

Oct. 29, 1929.

C. N. NEBEL

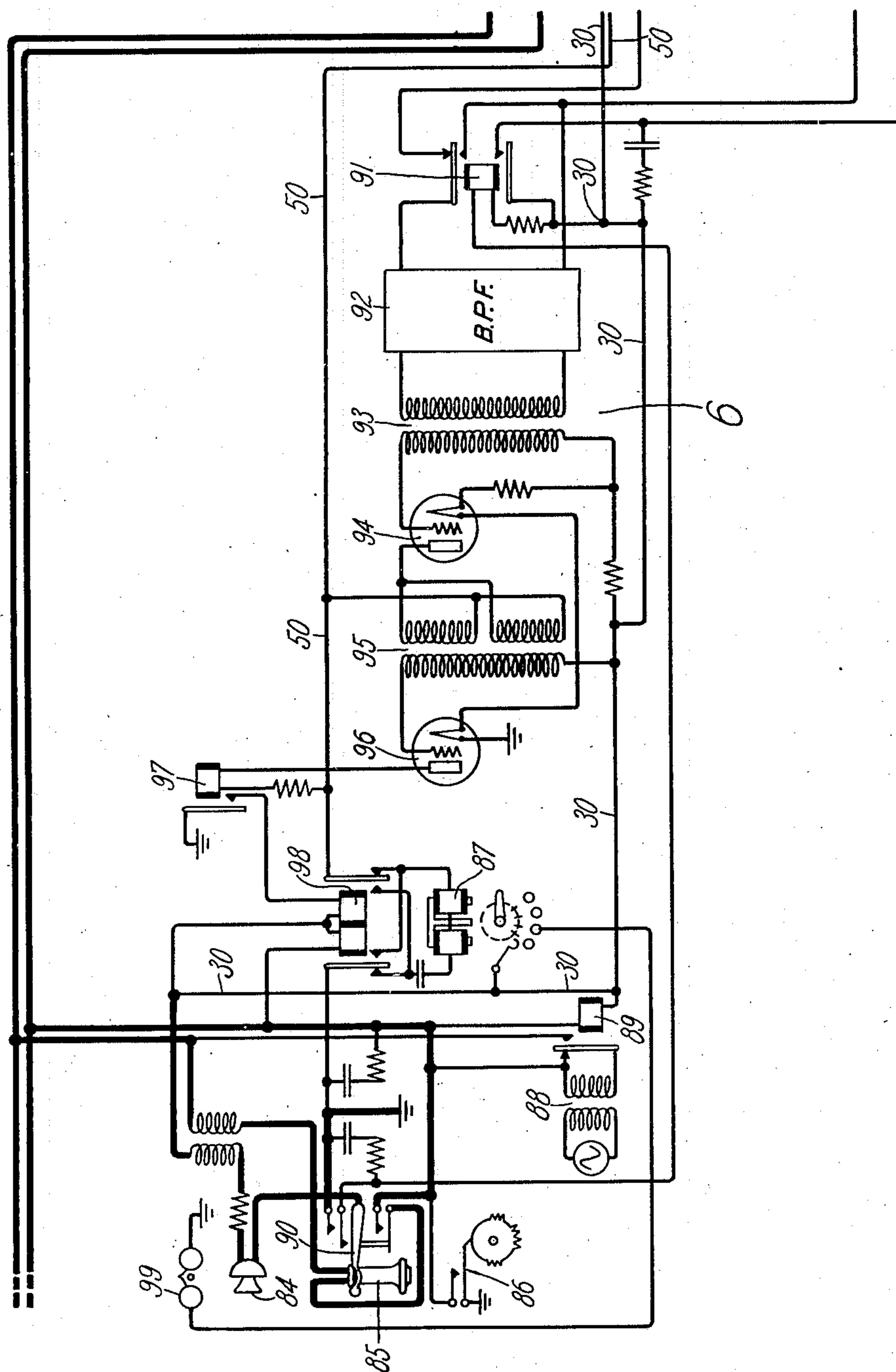
1,733,553

POWER LINE CARRIER CURRENT SYSTEM

Filed June 4, 1928

3 Sheets-Sheet 1

FIG. 1.



