relay 289 which controls the connections to the outgoing channel of repeater R—E, is energized over a circuit extending from grounded battery 231, through the outer left hand armature and contact of relay 169, lower winding of relay 289, outer left hand armature and front contact of relay 195, to ground. Since relay 289 is energized, the secondary winding of transformer 211 is connected through the front contacts and the armatures of relay 289 to the input circuit of the amplifier 219. The tone of 150 cycles frequency in the primary winding of transformer 211 is induced in the secondary winding of this transformer and is thus impressed upon the input circuit of amplifier 219 and caused to modulate the outgoing carrier waves of 70 kilocycles frequency. These carrier waves, modulated in accordance with the tone of 150 cycles frequency, pass into the receiving channel at station C and are demodulated in the usual manner. When the operator at station C raises his receiver, he will hear the busy tone, apprising him that station A, which he seeks to call, is in service. When the operator at station C replaces his receiver on the switchhook, the apparatus at station C will return to normal, and the carrier waves of 110 kilocycles frequency will cease to flow to the power line from the outgoing channel at this station. The apparatus at the repeater R—E will therefore return to normal. The common relay equipment at the repeater will also return to normal with the exception of relay 174, assuming that stations A and B are still in service, the relay 174 remaining operated to permit the transmission of the busy signal in case stations C or D should again attempt to communicate with a busy station at the left of the repeater. It will be evident that the busy signal will also be transmitted automatically to any station at the left of the repeater which attempts to communicate with a station which is already in service at the right of the repeater.

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

The invention claimed is:

1. A transmission system comprising a line adapted for the transmission of power currents and signaling waves, a repeater for repeating said signaling waves with a change in a characteristic thereof, and means for transmitting signaling waves simultaneously over portions of the line on each side of said repeater.

2. A transmission system comprising a line adapted for the transmission of power currents and signaling waves, a repeater for repeating said signaling waves with a change in the frequency thereof, and means for simultaneously transmitting signaling waves comprised within mutually exclusive bands of frequencies over portions of the line on each side of said repeater.

3. A transmission system comprising a line adapted for the transmission of power currents and signaling waves, a repeater for repeating said signaling waves, means for establishing communication over a portion of said line, and means for transmitting a busy signal over another portion of said line when the first mentioned portion of said line is in service.

4. A transmission system comprising a line adapted for the transmission of power currents and signaling waves, a repeater connected to said line, a plurality of stations connected to said line on each side of said repeater, means at each station to transmit waves receivable only by said repeater and other stations on the same side of said repeater, and means responsive to waves incoming at one side of said repeater to transmit waves receivable by stations on the other side of said repeater.

5. A carrier wave transmission system comprising a transmission line including a repeater and a plurality of stations on each side of said repeater, the repeater and said stations having means for transmitting and receiving carrier waves, and means for establishing communication between stations on one side of said repeater while permitting communication between stations on the other side of said repeater.

6. A carrier wave transmission system comprising a transmission line including a repeater and a plurality of carrier wave transmitting and receiving stations on each side of said repeater, means for establishing independent communication between stations on either side of said repeater, and means for transmitting a busy signal to stations on one side of said repeater when stations on the other side of said repeater are in service, and receive a call from a station on the opposite side of the repeater.

7. A transmission system comprising a transmission line including a repeater and a plurality of stations on each side of said repeater, means at each station for transmitting properly arranged groups of impulses of high frequency waves to call any other station, means at said repeater for repeating said groups of impulses, and means responsive to certain groups of impulses composed of high frequency waves to establish communication between stations on one side of said repeater while permitting communication between stations on the other side of said repeater.

8. A transmission system comprising a transmission line including a repeater and a plurality of stations on each side of said repeater, means at each station for trans-

mitting properly arranged groups of impulses composed of high frequency waves to call any other station, means at said repeater for repeating said groups of impulses, means responsive to certain groups of impulses to establish communication between stations on either side of said repeater, and means for transmitting a busy signal to stations on one side of said repeater when stations on the other side of said repeater are in service and a call is received from a station on the opposite side of the repeater.