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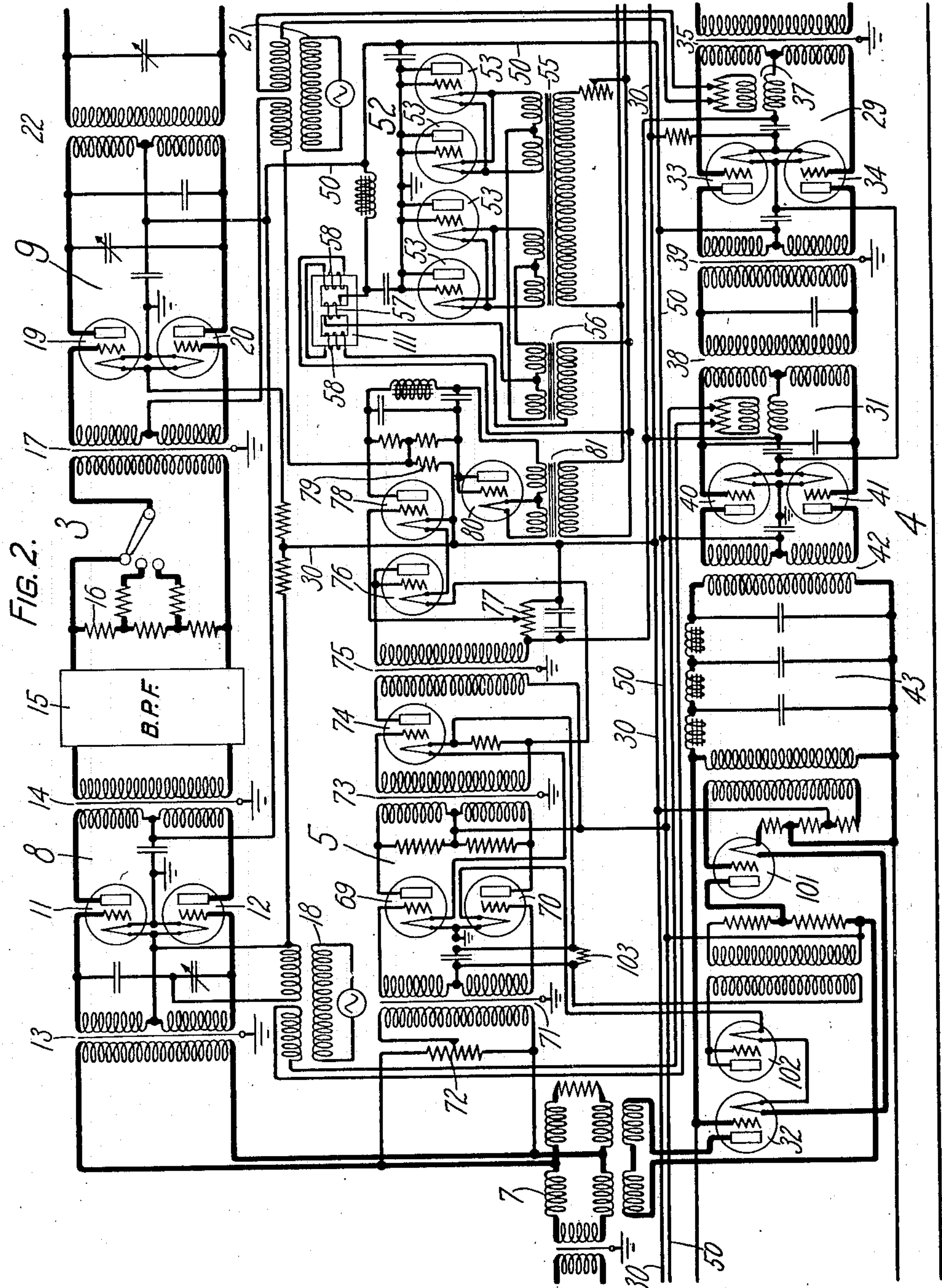
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3 Sheets-Sheet 2



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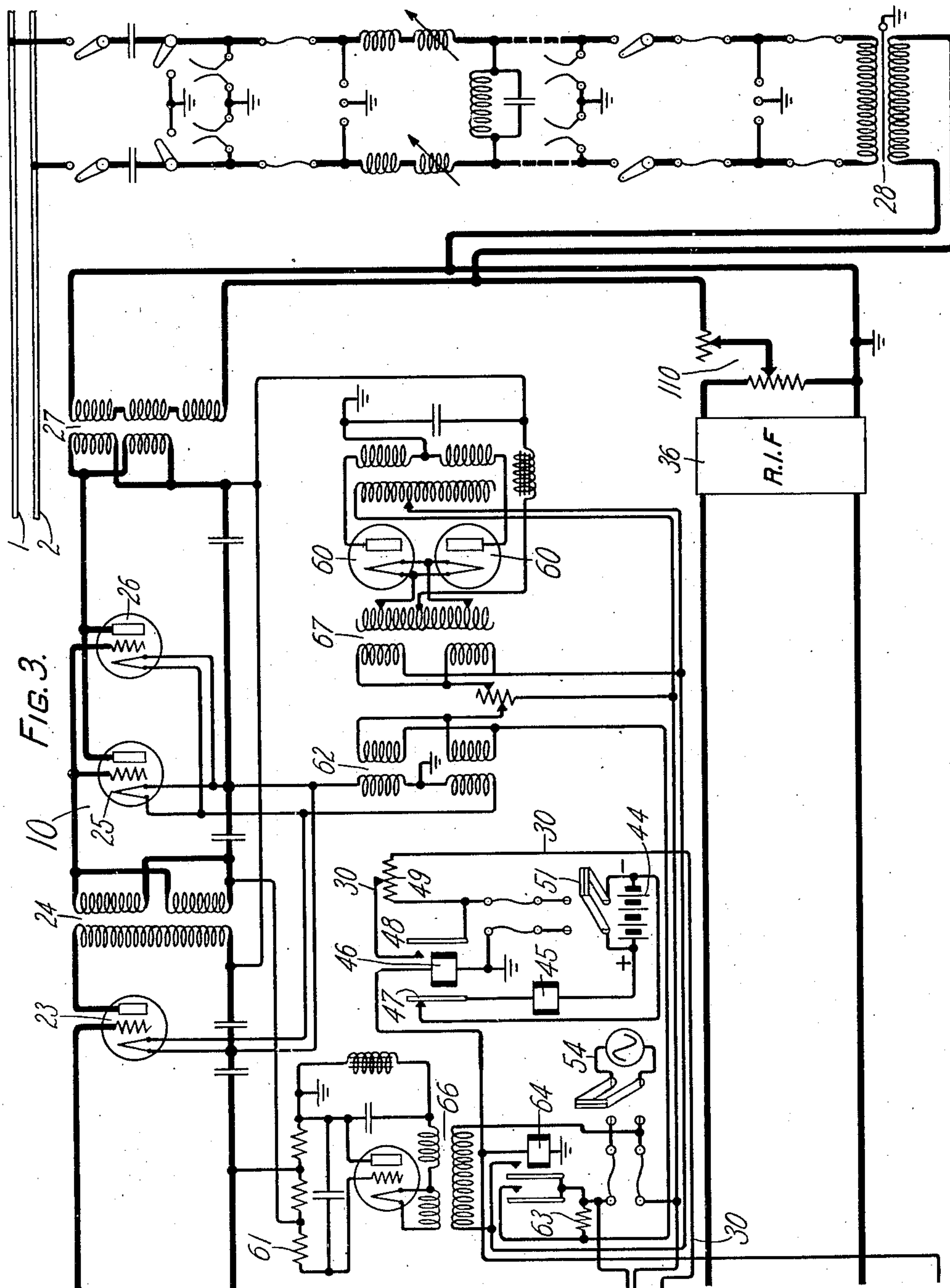
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POWER LINE CARRIER CURRENT SYSTEM

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3 Sheets-Sheet 3



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POWER-LINE CARRIER-CURRENT SYSTEM

Application filed June 4, 1928. Serial No. 282,810.

This invention relates to communication systems, and particularly to carrier current systems for communication over power lines carrying low frequency power current.

5 One object of the invention is to provide a communication system that shall effect a duplexing operation and prevent interference between the transmitted and received signals in an improved manner.

10 Another object of the invention is to provide a carrier current communication system that shall employ the same side band for transmitting and receiving signals and that shall control the negative grid bias on the
15 modulating and demodulating tubes in the transmitting and receiving channels at any station in an improved manner to effect duplexing operation.

A further object of the invention is to provide a power line carrier current communication system of the above indicated type that at any station shall normally maintain the receiving channel open to receive signals and the transmitting channel blocked to prevent
25 operation.

Carrier current communication over power lines carrying high voltage power currents of low frequency is difficult in many cases by reason of the currents which are produced by the so-called corona. It has been found by
30 experiment that the currents produced by corona appear at all frequencies and cannot be satisfactorily overcome by filtering means alone. In order to overcome the noise caused
35 on a transmission line by reason of corona it has been found advisable to raise the transmission level to a point above the level of the currents produced by corona. In the system which is used to disclose the invention
40 and described hereinafter, a single side band is employed for transmitting and for receiving in order to eliminate filtering operations and to enable the transmission level to be raised to a point sufficiently above the noise
45 level to insure good communication.

In the power-line carrier-current communication system which serves to disclose the invention and in which a single side band is employed for transmission in both directions a plurality of carrier current signal sta-

tions are connected to a power line carrying high voltage low frequency currents. The transmitting channel at each station comprises a modulating device for modulating audio-frequency currents with an intermediate carrier current, and means for selecting
55 one of the side bands, preferably the lower side band. A second modulating device is provided for modulating the lower side band from the first modulating device with a carrier current of radio frequency. The lower
60 side band from the second modulating device is selected and transmitted to the called station.

The receiving channel at each station embodies two demodulating devices, and means
65 for detecting the signal currents. Calling between stations is preferably effected by a current having a frequency within the audio-frequency range. The calling current is
70 modulated and demodulated in the same manner as communication currents.

In order to prevent interference between the transmitted and received currents, which are located within the same frequency band,
75 means are provided for blocking the transmitting channel at any station when signals are being received from a distant station and for blocking the receiving channel when signals are being transmitted to a distant station.
80 The blocking of the transmitting channel is effected by placing a blocking negative potential on the grid of the second modulating device and blocking of the receiving channel is effected by placing a blocking negative potential on the grids of the two demodulating devices. Normally when a station is not in operation a blocking potential is maintained on the grid of the second modulating device and the receiving channel is
85 left open for receiving a call at any time.