9. A carrier wave transmission system comprising a transmission line including a repeater and a plurality of stations on each side of said repeater, means at each station to transmit high frequency waves of a character receivable only by said repeater and other stations on the same side of said repeater, and means responsive to high frequency waves incoming at one side of said repeater to transmit high frequency waves of a character receivable by stations on the other side of said repeater.

10. A transmission system comprising a transmission line including a repeater and a plurality of stations on each side of said repeater, means at stations on one side of said repeater to transmit and receive waves comprised within either of two bands of frequencies, means at stations on the other side of said repeater to transmit and receive waves comprised within either of two other bands of frequencies, and means responsive to waves incoming at one side of said repeater to transmit waves comprised within a band of frequencies receivable at stations on the other side of said repeater.

11. A carrier wave transmission system comprising two line sections, stations connected to each line section having means to transmit and receive carrier waves, a repeater connecting said line sections having means to repeat carrier waves with a change in a characteristic thereof, and means for simultaneously communicating between stations connected to each line section.

12. A transmission system comprising two line sections, stations connected to each line section, a repeater connecting said line sections, means at stations connected to one line section to transmit and receive waves comprised within either of two bands of frequencies, means at stations connected to the other line section to transmit and receive waves comprised within either of two other bands of frequencies, and means at said repeater responsive to waves received from one line section to transmit waves comprised within a band of frequencies receivable at stations connected to the other line section.

13. A transmission system comprising two line sections, stations connected to each line section, a repeater connecting said line sections, means at each station for transmitting properly arranged groups of impulses composed of high frequency waves to call any other station, means at said repeater for repeating said groups of impulses, and means responsive to certain groups of impulses composed of high frequency waves to establish communication between stations connected to the respective line sections.

14. A transmission system comprising two line sections, stations connected to each line section, means at said stations for transmitting and receiving selective calling signals of high frequency waves, a repeater connecting said line sections and arranged to repeat said calling signals, and means at said repeater responsive to certain calling signals of high frequency waves received from one line section to condition the other line section for independent transmission between the stations connected thereto.

15. A transmission system comprising two line sections, a plurality of stations connected to each line section, means at each station for transmitting and receiving selective calling signals composed of high frequency waves, a repeater connecting said line sections and arranged to repeat said calling signals with a change in the frequency of said waves, and means at said repeater responsive to certain calling signals to condition each line section for independent transmission between the stations connected thereto.

16. A transmission system comprising two line sections, stations connected to each line section, a calling system including a selector at each station responsive to properly arranged groups of impulses, a repeater connecting said line sections and arranged to repeat said groups of impulses, and a selector at said repeater responsive to certain groups of impulses to condition each line section for independent transmission between the stations connected thereto.

17. A transmission system comprising two line sections, stations connected to each line section, a calling system including a selector at each station responsive to properly arranged groups of impulses, a repeater connecting said line sections and arranged to repeat said groups of impulses, a selector at said repeater responsive to certain groups of impulses to condition either line section for independent transmission between the stations connected thereto, and means controlled by said selector for transmitting a busy signal to stations on one side of said repeater when stations on the other side of said repeater are in service.

18. A transmission system comprising two line sections, stations connected to each line section, a repeater connecting said line sections, means at stations connected to one line section to transmit and receive waves comprised within either of two bands of fre-

quencies, means at stations connected to the other line section to transmit and receive waves comprised within either of two other bands of frequencies, means at said repeater responsive to waves received from one line section to transmit waves comprised within a band of frequencies receivable at stations connected to the other line section, and means at said repeater responsive to certain waves to condition each line section for independent transmission between the stations connected thereto.

19. A transmission system comprising two line sections, stations connected to each line section, a repeater connecting said line sections, means at stations connected to one line section to transmit and receive waves comprised within either of two other bands of frequencies, means at said repeater responsive to waves received from one line section to transmit waves comprised within a band of frequencies receivable at stations connected to the other line section, a selector at said repeater responsive to certain waves to condition either line section for independent transmission between the stations connected thereto, and means controlled by said selector to transmit a busy signal to stations connected to one line section when stations connected to the other line section are in service.

In witness whereof, I hereunto subscribe my name this 23rd day of February, A. D. 1927.

HENRY B. ARNOLD.