During transmission from one station to any other station the audio-frequency currents, which may be either the calling currents or the voice frequency currents, operate
90 control circuits for removing the blocking negative potential on the grid of the second modulating device and place negative blocking potential on the grids of the two demodulating devices. When communication or call-
100

ing currents are received at a station from a distant station, control circuits are provided for holding the negative blocking potential on the grid of the second modulating devices and for insuring against placing of any blocking negative potential on the grids of the two demodulating devices.

The transmitting and receiving channels are connected to the power line by a suitable coupling filter, preferably in the manner disclosed in the application of W. V. Wolfe, Serial No. 664,147, filed September 22, 1923, Patent No. 1,678,133, granted July 24, 1928, or in the application of W. V. Wolfe, Serial No. 166,664, filed February 8, 1927. If so desired an extension circuit of the type disclosed in the application of H. B. Arnold, Serial No. 257,864, filed February 29, 1928, may be provided.

In the accompanying drawings Figs. 1 to 3, inclusive, are diagrammatic views of a communication system constructed in accordance with the invention.

Referring to the drawings a power-line carrier-current signaling station is shown connected to a power line comprising conductors 1 and 2. The carrier-current station comprises a transmitting channel 3, a receiving channel 4, duplex control circuits 5 for governing the operation of the transmitting and receiving channels so as to prevent interference between the transmitted and received currents, and calling or signaling circuits 6 for selectively calling any other signal station connected to the power line. The transmitting channel 3, which is connected to the local line circuits by a hybrid coil 7, comprises two modulators 8 and 9 and a power amplifier 10. The modulator 8 comprises two three-element thermionic tubes 11 and 12 which are connected together in push-pull relation. A transformer 13 is provided between the hybrid coil 7 and the input circuits of the modulator tubes 11 and 12 and an output transformer 14 is provided for connecting the output circuits of the modulator tubes through a band pass filter 15, a potentiometer 16 and a transformer 17 to the modulator 9. An oscillator 18 of any suitable type is coupled to the input circuits of the modulator tubes 11 and 12. Preferably, the oscillator produces a current having a frequency of substantially 28.6 kilocycles. The current from the oscillator 18 is modulated with audio-frequency currents received through the hybrid coil 7. The audio-frequency currents which are modulated with the currents from the oscillator 18 may be either calling or communication currents. The modulator tubes 11 and 12 being connected in push-pull relation, serve to suppress any current of carrier frequency in the modulator output circuit. One of the two condensers connected across the secondary winding of the input transformer 13 may be ad-

justed to maintain a balance between the two modulator tubes. The band pass filter 15 serves to select the lower side band from the currents in the output circuit of the modulator 8.

The modulator 9 comprises two three-element thermionic tubes 19 and 20 which are connected in push-pull relation. The lower side band received from the modulator 8 is modulated by the tubes 19 and 20 with a carrier frequency between 77 and 177 kilocycles received from an oscillator 21. The oscillator 21 is connected to the input circuits of the modulator tubes 19 and 20. An output transformer 22 is provided for connecting the modulator 9 to the power amplifier 10. The windings of the transformer 22 are tuned in order to select the lower side band from the output of the modulator 9. The carrier frequency received from the oscillator 21 is suppressed by reason of the two modulator tubes 19 and 20 being connected in push-pull relation with respect to each other. It may be noted that the frequency of the current produced by the oscillator 18 connected to the modulator 8 is maintained substantially constant at all times during the operation of the system, whereas the frequency of the current produced by the oscillator 21 connected to the modulator 9 may be varied in order to maintain the frequency of the current transmitted from each signaling station substantially the same.

The power amplifier 10 comprises a three-element thermionic tube 23 which is connected by transformer 24 to two three-element thermionic amplifier tubes 25 and 26. The amplifier tubes 25 and 26 are connected in parallel relationship with respect to each other between the transformer 24 and an output transformer 27. The transformer 27 is connected through a transformer 28 to the coupling circuits connected to the power lines 1 and 2. The coupling circuits preferably comprise suitable apparatus for protecting the carrier-current signal station against the very high-potential power currents carried by the power conductors 1 and 2. The coupling circuits also include a coupling filter of the type shown in the application of W. V. Wolfe Serial No. 166,664, filed February 8, 1927, for selecting the calling and communication currents from the power currents carried by the power line. Inasmuch as the coupling circuits are not considered a part of the invention, a detailed description thereof is deemed unnecessary.

The receiving channel 4 comprises a demodulator 29, a second demodulator 31 and an amplifier 32. The demodulator 29 comprises two thermionic tubes 33 and 34 which are connected in push-pull relation with respect to each other. The input circuits of the tubes 33 and 34 are connected by a transformer 35 and a receiver input filter 36 to

the transformer 28 and the coupling circuits. The receiver input filter 36 selects the lower side band which has been transmitted over the power line. As hereinbefore set forth, the same side band is used for transmission in both directions. The means for duplexing the transmitting and receiving circuits will be set forth in detail hereinafter. The oscillator 21, which supplies a high frequency carrier current to the modulator 9, is connected by a transformer 37 to the input circuits of the demodulator tubes 33 and 34 so as to beat with the incoming lower side band. The output circuits of the demodulator tubes 33 and 34 contain currents, the frequencies of which are the same as those which were induced into the first modulator in the transmitting channel of the transmitting station. There are also present in the output circuit of the demodulator 29 other products of demodulation which are not of any use and which are suppressed in the tuned circuits formed with the transformer 38 connected to the output transformer 39. The tuned transformer 38 is connected to the input circuit of the demodulator 31. The demodulator 31 comprises two three-element thermionic tubes 40 and 41 which are connected in push-pull relation with respect to each other.

Carrier-current for the second demodulator 31 is supplied by the oscillator 18 which is connected to the first modulator 8. The output circuit of the second demodulator 31 contains in addition to many unwanted products of demodulation audio-frequency currents, the frequencies of which correspond to the frequencies of the currents introduced into the first modulator at the transmitting station. The output circuit of the demodulator 31 is connected through a transformer 42, a filter 43 and the amplifier 32 to the hybrid coil 7.

In the input circuit of the receiving input filter 36 relatively high series and shunt resistance elements 110 are provided for attenuating the received currents. Communication is effected by maintaining a very high transmitting level with respect to the level of the noise currents. By maintaining a high ratio of received signal currents to received noise currents, it is possible to attenuate the total received signal and noise currents by an amount sufficient to render the noise level unobjectionable and still allow signaling level for satisfactory communication. This attenuation, as above set forth, is obtained by the series and shunt resistances 110 which are connected in circuit between the coupling circuits and the receiver input filter.

A battery 44 is provided for supplying heating current to the filaments of the thermionic tubes at a signal station with the exception of the filaments for the amplifier tubes 23, 25 and 26. The battery 44 preferably supplies current of approximately 30-volts.

Normally, a suitable rectifier 45 is connected for charging the battery 44. A relay 46, which is controlled in a manner to be hereinafter set forth, stops the charging of the battery 44 whenever calling or signaling is taking place. Relay 46 is provided with an armature 47 for controlling the charging of the battery 44 by the rectifier 45 and a switch member 48 for shunting a portion of a resistance element 49 in series with the battery 44. Normally, when a switch 51 is closed with the relay 46 deenergized, the positive side of the battery 44 is grounded and the negative side is connected through the resistance element 49 and the conductor 50 to the various filaments and relays to be operated by the battery. Upon operation of the relay 46, the charging of the battery is stopped and in order to compensate for the reduction in voltage that must necessarily ensue, a portion of the resistance 49 in series with the battery is shunted.

Plate current for the modulator and demodulator tubes is supplied by a rectifier 52 having four thermionic tubes 53. The filaments of the tubes 53 are supplied with alternating current by a transformer 55 from a suitable source 54 of alternating current. Space current for the rectifier tubes is supplied by a transformer 56 from the same source of alternating current. A winding 57 in the rectifier circuit is coupled to a winding 58 in the primary circuit of the transformer 56 in order to compensate for changes in voltage that may be effected. The winding 58 is wound on a saturated core member 111 to vary the potential on the primary winding of the transformer 56 in accordance with the potential of the rectified current. An increase in the potential of the rectified current will react through winding 57 and control the winding 58 so as to reduce the potential impressed on the primary winding of the transformer 56. The negative side of the rectifier 52 is grounded and the positive side thereof is connected to a conductor 50.

The amplifier tubes 23, 25 and 26 in the power amplifier 10 are supplied with plate current from a rectifier 60 and with grid biasing potential from a rectifier 61. The rectifiers 60 and 61 are supplied with alternating current from the source 54. Filament heating currents for the tubes 23, 25 and 26 are supplied by a transformer 62 connected to the source 54. Normally, the primary winding of the transformer 62 is connected to the source of alternating current 54 through a resistance element 63 so as not to maintain normal temperature on the filaments of the tubes 23, 25 and 26. Upon operation of the signal station in the manner to be hereinafter set forth a relay 64 is operated for short circuiting the resistance element 63 to permit the heating of the filaments in the amplifier tubes 23, 25 and 26 to normal temperature.

Relay 64 also serves to connect the rectifier 61 and the rectifier 60 to the source of alternating current 54. A transformer 66, which is connected to the source of alternating current by the relay 64, supplies heating and space current to the rectifier 61 and suitable filter means is provided in the rectifier circuit in order to smooth out any ripples in the biasing potential supplied to the grids of the amplified tubes 23, 25 and 26.

A transformer 67 which is connected to the source of supply 54 by the relay 64 supplies heating current to the two tubes of the rectifier 60. Rectifier 60 as hereinbefore set forth supplies space current to the amplifier tubes 23, 25 and 26.

The duplexing operation of the system is effected by blocking the transmitting channel 3 when receiving channel 4 is in operation and by blocking the receiving channel 4 when the transmitting channel 3 is in operation. The blocking of the transmitting channel is effected by applying a blocking negative potential to the grids of the two modulator tubes 19 and 20. Blocking of the receiving channel is effected by applying a blocking negative potential to the grids of the four demodulator tubes 33, 34, 40 and 41. Normally, when the system is not in service the transmitting channel is maintained blocked and the receiving channel is held open to receive a call or signal at any time.

The duplexing apparatus for controlling the blocking of the transmitting and receiving channels comprises two amplifier tubes 69 and 70 which are connected in push-pull relation to a transformer 71 and a potentiometer 72 to the transmitting channel connection to the hybrid coil 7. The output circuits of the amplifier tubes 69 and 70 are connected through a transformer 73 to an amplifier tube 74, which in turn is connected through a transformer 75 to a rectifier tube 76. A variable resistance element 77 in circuit with the rectifier tube 76 controls the blocking potential which is impressed on the grids of the four demodulator tubes 33, 34, 40 and 41. A potential from the resistance element 77 also governs a control tube 78. The control tube 78 governs the current flow through a resistance element 79. The resistance element 79, which has potential impressed thereon from a rectifier 80, is in the plate circuit return of the control tube and supplies negative blocking potential to the two modulator tubes 19 and 20. The rectifier tube 80, which is supplied with alternating current by transformer 81 from the source of alternating current 54, normally maintains sufficient potential across the resistance element 79 to apply a blocking negative potential to the grids of the modulator tubes 19 and 20. The blocking potential applied to the modulator tubes is governed by the control tube 78. Suitable filter means and a

potentiometer are included in circuit with the rectifier 80. The connection of the grid of the control tube 78 to the resistance element 77 may be varied in order to vary the time of blocking and releasing the transmitting channel. Suitable condensers are connected across the resistance element 77 for smoothing out the potential supplied to the grids of the demodulator tubes 33, 34, 40 and 41.

The operator's signal set comprises the customary transmitter and receiver 84 and 85, transmitting key 86 and a selector 87. The transmitting 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. This transmitting key may be adjusted to transmit the proper code or combination of impulses for calling any station on the line. The selector 87 may be of the type disclosed in U. S. Patent No. 1,343,256 to J. C. Field, issued June 15, 1920. An oscillator 88 producing a current having a frequency within the audio-frequency range and approximately 1615 cycles is provided for supplying current for calling purposes. A relay 89, which is controlled by the key 86 and the receiver switchhook 90, controls the connection of the oscillator 88 to the hybrid coil 7 and the transmitting channel. The selector 87 is operated in accordance with the code or signals transmitted by the key 86 and by signals received from a distant station. The filter 43 is not only connected to the hybrid coil 7 through the amplifier 32 for supplying communication currents to the operator's signal set, but is connected by a relay 91 to a band pass filter 92. The band pass filter 92 sharply selects the frequency which has been selected as a calling frequency, preferably the frequency above mentioned for the oscillator 88. The band pass filter is connected by a transformer 93; an amplifier tube 94 and a transformer 95 to a detector tube 96. The detector tube 96 controls a relay 97 which, in turn, controls a relay 98. The relay 98, which is also controlled by the key 86, governs the operation of the selector 87. The detector tube 96 and the amplifier tube 94 are supplied with filament current and space current in the same manner as the modulator and demodulator tubes hereinbefore described. The selector 87 is adapted to complete a circuit from the 30-volt conductor 30 for operating the call bell 99, or to complete a circuit for signaling an operator at an extension station. The extension station is disclosed and claimed in the application of H. B. Arnold, Serial No. 257,864, filed February 29, 1928, and a description thereof in this application is deemed unnecessary.

Calling a distant station

Upon removing the receiver 85 from the switchhook before operating the key 86 to

transmit a code of signals over the power line to a distant called station, a circuit is completed for operating the relays 91, 46 and 64 to supply all the tubes in the receiving and transmitting channels with filament and plate current. Raising the receiver switchhook completes an energizing circuit for the relay 91 from the battery 44. The relay 91 operates one switch member to disconnect the band pass filter 92 from the receiving channel and prevent the selector 87 being operated by any signal impulses transmitted from a distant calling station. A second switch member of the relay 91 serves to complete circuits from the battery 44 for operating the relays 64 and 46. The relay 46 as hereinbefore set forth stops the charging of the battery 44 and short circuits a portion of the resistance element 49 from the battery circuit. The relay 64 connects the rectifier 61 to the source of supply 54 for supplying grid biasing current to the amplifier tubes 23, 25 and 26. The relay 64 also connects the rectifier 60 to the source of supply 54 for furnishing space current to the amplifier tubes 23, 25 and 26 and, moreover, increases the filament current supplied to the amplifier tubes. The key 86 is operated in accordance with any code of signals required to signal the called station. Circuits are completed by the key 86 for operating the relay 89 which controls the oscillator 88 and for operating the relay 98 which controls the selector 87. The relay 89 connects the oscillator 88 through the operators local line to the hybrid coil in accordance with the code signals being transmitted. The signal impulses, which are within the audio-frequency range, are first modulated with an intermediate carrier-current by the modulator 8 and the lower side band selected by the band pass filter 15. The lower side band selected from the output circuit of modulator 8 is then modulated with a radio frequency carrier current and the lower side band selected by the tuned transformer 22. The lower side band selected by the transformer 22 is amplified by the power amplifier 10 and transmitted over the power line conductors 1 and 2 to the distant station. The called station which is similar in construction and operation to the station shown on the drawings receives the transmitted impulses through a receiving channel similar in construction to the receiving channel shown in the drawings. The demodulators 29 and 31 demodulate the received impulses and supply the amplifier 94 with audio-frequency impulses corresponding to those transmitted from the oscillator 88 at the transmitting station. The amplifier 94 is connected to detector 96 which controls the relay 97 in accordance with received impulses. The relay 97 operates the relay 98 which, in turn, operates the selector 87 to sound the call bell at the called station.

During calling and also during signaling, the duplex control circuits operate to prevent interference between the transmitted and received currents. Prior to the transmission of any calling impulses to the transmitting channel, the grids of the two modulator tubes 19 and 20 are blocked by a negative potential obtained from across the resistance element 79. At this time no blocking potential is maintained on the demodulator tubes so that the station is in condition to receive a call. Upon transmission of calling impulses from the oscillator 88 or voice impulses from the transmitter 84, a certain per cent of the transmitted current is supplied to the two amplifier tubes 69 and 70. Current thus supplied to the amplifier tubes 69 and 70 is further amplified by the amplifier 74 and is rectified by means of the rectifier 76 and made to flow through the resistance 77. The voltage drop across this resistance is supplied to the grids of the demodulator tubes 33, 34, 40 and 41. Part or all of the voltage in resistance 77 is also impressed on the grid of the control tube 78 thus stopping the flow of plate current in this tube and reducing the potential impressed across the resistance element 79. This removes the blocking potential impressed upon the modulator tubes 19 and 20. Thus, a negative blocking potential is impressed upon the grids of each demodulator tube and the negative blocking potential on the modulator tubes 19 and 20 is removed. Upon receiving an impulse from a calling station through the receiving channel, a certain per cent of the received current is supplied to an amplifier 101 from the low pass filter 43 and is rectified by a thermionic tube 102 for controlling the potential impressed on the grids of the two amplifier tubes 69 and 70. In circuit with the rectifier 102 is a resistance element 103 to which is connected the grids of the amplifier tubes 69 and 70. Thus, a negative blocking potential is impressed on the grids of the amplifier tubes 69 and 70 in accordance with the potential across the resistance element 103 and consequently in accordance with the current impulses in the receiving channel. As hereinbefore set forth, a blocking potential is normally maintained on the two modulator tubes 19 and 20 from the resistance element 79 and the receiving channel is left open. When a blocking potential is impressed upon the amplifier tubes 69 and 70, no change can be effected in the receiving and transmitting channels inasmuch as no further operation of the duplex control circuits 5 can be effected until after the blocking potential is removed from the amplifier tubes 69 and 70. Thus, it is apparent during operation of the transmitting channel, a negative blocking potential is maintained on the two demodulators 31 and 29 and during the receiving of signal impulses a negative blocking potential is maintained on

the grids of the modulator 9. Furthermore, during the receiving of a message from a distant station the duplex control circuits serve to insure against any blocking of the receiving channel or removal of the blocking in the transmitting channel.

Inasmuch as one single carrier frequency is used for transmitting in both directions, it is desirable to control the oscillators 21 at the various signal stations to produce substantially the same carrier frequency. A test for such purpose may be effected by connecting the oscillator 88 at a master station to the operator's local line for transmitting over the power line a current modulated with the audio-frequency current received from the oscillator 88. At the different stations along the power line the operators will connect their audio-frequency oscillator 88 to the output circuit from the second demodulator and determine whether or not a beat tone is produced. The operators at the distant stations vary the frequency produced by the oscillator 21 connected to the second modulator in accordance with the beat tone produced. In such manner the carrier frequency of all stations may be adjusted to agree with the master station transmitting the signals from an audio-frequency oscillator 88.

Modifications in the system and in the arrangement and location of parts may be made within the spirit and scope of the invention, and such modifications are intended to be covered by the appended claims.

What is claimed is:

1. In a power-line carrier-current signal system having the sending and receiving currents located within the same frequency band, a signal station having a transmitting channel with a three-element modulator tube therein and a receiving channel with a three-element demodulator tube therein, means operated upon transmission of a signal from said station for placing a negative blocking potential on the grid of the demodulator tube, and means operated upon receipt of a signal for maintaining a negative blocking potential on the grid of the modulator tube and for insuring against placing a blocking potential on the grid of the demodulator tube.

2. In a power-line carrier-current signal system having the sending and receiving signal currents located within the same frequency band, a power line having a plurality of signal stations connected thereto, each of said stations having receiving and transmitting channels, means at a station when idle for blocking the transmitting channel and for maintaining the receiving channel in condition to receive signals, means operated upon transmission of signals for removing the blocking mean on the transmitting channel and for blocking the receiving channel, and means operated by received signals for maintaining the blocking means on the transmit-

ting channel and for insuring against blocking the receiving channel.

3. In a carrier-current signal system having the sending and receiving signal currents located within the same frequency band, a power line having a plurality of signal stations connected thereto, each of said stations having a transmitting channel with a modulating tube therein and a receiving channel with a demodulating tube therein, means when a station is idle for blocking the modulating tube in the transmitting channel and for maintaining the receiving channel in condition to receive signals, means operated by transmitted signals for removing the blocking means on said modulator and for placing blocking means on said demodulator, and means operated by received signals for maintaining the blocking means on said modulator and for insuring against blocking said demodulator.

4. In a carrier-current signal system having the sending and receiving signal currents located within the same frequency band, a power line having a plurality of signal stations connected thereto, each of said stations having two separate modulators in the transmitting channel and two separate demodulators in the receiving channel, each of said modulators and demodulators comprising an electric discharge tube, means when a signal station is idle for maintaining a negative bias on the grid of the tube in one modulator to block the transmitting channel and for maintaining the receiving channel in condition to receive signals, means when a signal is being transmitted for removing the negative blocking potential on the grid of the modulator tube and for applying a negative blocking potential to the grid of a demodulator tube, and means when a signal is being received for insuring against placing of a negative blocking potential on the grid of a demodulator tube and for maintaining the negative blocking potential on the grid of the modulator tube.

5. In a carrier-current signal station, a transmitting channel having two series connected modulators therein, each of said modulators comprising a three-element thermionic tube, a receiving channel having two series connected demodulators therein, each of said demodulators comprising a three-element thermionic tube, means when the station is idle for maintaining a negative bias on the grid of one modulator tube to block the transmitting channel and for maintaining the receiving channel in condition to receive signals, means when a signal is being transmitted for removing the negative blocking potential on the grid of the modulator tube and for applying a negative blocking potential on the grids of the two demodulator tubes, and means when a signal is being received for insuring against placing of a negative

blocking potential on the grids of the demodulator tubes and for maintaining the negative blocking potential on the grid of the modulator tube.

6. In a power-line carrier-current signal system having the sending and receiving signal currents located within the same frequency range, a transmitting channel at each station having two modulators therein, each modulator comprising a three-element thermionic tube, a receiving channel at each station having two demodulators therein, each demodulator comprising a three-element thermionic tube, means when a station is idle for maintaining a negative blocking potential on one of the modulating tubes and for maintaining the receiving channel in condition to receive signals, means operative upon transmission of a signal for removing the negative blocking potential from the grid of the modulator tube and for placing a negative blocking potential on the grids of the two demodulator tubes, and means operative when signals are received for maintaining the negative blocking potential on a grid of the modulating tube and for insuring against placing negative blocking potential on the grids of two demodulating tubes.

7. In a carrier-current signal station, a transmitting channel having a three-element electric discharge device therein, a receiving channel having a three-element electric discharge device therein, means when the station is idle for maintaining a blocking negative bias on the grid of the tube in the transmitting channel and for maintaining the receiving channel in condition to receive signals, means when a signal is transmitted for placing a blocking potential on the grid of the tube in the receiving channel and for removing the blocking potential from the grid of the tube in the transmitting channel, and means when a signal is being received for insuring against placing a blocking potential on the grid of the tube in the receiving channel and for maintaining the blocking potential on the grid of the tube in the transmitting channel.

8. In a carrier-current signal station, a transmitting channel having a three-element electric discharge tube therein, a receiving channel having a three-element electric discharge tube therein, means when the station is idle for blocking the transmitting channel and for holding the receiving channel in condition to receive signals, means controlled by signals transmitted from the station for removing the blocking means on the transmitting channel and for blocking the tube in the receiving channel and means operated by received signals for maintaining the blocking means on the transmitting channel and insuring against blocking the tube in the receiving channel.

9. In a carrier-current signal system, a

transmitting channel having a three-element electric discharge device therein, a receiving channel having a three-element electric discharge device therein, means for normally maintaining a negative blocking potential on the grid of the device in said transmitting channel and for maintaining the receiving channel in condition to receive signals, means for transmitting signals to remove the negative blocking potential on the tube in the transmitting channel and to place a negative blocking potential on the device in the receiving channel, and means upon receipt of signals for maintaining the negative blocking potential on the device in the transmitting channel, and for insuring against placing a blocking potential on the grid of the device in the receiving channel.

10. In a carrier-current signal system, a transmitting channel having a three-element electric discharge device therein, a receiving channel having a three-element electric discharge device therein, means operative upon transmission of signals for placing a negative blocking potential on the grid of the device in the receiving channel, and means operative upon receiving signals for holding the negative blocking potential on the grid of the device in the transmitting channel and for insuring against placing a negative blocking potential on the grid of the device in the receiving channel.

In witness whereof, I hereunto subscribe my name this 29th day of May, 1928.

CHARLES N. NEBEL.